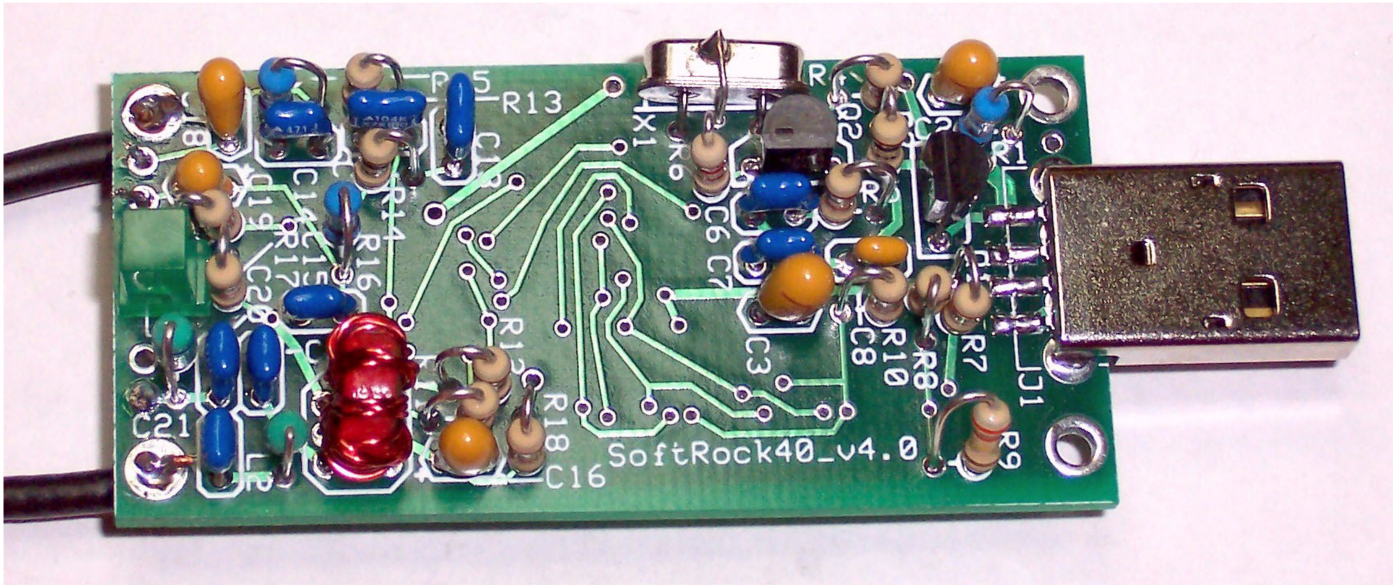
Issue #6 Summer 2005

AmQRP.ORG HOMEBREWER

JOURNAL OF THE AMERICAN QRP CLUB

KB9YIG
KD5TFD

SoftRock-40 Receiver



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Homebrew Fever

Like most active QRPers, I have a love affair going on with my ham shack. I get immense pleasure from spending lots of time in this special place; and over time I've constructed it to have all the conveniences to prolong that relationship. The hub of this nerve center is a pretty powerful, Internet-connected Windows computer that runs my FlexRadio SDR-1000 HF rig, and houses the development environments for my Micro908 projects and other DSP/microcontroller projects. I write/edit Homebrewer Magazine from here and I have an elaborate music recording environment built up around the PC. If I swivel the chair to the left I can reach over and grab a banjo, mandolin or guitar and relax while picking with some tunes that are always playing on the XM Radio ("track 14" for those of you who know XM.) I can swivel to the right I enter the "measurement zone" of my kingdom containing the scopes, power supplies, spectrum analyzer, signal generator and frequency counter. I can turn-and-slide over to the workbench where I have an ever-hot Weller soldering station and an abundance of parts and open prototype circuits built from the various authors contributing QRP project articles over the six years that I've been doing the magazine gig. My family knows where to find me during quiet times in the house, and the dog sleeps at my feet into the wee hours of many nights. Life is sweet.

"So what" you say? Well, I daresay that this ham shack scenario is, to one extent or another, very similar to what each of you readers have … and homebrewing is the common thread that binds it all together. Or rather, homebrewing is the common thread that binds **us** all together. Not many normal people (e.g., my wife or the guys at work) understand the drive we each have to spend hour after hour hunched over circuits with curls of smoke wafting up into the air, or why we dance with elation around the shack after making a contact using that one milliwatt tangled ball of components, wire and solder called a VFO. But you would, because we each have the fever … *homebrew fever.*

> *"Homebrew fever got a hold on me*
>
> *Got me shakin' so hard I can hardly see."*
>
> *-- Northern Lights (bluegrass)Band*

Admittedly, the "homebrew fever" referenced in the lyrics above is probably caused in a different way, but the effects are the same. Like me, you readers probably have a whole bunch of unbuilt kits stacked up on a shelf and an ever-present vow to be getting to it soon. But you can't because you heard that the AmQRP or KD1JV or Elecraft is coming out with a new kit and you want to get it and devour it first. But the Spartan Sprint is coming up soon and you need to get your homebrew rig ready for it. But there's this new technology called SDR and someone has a real inexpensive and easy way to try it out and you want to understand it. But you heard of a new magnetic loop antenna design being supported in Murph's *HAMCALC* program and you want to try it out first. But, but, but … that's homebrew fever!

I'm not sure if it's a cure or an accelerant for the virus we all have, but the single most exciting aspect of this homebrew fever is you! The information we all bring to the table, the ideas, the challenges, the new designs, the explanations of old myths, and homebrewing experiences on the bench all form a camaraderie that transcends the physical distances separating us. We each have friendships, and at time collaborative designs, with similarly-afflicted homebrewers whom we have never seen face-to-face. Yes, the wonders of the Internet, but also the wonders of the projects contributed by some very smart people in the pages of Homebrewer, SPRAT, QRP Quarterly and similar magazines of yesteryear. We owe a great debt of gratitude to those unsung heroes who planted the seeds of the virus in each of us. The projects in these pages live on and are added to the great body of reference material that will be used by future generations, and *we're seeing it happen live!* We must enjoy it, revel in it, contribute to it, ask questions about it, stay current with it … and we must build it and share our results.

IN THIS ISSUE

Speaking of sharing results, the contributing authors have once again overwhelmed us and allowed us to produce a terrific issue of Homebrewer Magazine. Contained in more than 500 pages of full color, high resolution graphics, we have a mixture of easy and complex, quick and extended, antennas and radios, digital and analog … something for everyone to build, and educational for everyone even if you don't build up a given project.

The highlight of the issue, and the cause of a great deal of excitement in the QRP community during August-September, is something called the **SoftRock-40 Receiver**. This little 1"x2" board from designers Tony Parks **KB9YIG** and Bill Tracey **KD5TFD** plugs into the USB port of your computer and works together with a powerful software application from FlexRadio called "PowerSDR" to provide a 40-meter receiver with absolutely stunning performance. The exciting *quadrature sampling detector* enables the software on the PC to pull out signals as low as 40 dB, thus rivaling some higher-end commercial receiver performance.

Bruce Beford, **N1RX** provided a nice service to many on QRP-L by experimenting with a different crystal to move the **SoftRock to 30 meters**. He obtained some crystals in quantity and supplied them at cost to SoftRock owners wishing to modify their kit … and Bruce wrote up a nice article for Homebrewer explaining how he went about designing the mods.

And speaking of quadrature sampling receivers, we had a surprising contribution from a pair of wonderful designers from Finland, Juha Niinikoski **OH2NLT** and Matti Hohtola **OH7SV**. These guys designed and built an award-winning, 0-8 MHz DDS-based QSD receiver called the **JUMA-RX1** that has nice specifications – and I'm currently in the process of building this one up myself!

Software Defined Radio (SDR) radios are becoming quite popular these days, much due to the excitement and interest generated by FlexRadio Systems' **SDR-1000** transceiver. We had a review of this radio way back in in Homebrewer issue #1, but **QST** recently published a wonderful review of this same radio and covered the many new features that have been added since we saw it here. So in joining with the surge in popularity of SDR, we re-published our original SDR review written by designer Gerald Youngblood **K5SDR**. We also have included the well-done QST review. And lastly we have added the technical overview of SDR technology that software radio guru Bob McGwier **N4HY** did for us in the Atlanticon 2004 Forum. This is a one cool collection of SDR reference material!

By the time this issue gets into your hands, the AmQRP likely will have announced details and availability of the **DDS-60 Daughtercard**. The article in this issue describes how we extended the frequency range of the original DDS Daughtercard by going to an AD9851 DDS chip and including the DDS Amp project right on the main DDS card itself. We went to using the

AD8008 op amp to provide a nice, flat signal level right out to 60 MHz, and we retained the use of the SMT trimpot to allow output level adjustment. Then as a builder option, we provide DS-1804 digipot to allow the external controller software to also change the output level. Pretty neat!

Again along the line of DDS signal generation … two DDS chips have got to be better than one, right? Lyle Johnson, **KK7P** thinks so, and he provided an article describing his **DDS2 dual chip design** that forms a building block for a software defined radio clock generation circuit. By operating two RF clocks of the same frequency but having 90-degree phase difference, one has the start of some great signals to drive QSD and QSE circuits on an SDR radio.

We are also fortunate to be able to include **KK7P's** Atlanticon presentation of **Digital Building blocks for Analog Radios**. He received rave reviews from the Atlanticon audience this past spring, and now you'll have a chance to see into the mind of one of the brightest QRPers in our midst.

Noted designer of the famous HAMCALC program, George 'Murph' Murphy **VE3ERP** worked with **W2AHW** to produce a design of a miniature magnetic loop called the **Octaloop**. Imagine having an Small Transmitting Loop (STL) antenna for 80m that is only 52" in diameter! Murph and Harold provide some clear and easy plans on how this can be effectively accomplished.

The PIC-based weather station article series from Dave Ek, **NK0E** has spanned two magazines and 5 years' time. We've provided here in this issue of Homebrewer the **full series of PIC-WX articles** and software so you can easily build up the project without referencing many back issues.

We are so fortunate to have the homebrewing expertise and talent of Paul Harden, **NA5N** with us as a regular contributor to Homebrewer Magazine! Paul's "**Handyman Series**" this time overviews the homebrewing techniques of Manhattan construction and you'll be absolutely thrilled in reading though his installment. Outstanding stuff!

Some years ago, we introduced **Craig Johnson's PIC-EL project board** along with the start of the Elmer 160 PIC-training course for hams. The "Pickle" board was very popular as it had lots of useful peripherals that we QRPers and homebrewers could use in actual applications on the bench. Not the least of them is the DDS Daughtercard, and because of it many people are now using the PIC-EL at heart of a precise RF signal generator sitting on their benches. Since the AmQRP recently spawned another run of the PIC-EL as a partial kit (board plus several hard-to-get components), and KangaUS stepped up to make up bags o' parts for the remaining components, Craig and I felt it more than appropriate to collect the PIC-EL documentation, add a little more to it and publish it all here together for Homebrewer readers. Enjoy!

Dave Ottenberg, **WA2DJN** is a regular contributor to Homebrewer Magazine and he prides himself in finding simple ways to produce useful instruments for the workbench. This time Dave found a nice test oscillator circuit and he packaged it in a plastic tube for use as a **signal injector**.

Another fairly-regular contributor to our Homebrewer journal is Phil DeCaire, **WB7AEI**. This time Phil explores the ever-present world of **Low Pass Filters** and provides us with some useful tools, simple equations and practical examples in their use.

Steve Holton, **N1NB** spent a lot of time with KK7P and me in designing the AF-908 DSP audio filter. In doing so, he became very familiar with the Micro908 hardware and software capabilities and he applied it in solving a challenge we made at this past Atlanticon: stabilize the Crystalizer! Steve designed a simple interface for the **Micro908 to control the Crystalizer** and wrote a nice program using a thermister in a control loop to keep the Crystalizer frequency right on the mark. By the way, he won first prize at Atlanticon for his effort here!

Victor Bresedin, **UA9LAQ** contributed two articles to Homebrewer this time, and in his own unique style provides us with some of his wonderfully-stated designer wisdom. His overview of his **20-meter receiver,** and a walk-through of an **experimental 2-meter antenna** provide a delightful and informative read.

Joe Everhart, **N2CX** has been doing the design series called **Power Meter Cookbook** for a number of issues. He is now getting to the point in this current installment of getting us past the "analytics" stage and on to practical incarnation of his designs. You can wire up the circuits he provides this time and make some great headway on better understanding the theory presented thus far.

We are very fortunate to have received permission from Murph **VE3ERP** to include his ever-popular and ever-improving **HAMCALC** program set on the Homebrewer CD-ROM. You can find his latest program (#78) in the Software section of this CD. Assistant editor Nancy Feeny **NJ8M** also felt that it would be useful in each issue to have a walk-through of one of HAMCALC's features in a real-life example, and she's provided a nice tutorial on **designing a power supply** with the appropriate programs in HAMCALC.

There are some good projects that just never lose their value over time, and it's curious how some designer/authors always tend to be the source of those projects. Jim Kortge, **K8IQY** designed the **Precision VXO** project some years ago and presented it at Atlanticon to a very eager audio. Then in the following months he provided the design for a mating **Crystal Measurement fixture** to give us homebrewers some real useful capabilities on the bench. We present both of these instruments again in the Homebrewer pages … if you missed building them the first time, here's a chance to reprieve yourself!

In the last issue, Al Gerbens, **K7SBK** introduced his Excel macro "program" called **AA908 Plot Gen** that took the raw data file produced by a scan of the Micro908 Antenna Analyst and displays a wonderful plot of the SWR, resistance and reactance. Never one to be satisfied with something that works (like all of us, I think!), Al made a raft of feature additions that further increase the usefulness of this tool.

Joe Everhart's **N2CX Test Topics and More** (TTAM) column this time around shows some basic electronics that are relevant for more than just test equipment. The "Designed for Test" section shows how to use a 75-ohm attenuator with other equipment and cables designed for a 50-ohm impedance using a so-called minimum loss pad. Joe's "Coming to Terms" section deals with series and parallel equivalent circuits, a topic that comes up now and again, particularly in conjunction with impedance matching. "Stimulus and Response" talks about power attenuators – how to design them and how to size the components that make them up.

Recurring columns are the staple of most magazines and Homebrewer readers are able to be regularly exposed to the experience, wit and storytelling grace of Richard Fisher **KI6SN** and Arland **K7SZ**. Through the KI6SN "QRP Operating" column we get a view into some of the **Field Day experiences** that some guys had this past summer. Then in two K7SZ "Tuning Up" columns this time we learn how **Digital Dickey** was converted from an analog world, and how that same analog world (a la that **troublesome Argonaut**) nearly did him in.

Ken Newman, **N2CQ** once again gives us a 3-month forecast of **QRP Contesting** events, including links to all the associated rules web pages. As an added treat, Ken supplied us with the full **5-year set of results from the Homebrewer Sprint** event that he runs during the spring and fall of each year. What a great compilation of contesting results!

THREE SPECIAL FEATURES!

We are very proud to present a first-of-its-kind (to the best of our knowledge) in our QRP publishing world by producing, editing and publishing an **instructional video** within the "pages" of Homebrewer Magazine. Joe Everhart N2CX and I (N2APB) collaborated to present a 45-minute video overviewing the technical aspects of the **Micro908 design**. This WMV file is able to be viewed in the standard Windows Media Player (or equivalent) on most computer systems, and we think you'll enjoy actually seeing the designers describing their project

There is another great bonus feature in Homebrewer this time that you can't find anywhere else. We had an opportunity **to interview the designers of the SoftRock-40** (Tony and Bill) and we provided this hour-long **audio file** on the Homebrewer CD for your listening pleasure. So not only can you read about this popular little rig, but you can hear from the designers in their own words about the project, the process they followed in developing it, and some of the future directions they'll next be taking the SoftRock. Be sure to listen in on this interview!

We are very thankful to Chuck Adams, **K7QO** for allowing us to include his comprehensive **Morse Code Training Course** in this issue of Homebrewer Magazine. Chuck is actively involved in training ham clubs in the proper learning and use of Morse code, and he is quite an accomplished in this communications mode. The K7QO Code Course consists of 149 MP3 files located on this CD, plus some expert guidance provided by Chuck and several related reference articles.

SOFTWARE on CD

There is a ton of software programs, source code, and other files relating to the articles and projects presented in this issue of Homebrewer. The best way to see and use these files is to use your file browser to navigate to the CD drive, and then into the Software folder. You will either see a folder with the name of the individual software program, or a zip file that contains a compressed file of all the related files for that named topic. These files will best operate when copied to your computer's hard drive. (Also, you should not attempt to run a program while it is still contained in the compressed zip file container – you will get unexpected results.)

Notable programs and files included in the Software folder this time include: HAMCALC 78, PIC-EL design and software files, GCGC (Great Circle), WA0SVL Conversion utilities, AA-908 Plot Gen, source code from all the PIC-WX articles, Serial DDS source code, Link908 source files, SoftRock-40 and PowerSDR source and installation files, software files for the JUMA-RX1 Receiver controller, TC908 Temperature Controller software, … and more. This folder is a software homebrewer's treasure trove!

Also, the **Why QRP?** presentation is included for your use at local club meetings. Lastly, as before, we have included the detailed Kits folders including all manuals, schematics, software, pcb layouts, etc., for current and popular QRP kits that have been produced over the years. This is a great reference bank of technical homebrewing information!

A FEW IMPORTANT CREDITS

I would be very remiss if I did not mention the absolutely stellar contributions that three people have been making to the AmQRP Club this year.

Tom Feeny (W8KOX) and **Nancy Feeny (NJ8B)** are the husband-wife team recipient of the 2004 QRPer of the Year award issued by the AmQRP at this past spring's Atlanticon, and they continue to make incredibly key contributions this year for the AmQRP. They manage to handle every major kitting challenge tossed their way, including the Micro908, DDS Amp, DDS Daughtercard, DDS-60, and more, but they directly assist in creating the documentation, ordering parts and handling replacement parts mailings. Further, and notably for the last three issues, Nancy has been my assistant editor here in our Homebrewer publication. Her reliable assistance has been extremely appreciated.

Bryan Williams, AA3WM is a person that almost everyone has come to know throughout this year and certainly one that N2CX and I have grown to rely on in a very great way. Earlier this year Bryan stepped forward to volunteer his efforts in helping to run the "gears and pulleys mechanism" of the club by handling all order processing (snail mail and Paypal), magazine subscription maintenance, Atlanticon operations, and a good chunk of kitting coordination. He's a very dedicated and reliable member from the NJQRP Club and without his help AmQRP would not be able to function as quickly or effectively.

Thank you Tom, Nancy and Bryan.

THE FINAL WORD

The river of life takes us each through many twists and turns over time. Sometimes the ride is straight and the waters are calm – other times we encounter branches sticking up through the surface, or even rapids and waterfalls that must be carefully navigated.

My life is currently experiencing some of those twisting waterways and I am unable to continue editing efforts for Homebrewer Magazine. I was recently accepted into a doctoral post-grad study program in network information security, and then my current employer decided to start downsizing … so in addition to the ramping up of some careful research, I (hopefully) will be starting a new job by the time this Homebrewer hits the streets; both situations need some very careful attention going forward.

I have been doing this QRP editing thing in one form or another for more than seven years, and we've helped advance the "state of the art", so to speak, most notably in these last three issues by going to CD-ROM format. As this issue continues to illustrate, the CD medium offers terrific opportunity to bring readers the kind of interesting and useful material that nobody else can provide – and I think most subscribers agree.

Thank you all for your support over the years, and especially for your confidence as we transitioned to the CD medium. The times were rough then, but I was steadfast in my vision of being able to create a very powerful technical journal in this format, and this has now been amply demonstrated. We will attempt to recruit another managing editor for Homebrewer so that we can continue providing this kind of great homebrewing material. I will of course stay close to the scene and will certainly contribute article material to Homebrewer and other QRP magazines. After all, I've got the fever ☺

So sit back in your computer chair and enjoy digging through Homebrewer #6. Print out selected articles for use in the "reading room" or put the files on your PDA for remote study, as N2CX does. We believe Homebrewer CD Magazine is a unique and valuable contribution to our hobby and all of us writers and editors are very proud to produce it for you. We hope you enjoy it.

And remember … we do homebrewing here, and we love it. Keep the fever!

72, George N2APB *n2apb@amqrp.org*

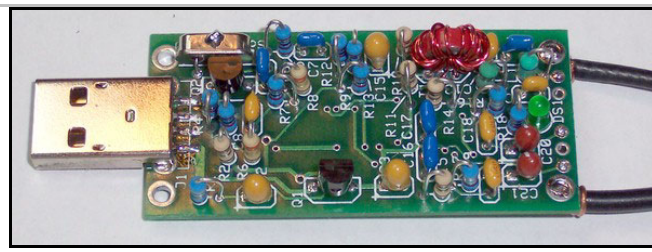
Tony Parks, KB9YIG
Bill Tracey, KD5TFD

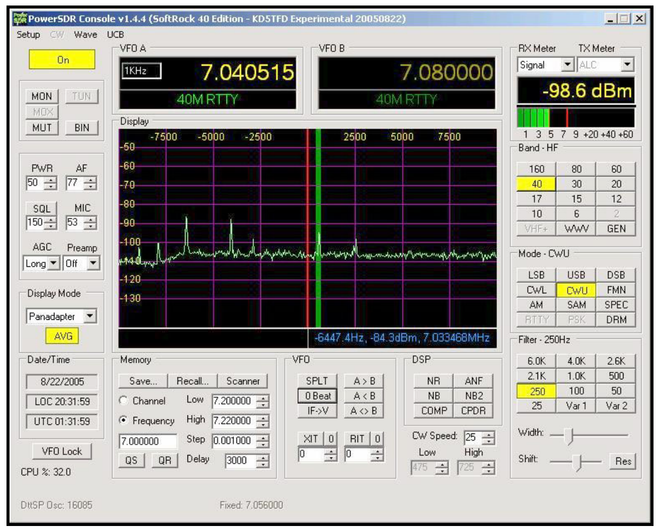
SoftRock-40

… a 40-meter SDR receiver with simply outstanding performance!

Looking for a quick and easy way to try out Software Defined Radio? If so, this project is definitely for you. By building up a bare-bones "quadrature sampling detector" and using it with freely-available software on your computer, you can make a 40m receiver that has more bells & whistles than you can shake a stick at, and get MDS performance better than -130 dBm!

To help spread the word about SDR and its capabilities, the SoftRock-40 is currently available as kit from the AmQRP Club. See ordering details at the end of the article.





The term *Software Defined Radio* used to conjure up images of heavy-duty computing iron, complex DSP circuit boards and esoteric circuits requiring one to be a digital guru in order to be able to construct and use it all. But this all changed when Flex-Radio's "SDR-1000" transceiver came to the market about 18 months ago. Gerald Youngblood, K5SDR (ex-AG5OG) designed and started selling a clever 3-board transceiver that worked in conjunction with powerful signal processing software running on a PC. This effort was chronicled in a series of four articles in QEX, and in a technical article in Homebrewer Mag issue #2, which is presented again in our current issue.

But now there is an even **easier** and **less expensive** way to play with an SDR radio! Read on …

Enter the SoftRock-40 Receiver

Ken N9VV, a digital mode aficionado within the QRP ranks, perhaps describes the SoftRock-40 the best …

> *The SoftRock-40 gets its name from the term "Software Defined Radio" and the famous "Rockmite" from Small Wonder Labs. The little receiver draws on the rich heritage of the QRP community along with leading-edge ham software technology. This miniature board receives 7030-7078 kHz using a modified version of the PowerSDR Console from FlexRadio. The SoftRock-40 draws its power from a USB port on your PC and has only two connections: ANT and soundcard line-in. The SoftRock-40 demonstrates the basic principles of SDR and is very inexpensive.*
>
> *The SoftRock-40 does not achieve the performance of the SDR-1000, however it is a fun little kit and shows you what can be done with clever hardware circuitry and very sophisticated software*
>
> *FlexRadio has presented its PowerSDR Console as an OpenSource project. That means that all the source code is readily available on the FlexRadio website at no charge.*

The original effort started just several months ago as a little 40 meter QRP CW transceiver. The idea was to promote the SDR-1000 and its mating PowerSDR software with an inexpensive way to sample the technology.

We started experimenting with a simplified version of the basic components of an SDR receiver and determined that we could indeed produce a low-cost, minimalist SDR receiver. We figured that we could start with the basic quadrature sampling detector (QSD) building block, add some buffers and interface circuits, and then use it with the same powerful PC software that is available for the SDR-1000. The results were very positive and we dubbed the receiver the SoftRock-40.

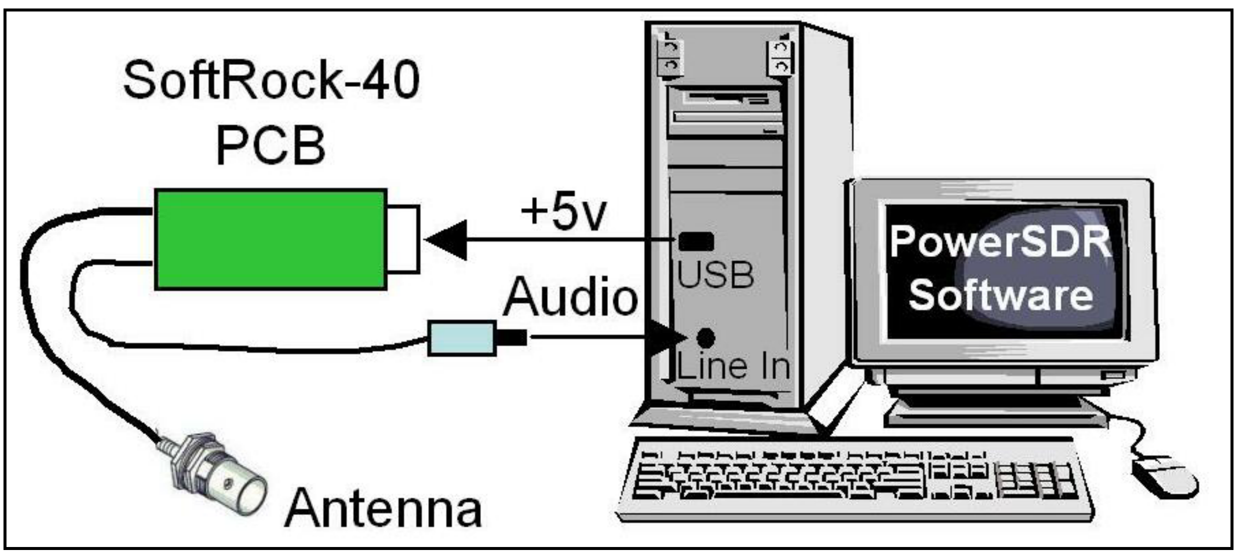


Fig 1: "Minimalist SDR Receiver"
SoftRock40 hardware + PowerSDR software

The components for the SoftRock-40 Receiver fit neatly onto a 1” x 2.3” pc board that plugs into the USB port on your PC. Merely connect an antenna, plug the audio cable into the ’line in’ input on the computer, and then run a slightly-modified version of the Flex-Radio PowerSDR Console software program. That is all you need to do to have full-featured 40-meter receiver that runs circles around some commercial radios that cost ten times more than the SoftRock-40. And to top it off, the AmQRP Club is producing a SoftRock-40 kit for only $23, so just about anyone can now try out this basic approach to Software Defined Radio! *[See kit ordering details at the end of the article – ed.]*

Fig 2: SoftRock-40 pcb plugged into USB port on a desktop computer. The little receiver is powered from the USB port. A cable supplies audio to the ‘line in’ connector for the PowerSDR software to process the I & Q signals, while another connects to a 40-meter antenna.

Design Overview

The SoftRock-40 Receiver is comprised of two major components – hardware and software. The hardware in this radio downconverts and quadrature samples a 48 kHz swath of RF that is then fed to the soundcard in a computer. The software program running on the computer then performs final tuning, filtering, AGC and demodulation.

The design work was split along the hardware and software lines. Tony KB9YIG took the initiative of designing the circuit and prototyping several iterations of the hardware, while Bill KD5TFD was the driving force on modifying and adapting the open source of the PowerSDR Console software to work with this new hardware. Of course we worked closely and frequently communicated throughout the summer, but an interesting thing is that we've never met in person! More on this collaboration aspect later.

Hardware

The hardware portion of the SoftRock-40 could not get much simpler. Referring to the block diagram shown below in Fig 3, a crystal-controlled oscillator generates a 28.224 MHz reference signal that gets buffered and divided in half twice to produce reference clock frequencies at 14.112 MHz and 7.056 MHz. These clocks are fed to a simple-yet-effective circuit called a Quadrature Sampling Detector, or QSD for short, which samples the bandpass-filtered RF signal coming in from the antenna.

As a result of the sampling, the QSD outputs two signals at audio baseband frequencies representing the downconverted RF signal where the two signals have the same frequency components but are in quadrature to each other, meaning they have a 90° phase difference. The in-phase signal 'I', and quadrature signal 'Q' are amplified and are then delivered as audio input to the line-in input on the PC for processing by the PowerSDR software.

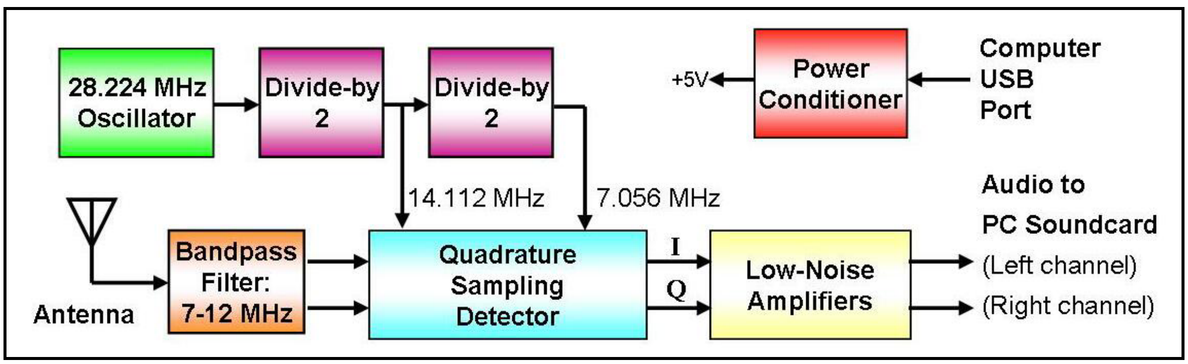


Fig 3: SoftRock40 Block Diagram

Let's take a walk through the schematic diagram and we'll describe the functional blocks and the basics of its operation. For this discussion, please refer to the SoftRock-40 schematic v3.1 located later in this article.

QSD: Quadrature Sample Detector

The heart of this receiver is the Quadrature Sampling Detector, as implemented with the FST3126 integrated circuit (U3). The FST3126 is a fast and low cost bus switch in a small package that can switch linear circuits.

Figure 4 illustrates a simplified version of the detector. It may be logically thought of as a dual-pole rotary switch rotating at the carrier frequency rate of 7.056 MHz. Integrating capacitors C16 and C17 each sample the RF signal for 50% of the carrier period – C17 integrates the RF '+' signal from 0°-90° and 180°-270° to form the quadrature (Q) component, and C16 integrates the RF '-' signal from 90°-180° and 270°-360° to form the in-phase (I) component. With I and Q, we can demodulate or modulate any type of signal.

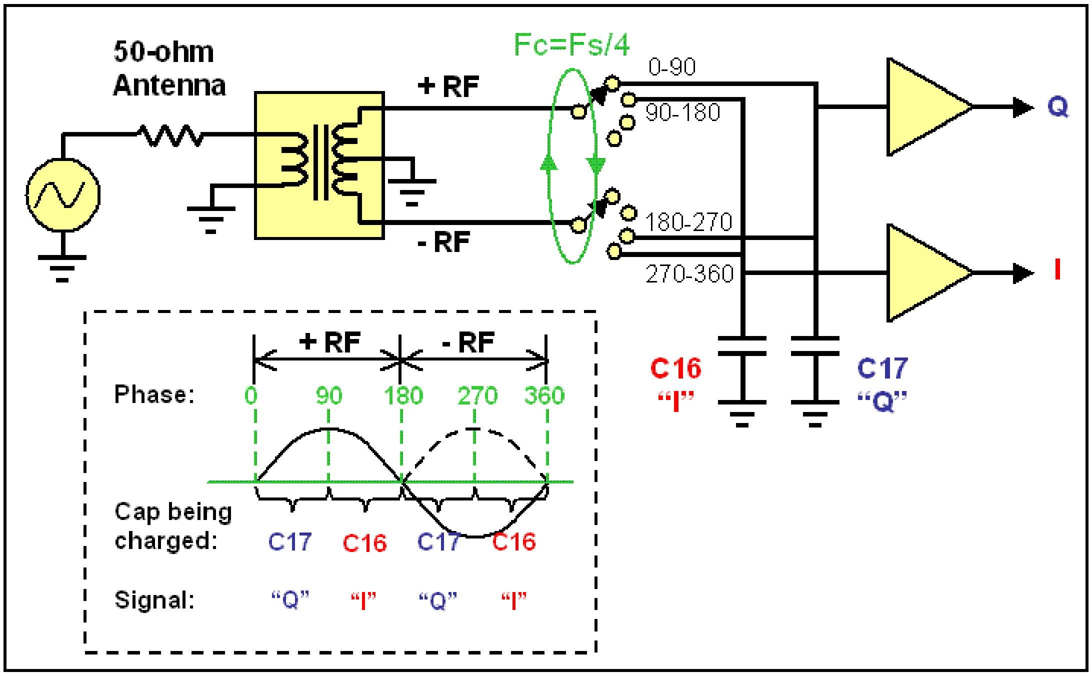


Figure 4 – Single Balanced Quadrature Sampling Detector (QSD)

The following diagram represents the waveform timing presented to the bus switch U3.

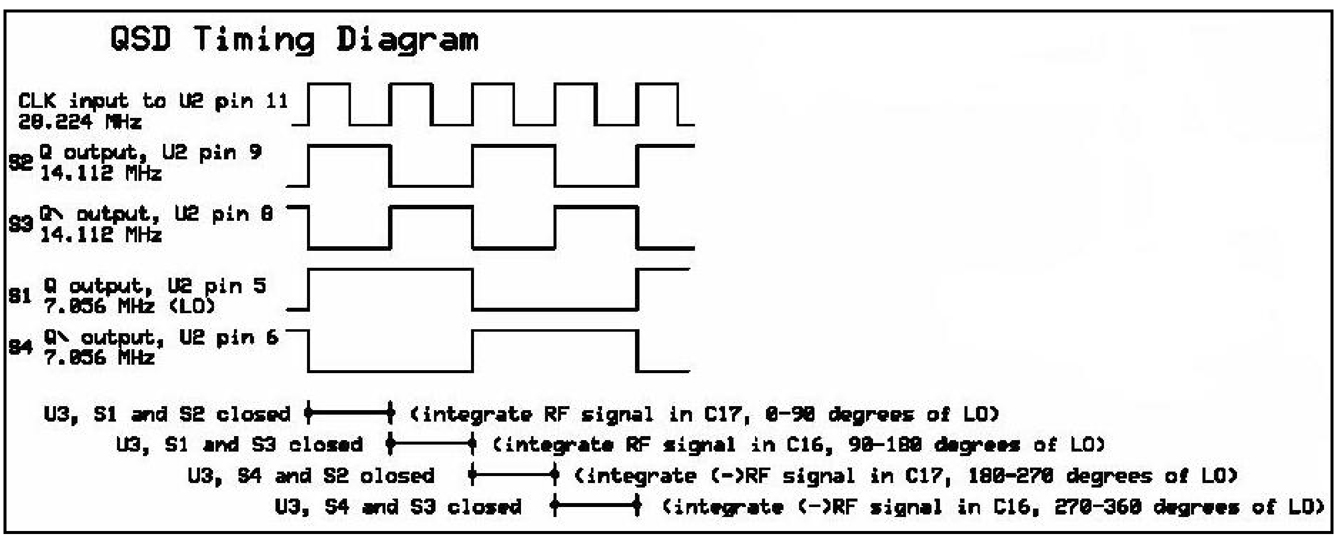


Figure 5: QSD timing diagram shows the clocking and integration time relationships.

So you can see the four equal and repeating time periods during which the switches were closed, thus charging the capacitors to produce four quadrants of signal integration: 0°-90° degrees, 90°-180°, 180°-270°, and 270°-360° referenced to the 7.056 MHz clock signal from U2. These integrated signals on the I & Q capacitors form the basis of the signals that get amplified and presented to the PC as audio for DSP processing performed by the software. The signal processing includes filtering, demodulation, AGC and various noise limiters.

Power Input

A USB Type-A connector was selected to provide 5V to the SoftRock-40 pcb. DS1 serves as a power indicator and Q1 acts as an active filter to remove high frequency noise. Its base (and hence emitter) are held at near-constant voltage by the lowpass filter R1 and C2, thus providing a relatively-clean power source to the board. The receiver only pulls about 20 milliamps so this 5V filtering circuit is quite adequate.

Crystal Oscillator: Q2

A basic Colpits crystal oscillator is employed as a reference clock generator operating at 28.242 MHz. The output level at the emitter of Q2 is about 200 mV p-p, so a high speed voltage comparator buffers the oscillator output and provides a 0-to-5 volt clock signal to a clock input of the first flip-flop in U2. At the inputs of the comparator, R6, R7 and R8 establish the comparator switch threshold.

Integrated circuit U2 contains two high-speed flip-flops and is used to produce the core timing signals required for the QSD operation. The first flip-flop divides the reference clock signal in half, as illustrated in the second waveform of Figure 4 (above), to produce a 14.112 MHz square wave. This signal is presented to one pair of QSD switches in U3. This same 14.112 MHz clock is also divided in half again by the second flip-flop to produce a 7.056 MHz clock, which is presented to the other pair of QSD switches in U3. These clocks drive the four switches to perform the four-quadrant RF signal integration illustrated in Figure 4.

RF “Front End”: BPF and T1

The SoftRock-40 front end is designed to accommodate the connection of a 50-ohm antenna. A simple 5-12 MHz bandpass filter (BPF), centered at approximately 7 MHz, is used to limit the spectrum signals reaching the QSD.

By the way, the BPF could be used to cover 30 meters as well as 40 meters, and all that would be needed to make the SoftRock-40 work on 30 meters would be a crystal in the range of 40.4 MHz to 40.496 MHz. More on this later in the “Future Directions” section.

At 7 MHz, the BPF presents a 50-ohm impedance at its input when terminated with a 50-ohm impedance at its output, which is the primary side of transformer T1. The QSD circuit on the secondary of T1 has an impedance of a little over 10 ohms, as established by R10 and R11. The square of the T1 turns ratio (13:6) reflects that 10 ohms to the primary as approximately 50 ohms, thus establishing the proper termination impedance for the output of the BPF.

The coupling transformer T1 is center-tapped so that opposite ends of the secondary represent +RF and -RF versions of the RF input signal. The + and - RF signals are needed with the arrangement of switches in U3 to properly integrate the I and Q signals in capacitors C16 and C17. One-half of the secondary is active during each quarter cycle of the 7.056 MHz clock frequency.

The center-tap of T1 is biased up to 2.5V by the resistive divider formed by R12 and R13. This ensures that the linear RF signal swing is maximized as an input to the switch, which is powered at +5V. If that center-tap point were any higher or lower than 2.5V, the RF signal being presented to the QSD switch U3 would either be clipped at 5V or 0V, respectively.

Output Amplifiers: U4

The I and Q signals produced by the QSD integrating the RF signals on C17 and C16, are amplified by two low-noise op amps contained in the single package U4. The initial design concept was to connect the output signals of the QSD directly to the line-in inputs of the PC. It was quickly pointed out by several on TeamSpeak that the noise figure of a PC sound card, typically 40 dB, was not good enough for this direct connection. Proper operation of the receiver would require low noise amplification of the two signals prior to the line-in sound card inputs.

The same voltage divider that biased up the center-tap of T1 is also used to establish a bias on the inputs of the OPA2228 low-noise amplifier (U4). In this way, the inputs are also operating at the same level to maximize the linear range of the amplified I and Q signals.

The voltage gain of each op amp is about 500, as established by the classic Av=Rf/Rin formula. This would be 4.99K/10 for each signal path, where the feedback resistors are R16 and R17, and the input resistors are R10 and R11.

The approximate overall voltage gain of the system, from RF input to I and Q audio outputs to the computer, is about 35 dB. A -30 dBm RF signal on the input corresponds to an audio output of about 1.05 Vpp on each of the I and Q outputs. Clipping started at about -20 dBm.

The I and Q audio signals are then routed off the board to the computer by means of a shielded stereo cable terminated in a 3.5mm stereo plug.

Software

The software part of the SoftRock-40 project turned out to be rather straightforward, building on the solid foundation of the PowerSDR Console software program created for the SDR-1000 transceiver hardware. All that was needed was some fairly simple changes to the PowerSDR code to handle the SoftRock-40 board. Most of these changes were in the area of tuning and hardware control. More on these changes later.

The PowerSDR Console program presents a virtual front panel that looks just like the front of a real fancy (read: expensive) transceiver with lots of pushbuttons, controls and a graphical spectral display of the received frequency.

Most controls in the software perform a single function. Some might say: "I am accustomed to using a tuning knob, but there's no tuning knob on my PC!" The PowerSDR Console actually uses a unique mousewheel tuning control. If you've got to have a tuning knob, there are knobs available that attach via USB port that work well with the PowerSDR software. The **ShuttlePro** (www.contourdesign.com/shuttlepro/) and the **PowerMate USB knob** from Griffin Technology (www.griffintechnology.com/products/powermate/) have both been used with the PowerSDR software.

It is amazing how many features Flex Radio has packed into the PowerSDR Console software. Ten different bandwidth settings can be selected with a click of a button. The widest is 6 kHz and the smallest 25 Hz. Other selectable values are 4, 2.6, 2.1, and 1 kHz, and 500, 250, 100, 50, 25 Hertz. All filter bandwidths are available; there is no need to buy expensive crystal filters - it's all in the software. If you need a very special bandwidth setting, you can change the software for any bandwidth between, say, 10 Hz and 40 kHz. It is "Free (as in freedom) software", with source code freely available under the GNU Public License, and one can make custom changes in the code using the C# and C source code provided by Flex-Radio … and this is just what I did to adapt PowerSDR Console to control the SoftRock-40 hardware.

The pairing of the relatively simple SoftRock-40 with the powerful PowerSDR software makes for a surprisingly full featured homebrew receiver. All the features of a major commercial receiver, multiple filters, all mode operation, and CAT control are all available through the software.

For a more complete description of the PowerSDR Console software, including a walk-through of its controls and functions, see the SDR-1000 article in this issue written by Gerald Youngblood K5SDR himself!

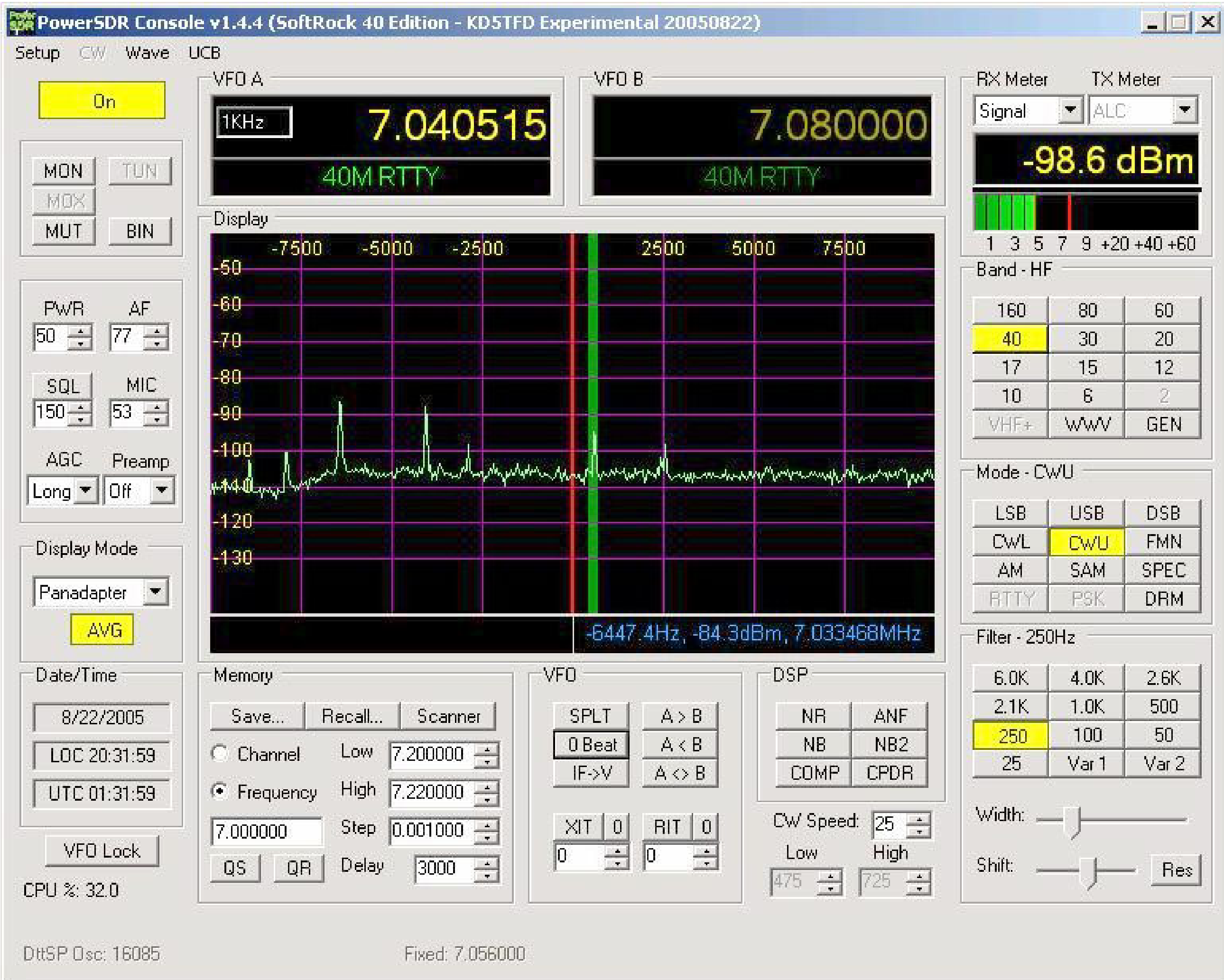


Figure 6: The SoftRock-40 “front panel” is based on the PowerSDR Console software from Flex-Radio.

The changes needed to make the existing PowerSDR software work with the SoftRock-40 were fairly minor. The existing PowerSDR code is composed of a number of major pieces of code. The Console code handles the GUI and screen drawing, a DSP engine that does all of the filtering and demodulation and a hardware control block that controls the SDR-1000 hardware.

To adapt this code for the SoftRock-40 only a few minor changes were needed. In the hardware control layer, all that was needed was to change it to ignore the fact that there was no hardware to control, as the SoftRock-40 has a fixed oscillator.

The second necessary change was to adapt the tuning code in the PowerSDR to the SoftRock-40’s fixed-frequency oscillator. Tuning is accomplished in two steps. The first tunes the DDS hardware (that drives the QSD) to be about 11.025 kHz below the signal of interest to avoid spurs from the DDS. The tuning of the DDS is limited to frequencies that generate a minimum number of spurs.

The second step of tuning actually happens in a software mixer in the DSP code running on the PC. It mixes the approximate 11.025 kHz input from the hardware down to baseband. The actual frequency used in the DSP mixer is adjusted to compensate for the spur-avoidance tuning of the DDS.

This hardware and software down conversion architecture allows the SDR-1000 to avoid DDS spurs and also to avoid noise and gunk around DC.

For the SoftRock-40, we just needed to change the tuning code to use only the DSP software mixer for tuning. The Console code also limits tuning to +/- ½ the sampling rate (48 kHz in the current code) of the central frequency of the SoftRock-40.

The latest level of PowerSDR modified for the SoftRock-40 can be found at: http://ewjt.com/kd5tfd/sdr1k-notebook/sr40/sw.html. The source code and executable files are both provided. The web page also has instructions on how to setup and run the software with the SoftRock-40.

Future Directions

As previously mentioned, the SoftRock-40 represents a minimalist SDR design, meaning that it cannot compete with the designs of more complex software defined radios like the SDR-1000 from Flex-Radio. However the low-cost nature and sheer simplicity of the SoftRock-40 hardware, when combined with the incredible power provided through the PowerSDR software running on the PC, all work together to make the project an astounding value. The educational benefit gained by using these basic circuits, and the excitement of operating a receiver with this degree of performance cannot be overstated.

We are already considering some enhancements that would increase the utility of this "SDR demonstration" project.

The 74AC74 used for U2 provides an upper limit in its current configuration; we can reach 30m fairly easily, but may have trouble at 20m. An asymmetry of clock signals comes about from the delay in switching within the chips, resulting in the 7 MHz clock getting too far delayed from the 14 MHz clock to maintain the symmetry in the QSD. The HC parts were preferable from this perspective but didn't have the performance. With different components, higher frequencies may be achieved.

The LO presents a fairly strong "bleed-thru" signal and some of the spectrum is thus unable to be used because of the artifacts of the mixing architecture. When trying to tune down close to the spike one runs the digital oscillator at around 100 Hz, and with 60 Hz noise present the mixing products will be at 40 and 160 Hz. Perhaps some adaptive noise filters in software would be able to help out a lot in the future.

Pairing up the SoftRock-40 with a DDS chip and some computer control logic, along with some adaptations to the PowerSDR to control the DDS, would make a very capable receiver with some unique capabilities. See the next two sections where we describe the efforts done by KD5TFD and N2APB in this area. Such an approach to creating a computer-controlled receiver like this might use the Dream Digital Radio Mondiale (DRM) software decoder to listen in to Digital Shortwave that is starting to appear on the air.

We may try adding a USB-based sound chip to provide a direct interface to USB so it can be used with any computer with a USB port - no sound card required! For laptops, this is especially cool because most of them lack a stereo 'line in' connector for the internal sound card.

The current QSD bandwidth is about 48 kHz, as set by the sampling capacitors and the feedback capacitors on the I and Q amplifiers. These capacitor values would need to be reduced proportionally in order to use 96 or 192 kHz sampling rates.

Doing a Linux version is another thing to be done. The core DSP code (DttSP) runs on Linux, so all that is needed is a nice GUI console to go along with it. On Linux, there is also the GNU Radio (www.gnu.org/software/gnuradio/) code that should work with this board.

The neat thing about all of this is that most of the enhancements that go into the PowerSDR code will also be useful for the SoftRock, so it will get more features over time as people extend the software.

We'd also like to try the SoftRock with some of the other SDR software currently available. We've already used the board with Alberto Di Bene's (I2PHD) SDRadio (http://sdradio.org) program with good results. Phil Covington (N8VB) is planning on doing a SoftRock-40 version of his PowerSDR-derived SharpDSP code. This can be found at www.philcovington.com/SDR.html. A neat feature currently in Phil's code that will soon be available in PowerSDR is the capability to have multiple simultaneous receivers within the bandwidth sampled by the sound card. Since it is all just software, having multiple receivers within the swath of RF coming from the hardware is only a simple matter of software. You would just need to setup another software mixer, filtering and demodulation chain and you've got multiple receivers.

Software changes required for a second simultaneous receiver include a second software mixer along with a second filtering and demodulation chain. GUI changes would also be needed to show what frequency the second receiver is tuned to and its selections for the filter bandwidth, mode, etc. Sounds like this would be a good way to listen to the QRP fox and all those hounds at the same time!

"Using a DDS Card to Drive the SoftRock-40" *... Bill, KD5TFD*

When I built my SoftRock-40, I wanted to perform some experiments and pair it up with a DDS Daughter Card from the AmQRP to give it more tuning range, so I replaced some of the components on the SoftRock-40 board with headers so I could tie-in the DDS signal from the daughtercard.

Specifically, I replaced the Q1 pass transistor with a 78L05 5V regulator and did not populate R18 and R1. I also put headers in place of R2 that powers the crystal oscillator, and C8 that feeds the output of the oscillator to the comparator. I also mounted headers at R18 (for input power to the 78L05) and at C2 (shorted together for ground). I then built a little daughter board where I mounted R2 and C8 so I could run the basic stock version of the SoftRock-40.

The basic version works great. IQ amplitude and phase balance of the down-converted signal looks good and is easily balanced using the PowerSDR software. A modified version of PowerSDR tunes +/- 24 kHz using the DttSP receive oscillator (www.dttsp.soundforge.net). I also looked at the IQ output of the board from 6.9 MHz to 7.2 MHz. The amplitude and phase response look fairly linear in this range, so tuning wider ranges should be quite workable when using 96 kHz and 192 kHz sampling rate sound cards.

Using an NJQRP DDS Daughtercard and an Atmel AVR Butterfly controller card, I was able to create a VFO using KD1JV software. I figured this would make a good LO to drive the SoftRock-40, so I connected them all together using a carrier board from ERCOS Technology, with the result shown below. *[Online links for all these components/vendors are given in the Notes section at the end of the article. – ed.]*

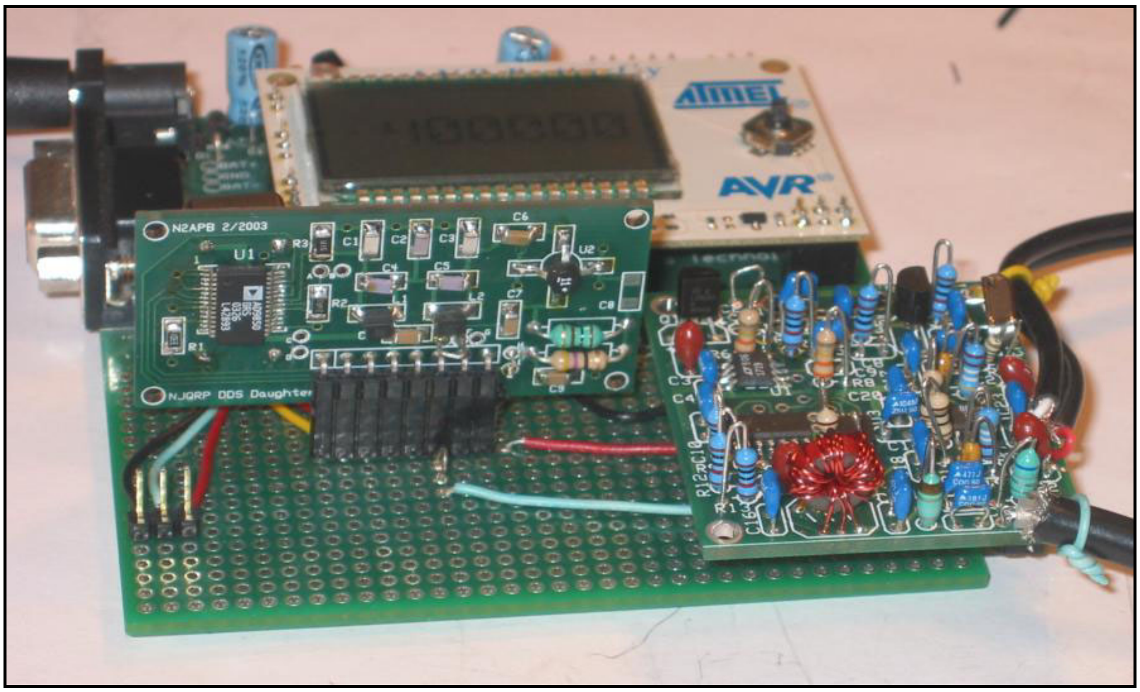


Figure 7: SoftRock-40 (on right) being controlled by an AVR Butterfly card driving an NJQRP DDS Daughtercard, thus replacing the fixed crystal oscillator and allowing the SoftRock-40 to reach across the entire 40m ham band. ***[Note: The square pcb SoftRock-40 board used in this experiment was an earlier prototype. – ed.]***

In this lash up, the Butterfly and KD1JV's software is used to control the NJQRP DDS Daughtercard. The output of the DDS card is fed via a 47 pF cap to the SoftRock-40 through the header installed in place of C8. The header at R2 is left open, disabling the oscillator on the SoftRock-40 board.

Results of the breadboard are quite good. Using the DDS card to drive the QSD allows the tuning range of the SoftRock-40 to be moved all over the 40-meter band.

"Using a <u>new</u> dual-DDS Card to Drive the SoftRock-40" *… George N2APB*

While working with Lyle Johnson (KK7P) on a new dual-DDS card that he is developing, reported in a separate article in this issue, it dawned on us that we might be able to generate the quadrature clocks using two independent DDS chips as the local oscillators of this IQ receiver. Having precise frequency and phase generation capability with the two DDS chips, we suspect that the "DDS2" card plus the generic SoftRock design with replaceable bandpass filters on the front end would allow us to create a low-cost, stable and powerful multi-band SDR rig.

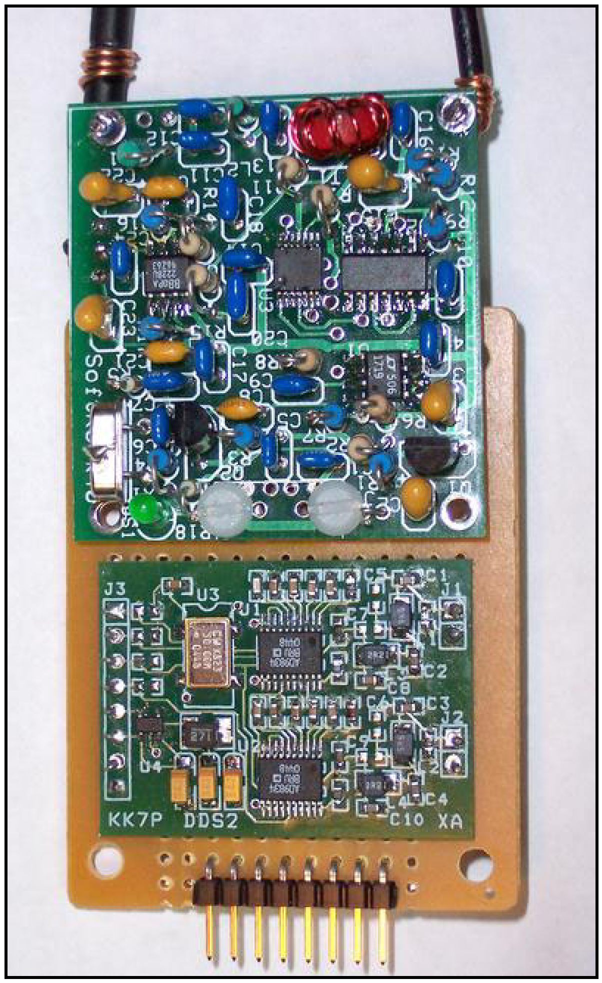


Figure 8: New KK7P "DDS2" card (bottom card) serving as an extremely flexible and precise dual clock generator for a prototype of the SoftRock-40 receiver (upper card), making multi-band operation possible. This sub-assembly can be plugged into the AmQRP Micro908 motherboard in place of its current (single) DDS Daughtercard. With a new software driver for this DDS2 card, the Micro908 rotary encoder and LCD serve as the "front panel" for controlling the SoftRock-40 receiver operation anywhere on the 40m ham band.

Further integration of a DDS and a microcontroller with a SoftRock-40 would allow for an inexpensive full band coverage SDR type receiver. Here's an example of what we mean.

Shown below is a photo of the KK7P DDS2+SoftRock cards positioned inside the AmQRP Micro908 instrument. Since the Micro908 has the rotary encoder and pushbuttons for user controls, LCD, and DSP card for demodulating the audio IQ signals, one can easily envision how a self-contained and portable SDR rig can be developed without being tethered to a PC!

Figure 9: DDS2+SoftRock board in place inside the Micro908 instrument. The Micro908's user interface and built-in nature of the DSP card (daughtercard in the lower right corner) make a standalone Software Defined Radio quite possible. In this prototype, the SoftRock audio signal cable is plugged into the input jack of the Micro908 enclosure (cable input at upper left of diagram), which then routes the audio signals over to the DSPx Daughtercard on the motherboard.

Teamspeak Collaboration

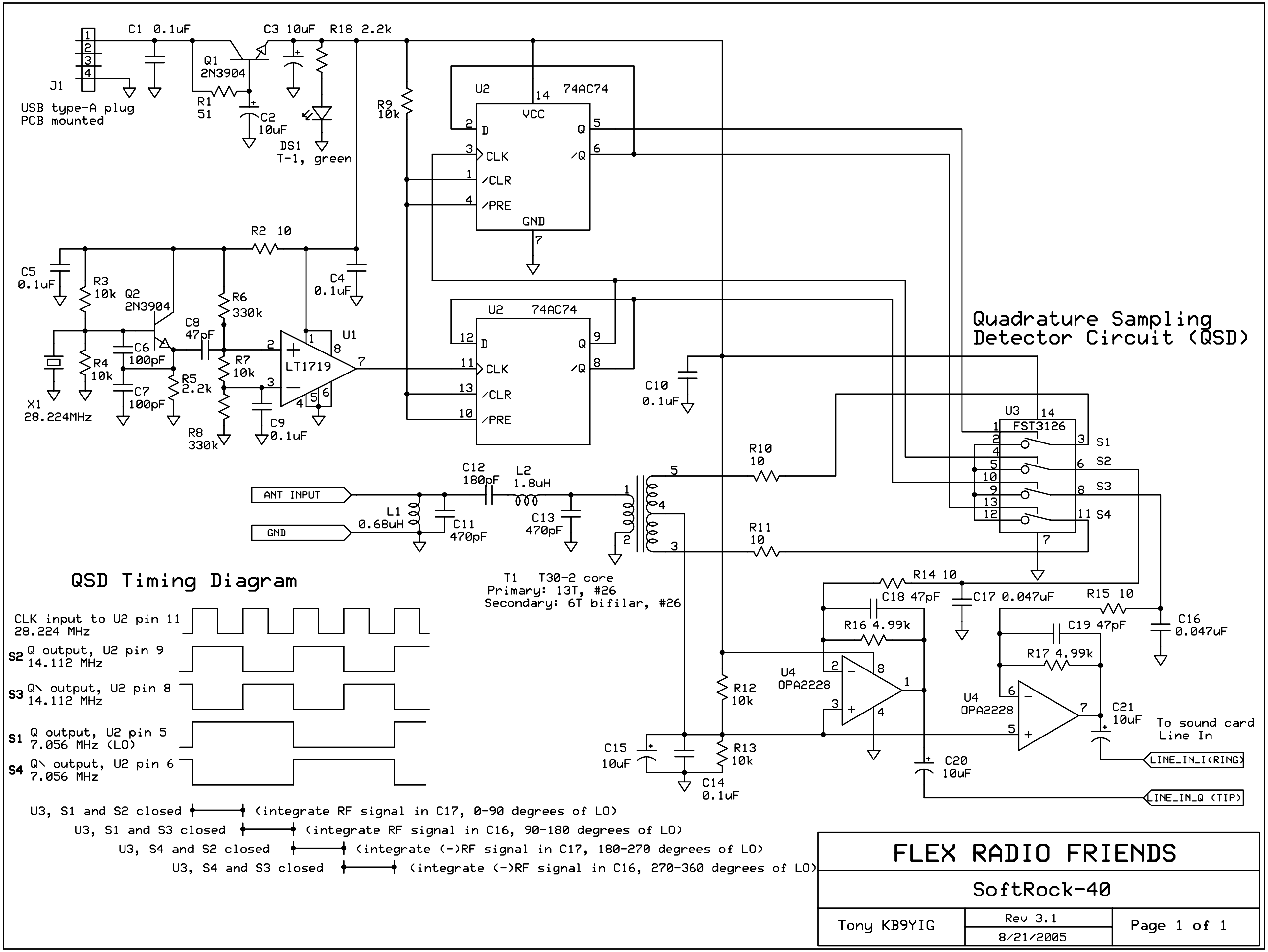
One of the things that made this project possible was the collaborative environment available on the Internet these days. In particular the Flex Radio Friends Teamspeak VoIP conferencing server hosted by AA4SW provided a great virtual place for hams experimenting with SDR technology to meet and talk shop. The breadth and depth of the skills the amateur community has is truly amazing, and to be able to tap into this community knowledge was one of the things that enabled the design of this board. I believe amateurs on four continents contributed ideas and suggestions on the design of the radio as its design evolved.

Thanks & Acknowledgement

This has been a fun project to put together. Thanks to Steve Weber (KD1JV) for publishing his Butterfly DDS code, and to the NJQRP folks for their DDS Daughtercard. Thanks to Lyle Johnson (KK7P) and George Heron (N2APB) for working on some of the advanced uses of the basic design, and to the AmQRP Club for making the SoftRock-40 kit available, thus enabling many others to experience this same excitement.

Also thanks to all the Flex Radio Friends who collaborated with us along the way on TeamSpeak, tossing around ideas on building a simple SDR receiver.

And thanks especially to Gerald Youngblood (K5SDR), Bob McGwier (N4HY) and Frank Brickle (AB2KT) for the GPL licensed PowerSDR and DttSP software, and for the pioneering they did in developing the SDR-1000 transceiver, upon which the SoftRock-40 is based.



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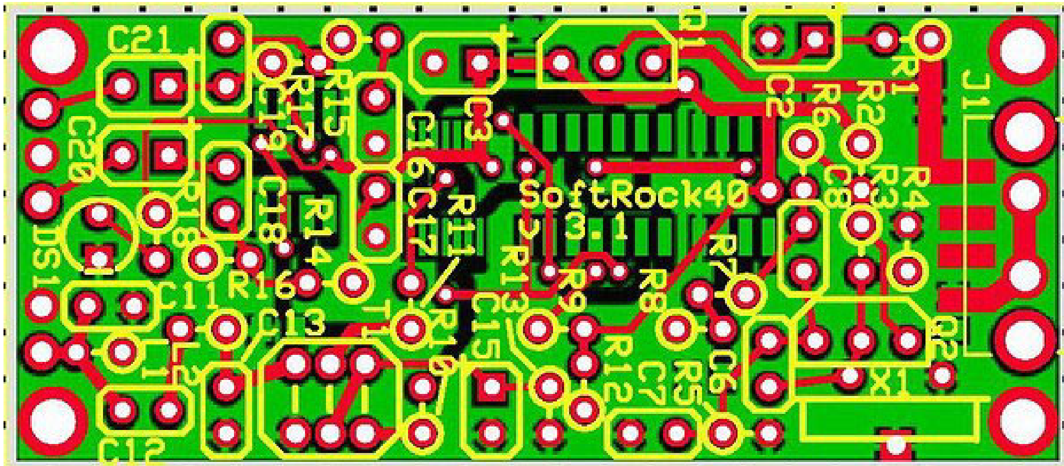
Parts Layout for the SoftRock-40 v3.1:

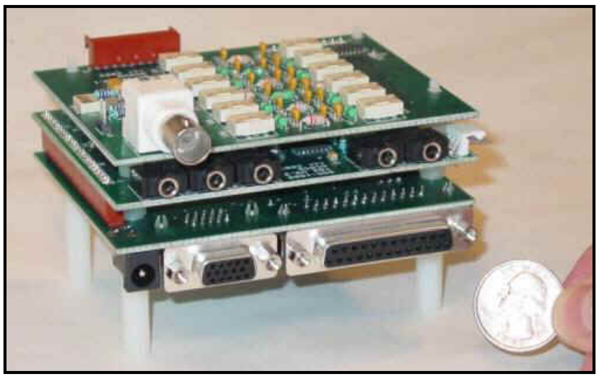


Parts List for the SoftRock-40 v3.1 (Aug 3, 2005):

QTY	Designators	Part description
6	C1, C4, C5, C9, C10, C14 (all on bottom of board)	0.1 uF ceramic, smt 0805
5	C2, C3, C15, C20, C21	10 uF, 16 V, Tant., 0.1 in. lead spacing
3	C8, C18, C19	47 pF, 0.1 in. lead spacing
2	C6, C7	100 pF ceramic, 0.1 in. lead spacing
2	C16, C17	0.047 uF, ceramic, 0.1 in. lead spacing
1	C12	180 pF, ceramic, 0.1 in. lead spacing
2	C11, C13	470 pF, ceramic, 0.1 in. lead spacing
5	R2, R10, R11, R14, R15	10, 1/4 W
6	R3, R4, R7, R9, R12, R13	10k, 1/4 W
2	R5, R18	2.2k, 1/4 W
2	R6, R8	330k, 1/4 W
2	R16, R17	4.99k, 1/4 W
1	R1	51, 1/4 W
1	L1	0.68 uH, axial lead inductor
1	L2	1.8 uH, axial lead inductor
1	T1	T30-2 core, 13T primary wound first with #26 wire
		6T bifilar secondary wound on top of primary with #26 wire in same direction
		Primary connected to via's next to C13.
1	X1	Xtal, 28.224 MHz, HC49US case, mound on side
		with case grounded by bus wire to square via
2	Q1, Q2	2N3904, NPN, TO-92 pack
1	DS1	T-1 LED, green
1	U1, nearest to J1, note "1" mark in copper at pin 1	LT1719CS8, SOIC 8
1	U2, note "1" mark in copper at pin 1	74AC74, SO14
1	U4, other end of board from J1, note "1" mark in copper at pin 1	OPA2228, SOIC 8
1	U3, note "1" mark in copper at pin 1	FST3126MTC, TSSOP 14, 25 mil lead spacing
1		USB A male pcb plug, smt pins
1		1/8 inch stereo cable with plug on one end, 3 ft.
1		RG174U, 4 feet, for antenna connection to board
1		PCB, SoftRock40 receiver

NOTES:

1) **SoftRock-40 Kit** – The AmQRP Club has kitted the SoftRock-40 Receiver version 3.1, as described in this article. Complete details can be found at www.amqrp.org/softrock40. The kit is available for $23 (US & Canada) and $28 (DX). Write check or M.O. payable to "The American QRP Club, Inc." and send to …
   The AmQRP Club, Inc.
   c/o Bryan Williams, AA3WM
   1706 Pheasant Court
   Easton, PA 18040
2) **SoftRock-40 Project Page** – The AmQRP Club is maintaining a master web page containing all the latest information and resources in support of the SoftRock-40 Kit. The project page is located at www.amqrp.org/softrock40.
3) **Flex-Radio SDR-1000:** www.flex-radio.com/




4) **K5SDR article series in QEX**: "A Software Defined Radio for the Masses": http://www.flex-radio.com/articles_files/
5) **SoftRock-40 Software**: www.ewjt.com/kd5tfd/sdr1k-notebook/sr40/sw.html
6) **NJQRP DDS Daughtercard** (www.njqrp.org/dds)
7) **Atmel AVR Butterfly controller card** (http://www.atmel.com/dyn/products/tools_card.asp?tool_id=3146)
8) **Steve Weber's (KD1JV) "Butterfly+DDS Daughtercard VFO Software"** (http://www.qsl.net/kd1jv/bfydds.HTM).
9) **Butterfly Carrier Board from ERCOS Technology** (http://www.ecrostech.com/Products/Butterfly/Intro.htm).

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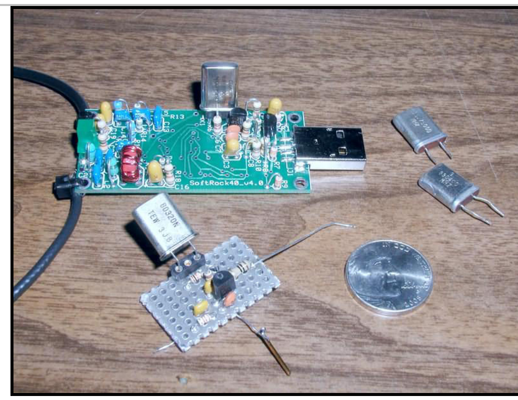
Bruce Beford, N1RX

The SoftRock-30

Make several easy modifications to the popular SoftRock-40 ***software defined radio*** *receiver and put it on 30 meters!*



When the SoftRock-40 “software defined radio” receiver kit was announced by the AmQRP Club, I had to have one, or rather several. Having learned from past experience that many interesting kits have limited availability, I ordered early and was lucky enough to get my orders on the list. While waiting for the kits, I downloaded the PowerSDR software from Flex-Radio and the modified files from Bill Tracey, KD5TFD. These modified files were necessary to make the Flex-Radio software work with the SR-40. Installation went smoothly and I was able to test the software with some sound files available on the Flex-Radio web site (www.flex-radio.com).

Once I had the software up and running, I turned my attention to studying the schematic and theory behind this little wonder. The quadrature sampling detector, or QSD, samples the incoming, bandwidth-filtered signal and converts it to two baseband audio streams related by quadrature, or 90 degrees out of phase. These are the I (inphase) and Q (quadrature) audio outputs to the computer’s sound card. With this hardware, the software is able to “tune” across a 48 kHz wide range of the radio spectrum. The implementation used in the SoftRock requires a local oscillator running at four times the desired center frequency. The softRock-40 kit has a LO running at 28.224 MHz which sets a center freq of 7.056 MHz. (28.224 divided by 4). Thus the SR-40 uses the computer to “tune” from about 7.032 to 7.080 MHz.

I immediately began to think about the possibility of adapting the SoftRock-40 for use on other bands. According to the AmQRP web site, the front end filter was set up to pass from about 7 to 12 MHz signals. The 30m band from 10.100-10.150 Mhz fits within the bandpass of the filter, and is 50 kHz wide. I reasoned that the SR-40 could be converted to 30m with very little change. All I had to do was get the QSD to center on a freq of 10.125 MHz, which would require an LO frequency of 40.500 MHz. If I could get the LO on 40.5MHz, I could cover practically the entire 30m band! The quest was on.

I checked my not-inconsiderable junk box for crystals. A frequency of 40.5 MHz is not real popular and I didn’t have any luck. I did some online searching, called a few surplus vendors that I have dealt with in the past, and found someone who had quantities of 40.500 MHz crystals in HC-49U holders. These could be just what I was looking for! He would only sell in quantities (or multiples) of 100, however. His price was very reasonable, considering the quantity, so I ordered 100. I looked at the manufacturer's web site, and checked the specs while waiting on them. They looked like they may work, so I made a preliminary posting to the QRP-L email list, to let others know what I was up to. If they worked out, I would make them available to all. Several people got back to me, and asked to be placed on a waiting list if the crystals worked out in the SoftRock. I also heard back from a very knowledgeable list-member who cautioned me that most crystals above about 24 MHz are third-overtone, rather than fundamental mode crystals. I double checked the spec sheet against the part number I was given. The manufacturer claimed that these were fundamental mode, BT-cut crystals (rather than the more common AT cut.) I was hopeful they would work, but was still waiting for the SoftRock kit itself, as well as for the crystals.

Before too long I had my SoftRock-40 kits and the new crystals in hand. I have done enough experimenting in the past to know that you first get something working in its original intended state, before you go futzing with it. The only change I made initially was to install a crystal socket of sorts, made from an old machined-pin IC socket. I cut a strip of three pins from the socket, and then removed the center pin … voila, a crystal socket. I plugged in the original 28.224 crystal and fired it up. It worked first time, with the sweet sounds of 40m CW filling the shack from the computer speakers. Success, and pretty cool!

After playing around on 40 meters to get the feel of the radio and software, I decided to try the crystals for 30m. With fingers firmly crossed, I installed the 40.500 MHz crystal. Nothing. Okay, this is not going to be "plug and play". I looked at the schematic and saw a common Colpitts oscillator configuration using a 2N3904 transistor. This transistor should be able to run at 40 MHz, so I didn't feel that was the problem. My gaze fell upon capacitors C6 and C7. The original values of 100 pF seemed a bit high for operation at the frequency I was trying. Time to experiment.

The fine traces and pads on the SoftRock-40 PC board would be quickly destroyed by repeatedly soldering and desoldering components to try different values. Therefore, I decided to breadboard a copy of the oscillator circuit. I made one up on a piece of perfboard with the original 100 pF caps for C6 and C7. Again, the original crystal would oscillate, but the 40.5 MHz version would not. I then tried removing the caps completely. The 40.5 MHz would work, but the 28.244 version would not. I settled on 33 pF capacitors for both C6 and C7. Using this value, both crystals (and all others I tried in the range on 8-40 MHz) would oscillate just fine. I then carefully removed the original caps from my SR-40 and replaced them with 33 pF caps. It immediately sprang to life with the 40.500 MHz crystal installed. I was on 30 meters with the SoftRock! I switched back to the 28.244 MHz crystal for 40 meters, and it still worked fine.

To get the PowerSDR software to read out the correct frequencies on 30m, you must change a setting in the program. Go to the Setup mode, and select the SoftRock tab. Uncheck the box that says "Fixed HW Osc". Enter the new center frequency of 10.125 in the Freq box, then re-check the Fixed HW Osc box. That's it. For the most precise readout, I compared the displayed frequency in PowerSDR with my Elecraft K2 listening to the same signal. I know the K2's calibration and drift characteristics. I then modified the center frequency entered in PowerSDR to eliminate any difference between the two rigs and I ended up with a new Fixed HW Osc frequency of 10.124360 MHz. This put me right on with the crystal I used. The crystals I have are plus or minus 100 ppm. That means up to 4 kHz difference at 40 MHz. After the division done by the SoftRock's clock circuitry, there is up to 1 kHz difference at 10 MHz. So my setting of minus 640 Hertz is right in there. Some slight tweaking of the image reject settings may also be needed for optimum performance when switching bands.

Figure 1 shows the modified oscillator schematic. The only changes from the original are the value of C6 and C7. The original 100 pF capacitors are replaced with 33pF. A socket for the crystal or a switch could be added to allow quick band changes. No other modifications are needed.

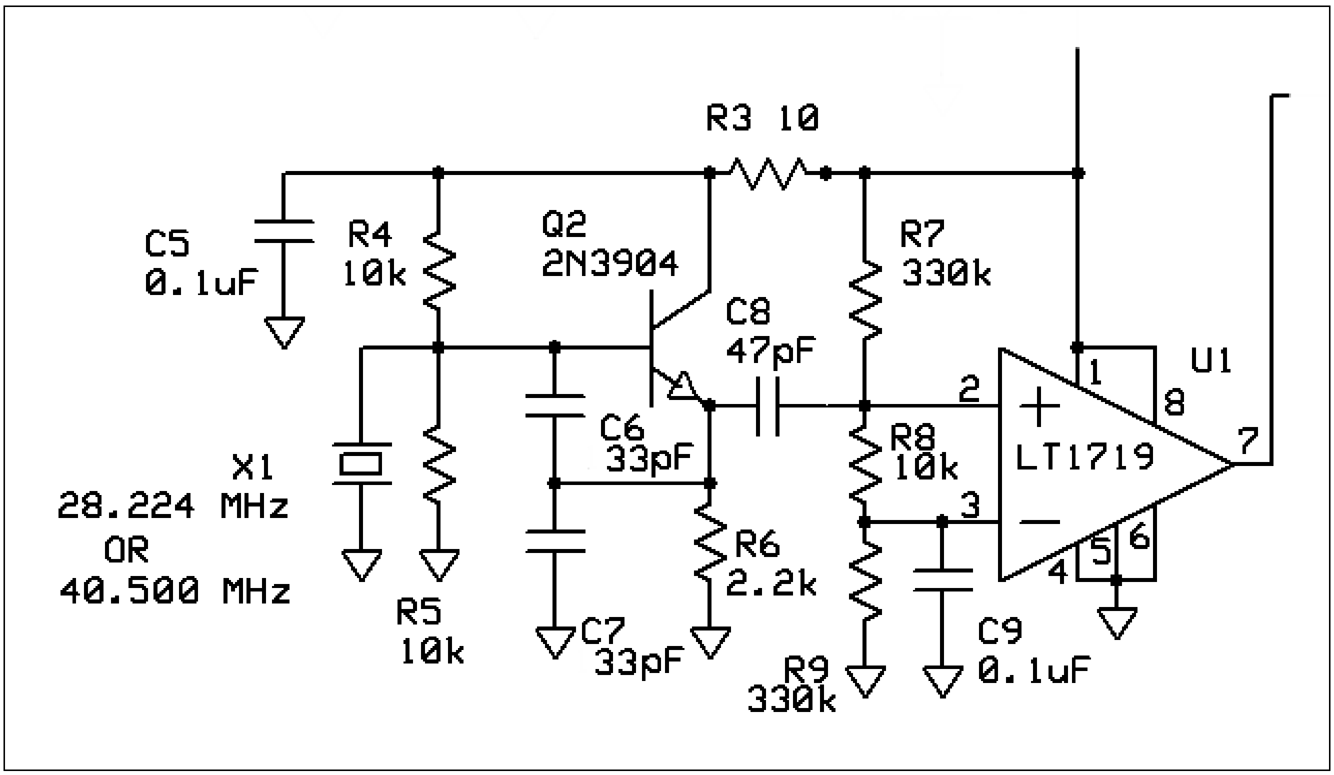


Figure 1: C6 and C7 values modified from original schematic allow use of 40m or 30m crystal

Figure 2 on the next page shows a photo of the modified hardware and the breadboard oscillator I used for my experiments. On the SoftRock-40 pc board, C7 and C8 are the two orange disc caps just in front of the crystal. The crystal is mounted in a socket, which can be seen more clearly on my breadboard oscillator.

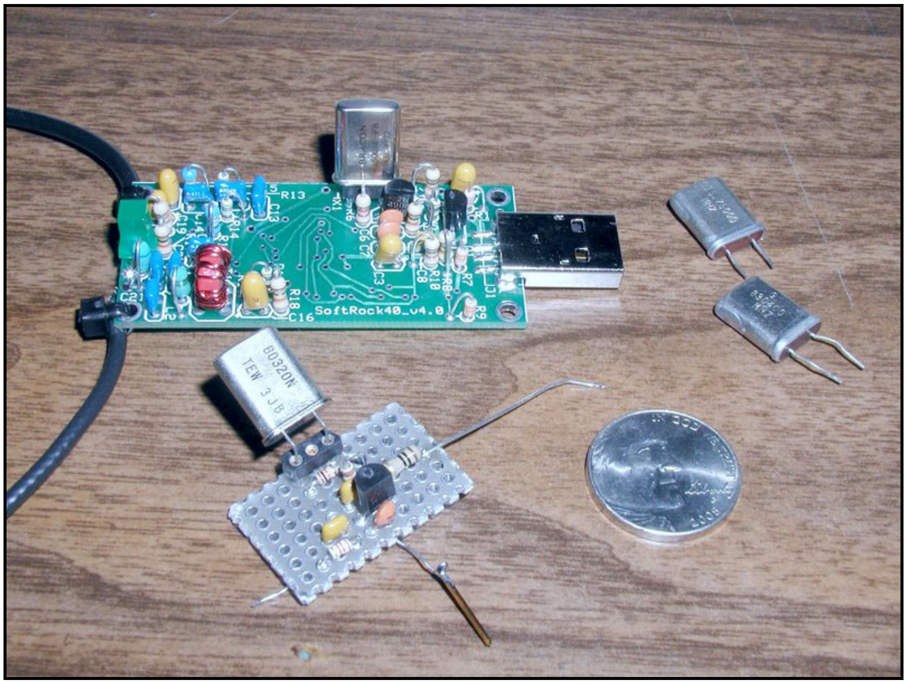


Figure 2: Modified hardware with breadboarded oscillator

There are other ways of moving the SoftRock's tuning around. Mounting the coupling cap C8 on a two-pin header would make for an easy way to disconnect the on-board oscillator. I have done this on one of my SoftRocks. This would allow LO injection from an outside source, like a DDS circuit. For sheer simplicity and signal purity, however, it is hard to beat this change to the onboard crystal oscillator. The fact that a crystal was found for the exact frequency required to cover the entire 30m band makes it seem like destiny.

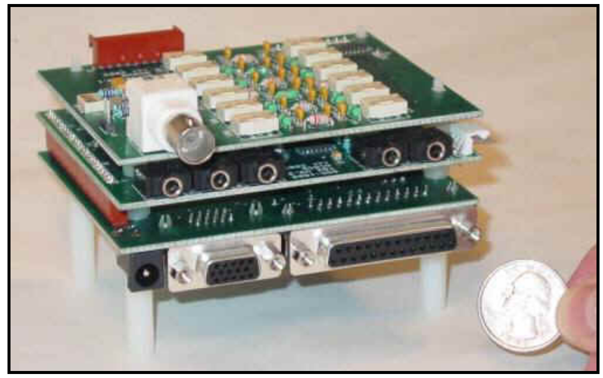
As of this writing I have shipped nearly 100 crystals to other experimenters so they can modify their SR-40s for 30 meter operation. I am making arrangements for a large quantity of the 40.500 MHz crystals so I may continue to provide them to those who also may want to make this modification on their own SoftRock-40. Interested parties may contact me via email at bruce.beford@verizon.net. A big thank you is due to Tony Parks, KB9YIG, and Bill Tracey, KD5TFD for the SoftRock-40 design and software, and to the kitters at AmQRP for working to make this fine project available to so many of us.

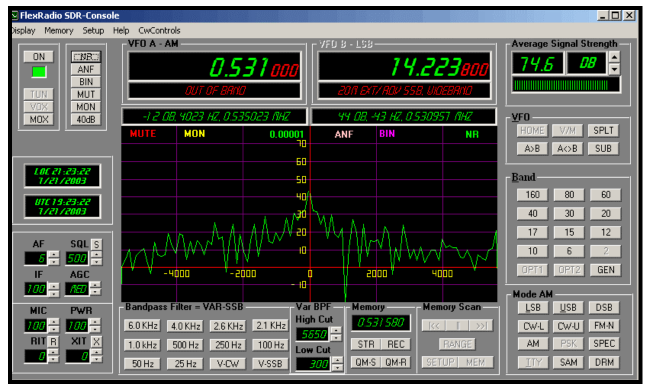
Bruce Beford, N1RX
Newport, NH

Gerald Youngblood, K5SDR

Homebrew Software Defined Radio with the SDR-1000 Transceiver

In 2002, K5SDR (ex-AC5OG) published a 4-part series in QEX concerning "Software Defined Radio" - a radio architecture in which signal processing is accomplished with software. The series concluded with the presentation of the SDR-1000 transceiver, which is of great interest to homebrewers and advanced experimenters.





Gerald Youngblood, AC5OG[2] is pushing the state-of-the-art of homebrewing ham radio equipment to new heights by producing leading-edge technology within the reach of average hams. This article sheds light on the main features and architecture of his dc-65 MHz "SDR-1000": a fully featured continuous receive, ham band transmit, all mode transceiver for experimentation and general use.

The SDR-1000 transceiver is an exciting radio to add to the ham shack. It brings state-of-the-art DSP capabilities to the ham and SWL user. The transceiver requires a 600 MHz PC (or faster) to run its large selection of powerful tools for receiving and transmitting. With 1 Hertz tuning steps from its DDS-VCO, the transceiver covers 12 kHz to 65 MHz in an ever-increasing number of bands.

The SDR-1000 is not an average computer controlled-transceiver. A minimal amount of hardware provides a DDS-VCO with a bi-directional I and Q mixer and a 2-watt PEP output amplifier. The PC does the rest. That includes sideband generation & demodulation as well as an array of AM & FM modes, soon to include PSK & RTTY. The PC also provides spectrum display and an array of filters and noise suppression options. By providing a high dynamic range input into the PC sound card, the computer can get to work and provide razor sharp DSP filtering to the signal that makes commercial hardware filters seem antique.

A complete description of the design can be found in a four part series in QEX[3]. Together with its numerous references, this series is a great tutorial on Software Defined Radio (SDR).

Software Defined Radio

Software Defined Radio is a radio architecture wherein nearly all signal processing is accomplished in software. This contrasts to other mainstream radios available today that use a microprocessor primarily for the user interface and perhaps some audio filtering. SDR radios also typically digitize and filter the last IF stage, e.g. at 40 kHz. In a basic sense, the A/D converter can be considered connected directly to the antenna. In this novel configuration the front end performs the sample and hold function on the signal to produce a continuous stream of time discrete values. The second step is accomplished by a sound card in the PC that uses a high-performance A/D converter to produce a true digital representation of the sampled signal. Everything after that is done by calculations in software.

Figure 1 shows a simplified system level block diagram. The left side of the diagram represents the SDR-1000 hardware front end, while the right side shows the signal flow through the DSP software running in PC.

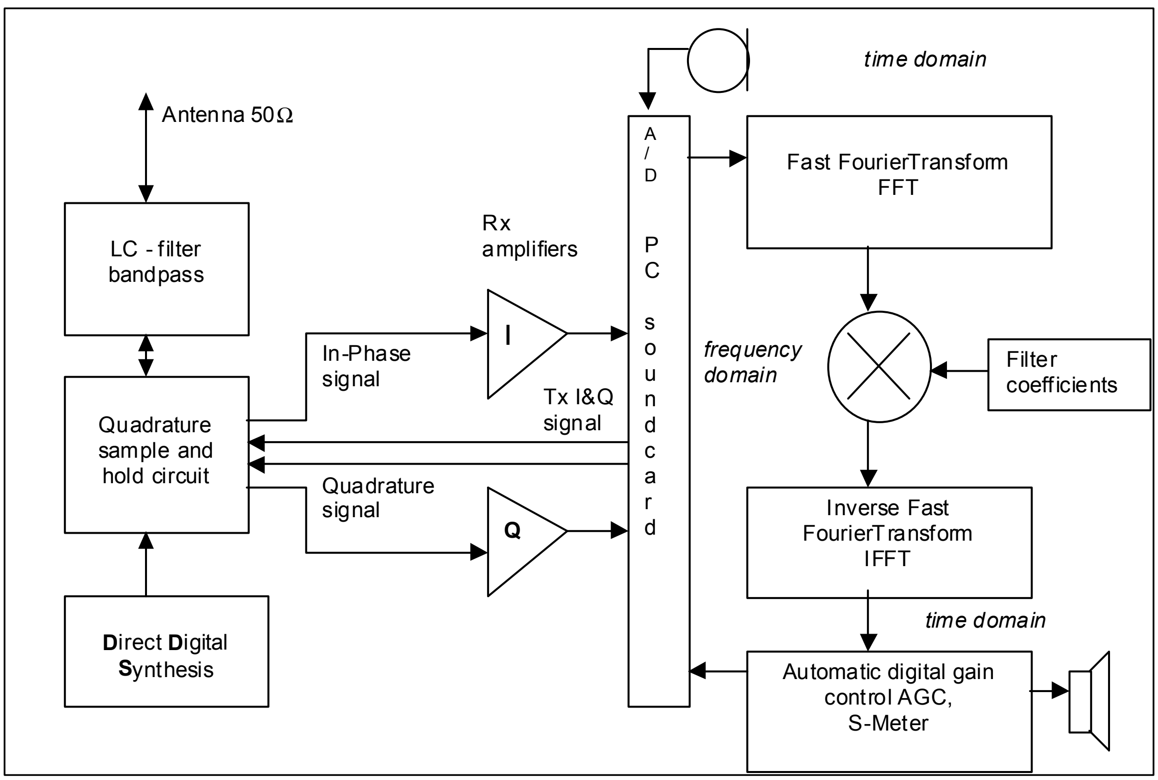


Fig. 1 System block diagram SDR-1000

The SDR-1000 hardware front end consists of three boards. The heart of the system is on the first board which provides a novel direct conversion scheme using state-of-the-art Direct Digital Synthesis (DDS) and a high quality crystal master oscillator.

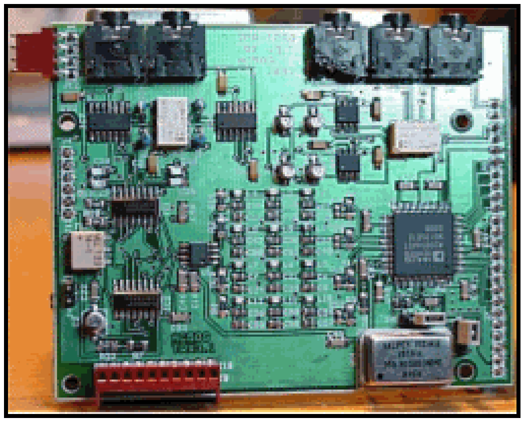


Fig. 2 XTAL, DDS and downconversion

The second printed circuit board contains the 1-watt power amplifier and conventional L/C filtering. Output filters using L/C components are the best solution for price, simplicity and quality.

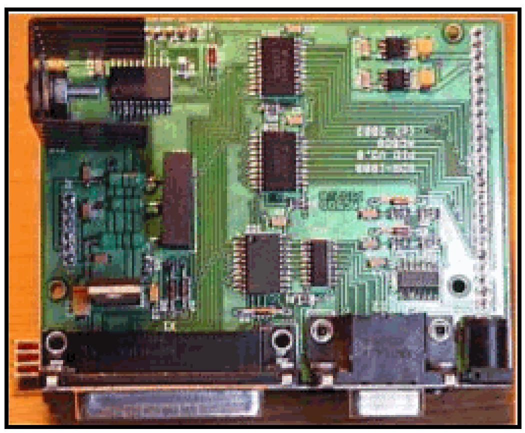


Fig. 3 Power supply and control

The third board contains the power supply regulators for +/- 15 volts and 5 volts. This board also contains the digital I/O latches that control the DDS frequency generation, and the relays that switch the filter banks and perform the Rx/Tx switching.

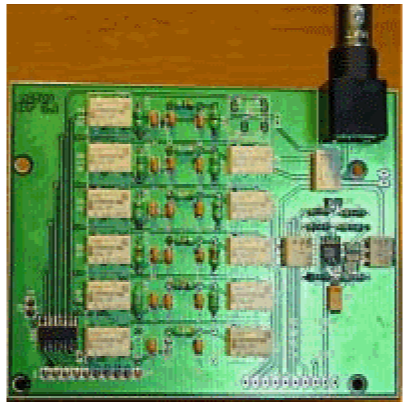


Fig. 4 Octave filters and 1 W PA

All in all, this stackable 3-board set is a neat little package measuring about 9cm x 7cm x10 cm (3.6" x 2.8" x 4").

What else do you need to become QRV? Well, an integral component in this SDR radio is a computer - either a desktop PC or a laptop. I use a Dell 8000 with an internal ESS Maestro 3 soundcard, which works well enough for me. Best results are achieved, however, when using a high quality soundcard like. the Turtle Beech Santa Cruz card. I still have to try this.

The boards require a 2 amp 12 volt power supply, as well as a 25 pin D printer interface connector and 1/8" phone jacks for computer left/right sound input and output. A BNC connector is provided for the antenna or external power amplifier.

User Interface

When I first saw the SDR-1000 User Interface, I felt very comfortable. It is immediately clear that it is a transceiver and not some esoteric piece of computer controlled equipment where one needs to study a 200+ page manual first and then practice regularly. Anyone who uses a conventional transceiver will be able to immediately operate the SDR-1000.

Most controls perform a single function. Some might say: "I am accustomed to using a tuning knob, but there's no tuning knob on my PC!" The SDR-1000 actually uses a unique mousewheel tuning control. It is amazing how many features Gerald has packed into the SDR-1000. Ten different bandwidth settings can be selected with a click of a button. The widest is 6 kHz and the smallest 25 Hz. Other selectable values are 4, 2.6, 2.1, and 1 kHz, and 500, 250, 100, 50, 25 Hertz. All filter bandwidths are available in the basic unit; there is no need to buy expensive crystal filters - it's all in the software. If you need a very special bandwidth setting, you can change the software for any bandwidth between, say, 10 Hz and 40 kHz. It is Open Software, you can make custom changes in the code using theVisual Basic source code provided with the SDR-1000.

The currently available operating modes include AM, which is nice to use for listening to medium or shortwave broadcasts and experimenting with different bandwidths. Single Side Band (SSB) is also available with selectable bandwidth on upper or lower sideband. Of course there is CW with selectable upper or lower sideband - i.e., true sideband selection. One of my favorite modes is CW with one of the narrow filters and the squelch usually set to a value of about 280. Then I get complete silence of the rx during pauses, and get just the desired CW signal when the other station transmits. This set up sounds like a code practice oscillator! Double sideband is another available mode; I suppose this is for binaural reception as described in the ARRL Handbook[5]. There is an experimental narrowband FM mode, although the only use of FM below 65 MHz is with the 10 Meter relays. This could prove useful in the future for a 2-meter undersampling receiver. But that goes beyond this general review. The last mode switches the SDR-1000 into a Digital Radio Mondial DRM[6] front end.

Of course there is a dual VFO with possibility of copying frequencies and working split mode in a pileup.

Tuning is accomplished in one of several ways. As an old fashioned ham I mostly use the mouse wheel "tuning knob" control to tune up and down the band. For a sked or when listening to a known broadcast frequency, I use the direct frequency entry method; I just type the number and hit return. A third tuning method is based on the spectrum analyzer display. Upon right-clicking the mouse, a fine crosshair appears and can be moved over the spectrum display. Then, with a click of the mouse, the transceiver is set to the actual signal[7] with the correct offset for the selected mode.

The audio frequency gain, intermediate frequency gain, microphone gain, transmission power and squelch controls are rather conventional. They are set either by numeric entry or by clicking on an up / down button. The same holds true for the receiver and transmitter incremental tuning (RIT, XIT).

The S-Meter displays the received signal strength in numerical and graphical form. It is possible to display the actual gain, a smoothed average of signal strength and the individual strength of the in-phase and quadrature signal of the so-called "analytical signal", which is the basis of digital signal processing.

The automatic gain control is accomplished in a fully digital manner and can be set in four steps: long, fast, medium and slow. This digital gain control eliminates a potential problem, which could easily arise in conventional receivers using a DSP[8] stage only after the last IF and then controlling the RF amplifier in the front end. All DSP stages introduce some delay on the signal and there is a tendency toward instability. The design of SDR-1000 avoids this.

We have not yet talked about the debug interface that appears when the main window of the SDR-1000 application is maximized. Using this dialog window, you can check the state of the I/O pins and the processing burden of the PC's CPU, which is about 21% (on an 800 MHz Pentium III processor) while listening to a CW station on 14.060 MHz. This is a quite useful feature for the software developer.

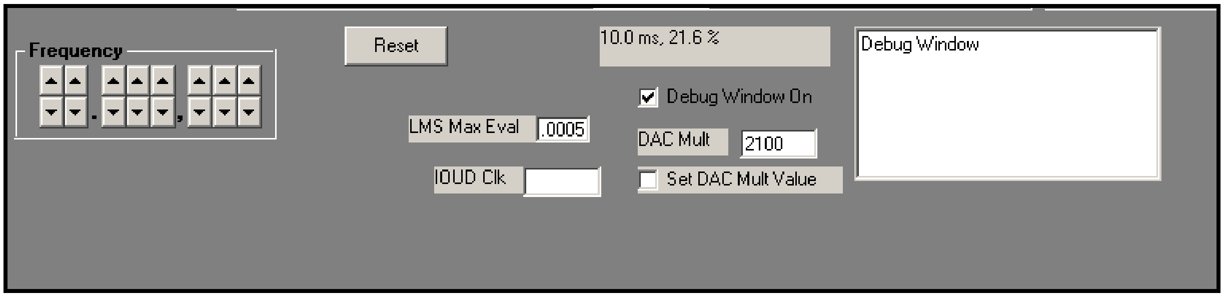


Fig. 5 Debug Window for the software developer

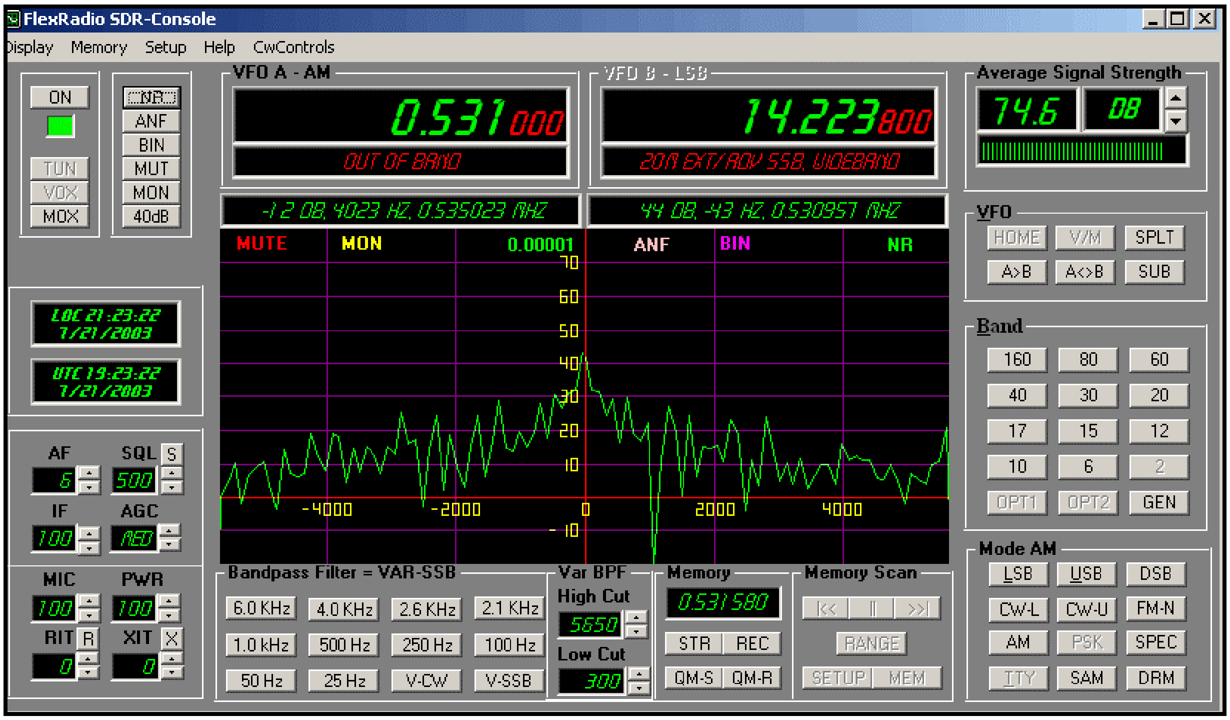


Fig. 6 The SDR-1000 Human Machine Interface

Operating features, impressions

When I got my SDR-1000 a few weeks ago I was eager to immediately use it even without a housing, which is possible thanks to the stacked circuit board design. It looks like a cube, standing on four feet with all cables protruding on one side.

A comprehensive companion manual, excellent support by the manufacturer, and a growing number of hams push the development of the software foreward. A web forum exists for owners of the SDR-1000 to discuss use and further development of "our" SDR. The Internet is used for discussion, support and distribution of software and documentation.

W5SXD is the contributor of a keyboard to CW interface - a useful addition to the user interface.

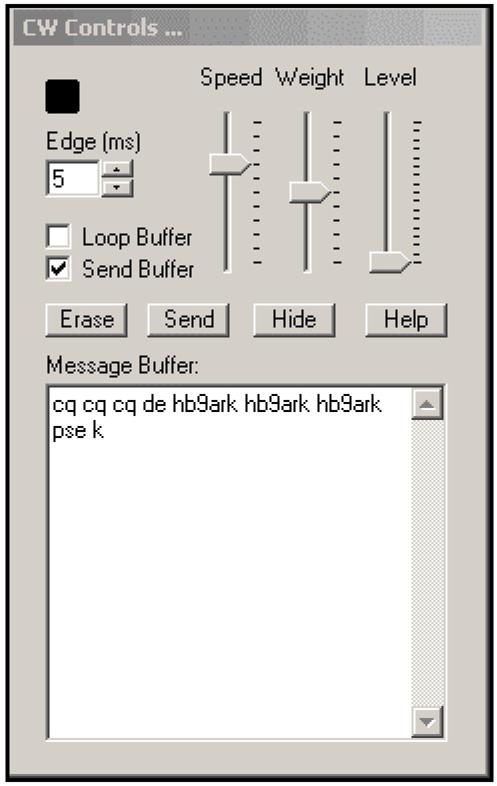


Fig. 7 CW controls

Things to improve

The basic functionality is available now, but the development process is still going on. Many more modes are yet to come. New high tech noise reduction techniques are available in an experimental state. There is huge potential for further development.

Performance

At the moment only preliminary performance figures are available. The transmit signal seems to be clean. The selectivity of the receiver is excellent. The sensitivity is okay, but does not yet reach the figures of the top class receivers - a preselector and preamplifier may help.

The classic way to characterize an analog receiver's behaviour may not be appropriate for all aspects of SDR. New measurement practices still have yet to evolve.

Memories and scanning

Is it necessary to adjust bandwidth and mode after each change of frequency? Not at all! On each band, the last four settings are stored on a stack and with a simple click one can return to the last setting, which is very convenient. In addition to this context saving store, there is a practically unlimited database for storage and retrieval of frequency, modes and call signs. These can be retrieved by memory number or by a preset hotkey, such as the F2 function key. Database entries can be structured in different groups.

Among other things, a scanning mode is planned for the future. All the coming enhancements and new modes are purely software. You can either wait until someone implements your feature or you can try it yourself. All the source code is open, allowing users of the SDR-1000 to compile the PC application program to create specialized user interfaces and custom modem processing.

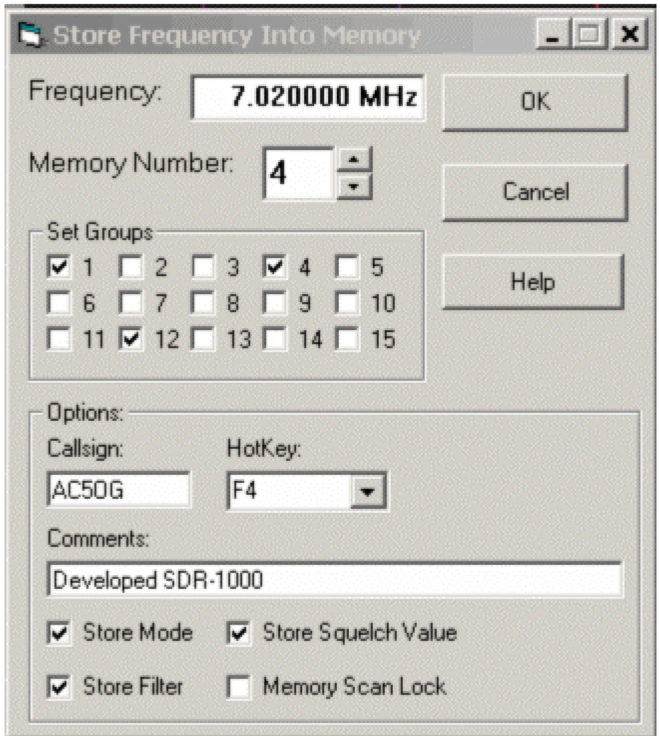
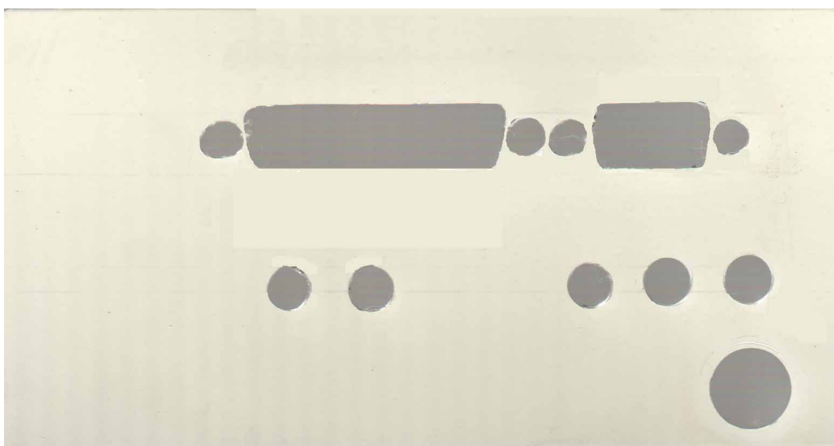


Fig. 8 View into the database

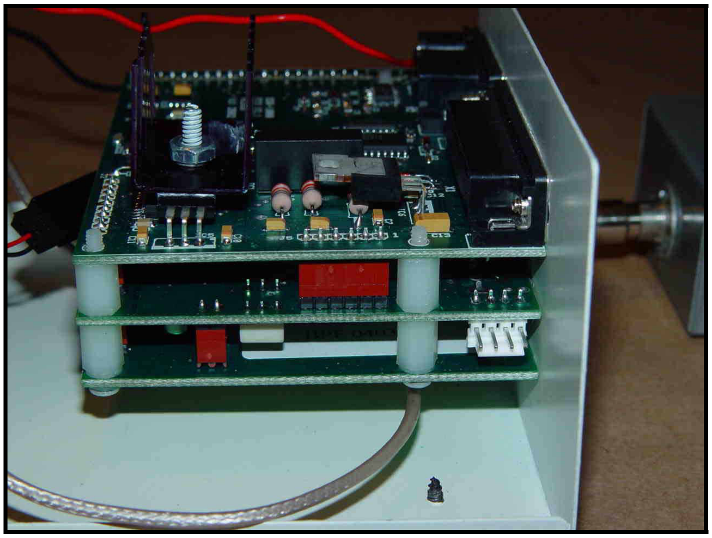
A Homebrew Enclosure

The three-board transceiver can be temporarily operated without a case. However when it's time, a Jameco[11] chassis #208910CD makes a good case for the SDR-1000 board set and provides extra room for a cooling fan and power amplifier! The boards should be mounted with the voltage regulator and heatsink facing up. A 12 volt computer fan (Jameco part #212804CD) is attached to the vent holes close by the heat sync to keep the hardware cool. The 5-V voltage regulator generates a lot of heat and could cause the VCO reference oscillator to drift a lot if heat is allowed to build up in the box. A template is available for drilling the front panel.

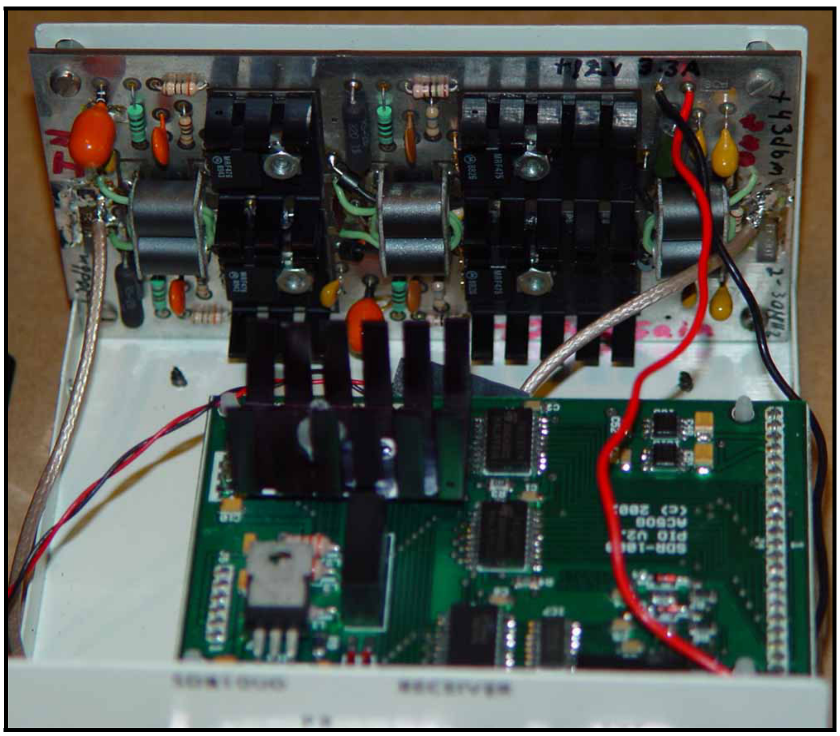
Figure 11: WD6CSV's SDR-1000 mounted in Jameco enclosure with transceiver connectors accessible on the rear panel. Others have used an empty K2 chassis.



A template is provided for drilling the front panel. The template is 5 ¼" x 2 ¾"



The 3 board set with fan is mounted as shown here.



In the WD6CSV installation a 20 watt Communications Concepts power amplifier was mounted in the back of the box for extra power.

A 4 amp power supply is required to power the SDR-1000 together with the 20 watt power amp. The ADT 1.5 – 1 output transformer of the SDR-1000 1-watt amplifier needs a 200-ohm ¼-watt carbon resistor added across its output winding . This is to provide a constant load to the SDR-1000 1-watt amplifier when switching between bands. The AN779L 20-watt power amplifier was inserted between the output transformer of the SDR-1000 1-watt amplifier and the final relay to the BNC jack. This provided 20 watts of output power without additional relays for switching in and out of receive and transmit modes. When operated with a power amplifier additional filtering will be required to keep harmonics to acceptable levels.

An external 20 meter filter is used to keep harmonics at -80 dBc when using the 20 watt power amplifier on 20 meters. A relay and band filter board is under construction, which will provide harmonic filtering for all transmit bands used with the 20 watt power amplifier. The SDR-1000 provides a connector to switch the relays needed for changing the filters for the added power amplifier.

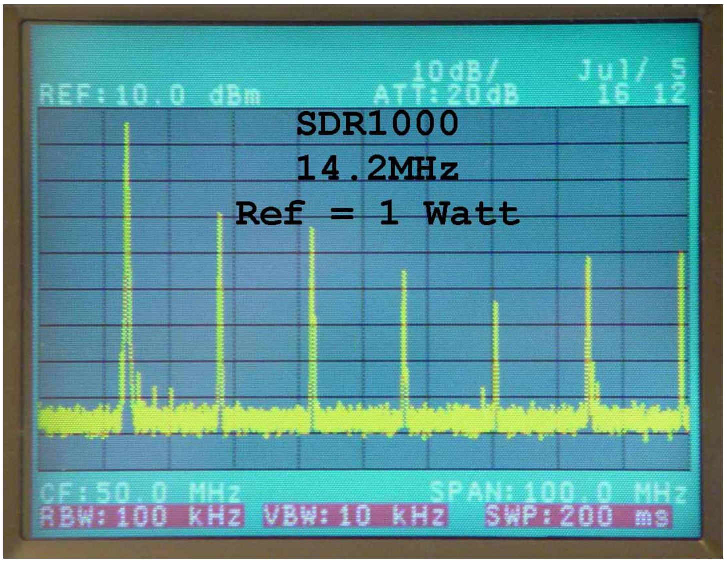


Figure 5 shows the RF spectrum generated by the SDR-1000 without the power amplifier or additional filtering on the 20 meter Ham band.

Figure 6 shows an external 20 meter filter used to keep harmonics at -80 dbc when using the 20 watt power amplifier on 20 meters. A relay and band filter board is under construction, which will provide harmonic filtering for all transmit bands used with the 20 watt power amplifier. The SDR-1000 provides a connector to switch the relays needed for changing the filters for the added power amplifier.

The SDR-1000 has already provided many out-of-state contacts on 20 meters at the 1-watt QRP level. It provides for interesting conversations on the Ham bands as operators try to understand the unusual capabilities and benefits of a PC-generated side band transceiver. With a 20-watt power amplifier the contacts have been very easy to come by. The razor sharp filters supplied by the PC software are most impressive. This rig has been an exciting adventure in homebrew and shows the added benefits of open source software on a community homebrew project! With software updates coming almost weekly it is mind boggling what a powerful transceiver this will be in another year!

Miscelleneous features

- A real time clock display shows UTC and local time, and date. The time is taken from the PC clock. If the PC clock is synchronized to an atomic clock, exact timing for weak signal modes is possible.
- The loop buffer in CW control permits automatically sending a beacon text.
- The display font can be selected between a standard Windows font and an LCD-like font.
- The HMI[9] software already has provision for controlling up to two transverters. The hardware I/O is present for controlling the transverters.

• Connections for an external power amplifier are available.

More bells and whistles

Some of the latest features added are a Synchronous AM detector (SAM) and a new forward Speech processor, a contribution by N4HY.

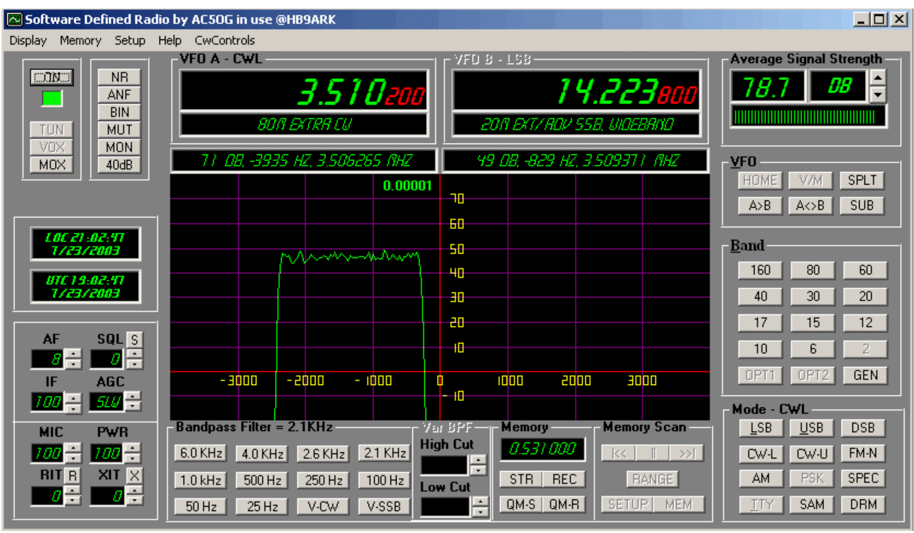
An elaborate spur reduction technique has been designed and implemented by N4HY.

If somebody really needs a physical tuning knob, Griffin Technologies has a great PowerMate control knob.

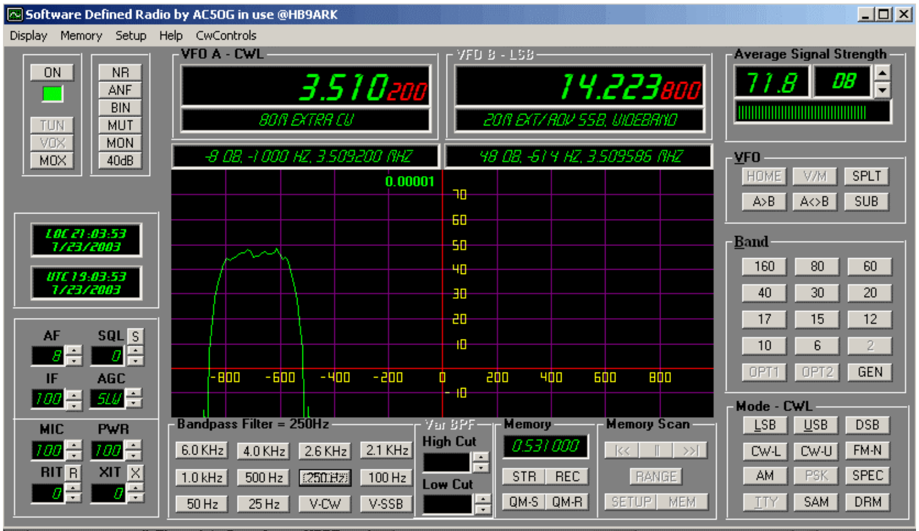
There are many more valuable inputs from the SDR-1000 community -- too many to state them all explicitly, so check out the Flex-Radio BBS where all the users group messages are available.

Fast Convolution Filter

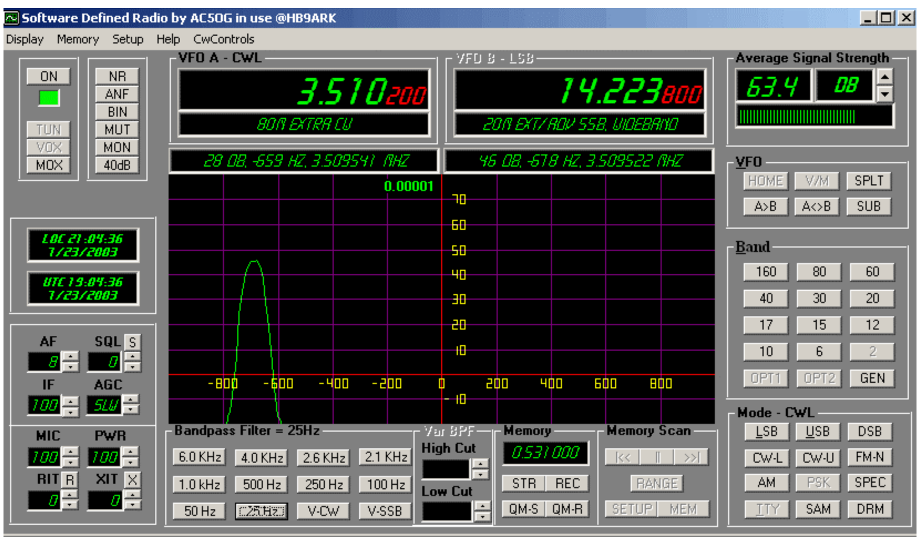
A broadband noise generator is connected directly to the SDR-1000's BNC antenna connector. A noise bridge is described in the ARRL handbook 2001, p. 26.37, using the noise of a Zener diode. The SDR-1000 is set to the desired bandwidth and the filter curve is immediately visible.



Fast convolution filter set at 2100 Hz



Fast convolution filter set at 250 Hz



Fast convolution filter set at 25 Hz

Conclusion

The SDR-1000 gives the average ham access to leading-edge technology, allowing one to homebrew high performance ham radio equipment. The transceiver demonstrates modern digital signal processing at an understandable level of complexity. While it is a challenge to understand SDR, it is also a joy to be able to experiment with signal processing using this transceiver.

The SDR-1000 is fast on its way becoming a full-featured, multi-mode HF transceiver for experimentation and general everyday use. It demonstrates contemporary homebrewing at its best. Major thanks to AC5OG for bringing this project to us all!

SIDEBAR ... *from Gerald Youngblood, AC5OG*

What a pleasure it has been to receive feedback from customers that the SDR-1000 has revived their excitement about experimentation in amateur radio. Their comments mirror my enjoyment as I worked on the Software Defined Radio (SDR) transceiver over the last four years. By opening the hardware and software design, customers are free to modify and contribute to product enhancements. It is fun to see that people much smarter than I are contributing code enhancements on a regular basis. Since introducing the SDR-1000 in April of 2003, a major enhancement has been made to the software almost every two weeks.

Just added recently by customer contribution were a CW keyboard keyer, DRM filtering, forward speech processing, AM modulation, synchronous AM detection, and PLL FM detection/modulation. A number of software enhancements are in the works, including an enhanced memory CW keyer, software noise blanking, and popular digital modes such as PSK31 and RTTY. It is truly exciting to have a radio that can be whatever you want it to be. I like to say, just dream it and code it. The cycle time from idea to reality with software enhancements can be minutes or hours, instead of days or months as it is with hardware.

Some customers have also ported the Linux based GNURadio to the SDR-1000. Others are using SM5BSZ's excellent Linrad software. One customer has even written his own version of the SDRConsole under .NET.

I am learning a lot about supporting the myriad of PC and sound card configurations that exist. It is essential to have a high quality sound card for use with the SDR-1000. Not all sound cards are created equal; in fact, most sound cards are of poor quality at best. The dynamic range and distortion products of the sound card will directly affect the quality of the SDR-1000 as a system. I recommend the Turtle Beach Santa Cruz as one of the best price/performance bargains on the market. Other excellent sound systems are the Creative Labs Audigy (PCI) and Extigy (USB). A reasonable performance PC is also required. I recommend a CPU speed of at least 600 MHz to run the latest software.

~Gerald, AC5OG email: gerald@flex-radio.com

*[**Editor's Note:** AC5OG recently received the ARRL 2002 Technical Excellence Award for his work with the SDR-1000. Congratulations!]*

NOTES

1) The authors can be reached as follows:
Martin Klaper, HB9ARK
email: HB9ARK@arrl.net
John Piri, WD6CSV
email: j.piri@mchsi.com

2) Complete information on the SDR-1000 may be found on the Internet at FlexRadio Systems (http://www.flex-radio.com). The 3-board transceiver, including the open software, may be purchased online at FlexRadio Systems.

3) QEX is a regular publication of the ARRL. (http://www.arrl.org/qex/).

4) FlexRadio Systems is located at 8900 Marybank Drive, Austin, TX 78750

5) A binaural I-Q-receiver in the Receiver, Transmitter, Transceiver and Projects chapter of the 2002 edition of the ARRL Handbook, p. 17.109

6) DRM is “Digital Radio Mondial”, a new broadcast modulation scheme producing near FM quality on shortwave channels. For further information see www.drm.org and www.drmrx.org

7) Similar to the PSK31 channel selection.

8) DSP means either "Digital Signal Processor" or "Digital Signal Processing"

9) Parts from Jameco may be ordered at www.jameco.com .

Product Review and Short Takes from *QST* Magazine

October 2005
Product Reviews:

Short Takes:

PRODUCT REVIEW

FlexRadio Systems SDR-1000 HF+VHF Software Defined Radio *Redux*

Rick Lindquist, N1RL
ARRL Senior News Editor

In product review terms it could become a serious challenge to keep up with the ever-evolving FlexRadio Systems SDR-1000—the first commercially available software defined Amateur Radio transceiver. This marks our second look at the SDR-1000. Must reading is our first snapshot, "SDR-1000 Software-Defined HF/VHF Transceiver," by Steve Ford, WB8IMY, in the April 2005 *QST* "Product Review." Steve noted some limitations and setup problems, and FlexRadio has addressed them. It now offers a fully integrated package including a PC to sidestep the problems of getting everything set up and configured to play together.

A Work in Progress

The improvements since our last look, involving both hardware and software, have been significant, and even more arrived or were in the offing as this review went to press—including *another* software increment. To avoid getting caught in an endless loop, we froze changes at *PowerSDR* software version 1.4.3.

The architects and developers of the current DSP code used in the *PowerSDR* software, Frank Brickle, AB2KT, and Bob McGwier, N4HY, worked closely during the development process with FlexRadio's Gerald Youngblood, K5SDR, and Eric Wachsmann, KE5DTO. The FlexRadio Web site, **www.flex-radio.com**, includes all software downloads, the Operating Manual and any documentation you'd ever need. There's also an excellent reflector and—at least so far—they're able to keep up with user inquiries and troubleshooting issues.

With cutting-edge technology like this, it's sure nice to know you're not out there alone!

A Marriage of Convenience

With the SDR-1000, the union of Amateur Radio gear and the personal computer has transitioned to the point that a transceiver's functions can reside in a virtual world we can't really touch or see. With the advent of the SDR-1000, the physical radio box has become a "peripheral" in the genre of software-generated data. As Steve Ford's earlier review noted, software defines this transceiver's functionality, so each *PowerSDR* revision can, in effect, represent a new—or at least an improved or different—transceiver.

Download and install, and you're *there*! The only thing you really need in the shack plus the SDR-1000, mic and key is a fast PC, and they now offer one.

The possibilities become *almost* limitless. There's still that pesky radio hardware box, the PC and a sound card and perhaps an accessory or two to contend with. The physical components of what we might call the SDR-1000 "system" do impose some real restrictions on what the transceiver is capable of now or in the future. The open-source software can accommodate a wide range of upgrades that might otherwise only be possible through hardware or firmware upgrades. There are no DSP chips to become obsolete in the SDR-1000, for example.

Bottom Line

The newest and fully integrated SDR-1000 system avoids most of the earlier start-up issues, resulting in a top performing radio "out of the boxes." New software updates will continue to add new features and further improve performance.

"The Radio that Keeps Getting Better"

That's what FlexRadio Systems calls its product, and the characterization is right on target. Since we first looked at the SDR-1000 earlier this year, its manufacturers wisely decided to market the full-blown transceiver in a form that's as close as possible to a turnkey system. This way, you don't require a software and RF engineering background to get up and running. The move also seems to have been an effort to appeal to a wide audience—to capitalize on the title of Gerald Youngblood's series, "A Software Defined Radio for the Masses," which won him the 2002 Doug DeMaw, W1FB, Technical Excellence Award. The articles appear in the July/August and September/October 2002 issues of *QEX* and are available on their Web site.

For most, the SDR-1000 system will be only marginally more difficult to set up than the average PC with a printer and another accessory or two. It more likely will require more tinkering—and maybe some hand-holding from FlexRadio—to tweak the system to suit your needs. While the full complement of equipment fills a small table or desktop (see lead photo), in most stations most of the equipment can be beneath the desk.

In addition to the SDR-1000 "black

box," the SDR-1000 "packaged system" now can include a Dell PC with a professional-quality Delta 44 sound card installed and configured, a Delta 44 "break-out box" (see Figure 1) for audio I/O connections, computer speakers, cables and an accessory connector kit to interface with the SDR-1000 and a parallel control cable. The PC with our system had a Celeron 2.4 GHz processor and 512 MB of RAM, and the limitations of the Celeron versus an Intel Pentium 4 (P4) processor were noticeable, especially for CW. FlexRadio now offers the 3.2 GHz P4 computer (the Dell Optiplex 170L) for the SDR-1000 package. For now, the *PowerSDR* software will only run under *Windows*—in our case, *XP Home* with Service Pack 2.

Options include a Dell flat panel display (monitor)—a must unless you happen to have a spare sitting around, an automatic antenna tuning unit with tuning capability to 10:1 SWR, a low power Down East Microwave DEMI144-28FRS 2 meter transverter that can fit inside the black box, a Contour *ShuttlePro 2* (see Figure 2) or Griffin *PowerMate* controller and a USB-to-parallel port converter.

Hardware Upgrades

A few changes have been made in the black box since our initial outing. "We improved the Quadrature Sampling Detector (QSD) out-of-band rejection by adding two resistors to properly terminate the filters," Youngblood explains. FlexRadio also swapped in an RF preamplifier with higher dynamic range.

The latter change could help to explain why the dynamic range numbers we measured with the preamplifier enabled were better on this version of the SDR-1000 than those taken with the preamp off. See Table 1. Note that the near-in third order IMD dynamic range is right up there with the best radios we've ever measured, and extends at least in to 2 kHz.

FlexRadio also corrected an anomaly noted in our original review—in which the box drew more current on 160 meters than on other HF bands—by changing the value of two resistors on the power amplifier.

The beauty part here is that all SDR-1000s, starting with the very first, can be upgraded to match the capabilities and performance of the latest unit off the line. In fact, our black box is the very same unit we used for the first *QST* review with upgrades added at FlexRadio. Youngblood says FlexRadio plans to offer similar upgrade service soon to existing SDR-1000 owners via a third party.

Getting Things Under Control

For all intents and purposes, you can control the radio using the *PowerSDR* "console"—which is what FlexRadio calls its

Figure 1—The break-out box for the optional M-Audio Delta 44 professional sound card allows making the connections without crawling behind the PC.

Figure 2—The optional Shuttle-Pro controller.

user interface—the PC keyboard and a wheel mouse. Steve's earlier review describes this.

The optional controllers are another way. Steve checked out the PowerMate for his review. We got the ShuttlePro 2 for this one. It's more than just a knob to tune the radio. It also has 13 buttons (9 are user-programmable, and labels to go under the button caps are provided). FlexRadio provides an *Excel* document that describes the assignable functions, which you record like macros in other software packages. Using the ShuttlePro or the mouse—or both—may leave your keyboard collecting dust, although it's handy for direct frequency entry and even for programming CW memories or a keyboard buffer.

Like the tuning knob on many conventional ham radio transceivers, the ShuttlePro's has a dimple (actually three of them). It also has a spring-loaded "shuttle" ring surrounding the tuning knob that simplifies quick frequency excursions. Move it a little and the frequency changes more slowly. Crank it over all the way (either right or left), and the frequency may change too fast for you to keep up. Both controls can be assigned to other functions.

I found it a pretty handy accessory although it's almost as easy to tune the radio using a wheel mouse. The ShuttlePro also requires some programming to assign the buttons. As an added bonus, however, it may be programmed for use with other applications by changing its "application" setting. This may be the only radio that can do your taxes when the band is dead!

CW Operation

As McGwier, a CW operator, told me, "This is definitely not a QSK radio." That's quite an understatement. As Steve Ford noted in his April review, CW operation was not yet the forte of the SDR-1000. It is now much closer to a serious CW radio—albeit only in semi-break-in mode. The processing power of the Celeron chip seemed to be a limiting factor in the case of our SDR-1000 system, and FlexRadio now recommends a P4 computer for high-speed CW operation. Intel P4 processors support a high-performance motherboard timer; the Celeron does not. CW operation is now far better than with the version described in the earlier review,.

The real issue is something called *latency*. This is essentially the time it takes for the PC to process a command once it's been issued; for example, sensing that the key or paddle has been pressed, switching into transmit and telling the black box to generate the necessary RF. This takes a finite period of time—almost instantaneous in human terms but lengthy in computer terms. In his review Steve called it "maddening delay."

Our *PowerSDR* version incorporates a "new keyer" design that, while it lacked some important features of the "old keyer," makes it possible to transmit serious CW. I've been operating CW for many years now, and I found with a little practice I got to the point where I was able to send passable CW at a fairly good clip—on the order of 30 WPM or greater—once I got used to the delay. Setting the Delta 44's buffer size to 512 (that is, 512 samples per audio buffer) while using the new keyer made key closure and the appearance of the corresponding sidetone in my headset very close to instantaneous. Although I could not altogether eliminate the delay, I was able to train my brain to work with it.

The "old keyer," which the user "selects" by unchecking the NEW KEYER in the software, includes CW memories into which you can type text, plus the ability to send text from a keyboard buffer at speeds up to the keyer's limit. If you're so inclined, you can send CW using the left and right mouse buttons or by via the "." and "/"

Table 1
FlexRadio SDR-1000

Manufacturer's Specifications	Measured in the ARRL Lab
Frequency coverage: Receive, 0.01-65 MHz; transmit, 1.8-2, 3.5-4, 5.33-5.4, 7-7.3, 10.1-10.15, 14-14.35, 18.068-18.168, 21-21.45, 24.89-24.99, 28-29.7, 50-54 MHz.[1]	Receive and transmit, as specified.
Power requirement: Receive, 1.0 A max; transmit, 25 A (max).	Receive, 0.9 A; transmit, 15 A. Tested at 13.8 V.
Modes of operation: SSB, CW, AM, FM.	As specified.
Receiver	***Receiver Dynamic Testing***
CW sensitivity, 500 Hz bandwidth, 26 dB INA setting: –141 dBm.[3]	Noise floor (mds), 500 Hz filter: *Preamp / off / low / med / high*[2] 1.0 MHz **–99 / –110 / –122 / –132 dBm** 3.5 MHz **–97 / –109 / –122 / –132 dBm** 14 MHz **–98 / –109 / –121 / –130 dBm**
AM sensitivity, 10 dB S/N: Not specified.	1 kHz tone, 30% modulation: *Preamp / off / low / med / high*[2] 1.0 MHz **51 / 18 / 4.4 / 1.5 µV** 3.8 MHz **65 / 20 / 4.8 / 1.7 µV**
FM sensitivity, 12 dB SINAD: Not specified.	For 12 dB SINAD: *Preamp / off / low / med / high* 29 MHz **31 / 9.6 / 3.2 / 1.0 µV**
Blocking dynamic range: Not specified.	500 Hz filter: Spacing 20 kHz (5 and 2 kHz data identical) *Preamp / off / low / med / high* 3.5 MHz **105 / 105 / 111[6] / 111[6] dB** 14 MHz **108 / 109 / 111[6] / 110[6] dB**
Two-tone, third-order IMD dynamic range 500 Hz filter, 90 dB.	Spacing 20 kHz (5 and 2 kHz identical) *Preamp / off / low / med / high* 3.5 MHz **81 / 83 / 97 / 96 dB** 14 MHz **86 / 85 / 99 / 98 dB**
Third-order intercept: Not specified.	Spacing 20 kHz (5 and 2 kHz identical) *Preamp / off / low / med / high* 3.5 MHz **+24 / +14 / +24 / +15 dBm** 14 MHz **+31 / +20 / +26 / +17 dBm**
Second-order intercept: Not specified.	*Preamp / off / low / med / high* **+70 / +73 / +75 / +74 dBm**
FM adjacent channel rejection: Not specified.	20 kHz channel spacing, preamp high: 29 MHz, **36 dB**.
FM two-tone, third-order IMD dynamic range: Not specified.	20 kHz channel spacing, preamp high: 29 MHz, 37 dB.
S-meter sensitivity: Not specified.	S9 signal at 14.2 MHz: See Note 3.

characters on the keyboard.

On the plus side, the software keyer permits a *wide* range of adjustment in weighting, rise time and debouncing.

FlexRadio has developed a hardware workaround to make CW operation more like "normal," although QSK operation is down the road. The workaround involves hard-wiring a keyer paddle to three pins on a serial port, but our software revision did not support this feature. For now, an external keyer is one option to obtain excellent CW results from the SDR-1000.

Listening on CW is superb. As Steve noted in his review, the radio's ability to generate binaural audio (provided you have a stereo headset) gives the bands—on both CW and phone—a new presence. The software filtering is fantastic. You can click your choice of preset filters or shape your own. Being able to narrow the bandwidth to 25 Hz essentially obviated the need for a manual notch, but there is an automatic notch. You can readily switch from the lower side to the upper side of a signal.

When changing from one mode to another, the filter shifts to the setting selected the last time you were in the new mode. There are no default filter settings for a given mode. This offers a level of flexibility not found in many conventional radios, particularly those that depend on crystal filters.

There's a passband shift slider, too (the SDR-1000's version of an IF shift). Very helpful. Don't like the default AGC settings? Set your own via the menu.

SSB Operation

SSB operation is a bit more routine, but, just as there's no QSK for CW, the SDR-1000 doesn't yet have provision for VOX (voice operated transmit). This is another feature on the wish list to the developers.

Nonetheless, I was able to easily interface my Heil ProSet Plus headset to the Delta 44 sound card's break-out box, although it did require some adapters. For the microphone input, a readily available 3.5 mm to 1/4 inch adapter plug into one input jack did the trick (it's also possible to configure a four-pin microphone connector to the jack on the front panel of the black box). For stereo audio output, I jiggered up my own adapter using two mono plugs to a 1/4 inch stereo jack.

Although the front-panel microphone input allows for push-to-talk, I was not able to hook up my Heil headset without going directly into the sound card—unless I wanted to devise my own adapter. Otherwise, you must either click the MOX (manually operated transmit) box on the console or hard wire some kind of foot (or hand) switch. If you're using the ShuttlePro 2, you can program one of its buttons to enable MOX. Holding down the "dit" side of the keyer paddle also switches to transmit, I discovered.

The audio reports I received were uniformly positive. When I opened up the 12-octave graphic equalizer (see Figure 6) to further polish the transmit audio, the results invariably drew additional praise.

To improve transmitted audio efficiency, the SDR-1000 lets users set something called *feed forward compression*. Unlike the typical audio or RF level audio compressor, the feed-forward design *anticipates* the compression level required rather than, as the manual put it, "simply following the signal around." Upping the value gives higher average power output without peaks, pumping or popping.

Additionally, version 1.4.3 of *PowerSDR* incorporates AGC leveling and a limiter to replace the clipper in earlier revisions. While you're transmitting and using the panadaptor setting to view the received (see Figure 7) and transmitted signal, you can view your signal's waveform, noting its overall bandwidth and its audio emphasis right there on the screen as shown in Figure 8. You can also view a signal histogram as shown in Figure 9.

While you can see your signal, listening to it by enabling the onboard monitor is not advisable, at least if you're using a 2.4 GHz Celeron or lesser PC. Remember the latency issue? The same thing occurs in voice modes, so when you speak, it takes a few milliseconds for the audio to appear in your headset. This "echo box" effect can be very disconcerting. Again, this is a PC issue, not really a radio issue, per se; sometimes fiddling with buffer settings yields better results. Faster computers and superior processors will conquer these latency issues. It made us again wish we had selected the faster P4 machine.

Digital Mode Operation

The SDR-1000 does not include out-of-the-box, integrated capability to operate on digital modes—something on Steve's wish

Manufacturer's Specifications	Measured in the ARRL Lab
Squelch sensitivity: Not specified.	At threshold, preamp high: SSB, 14 MHz, 5.0 µV; FM, 29 MHz, N/A.
Receiver audio output: Not specified.	See Note 4.
IF/audio response: Not specified.	Range at –6 dB points, (bandwidth): CW (500 Hz filter): 460-935 Hz (475 Hz); USB: 211-2816 Hz (2605 Hz); LSB: 213-2778 Hz (2565 Hz); AM: 2-5980 Hz (5978 Hz).
IF and image rejection: Not specified.	First IF rejection, 14 MHz, **114 dB**; image rejection, 14 MHz, **75 dB**.
Transmitter	***Transmitter Dynamic Testing***
Power output: HF—SSB, CW, FM, 100 W high, low, not specified; AM, not specified, 50 MHz—500 mW.	HF—CW, SSB, FM, typ 100 W high, <1 W low; AM (carrier), typ 25 W high, <1 W low. 50 MHz—not tested.
Spurious and harmonic suppression: Not specified.	**55 dB**; Meets FCC requirements.
SSB carrier suppression: Not specified.	**53 dB**.
Undesired sideband suppression: Not specified.	**55 dB**.
Third-order intermodulation distortion (IMD) products: Not specified.	See Figure 3.
CW keyer speed range: Not specified.	**1 to 54 WPM**.[5]
CW keying characteristics: Not specified.	See Figure 4.[5]
Transmit-receive turnaround time (PTT release to 50% audio output): <20 ms.	S9 signal, **170 ms**.
Receive-transmit turnaround time (tx delay): Not specified.	SSB, 150 ms; FM, 150 ms. Unit is unsuitable for ARQ-based digital modes such as PACTOR.[5]
Composite transmitted noise: Not specified.	See Figure 5.

Size (height, width, depth): 4"×10"×8.5"; weight, 6 pounds plus PC.

Values in bold text are changes from the SDR-1000 review in April 2005 *QST*.

*Measurement was noise-limited at the value indicated.
[1]100 W operation on HF bands only. Preselector required below 1.8 MHz.
[2]Preamp settings are actually gain settings on the display that represent preamp and attenuator combinations (see text for more details).
[3]Dependent on software calibration.
[4]Dependent on PC sound card (SDR speaker output requires amplified speakers).
[5]Dependent on PC (see text).
[6]Sound card A to D converter (ADC) in overload state.

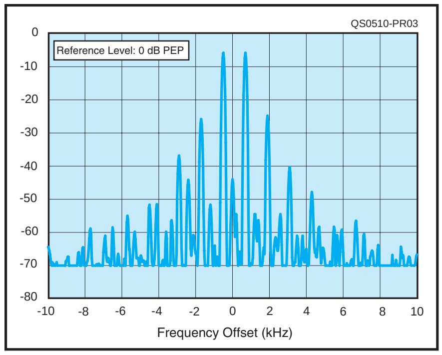


Figure 3—Worst-case spectral display of the SDR-1000 transmitter during two-tone intermodulation distortion (IMD) testing on HF. The worst-case HF third-order product is approximately 26 dB below PEP output, and the worst-case fifth-order is approximately 37 dB down. The transmitter was being operated at 100 W output at 1.85 MHz.

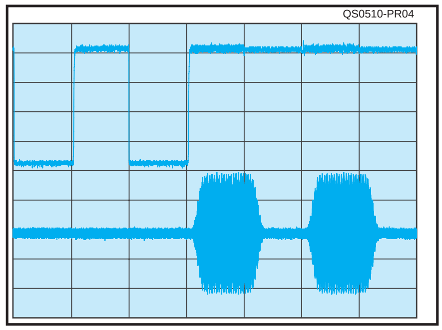


Figure 4—CW keying waveform for the SDR-1000 showing the first two dits in semi break-in mode using external keying. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure (first closure starting at left edge of figure); the lower trace is the RF envelope. Horizontal divisions are 20 ms. The transceiver was being operated at 100 W output on 14.02 MHz.

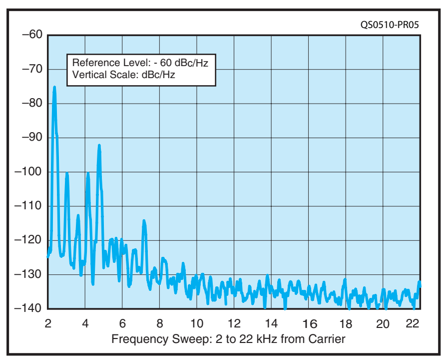


Figure 5—Worst-case tested HF spectral display of the SDR-1000 transmitter output during composite-noise testing at 14.02 MHz. Power output is 100 W. The carrier, off the left edge of the plot, is not shown. This plot shows composite transmitted noise 2 to 22 kHz from the carrier. Note the numerous spurs that are not part of the noise output.

list last April. FlexRadio says you should be able to use almost any soundcard-based digital application with the unit, but at this stage of development, you'll need a *second* sound card.

In fact, the Dell PC already has one that's not really being used. Since the Delta 44 handles the needs of the SDR-1000, the Dell sound card is available to serve digital-mode software. You'll also need a third-party *vCOM virtual serial port driver* developed by Phil Covington, N8VB, to create a no-cable-needed COM port for communication between the digital mode software and the *PowerSDR* software..

A *virtual sound card* that FlexSystems says is just around the bend will eliminate the need for a "real" (second) sound card to use digital mode software.

Some Feature Notes

Like almost any modern transceiver, the SDR-1000 offers memories—their number undoubtedly only limited by the size of your hard drive. These let you save frequency, mode, filter setting, tuning step size, call sign (if appropriate), squelch setting and AGC setting. Checking a box makes that memory available for scanning purposes.

The easy-to-read frequency readouts for the two VFOs display out to six decimal places, which some users might consider overkill. It was not possible to alter this to, say, five decimal places, with our software version.

Frequencies (and corresponding information) are saved in a table that you bring up by clicking the RECALL button. Click on a frequency you've saved and the SDR-1000 takes you right to it. *Ooops!* It doesn't close the table at the same time!

There are several band-stacking registers for each band. These save frequency, filter and mode settings. Very nice!

The sky's the limit as filter settings are concerned, both for transmit and receive. If you set the transmit bandwidth beyond 3 kHz, however, a little dialog box pops up: *Warning: Transmit Bandwidth. The transmit bandwidth is being increased beyond*

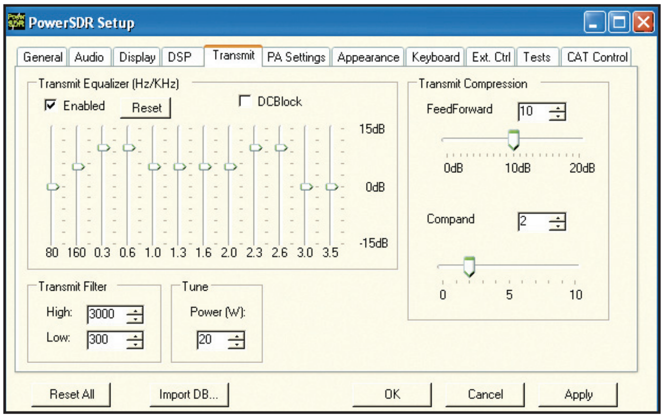


Figure 6—The *PowerSDR* Transmit setup tab permits adjustments to the 12 octave transmit audio equalizer, transmit compression, transmit filter and the "tune" power level.

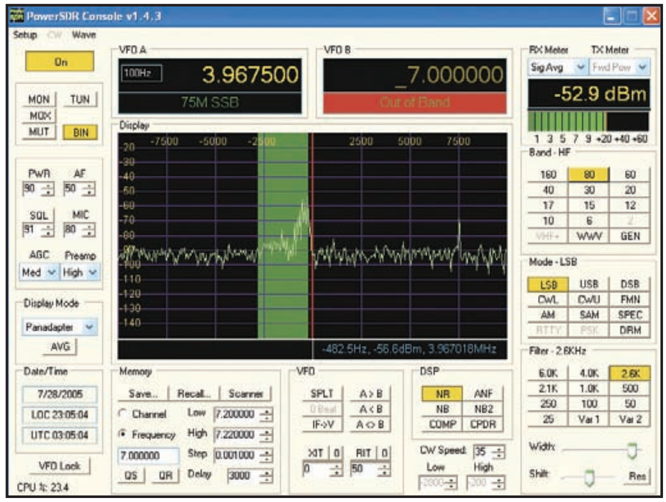


Figure 7—Receiving a 20 dB over S9 SSB signal on 75 meters.

3 kHz. As the control operator, you are responsible for compliance with current rules and good operating practice. The FCC's Riley Hollingsworth couldn't have said it any better.

Click OK and the SDR-1000 lets you set the transmit bandwidth as wide as you'd like anyway. This might be great for tailoring AM audio or for "enhanced SSB" experimenters.

You can pick the preset filters: 6.0, 4.0, 2.6, 2.1 and 1.0 kHz and 500, 250, 100, 50 and 25 Hz, plus two user-settable filters, VAR 1 and VAR 2, that you can adjust using the WIDTH slider. The results can be astounding.

Youngblood notes that there's no analog AGC ahead of the final "brick wall" receiver filter. "This means that it is not possible for signals outside the passband to modulate the AGC system," he says. The same filters are the final step in the transmit audio chain as well.

There are two noise blankers in the SDR-1000. NB2 is not a noise blanker in the traditional sense. Instead of chopping noise out of the signal—which can lead to distortion—Youngblood said it replaces noise impulses with something called a "sliding rank order median" estimate of the original signal.

It's possible to customize the console colors and even some of the design features. Don't like the default yellow frequency readout numerals? Change them to red or—as I did—to cyan. There's a palette of choices.

By the way, there's a label below each Amateur Radio band frequency that tells you where you are in terms of the ARRL band plan. For example, 40M EXT/ADV SSB if you're listening between 7.150 and 7.225 MHz, or 75M AM CALLING FREQUENCY if you're on 3.885 MHz. On general coverage, you'll usually get a hard-to-miss OUT OF BAND message on a bright red background. This jarring alert made me feel I was doing something I shouldn't be whenever I tuned through the HF shortwave broadcasting bands.

Obtaining audio from the SDR-1000 still means hooking up a headset or a set of amplified speakers to the sound card's break-out box. You certainly could use the amplified speakers that come with the Dell, although you'll need an adapter to connect to the Delta 44 break-out box. Under most circumstances, though, there's plenty of audio at least to drive a headset. Again, as Steve suggested back in April, FlexRadio might consider some means of being able to drive a regular speaker or speaker pair.

Some Performance Notes: Thinking Outside the Box

The professional-quality Delta 44 sound card has become the standard for the SDR-1000 because of its vastly superior dynamic range compared to the

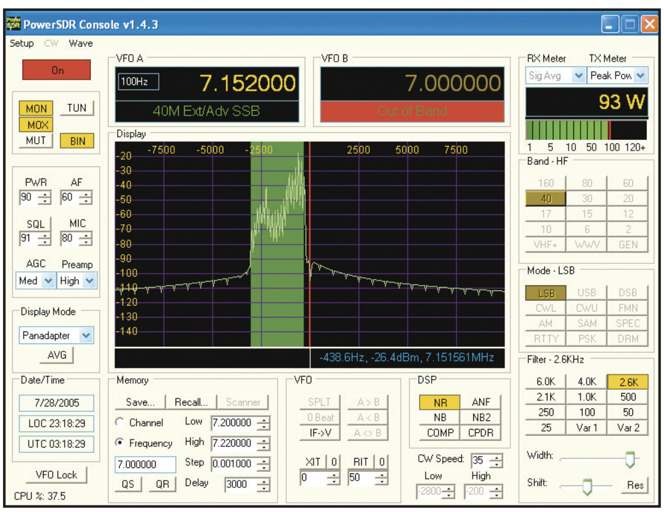


Figure 8—The *PowerSDR* console during an SSB transmission into a dummy load. The audio waveform is clearly visible within the green column representing the signal bandwidth, 2.6 kHz in this case. The "Out of Band" legend can be seen on VFO B.

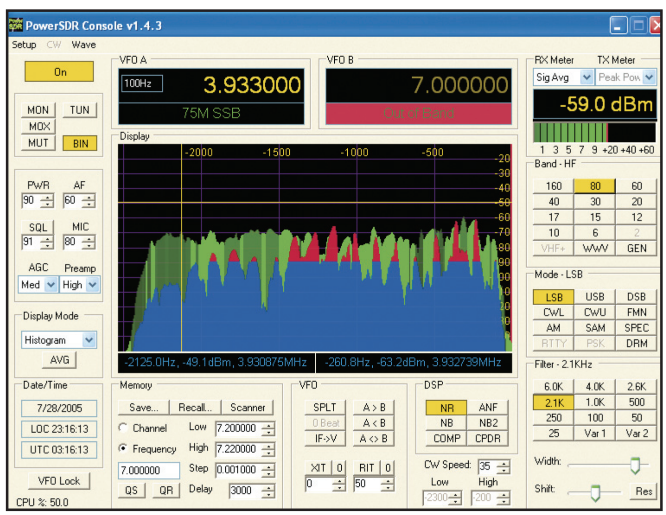


Figure 9—The "histogram" display on 75 meters. Setting the buffers at too low a value while using this display can chop "holes" in the received signal. This is an apparent computer processing issue.

consumer-quality unit in use during the original review. This move is especially important when you consider that once the black box provides the 11.025 kHz signal to the computer, the *PowerSDR* software does the rest at that intermediate frequency. So the sound card is paramount to good performance, and this shows in the numbers we measured in the ARRL Laboratory (see Table 1).

Two-tone, third-order (TT3O) intermodulation distortion (IMD) dynamic range is a great receiver performance benchmark. With the setup Steve Ford reviewed in April, this figure was in the modest mid-80s on 14 MHz—whether the preamp was on or off and whether the spacing was 20 kHz or the much more critical 5 kHz.

For this review, using the "medium" preamplifier setting as the factory default, the TT3O IMD dynamic range was 99 dB on 14 MHz, about as good as we've seen, and ever so slightly worse with the preamp on its highest setting—which actually was the point where the receiver's minimum discernable signal (MDS), or sensitivity, at 14 MHz was comparable to that of most conventional HF transceivers—that is, in the vicinity of –130 dBm.

Another popular benchmark is third-order intercept (TOI), which is derived from the receiver's sensitivity and its two-tone, third-order IMD dynamic range. At 14 MHz and using the medium preamplifier setting, we calculated the TOI for the SDR-1000 at a very respectable +26 dBm (it was +17 dBm at the high preamp setting).

Here's the thing, though. The ARRL Laboratory found that two-tone, third-order IMD dynamic range was essentially the same at 2 kHz as it was at 20 kHz and beyond. With a conventional receiver, you'd expect dynamic range at 50 kHz spacing, for example, to be much better, especially since it's well outside the passband of the typical 20 kHz roofing filter.

Consider, though, that the IF for what's essentially a single-conversion receiver in the SDR-1000 is 11.025 kHz—still in the audible range for most of us. This is what the sound card sees from the black box. The superiority of the Delta 44 sound card compared to the sound card we used in the previous review seems to account for this *seeming* dynamic range incongruity. In short, the sound card's inherent dynamic range becomes the receiver's, so it exhibits essentially the same dynamic range across its entire passband, which can be considerable.

The first IF rejection figure of 114 dB on 14 MHz tops my ICOM IC-756PROIII. The image rejection figure of 75 dB on the same band, due to the very low IF frequency no doubt, leaves a bit to be desired, however.

FM numbers were not as good as the typical FM radio. The 29 MHz FM adjacent channel rejection at 20 kHz channel spacing and using the high preamp setting was only 36 dB. FM two-tone, third-order IMD dynamic range was just 37 dB. Measurements on the order of twice these values would be more acceptable. Let's just say that this nice radio was reaching a bit too far when it tried to do FM. When informed of this, FlexRadio identified the problem as a software issue that they would address in the next release.

I encountered some birdies at odd places across the spectrum, some in the vicinity of –95 dBm (S5). In once case, the birdie was almost on top of a station I was trying to copy (around 7.02858 MHz), but when I tuned, the birdie shifted as well, and I was able to tune in the station in the clear.

A User-Defined Radio

The FlexRadio folks and those who are helping to develop the open-source software that defines their radio already are hinting at what lies ahead for their particular piece of gear. They invite—indeed, encourage—developers and users to cast their own ideas into the pot via the FlexRadio reflector, weekly *TeamSpeak* VoIP community forums and the source code that's the very heart (or brain) of the radio.

One might say that Amateur Radio SDR technology, as represented by the pioneering SDR-1000, is where SSB was in the years just after World War II. Then it was the subject of articles in technical journals and in *QST*, but not at a point where the average radio amateur was prepared—on a number of levels—to jump into the fray. Do you have to be a software engineer to own and operate an SDR-1000? No, but as Steve Ford suggested in his review last April, familiarity with the operation of personal computers and their potential to interface with radio equipment is a major plus.

FlexRadio encourages the more technically inclined to tinker with the open-source code. Wachsmann says the graphic user interface/*Windows* interface code is written in *C#* (pronounced "C sharp"), while the DSP is written in *C* (shared source with a *Linux* version). The *PowerSDR* source code is available free from the FlexRadio Web site's download page.

The Future is Now

Some plans already on the drawing board call for "a totally new look and feel with changeable 'skins,'" Youngblood told us. "We will be working on integrated remote operation, quad receivers in the passband, SO2R (single operator, two radios), real-time spots on the spectrum display, virtual sound cards for digital modes, *ad infinitum*." Youngblood says FlexRadio is in the process of adding support for the universal controller board that provides a 16×16 relay matrix for antenna and transverter control.

Manufacturer: FlexRadio Systems, 8900 Marybank Dr, Austin, TX 78750; tel 512-250-8595; **sales@flex-radio.com**; **www.flex-radio.com**. Price: Model SDR-ASM/TRA (fully assembled transceiver with 100 W amplifier and RF expansion board—no PC or sound card), $1375; SDR-ATU automatic antenna tuner module, $235; M-Audio Delta 44 professional sound card, $159; Shuttle-Pro controller, $99; Dell Optiplex 170L with software and hardware integrated and calibrated; 2.4 GHz Celeron, $769; 2.8 GHz Pentium 4, $899; 3.2 GHz Pentium 4, $1065; Dell E153FP, 15 inch flat panel display, $235.

W4RRY Electronic Battery Booster

Joel R. Hallas, W1ZR
QST *Technical Editor*

A real advantage of most modern solid state amateur gear is that it's designed to work from a nominal 12 V supply. This means that it should be an easy task to move equipment from the home station power source to mobile or portable operation under battery power. At first glance this seems to be the case, but as often happens, the devil is in the details.

So What's the Problem?

The problem is hidden in the word "nominal." The typical home station "12 V" supply actually puts out between 13 and 14 V. This is close to the voltage of an automotive electrical system while the engine is running and the alternator is keeping the battery at full charge. Most radio equipment is designed to operate in the same range, and our "nominal 12 V" system starts looking more like a "nominal 13.8 V" system!

Table 2

W4RRY Battery Booster Output as a Function of Input Voltage

Load A	*Input V*	*Output V*
2	13.8	13.8
20	10.8	13.8
20	11.7	13.75
20	13.3	13.8

AmQRP.ORG HOMEBREWER

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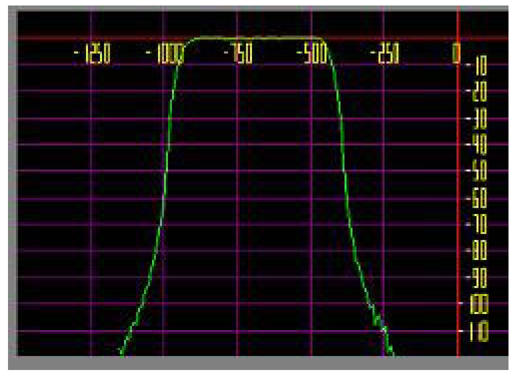
Software Defined Radios … The Future is Now

A Software Defined Radio (SDR) is a radio in which all modulation and demodulation functions are defined, and therefore configurable, through software. This creates tremendous flexibility to improve and adapt the capabilities of the radio over time without changing the hardware. The potential for amateur radio experimentation is virtually limitless in terms of performance improvement and the introduction of new operating modes.



Background

A Software Defined Radio (SDR) is a radio in which all modulation and demodulation functions are defined, and therefore configurable, through software. This creates tremendous flexibility to improve and adapt the capabilities of the radio over time without changing the hardware. The potential for amateur radio experimentation is virtually limitless in terms of performance improvement and the introduction of new operating modes.

The idea for the SDR-1000 Software Defined Radio was formed about six years ago while observing PSK31 running on a PC and sound card. Effectively, PSK31 uses the sound card and PC as a Digital Signal Processor (DSP) to perform modulation and demodulation of a digital signal. It became clear that a phasing-type transceiver could be built using the stereo inputs of the sound card for the in-phase (I) and quadrature (Q) signals. Four years and many hundreds of hours of study resulted a working transceiver that was described in the four part *QEX* series, "A Software Defined Radio for the Masses[i]." Interest generated by the articles was so strong that a decision was made to begin shipping the radio as a product in April of 2003. The articles, as well as complete information on the SDR-1000, are available on the FlexRadio Systems website at www.flex-radio.com.

The SDR-1000 ships with open source software written in Visual Basic 6, allowing users to modify and improve the code. Hams from all over the world have contributed to the enhancement of the SDRConsole code including both user interface improvements and advanced DSP code. Furthermore, a number of colleges and universities are using the SDR-1000 as part of their engineering curriculum.

The SDR-1000 continues to evolve based on input from the amateur radio community. This paper will focus on hardware and software enhancements that are in process and will be made available in the first half of 2004. The writing is a combined effort by Bob McGwier, N4HY, Gerald Youngblood, AC5OG, and Eric Wachsmann, FlexRadio software engineer.

SDR-1000 and SDRConsole Architecture – Gerald

As stated earlier, the SDR-1000 was described in some detail in the *QEX* series (endnote 1). The initial product consisted of a three-board set as seen in Figure 1. Recently, the enclosure shown in Figure 2 was added to allow a number of enhancement products to be added to the radio.

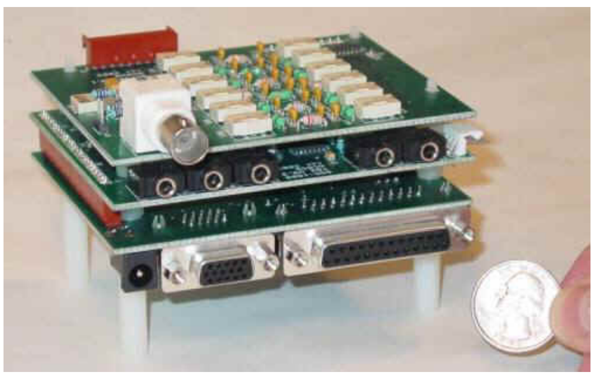


Figure 1 – SDR-1000 Board Set

Figure 2 – SDR-1000 Enclosure

The SDR-1000 incorporates a novel Quadrature Sampling Detector (QSD), which offers exceptional dynamic range as well as performing the function of a high Q tracking filter. Figure 3 illustrates a simplified version of the detector. It may be thought of as a rotary switch that rotates at the carrier frequency rate. Each of the four capacitors samples (or integrates) the RF signal for 25% of the carrier period at intervals of 0°, 90°, 180°, and 270°. By differentially summing the 0° and 180° signals and the 90° and 270° signals, we can generate the in-phase (I) and quadrature (Q) signals respectively. With I and Q, we can demodulate or modulate any type of signal. Not only is the carrier mixed to DC by the sampling process, the RC network formed by the antenna impedance and the sampling capacitors forms a commutating filter with a bandwidth of 1/(pi*n*R*C) (where n is equal to the number of sampling capacitors).

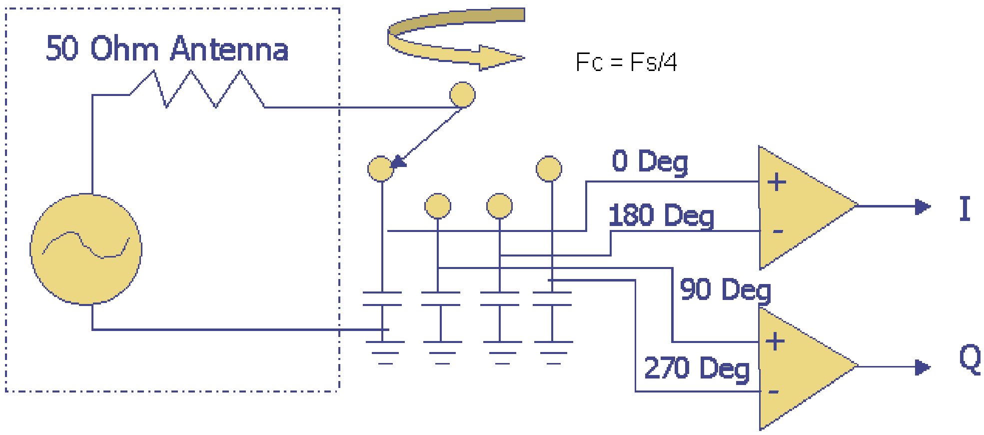


Figure 3 – Single Balanced Quadrature Sampling Detector (QSD)

The SDR-1000 uses a dual 4:1 MUX/DEMUX in a double-balanced QSD circuit that offers a 6dB improvement in large signal handling over the single balanced circuit shown in Figure 3. Using 5V parts, the QSD is capable of handling 10Vpp differential signals before going into compression. The double-balanced circuit also helps to suppress even-order harmonics. This large-signal handling capability allows more flexibility in gain distribution that is traditionally found in direct conversion systems. Gain can be placed in front of the QSD to improve the noise figure and reduce local oscillator radiation without significantly compromising large-signal handling capability.

While analog radios are properly characterized for distortion using third order (IP3) dynamic range, SDRs may not be adequately characterized in the same way. With a properly designed SDR, the radio will be highly linear up to the point of Analog to Digital Converter (ADC) full-scale saturation. When saturation is reached, the signal will be completely distorted and unusable. This means that third order products may not be detectable right up to about 1-2dB under ADC saturation. The full-scale voltage limit of the ADC will therefore set the maximum signal without distortion in a SDR. This may be as high as 4-5Vpp on some converters.

Because the SDR-1000 uses an offset baseband IF of 11KHz, it is possible to avoid many of the issues that have traditionally plagued direct conversion receivers. Above 1KHz, most of the 1/f noise, AC hum, and microphonic noise goes away and the dynamic range of the sound card greatly increases. Once the quantizing level of the ADC has been reached due to the total noise voltage in the filter bandwidth, it can actually resolve signals over a wider dynamic range than the 6dB per bit indicated by the converters resolution. For example, a high quality 16-bit converter has been observed to resolve signals in the frequency domain over >120dB range (noise floor to saturation). Therefore, the dynamic range of the ADC will have the greatest effect on the dynamic range of the receiver in most configurations. Figure 4 illustrates two tone dynamic range using –20dBm tones at 1KHz spacing. Spurs are shown to be approximately 95dB down from the fundamental tones. The measured spurs were actually first order spurs generated in the test equipment rather than third order spurs from the radio since they were demonstrated to change 1dB per 1dB of input attenuation.

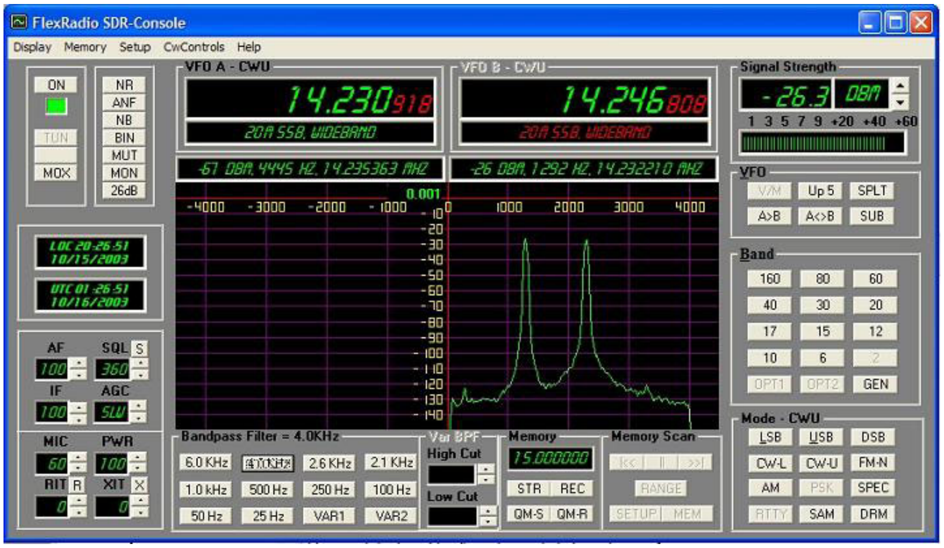


Figure 4 – Two Tone IMD Dynamic Range

The wide linear range of audio ADCs found in the better sound cards allows for some very interesting capabilities. First, it eliminates the need for analog AGC. This means that AGC can be performed digitally after the final filter, thereby greatly reducing the effects of strong adjacent signals. The effect is to remove the “pumping” of the AGC that is characteristic of analog AGC systems.

Further, by using double precision floating point values and fast convolution filtering in the frequency domain, we can achieve bandpass filter shape factors that exceed 1.05:1 (500Hz BW). A 2048-tap filter with 4096-bin FFT achieves stop band attenuation in excess of 120dB within 300 Hz of the 3dB cutoff frequency. Figures 5 and 6 demonstrate the frequency response characteristics of the 500Hz and 2.7KHz filters respectively. A description of the digital AGC system and fast convolution filters is provided in Part 3 of the *QEX* article series.

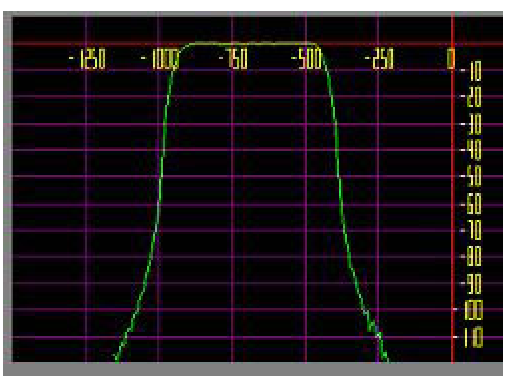


Figure 5 – 500Hz Filter

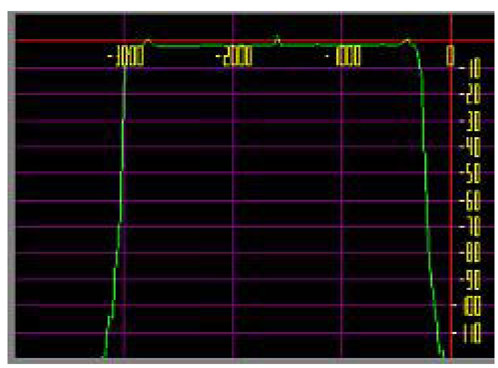


Figure 6 – 2.7KHz Filter

On the modulation side, we can also use the magic of DSP to do feed-forward compression of the audio signal to greatly improve average transmitted power without excessive distortion. The SDR-1000 uses a method of feed-forward speech compression wherein the gain is turned down quickly when the input signal is too large, but increases slowly if the signal drops off or ceases. This prevents the gain from increasing quickly between words. The net effect is similar to that of a good RF clipper without injecting distortion. VK6APH contributed the SDRConsole code for the speech compressor based on the algorithm in Marvin E. Frerking's book, "Digital Signal Processing in Communications Systems[ii]."

Another capability of the SDR-1000 is that it also functions as a high dynamic range spectrum analyzer. The SDRConsole, as seen in Figure 4 above, may be calibrated with a signal generator so that its spectrum display and digital readouts display the actual signal levels over a frequency range equal to just under the sampling rate of the sound card (typically 40KHz). Use of quadrature signals doubles the effective sampling rate over that of a single channel. As stated earlier, signals may be measured over a range of 120dB using a high quality sound card.

SDR-1000 Hardware Enhancements

There are a number of hardware add-on products in the works that will give the radio extended capabilities and performance. These include: a new RF Expansion board (RFE), 100W integrated linear amplifier, 2M transverter IF, and an automatic antenna tuning unit.

The SDR-1000 was designed for general coverage reception up to 65MHz. This requires compromise on the input band pass filters to minimize system cost. The RFE board will add 5^{th} order low pass filters for each amateur band to extend third harmonic rejection into the 100dB range. Further, it will add a 1.7dB noise figure preamplifier ahead of the QSD to significantly lower the noise floor without decreasing large signal handling capacity. With the preamplifier added, the gain behind the QSD may be decreased by the same amount as that added on the front end. This will not only improve the NF of the radio, but will also reduce local oscillator spur amplification by an equivalent amount.

The RFE also includes an experimental impulse generator that will allow for computation of the QSD and sound card impulse response. The impulse response will then be used to dynamically equalize the I and Q signals in order to maximize image rejection.

To determine the potential dynamic range performance enhancement that can be anticipated with the RFE board, an external low noise preamp was connected to the existing SDR-1000 board set. A Mini-Circuits ZFL-500LN (2.9dB NF) preamp was driven by a HP8640B signal generator and connected to the input of the BPF board. The maximum signal before ADC saturation and the noise floor was measured for harmonic frequencies from 1.75MHz to 56MHz. The measurements were performed at various baseband amplifier (INA) gain settings with and without the preamplifier. Table 1 provides the results of the testing. Note that for this test, dynamic range (DR) is defined as the difference in dB between ADC saturation and the FFT noise floor. By moving the gain ahead of the QSD (0dB INA gain), dynamic range is improved by 8-24dB depending on the frequency. A Toshiba Satellite laptop with integrated 16-bit AC97 sound was used for the measurements. Higher quality sound cards may improve performance of the system over those indicated here.

	SDR-1000 w/No Preamp						Production w/ ZFL-500LN @ 15V						SDR-1000 w/ ZFL-500LN		
Max Sig	-19.7			-34.1			-47			-62			-21.5		
INA Gain	26dB			40dB			26dB			40dB			0dB		
MHz	**Gain**	**Noise**	**DR**	**Gain**	**Noise**	**DR**	**Gain**	**Noise**	**DR**	**Gain**	**Noise**	**DR**	**Gain**	**Noise**	**DR**
1.750	0	-135	115.3	0	-136	101.9	0	-154	107	0	-155	93	0	-145	123.5
3.500	-0.9	-134	114.3	-0.9	-135	100.9	-1	-155	108	-1.1	-154	92	-1.1	-144	122.5
7.000	-0.8	-130	110.3	-0.8	-133	98.9	-0.6	-155	108	-0.8	-154	92	-1.1	-145	123.5
14.000	-0.3	-130	110.3	0	-131	96.9	-0.6	-154	107	-0.5	-152	90	-1.4	-145	123.5
28.000	-2.6	-125	105.3	-3	-127	92.9	-3.3	-153	106	-3.5	-154	92	NA	NA	NA
56.000	-4	-117	97.3	-4	-118	83.9	-4.2	-145	98	-4.2	-146	84	-4.4	-143	121.5
All measurements made with HP8640b signal generator into Kay 30-0 attenuator set to -20dB. Results measured on SDRConsole spectrum display.															

Table 1 – Dynamic Range Experiments

The RFE sandwiches between the existing BPF and TRX boards so that the BPF provides front end filtering for the low noise preamp. The 1W PEP driver amplifier (OPA2674) will move to the RFE board as well so that the existing BPF board will filter its output. The RFE will also provide control signals for the 2M microwave transverter IF, 100W linear amplifier and automatic antenna tuning unit described below.

Provision has been made in the enclosure design to incorporate a Down East Microwave DEMI144-28ECK low-power transverter kit as seen in Figure 7. It is designed to function as an IF for microwave transverters. In receive; it uses a high-level double-balanced mixer (+17dBm) and a three chamber helical filter. It provides 100mW of linear output in transmit mode. TR control and RF interface is provided through a single coax connection to the RFE board.

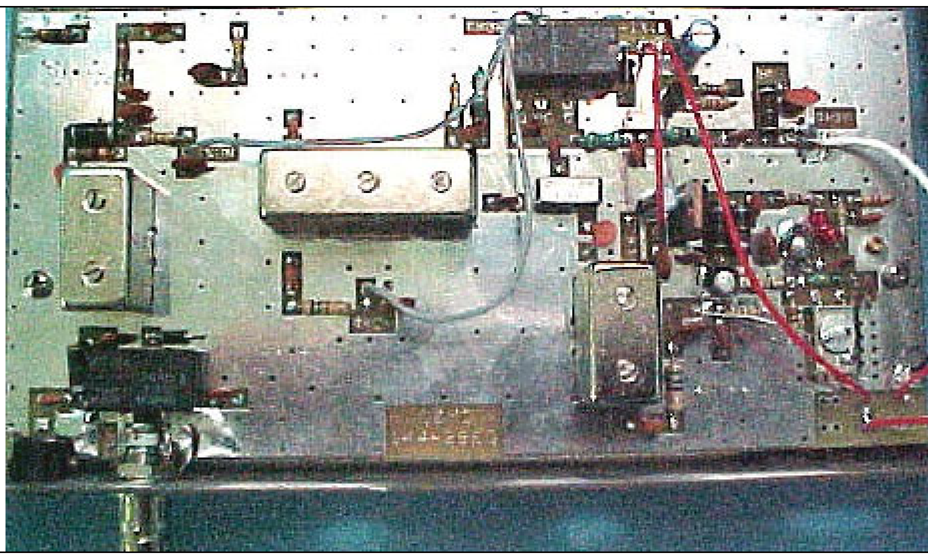


Figure 7 – DEMI144-28ECK 2M Transverter IF

A 100W PEP linear amplifier with low pass filters is being designed to fit in the SDR-1000 enclosure. The TR relay and filter relays will be controlled from the RFE board. Further details are not available at the time of this writing.

To round out the SDR-1000 accessories, a third party automatic antenna tuner will be integrated into the packaging. Once again, control will be provided from the RFE board.

SDR Console Software – Continued Growth

One of the nicest parts of this entire project has been the tremendous outpouring of software, ideas, new concepts, and contributed software by many different individuals. Each software author's contribution is prominently listed in the source of the software which is released GPL. There are now at least three functioning console packages in addition to that offered by Flex-Radio and more are on the way. Home brewing of add-ons to radios is alive and well in this project and embodied primarily in the software.

Noise Blanking and Pulse Removal

One of the banes of narrow band receivers are the effects of pulse noise. The worst offenders are typically semi-periodic pulse trains such as line or alternator noise; but we would also like to reduce the impact of single large pulses like switch openings and closings. One day, while listening to the broadcast band and a horrible set of pulses arriving in a pulse train, we attempted a truly simple noise blanker. If a signal value rose too far above the Root Means Squared (RMS) value, it was blanked, or set to zero. The effects were immediate and surprising. We then analyzed many noise blanking circuits and found they did little more than this, but in many cases, required a pulse train to work properly. This pulse removal usually operates on the wider signal inside the "roofing filter" while the pulse is still narrow. Then when the blanked pulse sample is passed through the filters that follow, the filter acts like an interpolator to smooth over the hole you have made in the signal.

In the lab, a weak signal was dialed up on 40 meters. It was a South American station that was just above the noise floor. At the antenna, 4V pulses were added! The noise blanker was engaged and the weak signal rose out of the hash and was completely readable. It is clear we are able to not only duplicate the typical noise blanker, but also in some ways exceed its performance. But there is no reason to stop there. We can afford to do a more complex algorithm than this since we do not have to pay for the associated hardware. Our only cost is the time to code the algorithm.

There are two promising algorithms we are exploring. We have developed one such algorithm and it is now included in the SDRConsole. Image processing algorithms have often developed rank order statistics in an attempt to look in the neighborhood of a pixel to see if "it fit" into the overall picture. If it does not "fit in", then it is declared to be speckle noise. Its value in the image is replaced by a combination of the surrounding pixels that more fairly represents the area of the offending pixel. The technique works wonders in the removal of speckle noise from the image.

We wondered how well this might apply to the removal of pulse noise in one-dimensional signals such as ours. In fact, we found it had already been investigated. Sanjit Mitra of the University of California Santa Barbara wrote a paper in which he described this exact algorithm. In his paper, he explains how to calculate the statistics and performs several tests. He called it the Signal Dependent Rank Order Mean Noise Reduction algorithm. How it works is really straightforward. We will consider our digitally sampled signal in groups of five adjacent samples

$$X(t)=[x(t-2),x(t-2),x(t),x(t+1),x(t+2)]$$

We will take every sample but the middle one and sort them into an increasing value array.

$$W(t)=[w(0),w(1),w(2),w(3)]$$

We will compute from this ranked ordering, the rank order mean. This simply means we will take the middle two values and average them.

$$\mu(t) =[w(1)+w(2)]*0.5$$

We will compare the signal at time t, x(t), with this rank order mean and then to its rank ordered neighbors. We will set two thresholds. We will test to see if it departs from the behavior of its nearest neighbors at one threshold. We compare it again to its farthest neighbors in our four long rank order vector against a larger threshold. If it does depart from the behavior of its neighbors more than these threshold values, we will replace the signal with the rank order mean $\mu(t)$. This has an immediate impact on the processed signal versus the blanked signal. We do not just zero out the signal and pray the filtering which follows will fill in the hole adequately. Anyone who has listened to a receiver with an activated noise blanker adjacent to loud signals knows how the AGC and cut-off action of the noise blanker can be modulated by these strong signals. In the SDROM case, we replace the offending value with a value that is determined from a smoothing of the surrounding values.

Initial Test Results of SDROM

In support of the picture-is-worth-a-thousand-words argument, we include the following in Figure 8 from our Matlab experiments when developing the algorithm. We have four signals in this graph. The blue trace (top) is the incoming simulated signal. It was the test signal during our development. It is a two-tone signal plus noise. We have added pulses to the signal. We have zoomed into a region of 160 samples around a pulse. The red trace (second from top) is the raw signal without pulses. The green trace (third from top) is what a traditional noise blanker would do and the black trace (bottom) is the SDROM output.

The differences are subtle to the eye, but profound to the ear. The large spike is clearly evident. We chose this spike in order to more clearly demonstrate the differences in the algorithms because it occurred near a peak voltage in the signal. At sample 62, you will notice that the blanker has just zeroed the signal, which causes a sharp edge, ***and the attendant clicks*** (just like key clicks) that accompany such an occurrence. The final black trace, the SDROM pulse noise canceller, has replaced the pulse with a smoothed version of the signal without the pulse. There will be no key click-like phenomenon with this approach. A traditional noise blanker incorporates these sharp edges that spray energy all over the spectrum, just like a key click.

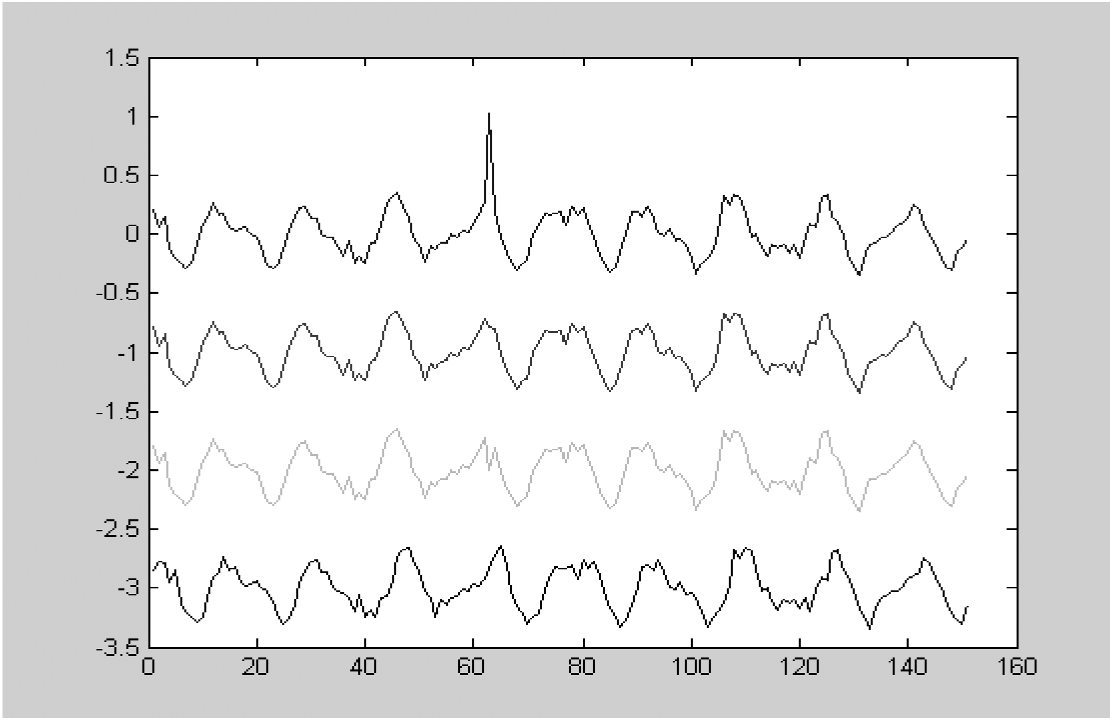


Figure 8 – SDROM compared to Noise Blanker

Nothing can more dramatically demonstrate this than the power spectrum.

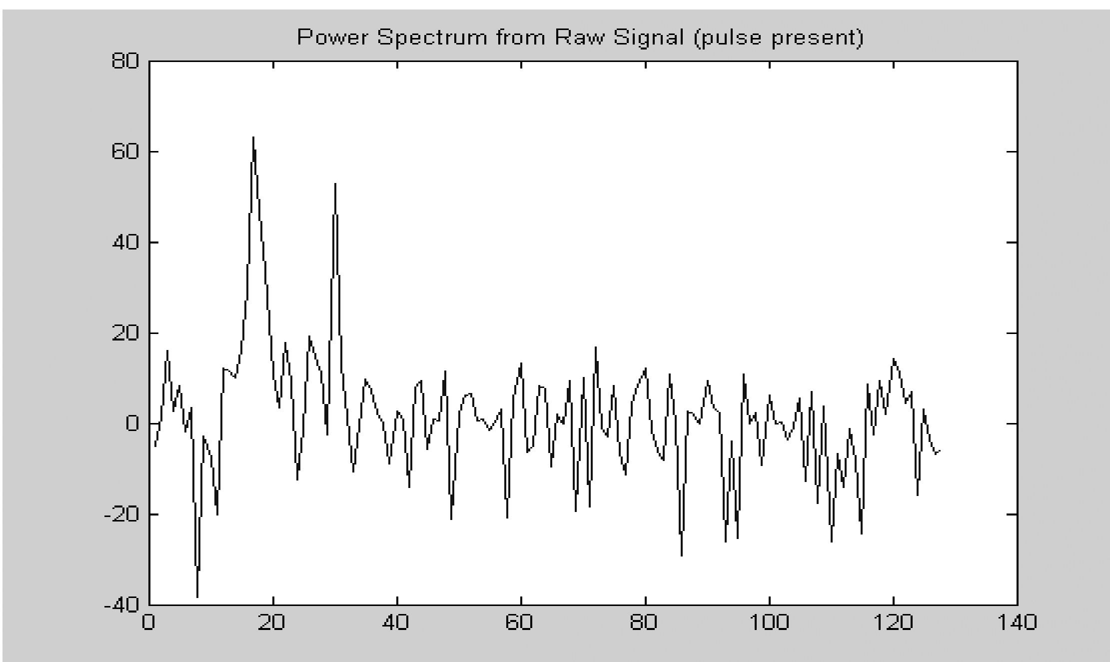


Figure 9 – Raw Signal

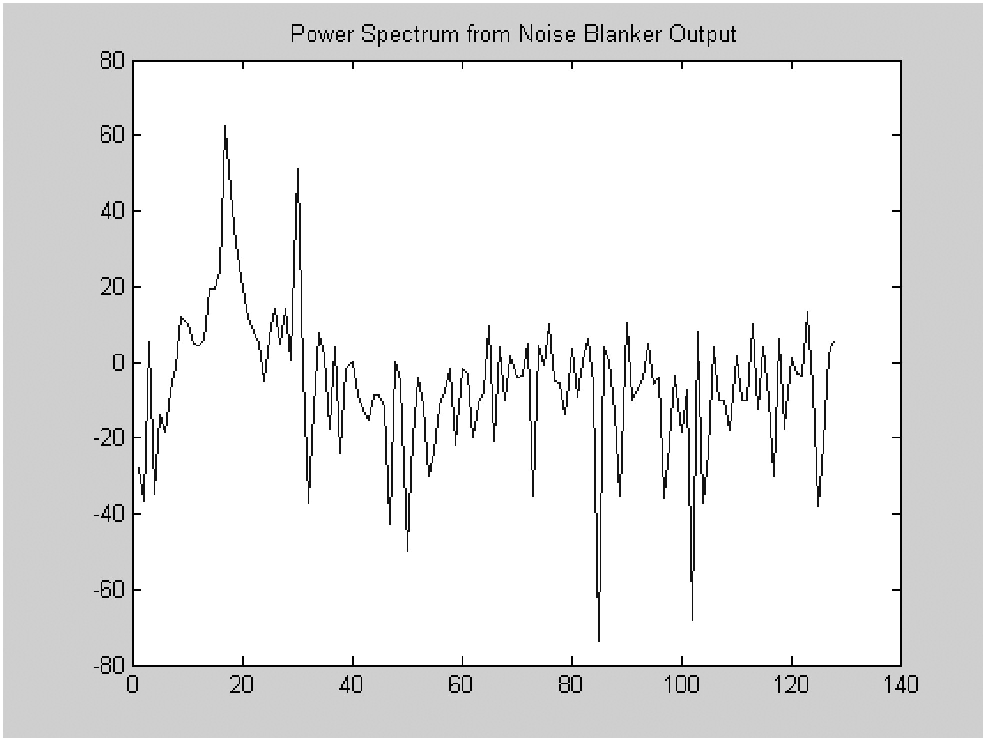


Figure 10 – Noise Blanker

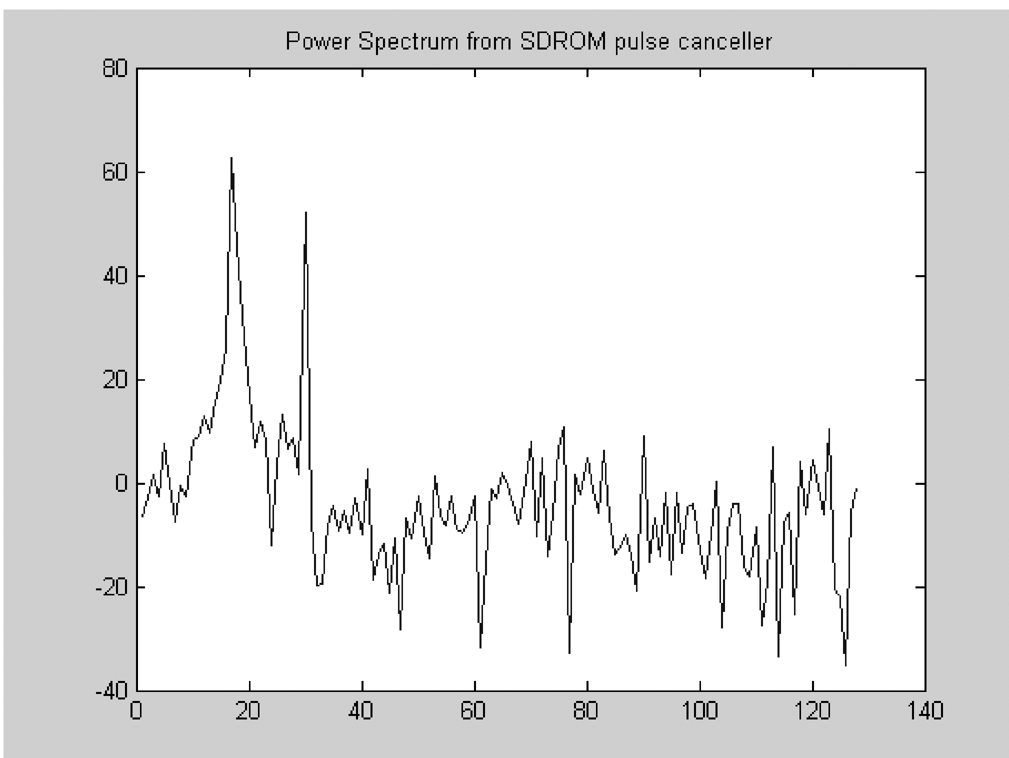


Figure 11 – SDROM

The differences are observed immediately if pointed out. The noise floor outside the area of the two tones is ***raised*** in the blanked signal over the signal with the pulse present. The

SDROM output has the noise floor depressed by 10 dB from the signal plus pulse and more from the blanker. This extra energy will not be mixing in a nonlinear fashion with signals of interest in the SDROM output. It is a marked improvement over the noise blanker. But it is not perfect.

The primary drawback to the SDROM as implemented by Mitra, et. al. is that it treats the pulse in the same manner as the blanker insofar as it makes the assumption that a pulse is a single isolated event and limited to one sample. This is easily improved on by doing SDROM recursively. That is, we consider the filtered signal when deciding whether to replace a value. This will allow for wider pulses than spikes. We have not implemented this but we expect small dB improvement in the noise floor from this added wrinkle.

Improving Image Rejection

The ultimate in noise pulse removal would be to know what the pulse looks like and to subtract it from the signal. This might seem miraculous until you know that Leif Asbrink has approached this in Linrad as describe in several recent *QEX* articles. Leif attempts to find the pulses and subtract their pulse shape, using two parameters from the incoming narrowband signal: the phase angle and the amplitude. In our attempts to make a real radio out of the SDRConsole, it was thought to be a deficiency of this approach that it required the user to determine a single pulse shape through a measurement procedure done once and assumed correct. It is clear that this is not perfect, though it produces good results in VHF+ noise and has been utilized by many VHF/EME/Microwave users. The imperfection shows up in the need for Linrad to continue to blank with the zeroing algorithm those small pulses that make it past this. To the extent that you do not have the pulses correct, or the amplitude or phase correct, you are ADDING PULSE BACK into the signal. It seemed that we could, in fact, do a complete automatic job of determining more parameters and improving the performance.

It has been decided to add a single pulse-generating engine just before the mixer in the new add-on RFE board. Rather than reiterate all of the advantages of this new board, we will detail our approach to the pulse shape here. (See Hardware Enhancements section for more on the RFE board.)

A terrific job of image rejection can be done if you know the phase and amplitude imbalance between the I and Q channels in the incoming signal. It would be ideal if this could be measured directly. We believe we can do this with a pulse generating mechanism. In our case, we need not know the exact relationship of our impulse response through our system, but rather its relative deviation from ideal. This is then easily added (convolved with) the filtering done for SSB, CW, etc. to remove the image in order to make both the I and Q response flat and equal with linear group delay across the spectrum of interest. In addition to accomplishing image rejection, this will give us the pulse shape of the ideal pulse entering the system and allow us to do a more complete job than Linrad can do with the one-size-fits-all impulse response. When we change bands (at a minimum), we will re-estimate the impulse response correction. Experimentation will allow us to determine if it needs to be done more often than once per Mhz change in frequency.

To that end, we derived a slow repeated pulse from a signal generator so that we could isolate one pulse at a time. The following graphs show a pulse as it has passed through the SDR-1000 hardware and has been captured upon passing through the most important element in any system, the sound card. The graph in Figure 12 show's the imaginary channel of the filtered signal in the area of one of these captured pulses. In a perfect world, this and its accompanying real part would be exactly the impulse response of the filter we have applied in the SDR-1000 console software that is applied for SSB detection. It would have nearly flat response in the passband and no phase or amplitude distortions. However, we live in the real world of real components of our mixer, instrumentation amplifiers in the SDR-1000 and op-amps in the A/D's in our sound cards. All contribute to distortion that hurts image rejection and keeps us from doing fancy noise reduction. Since we designed the bandpass filter in the IF, we know its impulse response perfectly. We register the location of the pulse and place it where we believe we have captured most of the response that can be seen above the noise floor. We compare that to the complex impulse response of the filter and correct for distortions. This will yield "perfect" image rejection. It will also allow us to apply the subtractive pulse canceller in a completely automated way since we will have to account only for perturbations from the ideal of the now determined impulse response.

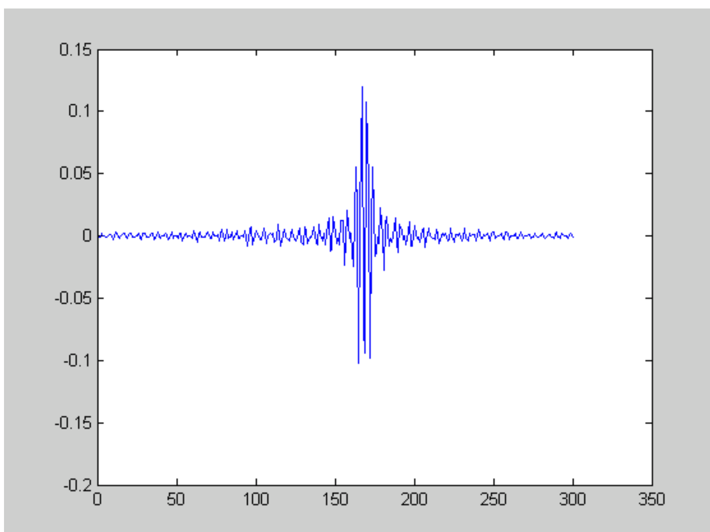


Figure 12 - A pulse time waveform in the Imag channel

In most of the modern transceivers available to us, we have DSP processors which do automatic noise reduction and automatic notch filtering. Most of them (if not all) use a Least Mean Square (LMS) adaptive filter first described by Widrow, et. al. and commonly referred to as the "Widrow" filter. This filter has a serious drawback. It uses the longer term correlations present in tones, speech, or Morse to produce a filter which either enhances them and reduces noise or notches them if they are undesired. This correlation is done very weakly and at one lag or "look into the past". A steepest descent based on this stochastic gradient is done. It is clear that this is a lossy and noisy look at the correlations needed to make this filter; yet it does work.

We would like to improve on this algorithm. One could use many different lags. As many lags as you will allow filter taps. This leads to a very expensive algorithm called Recursive Least Squares (RLS) and the unstable but fast versions of it known as Fast RLS or FRLS. Fortunately, there is another way that has recently been discovered outside of the area of noise canceling and notch filtering. We have adapted it for our use. It was developed in the echo-canceling world for multiple sensor microphone systems. Once you look past this function, you quickly see it is immediately applicable to other issues. It is known in that world as the Affine Projection Algorithm (APA) when you allow several more than one lag, but all the lags are adjacent to each other. There is an obvious extension of this to multiple lags that are not necessarily adjacent to each other, but cover a longer span. This can be extremely helpful in capturing more information about the signal. This version is known as Normalized Least Mean Square with Orthogonal Correction Factors (NLMS-OCF). A Google search will reveal numerous online documents if you need more detailed information.

Here, we will describe our first experiments and implementation. We have limited ourselves to APA in the Visual Basic console. This limitation will be removed in the upcoming versions of the console that will use other signal processing libraries and languages. For now, let's describe the results. We chose to use 3 lags to compare to our current signal sample in order to determine a good filter for our single experiment in notching a two-tone signal. We used the APA algorithm with a delay of 65 samples at 44100 samples per second. At that delay, we look at a filter with only 32 taps. We attempted to strain the algorithm with a short filter. In the end, we were amazed. Even in a noisy signal, given a short filter, we converged with the APA at a rate that was heretofore only achievable with RLS. In addition, it is automatically normalized for changing signal strengths due to AGC. It exhibits the better tracking behavior that is more akin to LMS, rather than RLS, which shuts down and stops listening unless you force it to listen by adding a memory leak constant to the RLS algorithm.

In 48 samples, we converged to a notch. In the power spectrum shown in Figure 13, we have two traces. One is before the automatic notch while the other is after. We have artificially shifted the notched spectrum down so they do not lie on top of each other. This extremely impressive result can only get better and more stable as we allow non-adjacent correlations of NLMS-OCF and improved performance across the spectrum if we choose distances that represent non-periodic signals more accurately.

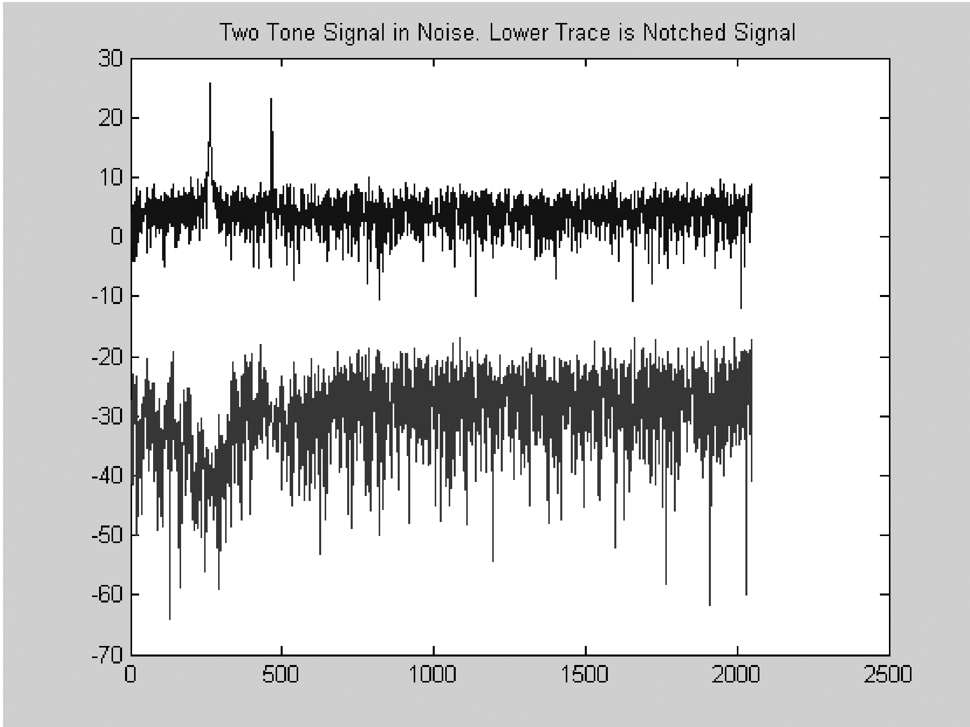


Figure 13 – Notched Power Spectrum

A serious drawback to the radio has been the way it operates as a CW rig, despite a Herculean effort by W5SXD. Frank Brickle, AB2KT, and author N4HY have come up with a technique to use Modulated CW (MCW) in order to gain full QSK without the drawbacks of using MCW. Since this is a software radio, we can afford to have an external circuit with a keyer chip and a tone generator that generates MCW. Some may be worried about spectral purity with this kind of excitation. However, we do not need to worry. We will do detection on the MCW signal inside the radio software rather than automatically transmitting it. We will then reconstitute the CW, with adjustable shaping and weight to be transmitted to the antenna. We will soon have RTTY and PSK31among the other modes already implemented. Rob Heard, in his own Delphi Version of the console, has implemented Slow Scan Television (SSTV) reception and is working on transmit capabilities. The full spectrum of narrow band communications on the ham bands is possible with this radio.

Recently, N4HY proposed an relatively easy scheme using the SDR to do frequency hopped spread spectrum using a compression-in-time algorithm that will enable the addition of synchrony signaling on every dwell while not losing or covering up the signal of interest.

Frank Brickle, AB2KT, has written an interesting article in a recent issue of *QEX,* which will lead inevitably to Cognitively Defined Radio. What this means is that the radio will detect a signal, classify it, and configure itself given the built in artificial intelligence to do so in the software defined radio.

AB2KT and N4HY are writing a full-blown console using Qt-Free as the GUI development engine and will be releasing the Linux/Alsa Sound/Qt console soon.

The following is a list of software developers listed in the latest beta version of the console software. The things they have contributed are too numerous to list but the radio would not be nearly as feature rich nor would it function as well without their contributions:

W5SXD, G6UVS, AA6YQ, W3IP, VE7APU, VK6APH, WK0J, N7TQM, N4HY, and AC5OG

New Object Oriented Architecture

While a firm groundwork has been established using the Visual Basic 6 (VB6) interface, it has become increasingly important to look at a new platform. With Microsoft making moves toward no longer supporting VB6[iii], we began to look at building the SDRConsole in a more recent language. Rather than simply porting the current code, we decided to take a bold step and redesign the entire console from scratch.

Using the lessons learned from the VB6 design process, we began with a very high level view of the software and broke each section into smaller logical blocks. Examples of such blocks are Digital Signal Processing (DSP), DataStream and Hardware. These blocks would be further broken down to a size that is easily maintained. Dissecting the project in this way allowed us to break up the coding responsibility much more easily. Using a Unified Modeling Language (UML) tool called ArgoUML helped us to visualize our software model. Figure 14 shows a portion of an early prototype of this model. Given the open-source nature of our project, easing the ability for customers to contribute directly toward the development of this new platform would be crucial to the software's continued success. With open source code and customers contributing code in their own specific areas of expertise, we have a uniquely diverse development team.

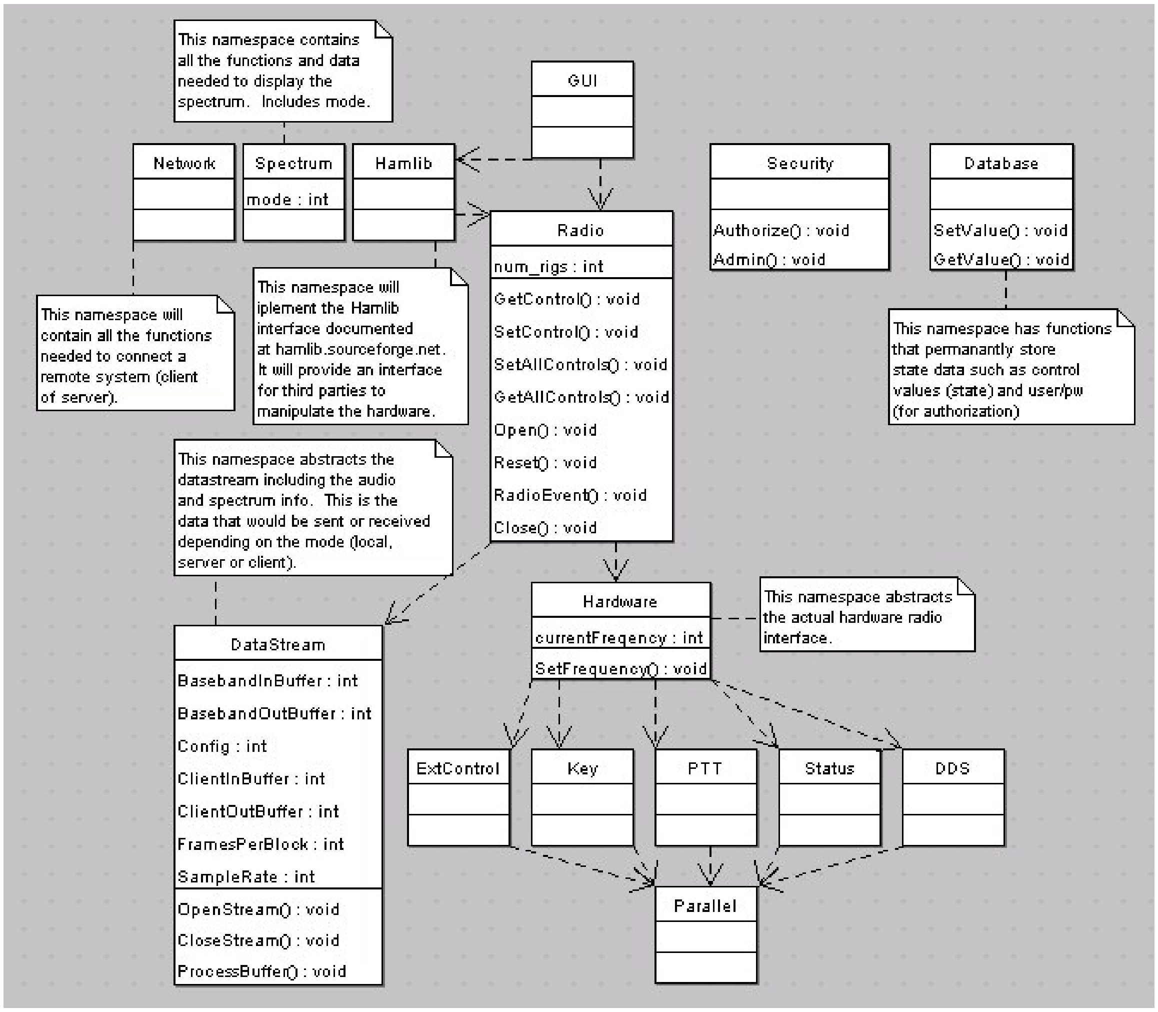


Figure 14 – UML Model

One of the major design points in our new software model was to provide support for both a binary executable interface as well as a web interface that could be accessed from any computer with access to the Internet. This would not be an easy undertaking, as we would have to consider such things as audio compression, data encryption and serialization. Despite the development cost, this feature is necessary for a cutting edge product such as the SDR-1000 and would open new doors of opportunity for remote radio applications. Imagine being able to pull up your radio interface and even transmitting using your PDA. This is the type of flexibility that we are aiming for with our new design.

In our search for an appropriate language, our options were somewhat narrowed by our strict criteria. While still wanting to offer an easy-access version for beginning programmers, our product would shine best in a multithreaded environment. We essentially needed something with the easy visual interface that Visual Basic offered while at the same time offering the power of C or C++. After a bit of research, C# seemed to be the logical choice. Further investigation revealed an extensive class library in the .NET Framework. With defined namespaces such as System.XML, System.Threading and System.Security, we would be able to quickly integrate powerful features such as RSA encryption, multithreading and serialization without spending months developing these libraries on our own[iv]. Linux and C#.NET versions of the console are being developed by Flex Radio, N4HY, and AB2KT. These will be demonstrated and distributed at the Dayton Hamvention.

One of the more exciting possible applications with the new object oriented architecture and the use of more modern development tools available in C#.NET and Linux is the easy ability to remote the transceiver hardware and to do the signal processing at the other end of the remote connection. An extremely exciting prospect for doing coherent combining of the signals from multiple radios is immediately available to the serious experimenter with minor modifications to the radio to allow for the injection of coherent DDS oscillator signals.

Having discussed the web-based access to the radio, it becomes obvious that not everyone is equally endowed with Internet connections. It would be very easy for the local server running, for example, a RealServer to save a known user's configuration, internet connection speed, and other factors so that when the unique user connects to the radio, the remote transmission to that user is configured appropriately for them. This information is easily stored in a database local to the radio and accessed upon connection.

In the early days when we were doing the initial development on the radio, some obvious expediencies came immediately to bear on the issue of getting the radio finished and software developed that would enable the experimenter to begin tinkering. AC5OG, as the developer, was not a DSP expert and not a real-time computing expert. A decision was made to use Intel's Signal Processing Library (SPL). This enabled fast, accurate, well written algorithms to be immediately available to the Visual Basic 6 console without having to be written from scratch, debugged, and optimized. However, as we move on to do other things with the radio and as Intel has dropped its support for SPL and substituted a fee for license based library known as PPL, we have decided to explore other options and some have become available for our experimentation with the new object oriented console.

We would like to re-use code across all platforms whether it be Linux, MacOS, or Windows. Recent developments have helped tremendously in that regard. A project that solves most of the really tough issues of dealing with audio and sound card issues was found in the PortAudio API. The PortAudio API project is on the web at http://www.portaudio.com. It has versions that enable one API to be used on Linux, MacOS, and Microsoft Windows. All versions of the code can have one interface to the sound system in the computer on which they are running. Eric Wachsmann has written a C# wrapper to talk to PortAudio for Microsoft Windows Visual Studio .NET 2003 and the API already comes native to run on Linux, and Unix (including FreeBSD which will run on the Mac).

We need a similar kind of library to do the primitive signal processing procedures that SPL did for us. In addition, we wish to begin doing the APA, NLMS-OCF, N-channel combining algorithm work and experiments not yet conceived by us but which we are fully aware will have features in common. The primary features will include a solid library to do linear algebra and matrix/vector manipulations as well as optimized fast Fourier transforms (FFT).

The latter was available for Visual Studio 6 as well as Linux and the Unices in the form of FFTW (see http://www.fftw.org). N4HY has recently ported FFTW-2.1.5, the most recent release version, to Microsoft Visual Studio (MSVS) .NET 2003 with all the project and solution files. This is available through a link on the Flex-Radio web site on the resources page.

The signal processing and linear algebra routines have been captured in a U.S. government supported open source effort known as VSIPL (see http://www.vsipl.org). Heretofore, no one known to us had ported this library to Microsoft Windows tools. It compiled and ran natively on Linux, Unix and MacOS (FreeBSD) systems. N4HY has managed to get all versions of VSIPL, which is written in C, to compile and make static and .dll libraries for MSVS.NET 2003. All library versions including using FFTW-2.1.5 as well as the native FFT in VSIPL, both static and dynamic have been made and tested. This library is also available as a link on the Flex-Radio resources page.

With the goal of portability in mind, it is not hard to understand why we would choose to use the Hamlib API for our control interface. Hamlib is a well documented library of ham radio controls designed to give third parties an easy interface with which to build their own third party applications which interface with many different radios[v]. In support of this idea, we decided to not only offer the public interface in our software, but to also implement our high-level control based, in part, on the Hamlib interface. Our software will then serve as a model that a third party could easily mimic to create a custom front end for our radio.

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[i] G. Youngblood, AC5OG, "A Software Defined Radio for the Masses: Part 1," *QEX*, Jul/Aug 2002, pp. 13-21; "A Software Defined Radio for the Masses: Part 2," *QEX*, Sep/Oct 2002, pp. 10-18; "A Software Defined Radio for the Masses: Part 3," *QEX*, Nov/Dec 2002, pp. 27-36; "A Software Defined Radio for the Masses: Part 4," *QEX*, Mar/Apr 2003, pp. 20-31.
[ii] Marvin E. Frerking, *Digital Signal Processing in Communication Systems*, Kluwer Achedemic Publishers, Norwell, MA.
[iii] Product Family Life-Cycle Guidelines for Visual Basic 6.0, http://msdn.microsoft.com/vbasic/support/vb6.aspx, Accessed 24 Feb 2004.
[iv] Class Library, http://msdn.microsoft.com/library/default.asp?url=/library/en-us/cpref/html/cpref_start.asp, Accessed 24 Feb 2004.
[v] Ham Radio Control Libraries, http://hamlib.sourceforge.com, Accessed 26 Feb 2004.

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Part 1

The Handyman's Guide to – HOMEBREW CONSTRUCTION PRACTICES From Copper to Manhattan

What is the difference between a QRPer and a Homebrewer? Not much, from what I have seen over the years. Where you'll find a QRPer, you'll generally find someone who loves to build his own equipment.

When it comes to homebrewing, there are two QRPer's that have set the standard (in my opinion). First is Bill Jones KD7S. Bill's homebrew gear, mostly crafted from ABS plastic, sets the standard that rivals professional equipment. Second is Jim Kortge K8IQY and his now famous 2N2/40 built *Manhattan style*. While this method of construction has been around for years, and many will argue who actually "invented" it, there is no doubt that Jim's 2N2/40 elevated it to a whole new level. The craftsmanship of these two master builders sets the standard many homebrewer's now strive to achieve.

Due to the continuing interest in these "build it from scratch" construction techniques, George Heron and Joe Everhart asked if I could prepare a basic guide for the **Homebrewer** based on some of the gear I have built or seen – which I am pleased to attempt. However, I make no pretenses that this is the complete guide to homebrewing. More precisely, it might be called *"Homebrewing Using Copper"* – and for good reason. Copper clad is readily available at hamfests and from many vendors (I get mine from Electronic Goldmine). Copper clad is very easy to work with, not only for the "circuit board," but for the construction of the enclosure and front and rear panels. It is also the main staple of "Manhattan Style" construction. And, best of all – it's fairly cheap!

I have used copper clad and Manhattan Style for many years myself, both for my QRP homebrewing, and prototyping circuits at work. Examples of both will be presented here.

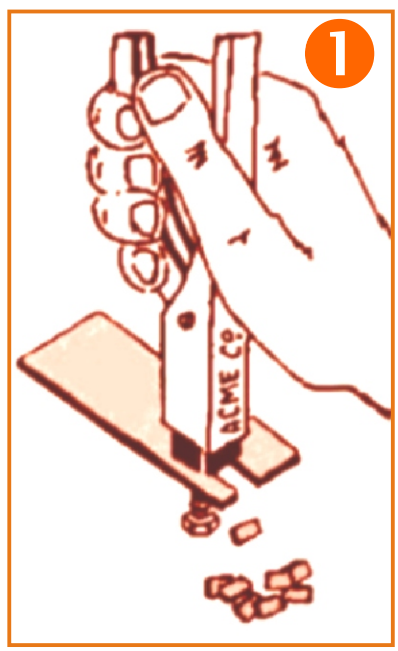
1. Let's Get Started . . .

MANHATTAN STYLE . . . What is it?

Simply put, ***Manhattan Style*** of construction uses small pieces of copper clad (the "pads") glued to the main copper clad circuit board (the "substrate") that serve as component mounting platforms. The electronic components are then mounted and soldered onto these pads. The main "substrate" board serves as the ground plane. Not only is this technique an easy and neat way to build a circuit, it also produces a very quiet circuit due to the solid ground plane.

When Jim Kortge, K8IQY, submitted his 2N2/40 at the FDIM building contest, one of the judges, Chuck Adams, K7QO, commented how the construction technique, with the IC's and electrolytic capacitors in neat rows, looked like an aerial view of Manhattan. Thus, Chuck is credited with dubbing it *Manhattan style* – the term it is well known as today amongst QRPers.

Making the "pads." There are numerous methods to make the pads. The most popular and easiest is using a ***nibbling tool*** to *nibble* out small pieces of copper clad from a larger piece, as shown in **Figure #1**. A nibbling tool costs $20 or less and used for making square cut-outs in 1/8" (max.) aluminum, such as for mounting a meter. The tool easy nibbles through .031" or .062" copper clad. The chards from the nibbling tool forms the pads, about 1/16" x 3/16". (Known as "chads" in Florida!).



Using a nibbling tool

Others make round or circular pads with a ***hand-punch*** tool from Harbor Freight or other sources. Dies of various sizes can be purchased for the hand-punch tool, with 3/16" or 1/4" diameter being popular sizes The tool punches-out holes in a piece of copper clad. The punched out material serves as the small, circular pads for Manhattan construction.

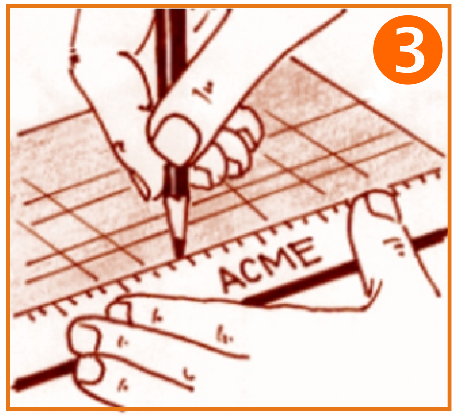
Still another method is to snap-off pads from a piece of ***perforated copper clad board*** as shown in **Figure #2**. The pads are twisted off with a pair of needle nose pliers or cut apart by a hefty pair of wire cutters. These pads are not as "pretty" as those made by a nibbling tool or circular hand punch, but work equally as well. The board can also be cut by following the perforated holes, using a coping or hack saw, to produce long strips, which can be cut-off at the desired length. One advantage of this technique is it allows you to make long strips that can serve as the +Vcc bus or making longer runs without having to connect two smaller pads with a jumper wire.

Using perforated copper clad circuit board for making the pads is another method, requiring no special tools.

Pads can be made from .031" or .062" thick copper clad, single sided or double sided.

Once the pads are made, it's a matter of placing them on the main circuit board for mounting the components. Before gluing on the pads, it is best to plan ahead.

Laying out the circuit. It is recommended to lay-out your circuit on a piece of paper, arranging the components in a logical circuit manner, similar to laying out a printed circuit board with paper and pencil. This will ensure that all of the components will fit on the size of copper clad board you have selected as the circuit board or substrate. One can build Manhattan Style by "building as you go," but problems fitting components, working yourself into a corner, or ending up with long wire runs reaching front panel controls can occur. Planning ahead by laying out the circuit first is by far the best way to ensure the finished product is correct to the circuit, functional, and the final appearance is nice and neat.

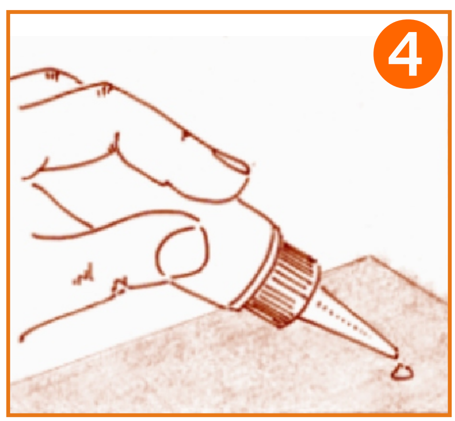


Draw footprints of each section and guidelines with pencil on the copper clad board. Planning ahead is important!

Once this is done, transfer the layout to the copper clad board with a ruler and pencil as shown in **Figure #3**. This provides guidelines for gluing down the pads and keeping things straight, square and symmetrical.

Gluing down the pads. Once the circuit has been layed-out, it is time to mount the pads on the main substrate board with small drops of super glue, as shown in **Figure #4**. And, small drops is the secret! Learn to issue a very small drop, smaller than the size of the pad, to keep excess from being squeezed out over the board when you apply the pad. It takes a little practice, but you can learn to apply the right amount with little waste.

There are many opinions as to what type of super glue works the best. Some prefer one brand over another, some prefer the gels. I have tried them all and have found little difference between them other than personal preference. I build most of my Manhattan circuits with the cheapest glue I can find, which is usually Duro-Bond Super Glue, with two tubes per package costing $1.79 or less at Wal-Mart or local hardware stores. The small "snout" on the tube is also relatively easy to keep clean and open.



Pads are "mounted" to the main circuit board with glue – usually with super glue. The secret is learning to administer a small drop of glue. This comes with practice.

The biggest problem I have found with different manufacturers or with the exotic applicators is keeping them clean. They work great – the first time.

But, when you come back to work on the project the following night, that fancy $5 tube has super-glued itself shut. You either can't get the protective cap off, or the tube has turned into a solid brick. Time for a new tube. A couple of cheap tubes of super glue goes a long ways when this happens.

To avoid these problems, I usually do two things when I'm done for the day:

1) Remove the applicator tip and run a resistor lead down the spout to open up the channel from excess glue. The excess may run or drip out the end. This will ensure the applicator tip is "open" when you place the tip back onto the tube. Without doing this, the super glue left in the tip can turn solid and hard, preventing it from being used again.

2) Clean the applicator tip and protective cap with a Q-tip or paper towel soaked in alcohol or acetone. Clean off all access glue, particularly on the threads for the protective cap. Then, clean dry with a piece of paper towel. If the paper doesn't stick – it's clean! This will ensure you'll get the protective cap off the next time you use the tube of glue.

These two simple cleaning steps can keep a tube of super glue useful for a long time. If not, that's why the cheap tubes of super glue should be used.

Positioning the "pads." The pad is placed on the drop of super glue and positioned into exact placement with an Exacto knife or other sharp object, as shown in **Figure #5 and #6**. For the first few seconds, the super glue will be slippery, allowing the pad to be easily positioned. Once in the desired position, push down on the pad against the main board to squish against the glue. It will be solidly glued into place in a few seconds.

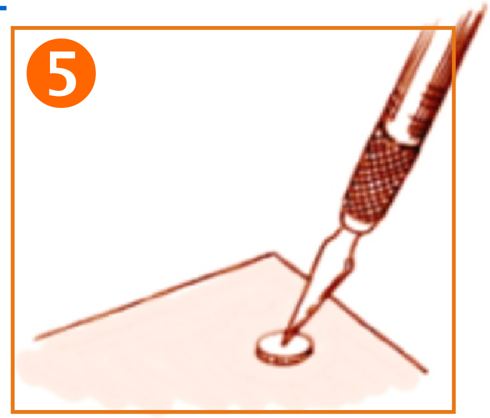
The method I often use is to place the pad into position with a pair of sharp, needle nosed tweezers. Once in position, I push down on the pad with a small screw driver or the wooden shaft of a Q-tip. However, the tweezer method does not work well when using the punched-out circular pads.

After several seconds, the pad should be firmly attached to the substrate board. Some of the circuits I have built years ago using this method have the pads still firmly affixed to the board.

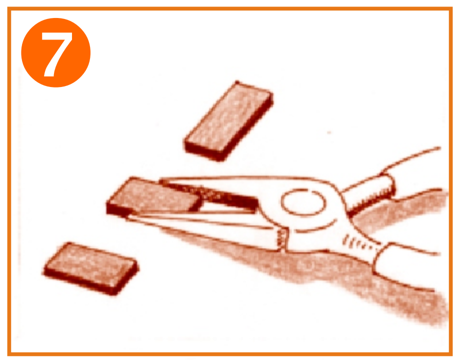
To remove a pad that got positioned in the wrong place, simply "twist it off" the board with a pair of needle-nosed pliers, as shown in **Figure #7**. Any pad that becomes dislodged from the board can be simply re–glued into place with a new drop of glue and holding in place for a few seconds.

Cleaning up. Once the excess glue had dried, it can be scraped off the board with a hobby knife or a small flat blade screw driver. It's up to the builder how picky one wishes to be with this. At a minimum, the board and pads should be cleaned with a hobby brush or toothbrush moistened with alcohol or acetate to remove oils, fingerprints and debris. This will make for easier soldering and a nicer appearance.

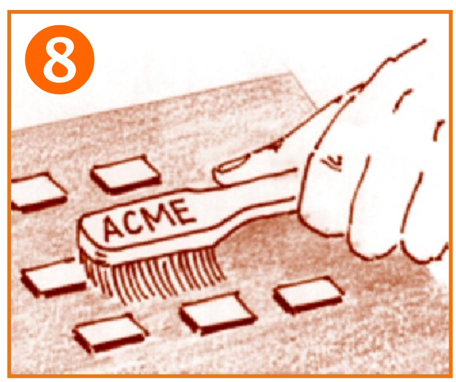
Acetone dissolves dried super glue better than alcohol. It is easily obtainable as fingernail polish remover in many stores. However, most fingernail polish remover sold today is "acetone free." Ensure you get a bottle that contains real acetone. I get a bottle of acetone based fingernail polish remover from Wal-Mart that works quite well. It costs 88 cents for a pint bottle and usually lasts for several projects.



Place the pads onto the drop of glue and position with an Exacto knife, other sharp object or tweezers..

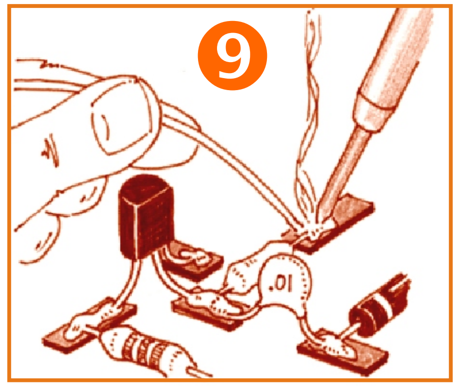


Remove a pad by a twist with a pair of needle-nosed pliers.



Clean board and pads with a brush and alcohol or acetone.

Melt solder! Once the pads are in place and cleaned, there is nothing left to do except mount the components onto the pads and solder in place according to the layout drawing. Of course, ground connections are soldered directly to the main substrate board, being the circuit ground plane, as shown in **Figure #9**.



The glued pads become the mounting platforms for the components, soldered in place.

I use a small hobby brush with hair or fiber bristles (not steel) for cleaning the pads. I use the same brush moistened with alcohol or acetone for cleaning the pads after soldering. This removes excess flux and debris, leaving a nice, shiny soldered pad.

Tools. In addition to the obvious — a soldering iron, wire cutters and the small pliers already discussed, several other small tools come in handy:
Tweezers are handy for positioning the pads when gluing to the board, in addition to holding small parts while soldering – particular surface mount components. *(Surface mount techniques will be presented in Part 2).*
Hemostats are another useful small tool for holding resistors or capacitors while soldering. They are locking, making it easy to hold the component with one hand while soldering with the other. Just ensure you don't over-squeeze the component to cause damage. Hemostats often allow a component to be held with a better grip than with tweezers.
Small screwdriver, flat-blade or phillips, is useful for holding down pads while the glue dries, pushing down ill-bent or stubborn component leads while soldering – even a lead bender to ensure smooth bends on component leads and internal wiring.
Q-tips are handy for cleaning or scrubbing around the pads after soldering, where a hobby brush may not often reach. Lightly moistened with alcohol or acetone, they are also useful for cleaning the components. When cut in two, the wooden shafts are also handy for holding down pads during gluing, or components while soldering.

Some of the small tools useful when building Manhattan style.

2. Some Practical Examples

THE ROCKMITE QRP TRANSCEIVER

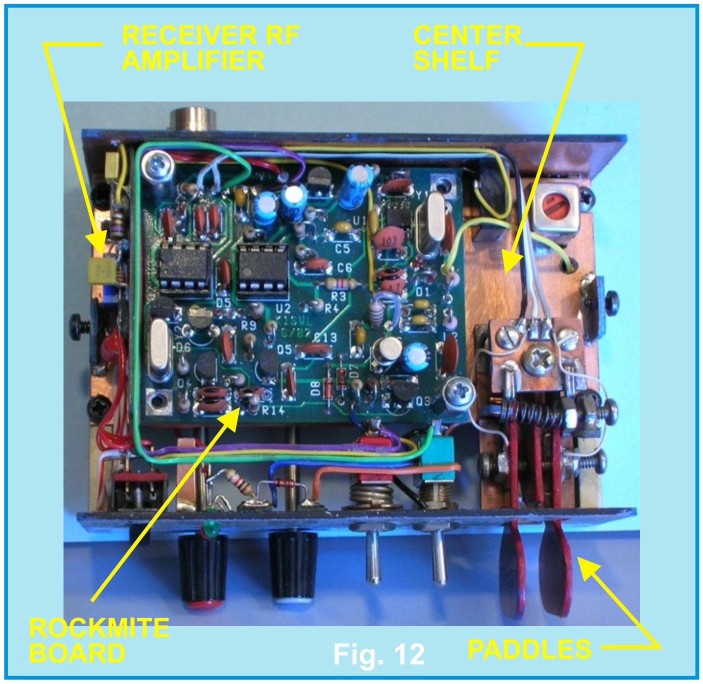
Like hundreds of others QRPers, I built a ***Rockmite*** about two years ago when the kit was first introduced. The Rockmite QRP transceiver is a kit from Small Wonders Lab, furnished with a printed circuit board. I decided to highly modify mine, building it in a custom enclosure with a set of homebrew built–in paddles, something I always wanted to do. Additionally, it served as a test platform for a 5W Class-E PA circuit. The entire rig, including the paddles, was built of copper clad, except for the top cover, made from a scrap piece of perforated aluminum and painted black.

Fig. 11

The front panel, shown in **Figure 11**, was made from a piece of copper clad. Holes were drilled and the "square holes" for the power switch and paddles were filed to shape with a small jewelers file. After drilling, the copper clad was brushed with emory paper to rough up the copper a bit before applying a light coat of gray primer paint. The second coat, applied the following evening (this is a big hint for painting enclosures!) was a coat of light avocado green. The following evening, when fully dry, the light blue trim and boxes for the transmitter drive and receiver RF gain controls were painted by hand using a small brush. The legends were applied using rub-off letters and sealed with a light coat of Krylon Protective Spray – available at many office supply or art stores. Clear enamel can also be used, but always test first on a scrap piece of material to ensure it doesn't "melt" the rub-off letters.

The front and rear panels were soldered to a copper clad "center" shelf, mounted about half the height of the two panels. This shelf serves to mount the Rockmite PCB and the paddles on the top (see**Figure 12**), and the transmitter components on the bottom.

The paddles are made entirely of pieces of copper clad, including the paddle pieces, as shown in the photograph of the top view. A 4-40 bolt and nut, with a spring from a BIC pen, formed the tension on the two paddles, while two other 4-40 machine screws serve as the dit and dah contactor and sets the spacing. It's not exactly a work of art, but they worked well, enough to have around 50 QSOs with this rig.

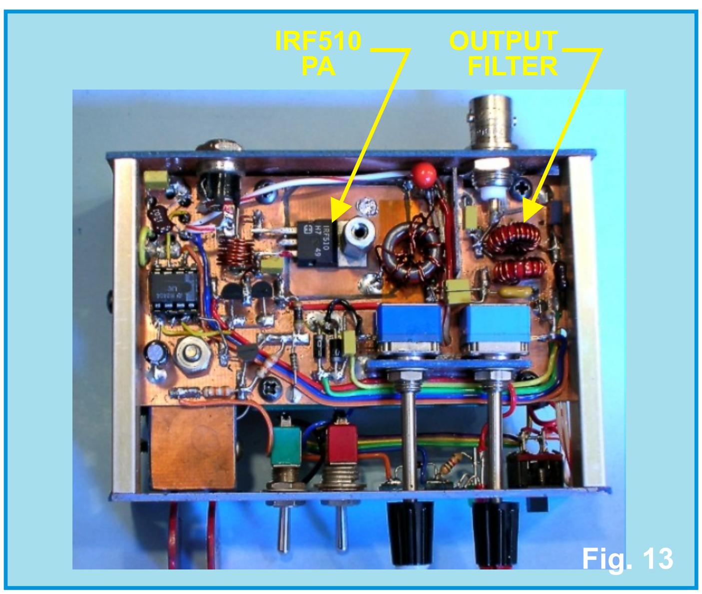


Top view of the Rockmite. The Rockmite PCB and the homebrew paddles are mounted on the top portion of the center shelf.

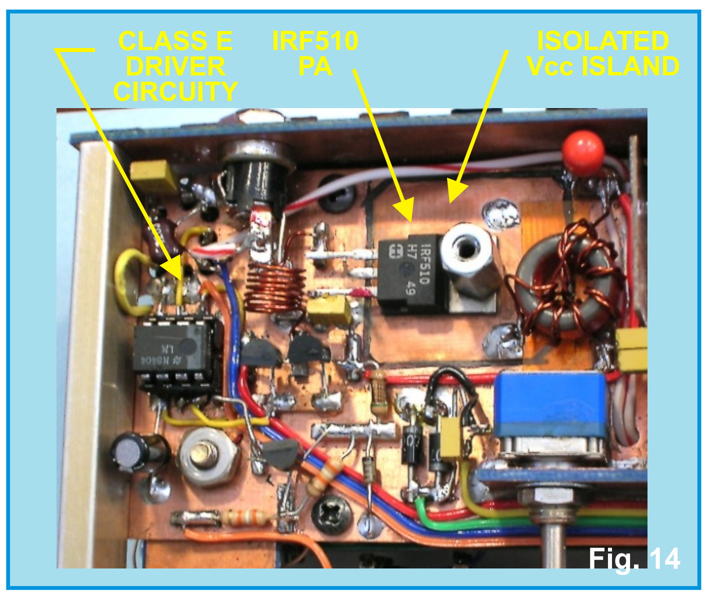
The transmitter was built Manhattan style, with the pads glued directly to the bottom of the copper clad shelf. The IRF510 was mounted to an island cut-out of the copper clad by a Dremel tool. Since the IRF510 tab is the drain, this isolated the +12v on the drain tab from ground. Most of the interconnecting wiring was performed by using flat ribbon cable as shown in **Figures 13 and 14**.

The intent of this particular custom-made Rockmite kit is to show the flexibility of copper clad. It was easy to form the copper pieces into the desired front and rear panels, the center shelf, and even the paddle pieces. Granted, it took a little cutting and filing to form some of the pieces, but far easier than forming the same pieces from aluminum or metal stock. Plus, it can all be easily soldered together.

By applying a light primer coat before the final color of spray paint, copper clad makes an attractive and durable front panel as well.



Bottom view of the Rockmite, showing the home-brew transmitter section built Manhattan Style.



A closer view of the transmitter section, showing the Manhattan style of construction.

MANHATTAN STYLE HOMEBREW TRANSCEIVER

I have built several QRP transceivers on different bands Manhattan style, mostly my own designs. In fact, that is one of the advantages I have found with Manhattan is how adaptable it is for a test platform. Changing components of different values to set proper biasing or gain is relatively easy, as is making circuit changes. Of course, too many circuit changes can get ugly as you try to fit things in you didn't originally plan on. But, it usually works fine. In the circuit shown here, I converted the RF amplifier from fixed gain to an AGC driven stage, moving around a few components from that originally planned.

The schematic (**Fig. 15**) is the "front end" portion of a 40M receiver I built, where T1 and T2 are Mouser 42IF124 IF cans. Q1 is a common base amplifier with the bias via R2 from the AGC line. C1 and C2 are the tuning capacitors to resonate T1 and T2 at the desired frequency (T1,T2 are 4.5uH nom. with no internal tuning capacitor). T1 is made resonant at the RF frequency and T2 at the IF frequency. Built Manhattan style, this RF amplifier and mixer scheme was fairly sensitive with a good noise figure.

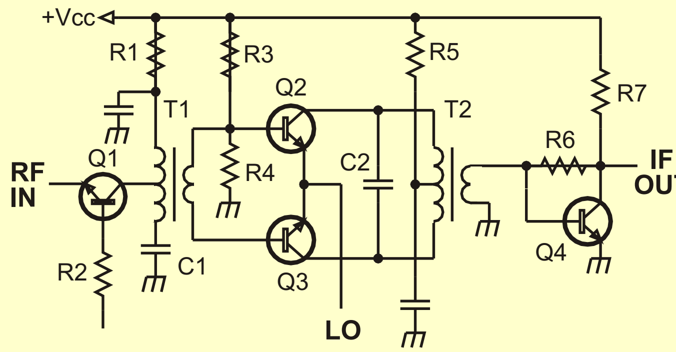


Fig. 15
Functional Schematic of the 40M "front–end"

The **Figure 16** photograph shows the "front end" portion of the receiver, based on the above schematic. With a little layout on paper first, the RF amplifier, receive mixer and 1st IF amplifier fits in an area about 1 x 2.5 inches. Interestingly, I also built a surface mount version of this same receiver, using the same IF transformers, and it took only about 1/4" less space! I used SOT-23 SMC 2N3904 transistors, which are about the same width as the TO-39 plastic versions. As a result, little space savings was noted – at least using this layout configuration.

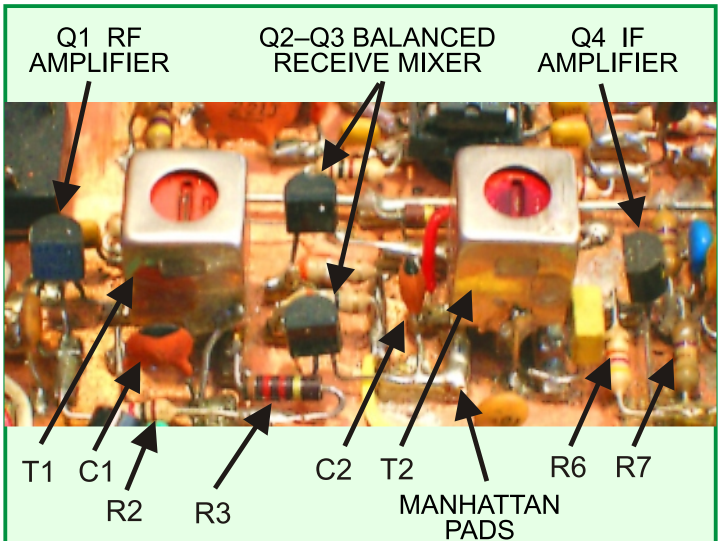
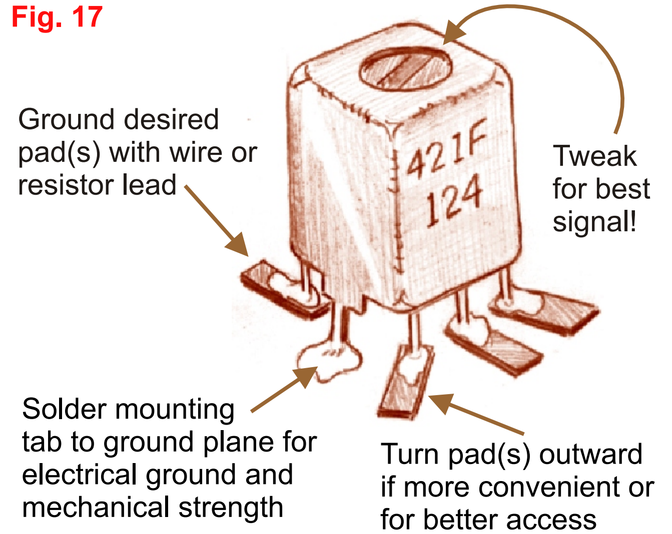


Fig. 16 – The "front-end" of a 40M QRP receiver built Manhattan style using IF "cans."

The IF transformers are mounted on the main board in standard Manhattan style. See **Figure 17**. The only caution is to ensure the IF "can" is soldered to the main board with either the mounting tabs (if they reach) or with a piece of solid bus wire or a scrap resistor lead folded in two. Solder on two adjacent sides of the IF can for a firm mechanical connection.

Likewise, ground the desired pads(s) by soldering a wire or resistor lead to the main board for grounding. All transformer pins should go to a Manhattan pad to keep the IF transformer "level." Soldering the wire to ground the pad(s) to the main board also helps with the mechanical mounting without depending solely on the super glue. Otherwise, with a "stiff" IF can, you can twist the pads off the board while adjusting the center slug if not soldered directly to the board.

Fig. 17



Mounting IF Transformers Manhattan style

Following the 1st IF amplifier is the crystal ladder filter, as shown in **Figure 18**. Four of the crystals are for the IF filter, the one on the far left is actually the crystal for the transmit oscillator. The transistor in the upper left of the photograph is Q4, the 1st IF amplifier in **Figure 16** on the previous page. The wire soldered along the tops of the crystals serve two purposes: 1) to ground the cans to the main board, and 2) provide mechanical rigidity. Without this ground wire, I find myself constantly bending over the crystals while I'm building and poking around in the circuit.

Figure 19 shows in a bit closer detail how the crystals and shunt capacitors are mounted to the Manhattan pads.

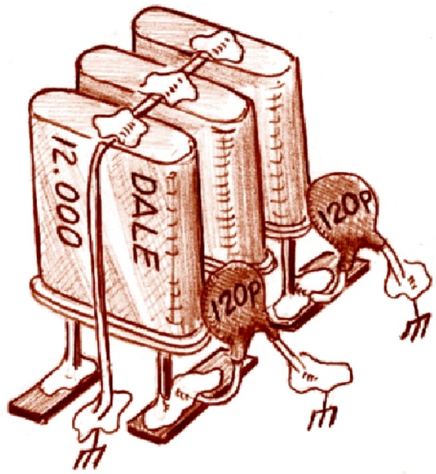
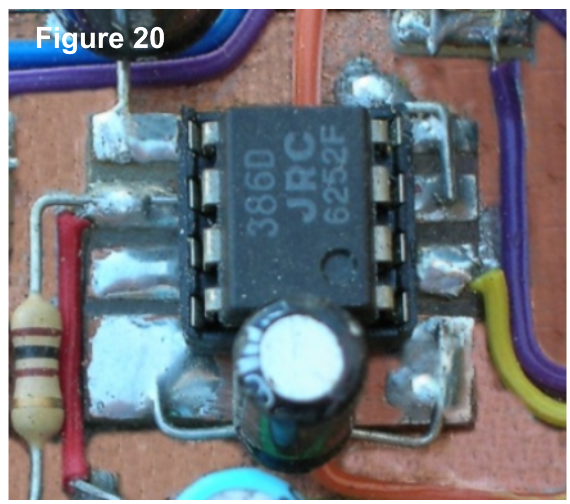


Figure 19

In mounting the crystals on standard Manhattan pads, the crytal leads need to be bent to fit. This is a case where cutting small strips of copper clad to length makes for a neater and more accessible assembly.

The IF Crystal Filter

Figure 20 shows the LM386 audio output amplifier I.C.. This is such a simple, yet effective audio amplifier, it has become the benchmark amplifier in most QRP rigs.



The LM386 Audio Output Amplifier IC

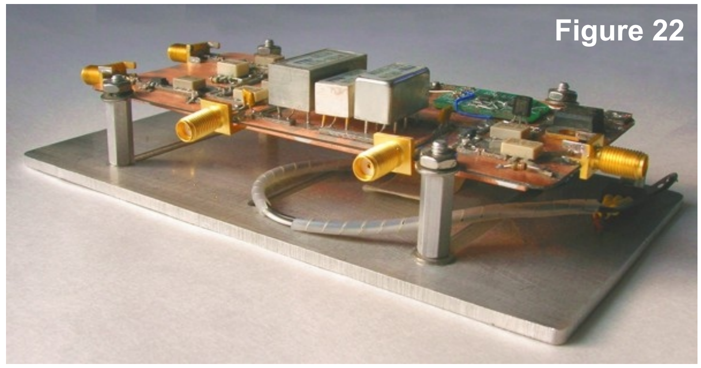
I mount ICs either on individual Manhattan pads, or build a single pad as shown in the photo of **Figure 20**. This pad is made from a single piece of copper clad, cut into the pads as shown by sawing away the copper between the pins with a hack saw, coping saw, or a Dremel tool with a cutting disk. Then, obviously, another cut down the length of the IC to separate pins 1–4 from 5–8. Either method takes about the same amount of time, though the single Manhattan IC pad does look nicer, in my opinion.

If you make a rig out of copper clad, including the front and rear panels, don't forget the copper on these surfaces can be used as well. **Figure 21** shows one rig I built with the PA output filter mounted on the inside of the rear panel, next to the Antenna BNC connector. In this particular case, I etched away the unwanted copper with a Dremel tool, though Manhattan pads could just as easily be used. To the left of the filter (not shown) is the TO-220 PA transistor – also mounted on the inside rear panel. This allows the rear panel to serve as a large heat sink.

The PA Output Filter mountedon the inside of the rear panel saves space

A MANHATTAN BUILDING JIG

One of the difficulties I've experienced building small circuits is the copper clad board, weighing only a couple of ounces, moves all over the workbench surface as you work on it.



A building jig for holding down the circuit board for Manhattan style of construction.

Shown in the photograph is a Manhattan Building Jig (MBJ) I built for holding down a circuit board while it is being built and tested. In this case, I used a piece of aluminum and milled out several slots. In these slots ride the screw heads for the threaded standoffs. On the top of the standoffs, the washers and nuts secure the circuit board. Once attached, the screws on the bottom of the plate are tightened to hold everything rigidly in place. This allows different sizes of circuit boards to be mounted onto the jig. I have found this simple jig to really ease construction and testing. Particularly testing. Once you get a couple of cables and wires connected to the board, the weight of the cables alone will pull the board right off the bench! A jig with a little weight and larger footprint will keep this from happening.

On the far right hand side of the jig, under the circuit board and hardly noticeable, is the TO-220 voltage regulator used for the circuit. This places the voltage regulator close to the circuit and the base acts as a heat sink.

Of course, a jig of this nature could be built out of plywood or even a piece of 2x4. In this case, the board is held down to the jig with wood screws or other fastening scheme.

MANHATTAN – VHF STYLE

One of the "modules" I am responsible for at the VLA observatory is called the "4/P Converter." This converts our low-band receivers, being 74, 196 and 308–348 MHz, to an IF of about 1.1–1.4 GHz (L-band), then upconverted again to our 8–12 GHz X-band IF. In order to checkout this upconverter, I would need 4 signal generators, one for the three receivers and one for the 1024 MHz LO. I'd get killed by my co-workers for sucking up 4 of the lab signal generators everytime I needed to work on this converter! And, I've got 28 more of them to build over the next 3 years. So, I designed and built a test set that simulates the three receivers and the 1024 MHz LO. Additionally, it contains a sweep generator for "sweeping" the bandpass shape of the RF and IF filters on a spectrum analyzer.

Fig. 23 – A Manhattan-built Test Set used to simulate three VHF receivers and contains a 1024 MHz Local Oscillator

This was a fun "ham radio" project at work. It was built largely from copper clad and Manhattan style. Most of the parts were ordered from Mouser, All Electronics, Electronics Goldmine and MiniCircuits. The overall "4/P Band Test Set" is shown in **Figure 23**. The copper clad circuit assemblies are mounted vertically with the push-button switches and potentiometer controls protruding through the front panel. Details of two of these assemblies, the 74MHz oscillator and the 200-400MHz sweep oscillator, are shown on the next page. The meters indicate the output power level, normally set to –35dBm to simulate the receivers. While this is not a ham radio QRP project, it does contain many construction techniques that can be applied to any HF or VHF project. (Although, it *was* built by a QRPer!). When I built this, I was a bit concerned at how the copper clad and Manhattan pads would behave at the VHF frequencies..It turns out, it works quite well. Wideband sweeps reveal only minor gain "suck-outs" between 600-1500 MHz. Rumors that Manhattan style should not be used above about 20MHz are thus unfounded, as proven with this project.

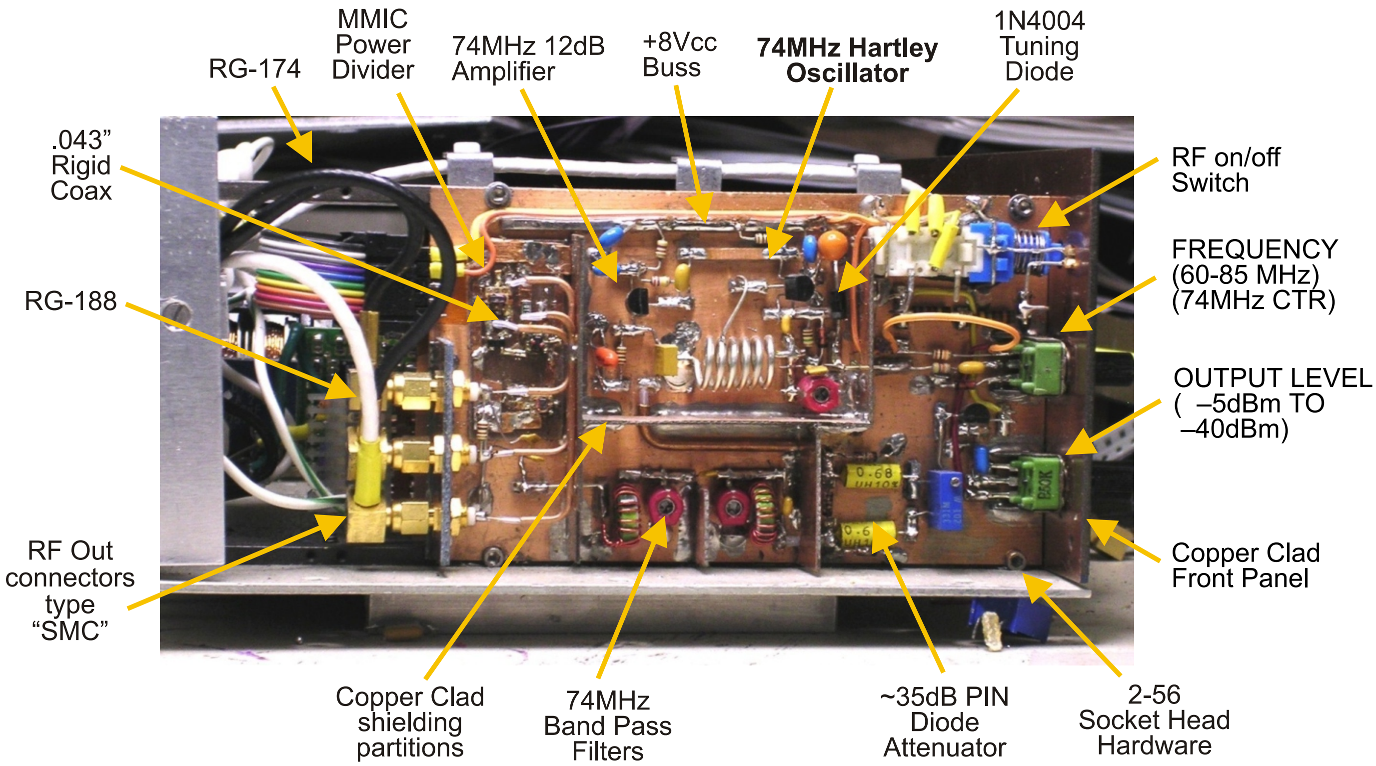


FIG. 24 — 74MHz OSCILLATOR (74MHz RECEIVER SIMULATOR)

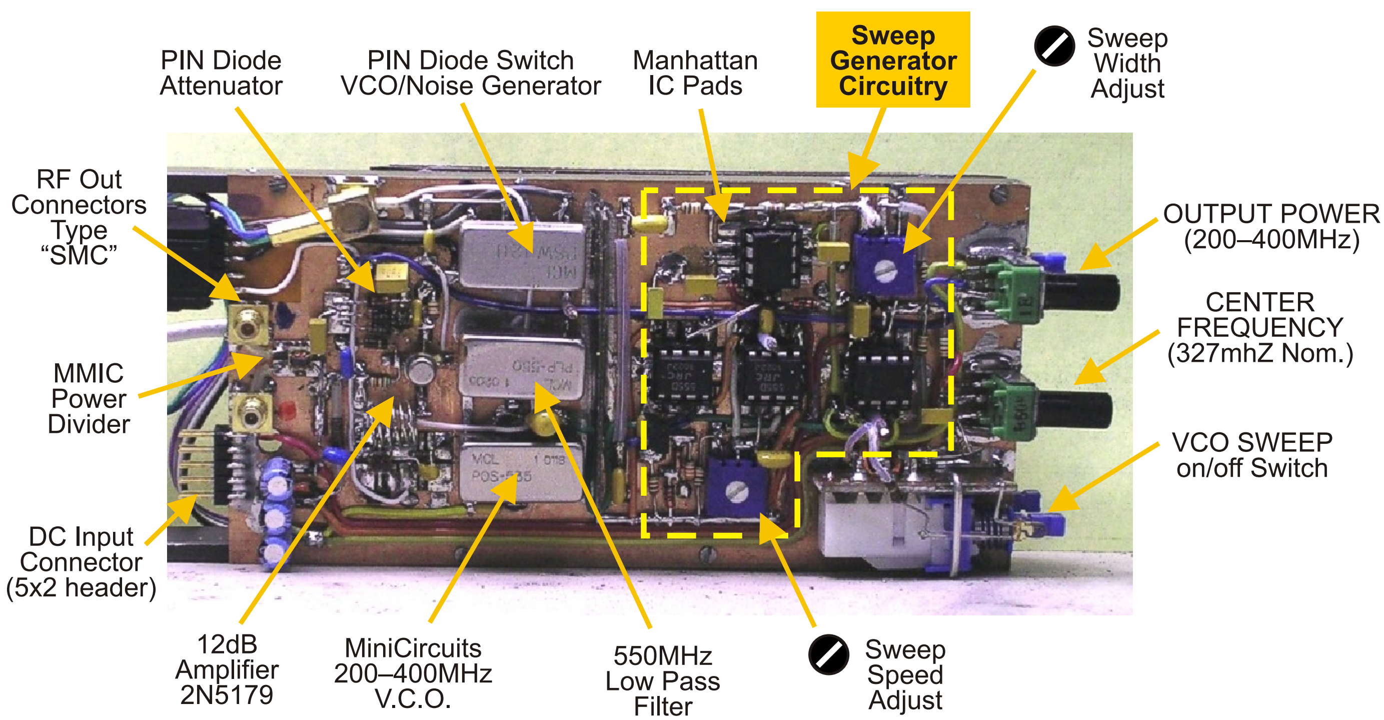


FIG. 25 — 200–400MHz SWEEP OSCILATOR (P-BAND RECEIVER SIMULATOR)

3. "Ugly" or Manhattan?

While the majority of this article focuses on Manhattan style of construction, it is not the only means to build a circuit. Since the dawn of radio, hams have built equipment "ugly style." Ugly has a charm of it's own.

Ugly began in the earliest days of vacuum tubes, where a circuit was built on a piece of smooth wood, mounting components between nails or screws – often just twisting the wires together, not soldered. Since a cheap piece of attractive wood in the early 1900s was a breadboard used by bakers, the term for this style of construction was called "breadboarding" – the genesis of the term still used today for building a one-of-a-kind circuit. Building on a breadboard could be anything from beautiful (**Fig. 26**)– to outright ugly.

Basically, building something ugly means "just throw it together" with little regard to appearance. Ugly also tends to imply building it cheaply as well, a common attribute of most hams – yesterday as well as today.

Today's breadboard tends to be a piece of copper clad. Component leads that are grounded are soldered to the copper clad surface as in Manhattan style. Everything else just gets soldered together, often with the components hanging in mid–air. The only concern is to make sure the component leads to do not touch ground or other things they shouldn't – often by bending or routing leads and wiring in a precarious manner. An example of this is the 7 MHz VFO built "ugly" as shown in the photograph of **Figure 27**.

A variation of the ugly circuit is called "dead bug." This technique is where the integrated circuits (the "bugs") are glued (or not) to a surface, face down, with the IC pins sticking up in the air for easy access. Wiring and components are soldered directly to these pins.

Regardless of the ugly method used, the circuits usually perform quite well. The biggest problem is stray capacitance from the often long component leads and wiring hanging in mid-air and in close proximity to each other. However, once the circuit is "tuned" to account for the stray capacitance, the circuit will work reliably – as long as you don't move or rearrange anything!

This becomes one of the biggest problem in ugly construction – duplicating the circuit. It often works fine for the first person building it, but when the circuit is built by someone else, results may vary. This is why early QRP publications seldom detailed how the circuit was built, as it was difficult to document to show exactly how the circuit was built.

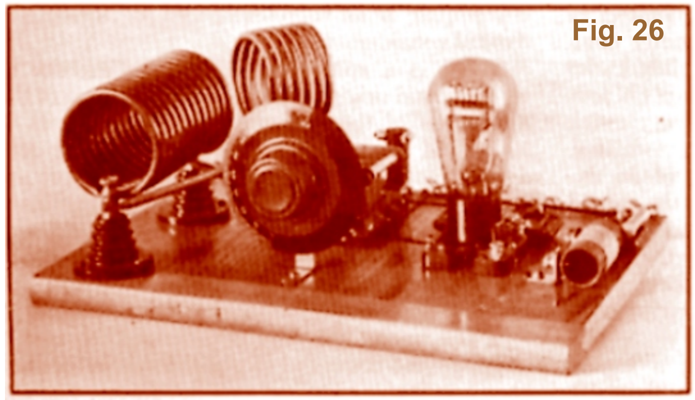


Fig. 26

From 1933 ARRL Radio Amateur's Handbook

Early ham equipment was often built on a standard 10 x 12.5 inch bread board, such as this 1930s "7000 kc low-power transmitter."

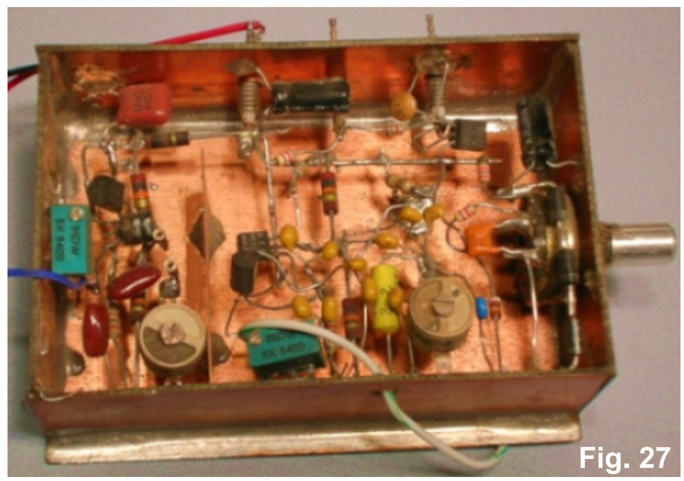


Fig. 27

The modern "breadboard" is often a piece of copper clad. This 7.0 MHz VFO was built "ugly style" in a copper clad "box."

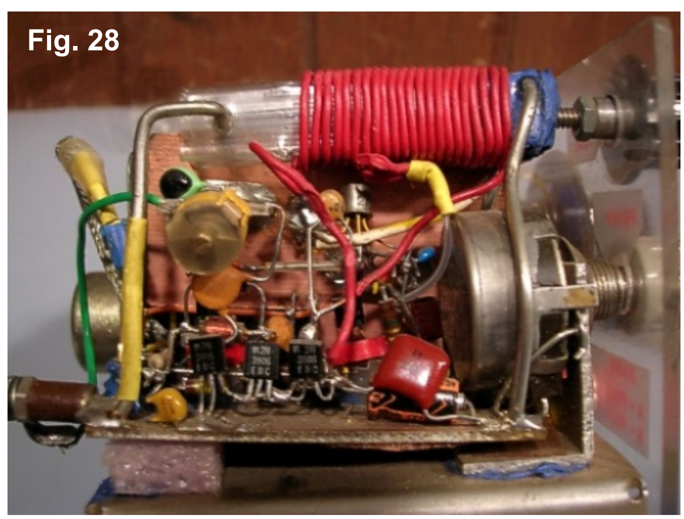
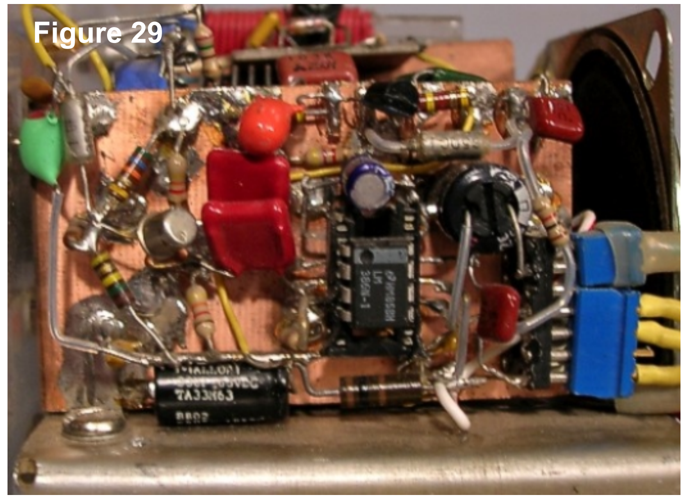


Fig. 28

A regenerative receiver built ugly style on a piece of copper clad. The coil is wound on an IC shipping tube.

In my opinion, this is the strongest advantage of Manhattan style for QRPers ... it is easy to document. Photographs or drawings illustrate exactly where each component goes and how it is built, ensuring consistency in construction amongst the various builders. This consistency also ensures the performance of the circuit will be about the same from unit-to-unit. This is why those people building Jim Kortge K8IQY's 2N2/40 were so satisfied with the results. Those who built it from the detailed drawings in the original QRPp article, the book, or on Jim's website, all ended up with a hot 40M transceiver with very similar performance to Jim's original. Had the 2N2/40s been built "ugly," this consistency in performance could not have been guaranteed. How would you document with any degree of accuracy the "ugly" circuit shown in **Figure 29**?



The AM detector and audio amplifier portion of a shortwave receiver built "ugly" style. The unused end-pins of the IC socket are soldered to the copper clad. The remaining socket pins are bent outward to make the connections.

This is why Manhattan style has become so popular with QRP homebrewers. The designer can *clearly* illustrate *exactly* how to build the circuit to guarantee the expected results. The builder has *precise instructions* to follow and can build the circuit with the confidence it will work. This is true with the seasoned builder as well as the beginner. This is why Manhattan style has become the biggest boost to building a circuit "from scratch" by QRPers. Circuits designed and built Manhattan become excellent construction articles, since the step-by-step instructions lie mostly in the illustrations or photographs.

This is not to say building a circuit "ugly" style is inferior. As already mentioned, problems can occur in attempting to duplicate the circuit. However, for building a one-of-a-kind circuit, ugly can be a quick, cheap, dirty way to get it built and get it on the air. Over the years, I have had many QSOs with homebrew rigs built ugly. A couple were really ugly! The classic "Ugly Weekender" 40M receiver by Wes Hayward W7ZOI and Roger Hayward KA7EXM is a good example of a very nice performing rig built ugly style. It was featured in the 1992 Radio Amateur's Handbook and in the ARRL's book "QRP Power."

There are few rules in building ugly. You simply "do your own thing" and get it working.

4. Conclusion

As most homebrewer's will tell you, there is nothing like the feeling of building a QRP rig and the thrill of having that first QSO with it. Whether you build ugly, a kit, or Manhattan style, QRPers will always be building their own equipment. This is why some of the QRP clubs and various vendors provide kits for building your own QRP transceiver. And, for those wishing to build a rig from scratch, this is why the QRP journals like the ***Homebrewer*** present as many construction articles as they can on the subject of homebrewing.

This article is intended for both the experienced builder and the new comer. If you've never built anything from scratch before, build a simple circuit using these techniques to "get your feet wet." AmQRP is committed to homebrewing. There will continue to be construction projects of different skill levels in future issues of the ***Homebrewer***.

In Part 2 **–** we'll continue with some of the construction practices employed in building circuits from scratch, including an emphasis on building with surface mount components, some various "hints and kinks," and a photo gallery of what others have built.

I am not a master builder of Manhattan. I never dreamed some of the stuff I've built would be featured in an article – or else I would have built them a little nicer! If you've built something from scratch, ugly or Manhattan, feel free to send me a photo or two to include in Part 2 to show what others have built, and how they built them. Likewise, if you have a construction hint or kink, send it to me and I'll gladly illustrate it for the next issue.

72, Paul Harden, NA5N
na5n@zianet.com

AmQRP.ORG HOMEBREWER

George Murphy, VE3ERP
with Harold Kane, W2AHW

The W2AHW OCTALOOP

A Subminiature Antenna for the Lower HF Bands

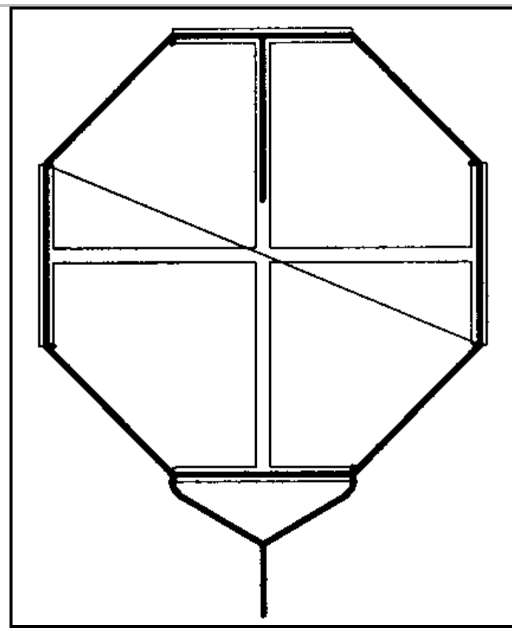
A 20 metre loop 16 inches wide?

A 40 metre loop 29 inches wide?

An 80 metre loop 52 inches wide?

A 160 loop 97 inches wide?

Impossible, you say? You say wrong!



Ted Hart's miniature W5QJR loop antenna[1] has been around for quite a while, and one of its loyal fans is Harold Kane, W2AHW, who has built several of them. Recently Harold began thinking about building loops for the lower HF bands, but does not have enough space for W5QJR loops. So Harold conceived a design for a subminiature version of Ted Hart's miniature loop, and asked if I would lend a hand by writing a computer program to do the required math. I jumped at the chance, because I am always on the lookout for new programs to add to my *HAMCALC* software[2], which already contained an updated design program for Ted Hart's W5QJR loop[3].

Safety First!

"The components in a resonating transmitting loop are subject to both high currents and voltages as a result of the large circulating currents found in the high-Q tuned circuit formed by the antenna . . . . . Be aware that even a 100-watt transmitter can develop currents in tens of amperes and voltages across the tuning capacitor (or stub) in excess of 10,000 volts"[4].

In other words, when designing an Octaloop ALWAYS use only coaxial cable that can handle the design voltages!

The Octaloop Concept

The configuration of a magnetic loop antenna is shown in Fig. 1. How it evolved from a basic dipole is best described as follows:

"Small antennas are characterized by low radiation resistance. Typically, loading coils are added to small antennas to achieve resonance. However, the loss in the coils results in an antenna with low efficiency. If instead of coils a large capacitor is added to a low-loss conductor to achieve resonance, and if the antenna conductor is bent with its ends connected to the ends of the capacitor, a loop is formed. Based on this concept, the small loop is capable of high efficiency"[5].

The keywords here are "large capacitor" (a large transmitting type capacitor is expensive) and "low-loss conductor" (a large conductor is good, a small conductor is not). In the W5QJR loop, to tune the antenna the large capacitor is a remotely controlled, step-motor driven special high quality and hard to find variable capacitor, and the large conductor is copper plumbing pipe. The smaller, simpler, and far less expensive W2AHW Octaloop (Fig. 4) utilizes coaxial cable as both the capacitor and the conductor.

The Octaloop requires minimum space and operates well at or near ground level - its performance changes little with height above ground. Its only deficiency, as in any small loop antenna, is narrow bandwidth.

The Octaloop Magnetic Loop Antenna

The Octaloop is a *small loop*. A *small loop* is, by definition, one with a total conductor length less than 0.1 wavelength. This size is based on the fact that the current around the perimeter of the loop must be in phase. When the perimeter is more than about 0.085 wavelength, this is no longer true[6].

For his Octaloop design Harold W2AHW was prepared to accept reduced efficiency due to reduced size (the efficiency of any loop antenna is proportionate to the encompassed area of the loop). He reasoned that much of the capacity required for resonance could be obtained by using coaxial cable for the loop, with the cable shield as the conductor and the cable's inherent distributed capacity in place of a capacitor. Most of the capacitance required to resonate would be in the loop itself, with a short tuning stub added to permit pruning to the exact design frequency of the loop. The properties of the cable's inner conductor are irrelevant, because it is not part of the circuit and is not connected to anything.

Efficiency

A major factor in the efficiency of any *small loop* antenna is the length to diameter ratio of the conductor. For any perimeter, the larger the conductor diameter the higher the efficiency. While any coaxial cable can be used in an Octaloop, high voltage types are recommended, such as RG-217 or RG-218. Higher efficiencies can be attained with low pF/ft cables such as RG-62A/9269 or RG-62B/9857, as long as the voltage rating is adequate. Avoid cables with foam dielectrics (due to manufacturing tolerances, the distributed capacity may be somewhat erratic). As a general rule-of-thumb, efficiency increases with the diameter of the cable and/or the perimeter of the loop, and the lower the pF/ft of the cable, the greater the perimeter.

There is no need to be alarmed by antenna efficiencies expressed in percent or decibels, which are theoretical mathematical relationships. All you need to know is what may seem to be a *huge* difference in efficiency percent or dB may mean only a couple of S units of signal strength at the receiving end. As with any electrically shortened antenna, Octaloops are less efficient than full size antennas, but can reasonably be expected to be more efficient than short base loaded vertical antennas, such as mobile and/or balcony railing whips. During the initial test of a prototype, Harold W2AHW worked a station 2,100 km (1,300 miles) DX on a 7.050 MHz Octaloop whose “official” efficiency is 2.5 percent!

If you are really into this efficiency percent thing, it is calculated by *HAMCALC*’s Octaloop[7] program or, in the case of whip antennas, *HAMCALC*’s Whip Antenna[8] program. You may be surprised to find many small whips designed for the lower HF frequencies have “efficiencies” as low as 1 or 2 percent - which probably explains why efficiency percent is rarely mentioned in the advertising claims of shortened HF antenna vendors! The upshot of all this is whip antennas work, and so does the Octaloop - probably better than many whips, and is directional as well!

Maximum radiation of a loop antenna is parallel to the plane of the loop (Fig. 6)[9]. The deep nulls to each side are very effective in reducing unwanted signals arriving from unwanted directions. The front-to-back ratio is 1:1, which means when you are in a QRP QSO with a DX station half way around the world you don’t have to worry about whether you are working long or short path!

Coaxial Cable as a Radiator

The Octaloop uses coaxial cable in a role for which it is not primarily intended so some experimentation may be required. Due to manufacturing tolerances, the actual capacity per foot for the cable you want to use may vary between different manufacturers, and even between different production runs by the same manufacturer, especially in the case of cables with foam dielectrics. The outside diameter of the braid and the capacitance per foot are critical factors in the Octaloop design, and if possible should be measured directly from a sample of the actual cable you intend to use. However, if these values are not known, they will be estimated by *HAMCALC* based on the standard equations for cable properties you specify[10].

Caveat Emptor

Let The Buyer Beware of flea market and “bargain” coaxial cable. The properties of the coaxial cable are crucial to the efficiency of an Octaloop antenna so it is imperative that the cable you use is a high quality product (preferably new) from a reputable manufacturer. An RG number printed on the cable does not necessarily mean it is the real thing! RG numbers are intended for cables which conform fully to the US MIL-C17D specification. However, RG designations are not protected trademarks, and it appears there is little to prevent manufacturers from selling inferior products with identical or very similar markings[11].

The Design Math

This is where the fun starts. All the equations are derived from the primary equation (see sidebar) for octagon loop antennas, by F.W.Grover of the US National Bureau of Standards[12,13]. The design objective is to find the length of a coaxial cable with a total distributed capacity equal to the capacity required to resonate a loop designed by Grover’s equation. Most of this length is in the loop itself, with the remainder in a tuning stub, pruned to resonance. Only the diameter, distributed capacity and voltage rating of the cable are relevant to the loop design. The characteristic impedance of the cable is irrelevant, since it is not being used as a transmission line.

The design process requires some iteration, which is easily performed by *HAMCALC's*(preferably version 78 or later)"Octaloop" program. The program output(Fig. 7)requires only three data inputs by the user - frequency, transmitter output in watts, and a 2 digit input to select a coaxial cable from a list displayed on the screen, or you can input actual measured values of a sample of the cable you wish to use.

Construction and Testing

This article is primarily concerned with describing a novel design idea, so construction details are left to the ingenuity of the builder. But by using Figs. 1 to 5 as a guide it should be a simple task to build an Octaloop with a minimal investment in coaxial cable, some plastic pipe and a few plastic pipe fittings.

Determine dimensions using *HAMCALC* and assemble the frame (some typical assemblies are shown in Fig. 5)from pipe large enough to allow threading your chosen coaxial cable through. The only tricky part is shown in Fig.5. From a piece of cable 8xA long sStrip the outer jacket from each end. Cut the inner conductor off flush with the ends of the braid, and solder short pieces of solid copper wire to, and extending a few inches past, the braid. These projecting wires are the terminals for the tuning stub. Insert each end of the loop into the top center fitting and fish out its terminal wire as you go, bending it up and out the top of the fitting. Use epoxy glue to secure the wires to the walls of the fitting (there will be high voltage potentials across these wires and you don't want them wiggling around and getting close to each other!). If you can find a cork of a size that will wedge the wires up against the walls of the fitting, so much the better! Cut your tuning stub at least 10% longer than the design length, tack solder the center conductor to one of the terminal wires and the braid to the other. Let the stub hang down outside the pipe ready for pruning.

A transmatch (a.k.a. "antenna tuner") is recommended at the rig end of the feedline. Connect the feedline, fire up the rig, and prune the stub until the antenna resonates at the design frequency. Finally, unsolder the stub, insert it down through the fitting into the vertical center pipe, solder it back in place and cut off any ends. Bang in the cork (if you have one), add a cap (a plastic bottle top) and seal it all up with your favorite sealing goop. Then make a few contacts to see how it works!

What To Do About Narrow Bandwidth

1. Try tuning your rig off the antenna design frequency, but not too fast or too far at a time. The SWR and the temperature of your transmitter's output stage are liable to rise very quickly! If you can live with the results then don't do anything. You are in the same boat (or vehicle) as many mobile stations and have just built yourself a dandy miniature directional antenna for the cost of only a few feet of coaxial cable mounted on a cheap and easy frame. Just the thing for QRP operators with crystal controlled transmitters!

And Finally . . . . .

Stray capacitances can upset the rather critical tuning of the loop, so install the loop well clear of any metallic objects. Always be aware that, even with a low power transmitter, very high voltage potentials can exist between the loop ends at the apex of the loop, so make sure this area is well guarded against children, pets, and visiting snoopy ham radio operators!

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Sidebar

GROVER EQUATION for OCTAGONAL LOOP ANTENNAS [12]

(as applicable to single turn loops)

$E_1 = .016 \times B$

$E_2 = 2.613 \times B/2D$

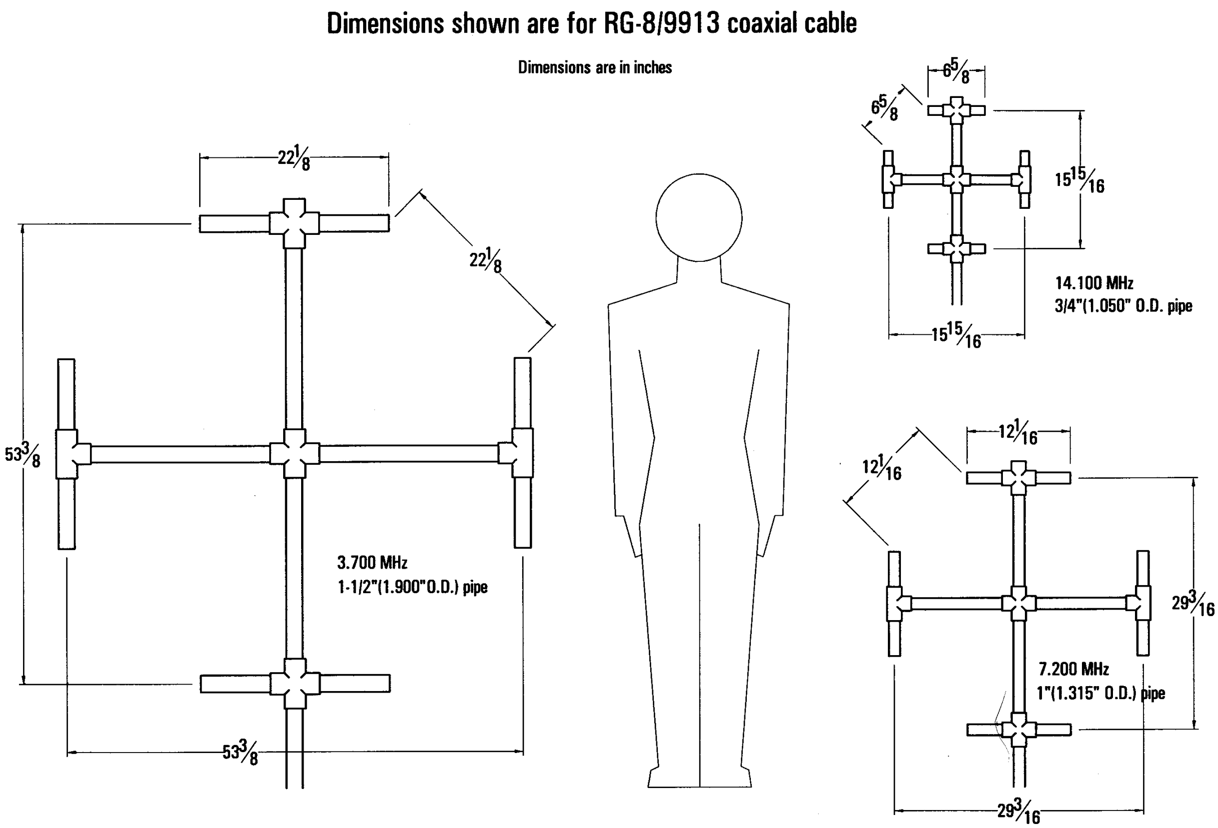
$E_3 = .07153 \times 2D/B$

$L_{UH} = E_1 \times (\text{Log}_{10}(E_2) + .75143 + E_3)$

where: B = length of each side in centimetres

D = diameter of conductor in centimetres

L_{UH} = inductance of loop in µH



PLASTIC PIPE FRAMES FOR OCTALOOP ANTENNAS

Fig. 1

W2AHW OCTALOOP

M = Delta match feedline connection points

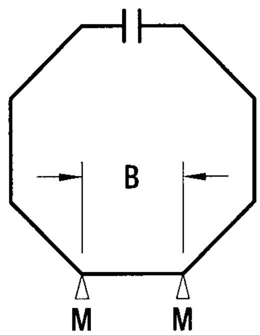


Fig. 2
SCHEMATIC

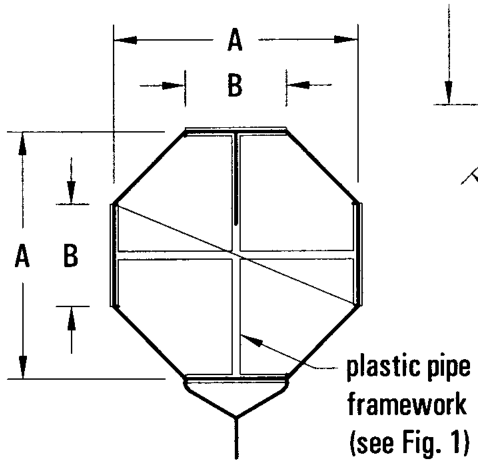


Fig. 3
ASSEMBLY

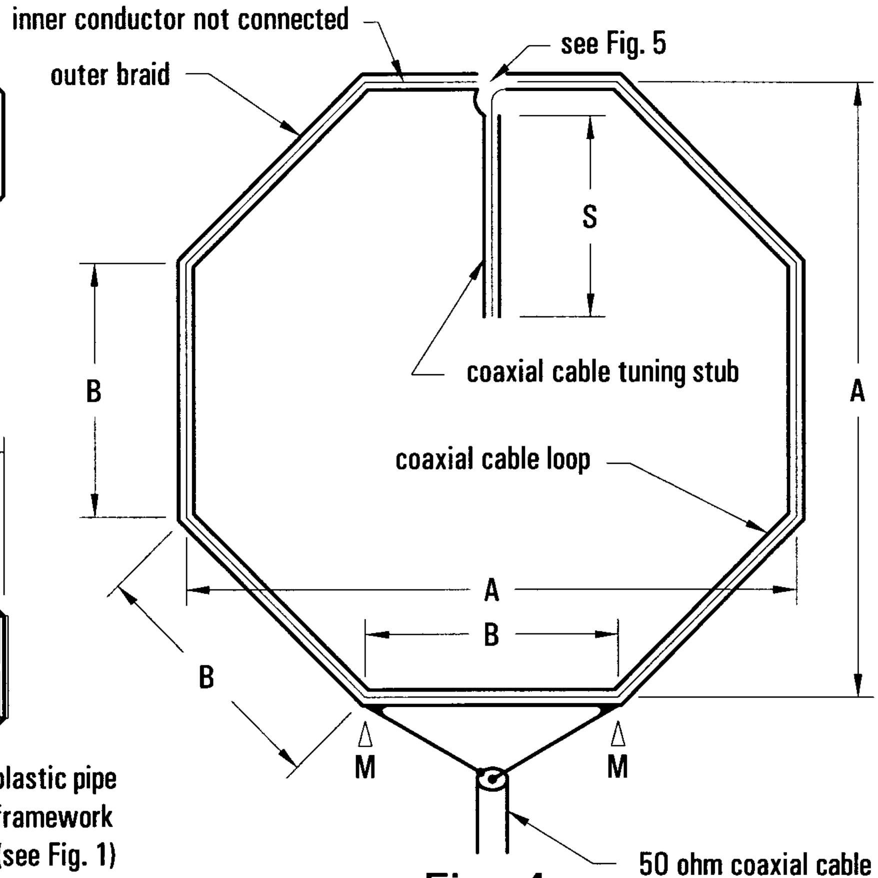


Fig. 4
CABLE DETAILS

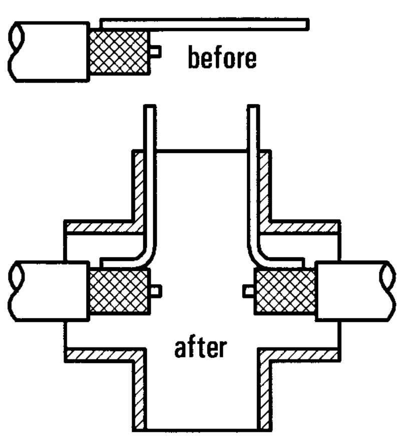


Fig. 5

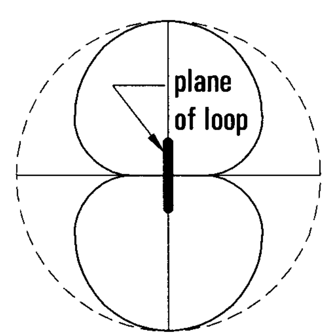


Fig. 6
RADIATION PATTERN


```
                    W2AHW OCTALOOP for  41.667 metres
═══════════════════════════════════════════════════════════════════════════════
        ═════(3)═════    RG-8/9913 - 600 max.volts              1 in.
        ║           ║     1» Coaxial cable loop            ══════╤ gap ╤══════
   1»   ║    2»║    ║     2» Coaxial cable tuning stub     ──────        ──────
        ║           ║    (3)  (see enlarged detail)        =«1»═╧═      ═╧═«1»=
        ║  |«-B-»|  ║     B = 1/8 of loop perimeter              │      ┌──┘
        ═════════════                                            └─┐  │
             └─┐ ┌─┘«─Delta match to 50 Ω coax feedline            ║  │  ║«2
   (4-sided loop shown, but octagonal loop described.)         Detail   (3)
───────────────────────────────────────────────────────────────────────────────
 Resonant Frequency........    7.200 MHz│Reactance at resonance....  102.511 Ω
 Length of each side.....B=   12.082 in.│Perimeter: 0.0589 wavelgth   96.652 in.
 Distance between sides..A=   29.167 in.│Inductance of loop........    2.266 µH.
 O.D. of coax braid........    0.298 in.│Coax cap'y per foot.......   24.60  pF.
 Cap'y needed to resonate..  215.633 pF.│Cap'y of cable in loop....  198.122 pF.
 Length of stub..........S=    8.543 in.│Cap'y of cable in stub....   17.512 pF.
 Radiation resistance......    0.0021 Ω │AC loss resistance........    0.0722 Ω
 Bandwidth.................   10.449 kHz│Loop Q....................  689
 Efficiency................    2.877 %  │Current at resonance......    5.797 amp
 Transmitter power (watts).    5.000 W. │Voltage across loop ends..      594 v.
───────────────────────────────────────────────────────────────────────────────
  (A  53 pF variable capacitor in place of stub will tune  6.678 to  7.511 MHz)
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ENDNOTES

1. Ted Hart, W5QJR, *"Small, High Efficiency Loop Antennas"*, QST, June 1986, page 33. The equations in the article have been updated in subsequent editions of *The ARRL Antenna Book*.
2. *HAMCALC* contains more than 300 computer programs of interest to radio amateurs, professionals, and educators. The latest version is available as a free download from <www.cq-amateur-radio.com>. Click on HAMCALC at the bottom of the left side of the home page.
3. *HAMCALC*, version 62 (preferably version 78) or later, "MINILOOP: Miniature Loop Antenna" program.
4. *The ARRL Antenna Book, 18th edition, page 5-11.*
5. This is a direct quote from *The ARRL Antenna Book*, 18th edition, pages 5-11 to 5-16, *"Small High Efficiency Loop Antennas for Transmitting"*. This entire section of the *Antenna Book* was written by Ted Hart, W5QJR.
6. *The ARRL Antenna Book, 18th edition, page 5-2, "The Basic Loop".*
7. *HAMCALC*, version 62 or later, "Octaloop Subminiature Loop Antenna" program.
8. *HAMCALC*, version 62 or later, "Mobile/Maritime Whip Antennas" program.
9. *The ARRL Antenna Book*, 18th edition, page 5-2, Fig. 4.
10. *The ARRL Antenna Book,* 18th edition, page 24-18, Table 2.

11. Peter Dodd G3LDO, *The Antenna Experimenter's Guide,* 2nd edition, The Radio Society of Great Britain, page 93.

12. *The ARRL Antenna Book*, 18th edition, page 5-4, Table 1.

13. *HAMCALC, version 62 or later, "Small Transmitting Loop Antennas"* program, which also applies Grover's equations to triangular, square and hexagonal loops.

14. *The ARRL Antenna Book,* 18th edition, page 5-14, Fig. 19.

Richard Fisher, KI6SN

REMEMBRANCES OF FIELD DAY 2005

They call it 'the wild' for a good reason. Here are some of the better tales from ARRL Field Day 2005.

Wayne Burdick, N6KR, kept things simple and very efficient with this spartan set-up at Henry Coe State Park, near Morgan Hill, CA.

N6KR: A FIELD DAY ADVENTURE DAVE BARRY WOULD LOVE

Wayne Burdick, N6KR, of Belmont, CA writes: "First, I'd like to say thanks to **George Zafiropoulos, KJ6VU,** of San Jose, CA and the **K6SRA** club for their good company and comfortable chairs at base camp (Henry Coe State Park, near Morgan Hill, CA). I really appreciate them trading me a BBQ'd sausage dog for my box of Pop-Tarts. Saved me from having to explain the box to Lillian (XYL).

"On Saturday, I backpacked up the hill from base camp with just the KX1 and enough No. 26 silky to put up a decent wire vertical. No feedline – just matched it with the internal tuner. I was determined to do the entire FD with internal batteries, too, so I had a fresh set of six lithium AAs.

"The bands were in great shape in Northern California. Bottom line? Haven't figured that out yet. But I did make 164 Qs, all on 20 and 40 meters, and all with 1.5 watts.

"If I had stayed up late or gotten up early in the morning I could have done a lot better; there was nearly no atmospheric noise on either band. In the morning I even dared call CQ (with 1.5 watts!) and ran a couple dozen on 40 meters. Batteries were still at 8.0 V key-down when I called it quits.

"The accompanying photo is of my solo operating position. I just bought the roll-up backpacking table and chair from REI - http://www.rei.com/product/549765.htm

"The funniest moment? A friend – I'll withhold the name and call – was helping set up my antenna. (A Really Good friend. *Still.)* He held the connector end while I tossed the weighted end, repeatedly, exhausting my stock of expletives.

“On my fifth try the weight cleared a high branch. Beside himself with joy, my happy helper unwittingly let go of the connector. The wire promptly settled into an upside-down ‘U’ with both ends 12 feet off the ground, unreachable.

“He tested the height with a disconsolate little hop (not even close!), then tried valiantly to hit the weights with rocks. I briefly considered a long running start, but rejected the idea. After all, he'd just had double knee surgery.

“Our last, best hope was a dead tree branch, covered with half-inch red ants, that appeared just long enough. Remember that famous photo of Marines erecting a U.S. flag at Iwo Jima? This event bears no resemblance to that noble effort.

“Imagine two six-footers, synchronized in a clumsy, bear-like dance, gripping the fat end of a branch and trying to swat a pair of dangling 5/8” hex-nuts with the tip. On a steep slope, looking directly into the sun. After a few tries we hit it.

“Mercifully, no other humans (in particular, Dave Barry) were around to witness this.”

K7QO: A QRP’ER FIELD DAY FREELANCER

Chuck Adams, K7QO, of Prescott, AZ writes: “I got invited to work FD this year with a club that is on the other side of a mountain range between Prescott and Verde Valley to the east of my QTH. Three members of the club Pres' family were in my ham class earlier this year and I had never met him.

“And within 45 minutes after I leave the house, **Ron Stark, KU7Y,** called to say he was in town for a big bluegrass fest. I was sorry to have missed him.

So just a few HIGHlights:

- Using a rig connected to a 400W solar array and 800AHr marine battery supply. Not suitable for backpacking. In a trailer only for this power source. Neat, and I didn't bother to ask how much.
- QTH at rest stop on the top of a mountain pass
- 15 meters higher than a sign that said 7,026-foot altitude. This is higher than Flagstaff.
- Having my old Kent key stick and going to an MFJ paddle that was not in the best of shape – the chrome copy of the BY-2. The Kent had been on loan to a local for several years, the old model. May have been the cold that caused this problem on old lubricants in the bearings, thus something to say for the Bencher BY-x series and those pointy pivots.
- Having computer with TRlog but no interface to the rig
- Using an IC 706 without a CW filter and at one time another op had moved the filter to inadvertently have me use a DC receiver until after a few hours I made a comment on how the receiver was hearing both sides. Give me a rig that isn't easily messed with.

- At midnight having three layers of clothes on and using the white cotton walking gloves for keyboard and paddle. I probably looked like the famous W7ZOI picture using a rig in the snow.
- I know there were pictures made late at night at this site. Making the best run rates when everyone else crashed and burned using the keyboard for log and paddle for Qs. Previously was using paper to log so helper could enter into computer. Part of a training exercise. I didn't have to write a single stroke during this time period. Now that's fun.
- Working a lot of you guys and girls and you not know who it was and sorry I didn't say anything. But it was fun.
- And as a CW op using the call W7EI. You want to hear the number of repeats on the call? I didn't think so . . . Lot of good operators got it right the first time though.
- Listening to War of the Worlds on CD during breaks (in Morse) and eating the snacks that I wanted.
- Having to go find a rock to stand on to get cell phone to work to call Phyllis and give report on how things were going. Only one bar was the highest signal level that I could get in the pass. My guess is that I was using a repeater across Verde Valley canyon. There are many places still left on the planet where radios will work and cell phones will not.
- Chilled to the bone and the heater in the mobile at high not helping while coming down off the mountain pass just before sunrise. Not even close to hypothermia, but I was cold.
- No attempt made to set any records, but just to have fun with a group that I did not know at all.
- Would do it again in a heartbeat.
- In fact, the next Spartan Sprint I think I'll drive over as it is only 45 minutes from the home spread. If the monsoon season isn't upon us as a million+ volts power source isn't going to do.

N5ESE: IN SEARCH OF THE PERFECT FD WIRE ANTENNA

Monty Northrup, N5ESE, writes from Austin, TX: “Well, I had an interesting Field Day. I decided to combine my search for the perfect wire antenna with my interest in QRPp operating during this weekend's Field Day.

“I did the ‘Lone Ranger’ thing again this year, setting up on the shaded corner of my brother-in-law's summer house on Lake Travis. As the primary rig, I used the Elecraft K2 running on battery power, and cranked down to 0.5 watts (yes, a half watt for the entire FD).

“For an antenna I erected two doublets at right angles, but these were not your run-of-the-mill dipoles. Using some surplus 22 AWG silver plated stranded Teflon wire I had purchased from N2GO back in September, I constructed a 374 foot doublet (187 foot each leg) AND a 176 foot doublet (88 feet each leg).

“Each was fed independently with 22 feet of 300-ohm ladder line. To support both of these at the center, I used the 32-foot DK9SQ Fiberglas telescoping mast, with the center insulators at about 25 feet. I bungee-corded the mast to the deck support at about 15 feet up; it stayed in place solidly the entire FD.

“Mind you, this is not your ‘quick and easy’ portable antenna. These antennas took me 4 hours to erect by myself in the Texas sun. (The brother-in law and XYL somehow remembered things they just *had* to do.)

“I used a slingshot coupled to a Zebco reel to launch lines over the oak and cedar to pull the antenna wire. Eventually, while consuming about two gallons of water, the wire was up, and with a minimum of cussing. Installed, the longer doublet ran north-south and the shorter doublet, east-west.

“Fortunately, the K2 (with the 160 Meter option kit) has a built-in antenna switch which accommodates two antennas with the press of a button on the front panel. We installed two of our infamous Altoids baluns, one at each antenna jack of the K2.

“The K2 tuned both antennas on all bands (160-10) to less than 1.2:1. I did notice that 17 meters would not tune to less than 2.5:1 on the longer antenna, but we weren’t using the WARC bands anyway.

“When I finally got around to operating – around 3 p.m. Saturday – I was determined to start out at 1/2 watt, but I was also ready to switch to a full gallon QRP if results really stunk. Fortunately, I didn't have to, as the antennas did their jobs very nicely and we barely struggled all weekend at the QRPp level.

“We eliminated the ‘CQ’ as an operating option at 1/2-watt. We’ve garnered more QSOs using that technique at the 5-watt level, but we stuck to ‘hunt-and-pounce’ as our sole operating modus all weekend.

“Having two antennas at the touch of a finger was an operating luxury for me, and I was surprised at the results. The 374-foot doublet performed superbly on 80 through 40, outperforming the shorter antenna in about 80-90 percent of contacts.

“On the other hand, the shorter antenna outperformed the longer on 20 meters, in about 75 percent of the contacts. For about 25 percent of all cases, the difference between the antennas was as much as 3 or 4 S-units.

“Most of the time though, the difference was only an S-unit or so, or there was no difference at all. Surprisingly, if there was any dominant directionality at all, I couldn’t tell by correlating observed antenna performance and contact location.

“So, how did the QRPp experiment go? Let me first say that I am NOT a contester. I tend to make a contact, writing it on scrap paper, then transfer it to the log and dupe sheet before I go on to the next contact. Definitely NOT your highly efficient methodolgy.

“I enjoy Field Day because it’s an opportunity to try some things I wouldn’t normally try – especially regarding antennas and portable scenarios. I started around 3 p.m. on Saturday and ended at 1 p.m. on Sunday, and I took numerous snack breaks and three 1-hour snoozes.

"I would guess-timate my total operating time was around 18 hours. Still, we managed 214 QSOs (all CW, of course). Those of you who are doing the math in your heads, this means an average QSO rate of about one every 5 minutes – the *real* contesters are guffawing right now, but the real contesters aren't using 1/2-watt.

"Using flea power, we garnished over 200 solid contacts; 30 of those were on a very noisy summertime 80 meters. We worked 68 ARRL Sections, including notably the Maritime provinces, Puerto Rico, and the Virgin Island (from central Texas). We worked 44 states, and 4 Canadian provinces.

"An estimated 88 percent of contacts were 1,000 miles-per-watt or better, and a dozen or so were 5,000 miles-per-watt or more. Not bad for a half-pint and a half-K of cheap hook-up wire."

AA5B: SIMPLE FIELD DAY PLEASURES AT 7,200 FEET

James Duffey, KK6MC, of Cedar Crest, NM, writes: "**Bruce Draper, AA5B; K5TX, Gary;** and myself operated **AA5B** as a 1A-Battery-QRP entry in Field Day. We had a great time and a good score. Preliminary compilation is:

80CW, 25 QSOs
40CW, 271
20CW, 578
Total, 874

QSO points 8,740
Bonus points 750

Total score 9,490

"This is not record setting, but we hope that it will be one of the better 1A

scores. The bonus points really help. It is worth the effort to get them. At 750 points and 10 points, that is the equivalent of 75 QSOs. That is roughly 2 hours of operating at our QSO rate.

"Propagation was worse than predicted. The solar flux was 77 on Saturday and 79 on Sunday as opposed to the 85 or so predicted. The A index was 20 and K was 4 both days. The solar flux was much lower than last year's 99, and the A and K were about the same, if I recall correctly. So we did very well with the current poorer conditions.

"The Sporadic-E skip allowed 20 meters to stay open late Saturday night and helped a lot. By staying on 20 meters we could avoid the pernicious static on 40 meters. While the spread in solar flux is quite wide at the solar minimum, the predicted average for 2006 FD is 71. Take that with a grain of salt, but don't expect a lot of 15 meter and above contacts next year.

"Bruce reserved a Forest Service group picnic ground at 7,200 foot ASL, south of Tijeras, NM as an operating site. This is a very nice site with 60 foot high Ponderosa pines for antenna supports. We operated there last year. There is also running water and composting bathrooms. It is nice to have these amenities. With a few joggers, it is a public area and a place to pitch ham radio to the public. There is always some interest.

“Due to a number of factors, we had problems recruiting operators (and good K2 rigs) to duplicate last year’s 6A record setting effort. So the three of us decided to go 1A. It was a good choice, and shifts were such that we actually operated fewer and shorter shifts than last year.

“Last year’s effort ranked 5th overall in nation, so we duplicated last year’s successful philosophy of simple antennas, dipoles oriented to reach the maximum ham population, simple QRP rigs, quick logging with computers, and battery operation.

“The antennas were a 40 meter and 20 meter fan dipole at 60 feet, oriented pretty much N-S. At Bruce’s urging, I had previously analyzed the best orientation for a simple antenna to cover the largest ham population. The dipole oriented N-S is a clear winner over beams or directional antennas here.

“We put up a vertical 80 meter antenna with 3 elevated radials in case 40 meters did something funky late. We did try 80 meters when 40 meters went long, but it was not too productive. Gary was right and now I think a dipole would be better than a vertical, but atmospherics caused by thunderstorms was probably as much a factor in our poor 80 meter performance as the antenna was.

“We used a K1 for 40 meters and 20 meters, and a QRP ++ for 80 meters. An LDG Z-11 auto tuner was used to keep the SWR low. We did logging with NA on an IBM laptop.

“Power was a pair of deep cycle batteries and an inverter for the laptop. When the sun was out, we charged the battery with a small solar panel for the bonus points.

“We set up Friday evening and Saturday morning. The three of us copied the special bulletin on Friday night, so we were all set to go at when FD began.

“We were on 20 meters until 0500 Z (11 p.m. local) when there was not much new on 20 meters, then shifted to a very active 40 meters. Forty slowed down around 0900 Z so we tried 80 meters without much luck and went back to 40 meters.

“At 1000 Z, 40 meters picked up and eventually we went to 20 meters at 1300 Z and stayed there until the end of the contest. Rates were good on 20 meters until the end; I worked 43 in the last hour on 20 meters and had several calling at once as the contest ended.

“Vicki, K5TX's better half, came up from town on Friday night and brought pizza. She also cooked us steak, coleslaw, beans, and garlic bread on Saturday night. Virginia, my wife, brought green chili breakfast burritos on Sunday morning. Food was good.

“A thunderstorm rolled in on Saturday night a little after 8 p.m. I was operating and kept counting the time between flash and bang. I decided to stop when it was 5 seconds. Murphy beat me to it.

“The inverter failed when the lightning got close, so the decision was made for me. I tend to wait too long in these situations. I am not sure that the inverter failure was related to the thunderstorm, as I cannot think of a mechanism, particularly since the radio and tuner were OK.

“With the thunderstorm and inverter failure, we lost about an hour. Fortunately we had another inverter. It was noisier than the first inverter though. It was very sensitive to orientation and body capacitive effects. Bruce resolved this by clamping the inverter between his legs when operating. No kidding. This was later refined to placing one’s bare foot on the inverter to minimize noise. It worked.

“We struck the site in less than an hour, another advantage of simple QRP operations. I was home by 1:30 p.m. local time.

“We worked several familiar QRP-L calls: **N1QS, K5ESE, WQØRP, WQ5RP, WØUFO, N4BP, K7RE,** and **WØCH** among them. I was looking over Bruce's shoulder when he worked WØCH. I noted that he was a QRPer, and Bruce said, "Yeah, he sent "Hi Jim."

“I think that from an installation viewpoint we would probably be better off with trap dipoles than with a two-band fan for a multiple band antenna. It is a lot harder to put four ends in trees in a straight line than just two. We are already trying to think about how to better this next year. Bruce has suggested several 2 person 1B stations at the same site.”

N1BQ: KICKING AND SCREAMING INTO THE CW WORLD ABOVE 50 MHZ

Brian Riley, N1BQ, of Underhill Center, VT writes: “For the last month before Field Day I have been ragging every local (Burlington, VT) FD group locally about having CW capability at their VHF / UHF stations. I was saying that it is:

- A cheap and easy two points
- A good thing to introduce newbies to Field Day CW
- What QRM?

“Sooo, FD 2005 rolls around and as soon as I make a Q on 6 meters SSB, I ask, ‘Can you do a CW contact?’ And what do I start hearing? ‘Uhhhhhh, we only have one key and it’s on 40 meters and he won’t let me use it.’ And ‘Uhhhhh, we don't have a key.’

“‘Well, I suppose if I ask [name deleted], he can set the transceiver up for me,’

And so on . . .

“[Picture N1BQ here starting to get ticked off.]

“Patiently I tell each of them, ‘. . . if and when you get your act together, we will be on 146.55 FM Simplex at the top of every hour.’

“Over the next few hours one by one they began to show up and we wandered from 6 to 2 to 70cm and did SSB and CW. I was getting to feeling pretty good about getting all this FD CW activity going on VHF / UHF when one last club to the north of us finally showed up on 2 meter FM and I asked if they could do CW . . . and here we go again.

“First he says he doesn't have a key. Then he says he doesn't know how to set up the transmitter. I began to lose it . I yelled ‘Go get [name deleted] I know he can get your act together!’

“He says ‘He went home to get something.’

“Did I mention this guy had a whiney voice? Now this guy is really ticking me off and I begin to really lose it . . . but I count to 10 inside and with a big melon-eatin’ grin I say ‘Look, you go get some wire cutters. Cut the mike cord and strip the wires and short them together like you might do in an emergency. That’s how you can send CW!’

“So there’s this long pause and he comes back haltingly “Uuuuhhhh, I don't think they would like me doing that!”

“He actually took me seriously! Me, I am having visions of their club president making me pay for a new mike cord. The people in the tent with me about fell off their chairs they were laughing so hard.

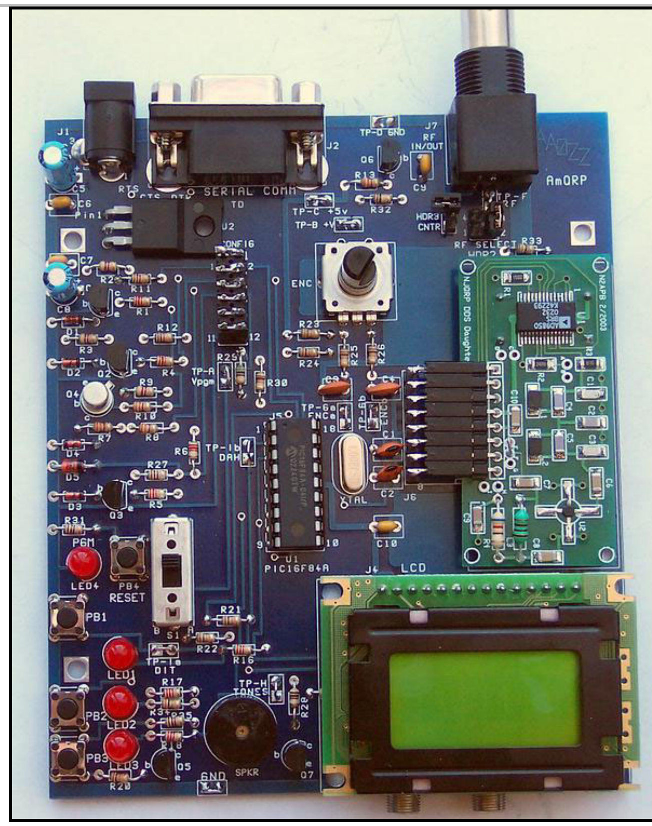
“The bottom line was that between CW being times-2 and QRP being times-5, VHF / UHF for N1QS was over 100 points further ahead than we had been in the past as were the clubs I browbeat into doing it.”

AmQRP.ORG HOMEBREWER

Craig Johnson, AA0ZZ

The PIC-EL

Here's a multi-function PIC-based project board that serves well for ham radio experiments: as a DDS VFO, a Morse keyer, and as a "trainer board" in learning how to program the PIC. Further, the PIC-EL contains an integrated, built-in serial programmer that allows one to download new programs directly from the PC and "burn" them into the PIC microcontroller ... without requiring any other specialized programming hardware!



Introduction

The PIC-EL is a multi-function PIC16F84A-based project board designed for experiments being conducted in the online PIC Elmer 160 course (http://www.amqrp.org/elmer160). The course material is geared around use of common I/O components -- pushbuttons, LEDs, LCD display, rotary encoder and speaker -- and experiments are designed to take the student through a step-by-step creation of software programs that beep, display and otherwise interact with the user. The "Pickle" board also has a built-in serial programmer that allows you to download new programs directly from the PC and "burn" them into the PIC microcontroller ... without requiring any other specialized programming hardware!

The PIC-EL Kit is still available in some form through the AmQRP Club (http://www.amqrp.org/elmer160/board) and is easy to assemble. You can use the schematic, parts list and photo included on this article to assemble the board according to the component outlines on the pc board. You then download programming software from the project website and use it to program software into the PIC … the first being a special test program to exercise the circuit components (LCD, LEDs, encoder, pushbuttons, et al) so you can see the Pickle board work right away. Then try loading up a program to have the PIC-EL board operate your DDS Daughtercard as a VFO!

Design Goals

The PIC-EL board was designed to accomplish two major functions:

1. To program 18-pin Flash/EEPROM PIC microcontrollers. The focus is on the 16F84, 16F84a and 16F628 microcontrollers, but the PIC-EL also provides the ability to program other PIC microcontrollers in an external user's circuit.
2. To demonstrate how a PIC microcontroller can be programmed to use components to accomplish tasks that are particularly interesting and beneficial to a radio amateur

The PIC programmer portion of the board has a 9-pin RS232 (DB9F) serial port connector. No provision is made at this time for connecting to a USB port or a parallel port to the programmer. External USB or parallel port programmers can be attached to the PIC-EL board via HDR-1.

The project / demonstration portion of the PIC-EL board was specifically designed with the radio amateur in mind. It allows the experimenter to understand how a PIC microcontroller can be used in a variety of applications. It allows the person to progress from controlling very basic components to more advanced components and projects.

General Board Description

An external power supply is required. It must supply 12 - 14v to the board via a 2.1 mm power jack.

Most of the PIC-EL board runs on 5v power. The exceptions are the DDS Daughtercard, the PIC high voltage programming signal line, and the speaker amplifier, which run on 12v power. An LM7805 voltage regulator converts the 12v input power to 5v. Since the Daughtercard requires 12v power, the another line is routed directly from the 12v input jack to the DDS Daughtercard connector (J6). A TO-220 style 5v regulator was selected so that power consumption limits would never be a problem.

Input power is filtered with a 4.7uf tantalum and .01uf ceramic capacitor on both sides of the regulator.

A 9-pin RS232 (DB9F) connector is used for the serial port connection.

Two modes of operation are selectable via the DPDT slide switch S1. One position is for Program (PGM) mode, and the other is RUN mode. LED-4 is illuminated when the switch selects PGM mode.

Here is a chart of the total current draw of the board in various conditions:

PGM mode – without Daughtercard - 13 ma
PGM mode – with Daughtercard attached - 88 ma
RUN mode – without Daughtercard - 13 ma
RUN mode – with Daughtercard active (running SIGGEN3 code) - 138 ma
RUN mode – without Daughtercard but speaker active at 4000 Hz - 65 ma
RUN mode – with speaker active and Daughtercard powered but not initialized -185 ma

The board's two major sections are divided by a 2 x 6 CONFIG header (HDR-1). The user can use this header to chose between the following options:

1. Use the PIC-EL serial port programmer and the PIC-EL project board PIC and associated components. Program and use the on-board PIC (U1) in socket J5.

   In this case, the user connects a jumper block on HDR-1 which shorts the six IN pins (pins 1 through 6) to the six OUT pins (pins 7 through 12).

2. Use an external programmer (e.g. USB or parallel port) and connect it to header HDR-1. The external programmer may draw 12v and/or 5v power from the IN side of HDR-1, pins 4 and 5 respectively. Whether or not the external programmer draws power from the IN side, it must always pass 12v and 5v power to the OUT side of HDR-1, pins 9 and 8 respectively. Simply shorting from the IN side power connections to the OUT side is fine. The external programmer is then used to program the on-board PIC (U1) in socket J5.

   In this case, the user connects the external programmer to HDR-1. The external programmer may get its power from the header or it may use another power source. In either case, the external programmer must supply power to the OUT side of HDR-2. The programmer supplies Clock, Data Out, and Vpgm to output pins 12, 11 and 10 of HDR-1. Data In is passed from the PIC microcontroller to the external programmer via the same data line (HDR-1, pin 11).

3. Use the internal programmer and connect to a foreign project board containing a PIC microcontroller. Any type of PIC microcontroller can be programmed in this manner.

   In this case, the user connects the external project board to HDR-1. The external board draws 5v and possibly 12v power from the IN side of HDR-1. The external project board receives Clock, Data Out and Vpgm on pins 1, 2, and 3 of Side A.

4. Use an external programmer and an external project board.

PIC Programmer Description

The PIC programmer has an RS232 (DB9F) serial port connection. Pin assignments are as follows:

Data Out is on RS232 pin 4 (DTR)
Clock is on RS232 pin 7 (RTS)
Data In is on RS232 pin 8 (CTS)
MCLR is on RS232 pin 3 (TD)

The RS232 lines representing Data Out and Clock are inverted and converted to PIC signal levels via NPN (2N2222A) transistor switches (Q1 and Q2) before going to the PIC microcontroller. Thus, for these two computer output signals passed via the serial port's DTR and RTS lines, low serial port signal levels (–12v) get converted to high PIC signal levels (+5v) and high serial port signal levels (+12v) get converted to low PIC signal levels (0v).

The MCLR signal is another PC output signal and it is sent to the programmer via the serial port's TD line. This signal is generated by the PC programming software in order to put the PIC in high-voltage programming mode. In this case, the PIC needs the two levels to be zero and approximately +12v. Transistor Q3 operates in a manner that is very similar to Q1 and Q2, except its collector voltage is higher. As before, it inverts the serial port signal levels but this time the low level (–12v) results in a MCLR signal of approximately 12.5v (depending on the power supply voltage) and the serial port high level (+12v) results in a MCLR signal of approximately zero volts.

One 2N2907 (PNP) transistor switch (Q4) is used in the programmer. It brings the Data In signal from the PIC microcontroller to the serial port connector. Again, its high and low levels are inverted. There is some additional circuitry associated with this signal to change the PIC levels to RS232 levels.

Project/demonstration Board Description

In RUN mode, PIC experimenters have an opportunity to use and understand the following hardware functions:

1. A 18-pin PIC microcontroller (16F84, 16F84A or 16F628)
   - Includes 4 MHz crystal
2. A dedicated pushbutton (PB-5) for Master Clear (Reset) of PIC microcontroller
3. A 1x8 LCD (one line, eight characters)
4. A rotary encoder (ENC-1) with shaft pushbutton (PB-4)
5. Three stand-alone pushbuttons (PB-1 through PB-3)
6. Three LEDs (LED-1 through LED-3)
7. A speaker (SPKR-1) with transistor driver.
8. All connections necessary to drive the NJQRP DDS Daughtercard from the PIC
9. A stereo jack for a CW paddle connection.
   - Ready for a PIC keyer implementation
10. A stereo jack with transistor driver for transmitter keying
11. A transistor “conditioner” to convert small signals to levels required for PIC input
12. A multi-purpose BNC connector
    - Selectable via a jumper at header HDR-2
    - Allow DDS output to be routed to the BNC
    - Allow DDS output to be routed to a “conditioner” and then to a PIC input pin
    - Allow an outside signal source to be brought in to the “conditioner” and then to the PIC input pin
13. A 2x6 pin Header block (CONFIG)
    - Allows attachment of a “foreign programmer” to this PIC project board
    - Allows attachment of this programmer to a “foreign project board”

PIC PROGRAMMER DESIGN DETAILS

The design of the serial port programmer is an adaptation of the classic programmer by David Tait. See Tait's PIC-related home page on the internet at: http://people.man.ac.uk/~mbhstdj/piclinks.html

The serial port programmer uses transistor buffers for each input and output signal. These buffers are particularly important in a serial port programmer because the serial port output signal levels are incompatible with the PIC's input voltage requirements. The serial port signal levels are nominally –12v and +12v. The buffer converts these (inverted) to +5v and zero volts.

The Data In signal requires a little more circuitry to function properly. Since the PIC generates nominal voltage levels of +5v (high level) and 0v (low level) and the serial port expects to see voltages which are in the range of +4v to +12v (high) and –4v to –12v (low), a PNP transistor (Q4), two resistors (R7 and R8), a diode (D4), and a negative voltage (TD), are used to adjust the levels. When the PIC generates a low level (0v), the voltage at the base of Q4 will be about 5v, as supplied by the 5v regulator.

The voltage at RS232 pin 4 (TD) is –12v when in active programming mode. This gets inverted by transistor Q2 to produce +12.5v as Vpgm to the header and then to PIC pin 4 (MCLR). This meets the PIC requirement for high-voltage programming. High voltage programming requires the programmer to quickly raise the voltage on the MCLR pin from zero to at least 4.5v higher than the PIC's run voltage (Vdd) of 5v.

At the present time it is not possible to use the PIC-EL board from a PC parallel port. The only major difficulty is getting the Data In signal to work properly. The parallel port's voltages are 0v for a low level and +5v for a high level. Since the TD signal never goes negative the circuitry that was used to pull the Q4 collector below zero for a low level does not work. In fact, the low level only goes down to approximately 3.2v when TD is asserted (0v). Additional circuitry could be added, but it is not included in this PIC-EL board.

How about a USB to serial converter? This should work but so far we have been unsuccessful. The high and low voltage levels from the USB to serial converter get converted to levels that appear to be compatible with the PIC-EL programmer circuitry, but we have not been successful in making it work.

Project / Demonstration Board Design Details

PIC system clock (crystal)

The system clock is generated by a 4 MHz crystal with two 22 pf capacitors. A simple RC oscillator could have been implemented instead, but since we are going to be experimenting with several timing-sensitive projects, an accurate clock is required.

LEDs

There are two direct ways to light an LED from a PIC microcontroller. The first is to connect a PIC output pin to a resistor and then to the anode of the LED with the cathode grounded. To light the PIC, the program needs to assert a logical high (+5v nominal) on the output PIC pin. The PIC "sources" the current to light the LED.

The other way is to connect a PIC output pin to a resistor and then to the cathode of the LED with the anode connected to +5v. In this case, to illuminate an LED from the PIC, the PIC pin needs to be brought to a low level. The PIC is a current "sink". One minor drawback of this method is that the PIC programmer must remember that the logic is reversed; i.e., the LED is illuminated when the PIC pin is set to a logical low, and it is dark when the PIC pin is logical high.

The second method is used in the PIC-EL board because it is easier to "sink" current with a PIC than to "source" current.

Ideally, to illuminate an LED, the current flow through it should be between 5 ma and 20 ma. In this design the current flow is determined by the size of the series resistors. The series resistors (R16, R17, and R18) are each 2.2k ohms. These values were selected in order to keep the circuit loading to a minimum, since the PIC pins to which they are connected are used for multiple functions. Since the voltage drop across each LED is about 1.8v, the voltage drop across the 2.2k resistors is about 3.2v. This means the current through the resistors and these LEDs is about 1.4 ma. This amount of current illuminates the LEDs sufficiently.

Pushbuttons

Three stand-alone normally-open SPST pushbuttons (PB-1, PB-2 and PB-3) are connected directly to PIC pins. They can be used for any type of control functions that the programmer wants to use them for. In addition, there is a normally-open SPST pushbutton (PB-5) that is activated by pressing in the encoder's shaft. This is also connected to a PIC pin and can be used as desired. One other normally-open SPST pushbutton (PB-5) is connected to the PIC's Master Clear pin and is used to Reset the PIC programmer.

Three of the PIC pins that have pushbuttons attached (PB-1, PB-2 and PB-3) also have pull-up resistors attached to Vdd (+5v). In general, using pull-up resistors is a good design principle and provides a good "stiff" pull-up. In the case of PB-4, no pull-up resistor is attached. This is not inadvertent, but is to demonstrate a principle. Certain PIC pins (Port B) can have internal weak pull-ups activated. (This is done by executing a PIC instruction which clears bit 7 of the PIC's OPTION register.) In this mode, the PIC in effect puts a 50k ohm resistor between each of these pins and +5v. This means the PIC is able to source .1 ma on each of those pins. The PIC Elmer course will demonstrate, with PB-4, how the PIC's weak pull-ups can be selected and will show that this is sufficient for a simple pushbutton detection.

The PIC's Master Clear pin (pin 4) also has a 10k ohm pull-up resistor (R30) to +5v and is switched via a normally-open SPST pushbutton (PB-5) to "near" ground. The pull-up resistor is essential here, since the PIC needs +5v on MCLR for normal PIC operation. The 10k resistor is sufficient here, since the Master Clear pin draws very little current.

The pushbutton has 100 ohm resistor in series to prevent voltages transients from locking up the PIC.

LCD

The LCD used in the PIC-EL demonstration board is has a single row of eight characters. It is a standard 5x10 dot matrix LCD that has a standard Hitachi 44780 controller. It is attached in such a way that it minimizes interaction with other functions of the PIC-EL. In particular, the PIC programmer (using PIC pins 12 and 13 - RB6 and RB7) still works properly when the LCD is connected in this manner.

The values of the voltage divider resistors (R14, R15) were selected to put the proper voltage on the LCD's contrast pin (pin 3).

Rotary Encoder

A mechanical encoder is attached to two PIC pins. Each of the encoder's signal lines produce 15 pulses per revolution, so a total of 60 transitions per revolution can be detected by the PIC microcontroller. Since the pulses of the two data lines overlap (gray code), the PIC program can also determine which direction the shaft is being turned.

Both of the encoder's data lines use pull-up resistors as well as series resistors. The capacitors attached to the data lines prevent excessive switch noise (bounce). Try it without the capacitors and see the difference.

The encoder's shaft also has a normally-open SPST pushbutton (PB-4) which is connected to a PIC pin.

Speaker

A miniature speaker (SPKR-1) is attached to a PIC pin by way of a simple transistor (Q5) driver. The transistor driver gives more "punch" to the speaker than could be attained by directly attaching it to the PIC pin to the speaker.

Note that a speaker is different than a piezo element which is often used in PIC projects. The difference is that a piezo element makes a "buzz" sound at a set frequency when a DC voltage is applied. On the other hand, the speaker in the PIC-EL responds to pulses generated by the PIC microcontroller, so the frequency is determined by the frequency of the waveform.

Signal generation with the NJQRP DDS Daughtercard

The NJQRP DDS Daughtercard can be plugged into the PIC-EL board by way of a socket (J6).

Appropriate PIC connections are made to the PIC and the required +12v is also supplied to the socket for the Daughtercard. Details of how the Daughtercard operates can be found on the NJQRP web page at http://www.njqrp.org/dds/index.html

The output of the Daughtercard is supplied back to the socket (J6) at pin 6. The PIC microcontroller can drive the DDS Daughtercard to produce an amplitude is approximately 600 mv with a frequency within the range of zero to 30 MHz.

Signal "conditioner"

A signal "conditioner" is provided to increase small amplitude signals to levels which are appropriate as an input into a PIC pin.

The output amplitude of the DDS Daughtercard is about 600 mv. This is too low to be fed directly back into a PIC pin for the demonstration of frequency counting. To make this work, the amplitude is increased by the signal “conditioner” circuitry. Notice that this is different than an amplifier in that it does not attempt to keep the sine-wave output. For purposes of frequency measurement, a square wave would be just as good as a sine wave.

Note that a Header (HDR-2) is used to select the source of the signal which goes into the “conditioner”. In one position, the output of the DDS Daughtercard is fed into the “conditioner”. In another configuration a signal from an external source can be brought into the PIC-EL board via the BNC connector (J7) and routed through the “conditioner” before going to the PIC.

CW paddle input via a stereo jack

A CW keyer will be implemented as part of the PIC Elmer course. The CW paddles are attached to the PIC by way of a 1/8” stereo jack. The jack connects one of the paddle connections to the tip and the other to the ring. Both pins have pull-up resistors (R21 and R22) attached to +5v.

Note that the two pins of HDR-3 must not be shorted together when using the paddle inputs to the PIC. If the pins are shorted together, the frequency counter “conditioner” circuitry puts a load on the pins such that a logical high cannot be achieved with the pull-up resistor R22.

Transmitter keying via a stereo jack

To key a transmitter with the output of the demonstration keyer, another 1/8” stereo jack is provided. The output of a PIC pin goes to a transistor driver which then goes to the tip connection of the stereo jack. When “keyed”, the transistor driver drives the voltage at the tip connection from approximately 5v to ground potential. When the PIC pin is “not keyed” the tip-to-ground connection looks like an open circuit so the tip remains at approximately 5v. This keying mechanism will work for most modern rigs because they are positive-keyed transmitters. Some older style transmitters (tube style in particular) used negative keying. Positive keying means that the radio has approximately +3 to 5 volts on the tip connection and the radio is keyed when this pin is shorted to ground. Negative keying transmitters often had something on the order of –30v on the tip connection and are keyed when this connection is shorted to ground. This keying circuit is for positive keying only, but if your radio requires a negative keying scheme, it can be done by adding a few extra components.

Frequency counter

To demonstrate how a frequency counter can be implemented, the PIC-EL has a special signal path which feeds into PIC pin 3 (RA4/T0CKI). This PIC pin may be used as a general purpose input/output pin but also has the unique characteristic of being able to bring a signal in for the PIC’s TMR0 counter. This counter is used by the frequency counter.

The frequency counter signal comes from the “conditioner” circuitry (Q6 etc) as discussed in another section.

Note that the two pins of HDR-3 must be shorted together when using the frequency counter.

CONCLUSION

PIC microcontrollers are powerful components that can be used for a wide variety of applications. The radio amateur can benefit from being able to understand and use them. While this PIC-EL demonstration board has allowed the experimenter to build and understand several useful amateur radio projects, these applications are just the beginning. The rest is up to you and your imagination.

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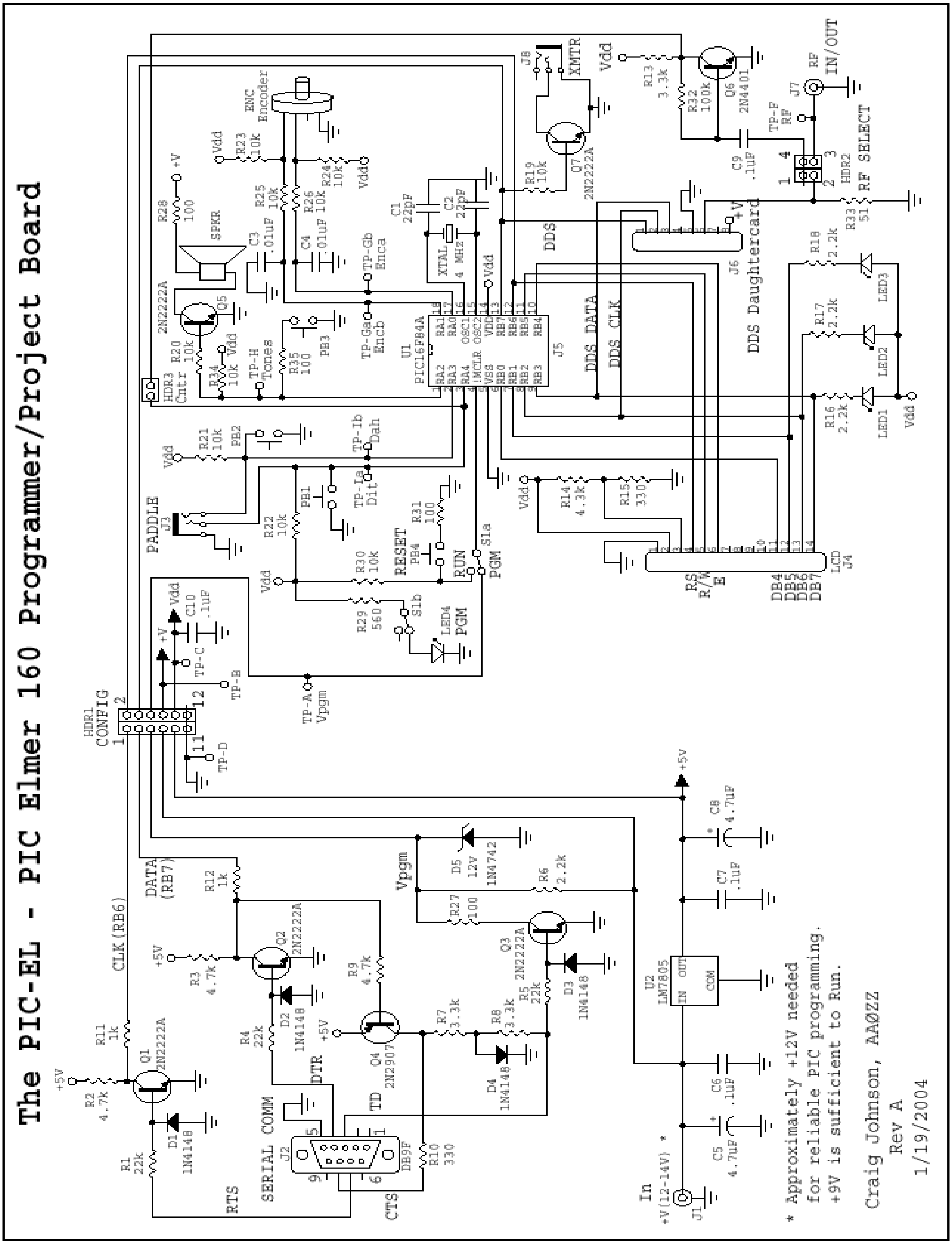


The PIC-EL - PIC Elmer 160 Programmer/Project Board
* Approximately +12V needed
for reliable PIC programming.
+9V is sufficient to Run.
Craig Johnson, AAØZZ
Rev A
1/19/2004

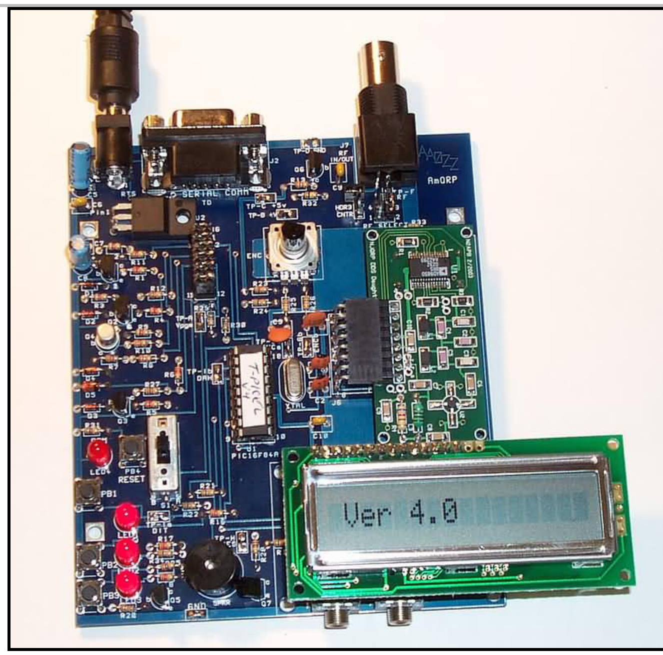
PARTS LIST

QTY	Designator	Description	All Electronics	Mouser	Digi-Key	Jameco
3	R1, R4, R5	22K (red, red, orange)		291-22K	22KEBK-ND	
3	R2, R3, R9	4.7K (yellow,violet, red)		291-4.7K	4.7KEBK-ND	
4	R6, R16, R17, R18	2.2K (red, red, red)		291-2.2K	2.2KEBK-ND	
3	R7, R8, R13	3.3K (orange, orange, red)		291-3.3K	3.3KEBK-ND	
2	R10, R15	330 (orange, orange, brown)		291-330	330EBK-ND	
2	R11, R12	1K (brown, black, red)		291-1K		
1	R14	4.3K (yellow, orange, red)		291-4.3K	4.3KEBK-ND	
10	R19, R20, R21, R22, R23, R24, R25, R26, R30, R34	10K (brown, black, orange)		291-10K	10KEBK-ND	
4	R27, R28, R31, R35	100 ohms, 1/8 W, (brown, black, brown)		291-100	100EBK-ND	
1	R29	560 ohms, 1/8 W (green, blue, brown)		291-560	560EBK-ND	
1	R32	100K ohms, 1/8W (brown, black, yellow)		291-100K	100KEBK-ND	
1	R33	51 ohms, 1/8W (green, brown, black)		291-51	51EBK-ND	
2	C1, C2	22 pF, ceramic disc ("22")		140-50N2-220J	P4841-ND	81533
2	C3, C4	0.01 uF, ceramic disc ("103M"		140-50Z5-103M		
2	C5, C8	4.7 uF, electrolytic (blue)		140-XRL16V4.7		
4	C6, C7, C9, C10	0.1 uF, monolithic, (small yellow, "104")		80-C317C104M5U	P4910-ND	25523
4	D1, D2, D3, D4	1N4148		625-1N4148	1N4148FS-ND	
1	D5	1N4742, 12V zener		625-1N4742A		
4	LED1, LED2, LED3, LED4	LED, T1-3/4 (red)	LED-1			
5	Q1, Q2, Q3, Q5, Q7	2N2222A transistor, NPN			PN2222A-ND	178511
1	Q4	2N2907 transistor, PNP		611-2N2907		
1	Q6	2N4401 transistor, NPN		611-2N4401		
1	U1	PIC16F84A microcontroller			PIC16F84-04/P-ND	145111
1	U2	LM7805 voltage regulator, 5V		511-L7805 ABV	497-1442-5-ND	
1	LCD	Liquid Crystal Display, 1x8 or 1x16 char	LCD-84		67-1778-ND	
1	XTAL	Crystal, 4 MHz		520-HCU400-20	X405-ND	137832
1	J1	coaxial power jack, 2.1mm		163-5004		
1	J2	DB9F serial connector				104951
2	J3, J8	audio jack, 1/8", stereo		161-3501		
1	J4	SIP jack, 14-pos'n		517-974-01-36		
1	P4	SIP plug, 14-pos'n		517-21029760 [1x20]	WM6436-ND (36 pos)	
1	J5	IC socket, 18-position	ICS-18			
1	J6	SIP jack, 8-pos'n, 90-deg			SamTec SSQ-108-04-T-S-RA	
1	J7	BNC jack, pcb mount		523-31-5538-10-RFX		
1	HDR-1	pin header, 0.1", 2x6 pos'n		571-41029770 [2x40]		
1	SKT-1	Boardmount SKT, 72p strip header, 0.1"		517-975-01-36 [2x36]		
1	HDR-2	pin header, 0.1", 2x2 pos'n		571-41029770 [2x40]		
1	HDR-3	pin header, 0.1", 1x2 pos'n		571-41029770 [2x40]		
2	shunt-1	shunt, 0.1", 2 pos'n		571-3828115		
4	PB1, PB2, PB3, PB4	SPST pushbutton, momentary	PB-126			
1	S1	slide switch, DPDT, pcb lunt	SSW-36			
1	ENC	rotary encoder, with pushbutton			P10860-ND	
1	SPKR	speaker/piezo			433-1020-ND 433-1028-ND	
1	PCB	5.25" x 4.5", double-sided, masked, silkscreen top				
1	Guide	Quick Assy Sheet				

Craig Johnson, AAØZZ

The PIC-EL and Beyond

The PIC-EL is a multi-function PIC16F84A-based project board that serves as the basis for the experiments being conducted by John McDonough, WB8RCR in the online PIC Elmer 160 course. Here, PIC-EL designer Craig Johnson describes some other PIC-based projects.



Introduction

The PIC-EL is a companion board for the "Elmer 160" project, an Internet on-line course taught by John McDonough, WB8RCR, that teaches people how to program PIC microcontrollers from Microchip and how to use them in ham applications.

The focus is on the 16F84, 16F84A and 16F628 microcontrollers, but the PIC-EL also provides the ability to program other PIC microcontrollers in an external user's circuit.

Goals

The following goals were set as the project started:

1. Make a companion board for Elmer 160 project which would demonstrate how to use various components that are "interesting" to hams.
2. Design the programmer to program 18-pin Flash/EEPROM PIC microcontrollers (16F84, 16F84a and 16F628).
3. Make a PIC Programmer with interface that would satisfy most users' needs.
4. Demonstrate PIC functionality by showing how various components could be connected.
5. Make it easy to use.
6. Keep the cost low.
7. Make the board 4" x 4.5" so that it can be mounted in a specific plastic case.

Springboard for other PIC-based Projects

While the PIC-EL demonstrates how to use the various components and as such is a stand-alone project, it was not necessarily meant to be final packaging for projects that are being demonstrated. Hopefully it will whet the appetites of many people, as they understand how to program PIC microcontrollers and how to connect the various hardware components to do these things. If we are successful, this should result in many new PIC-based projects being created.

In particular, here are some reasons why you may want to make a stand-alone board for your project after you learn to use the PIC-EL board:

- You my want to use an LCD display that has more than 8 characters
- You may not need all components on every project. (e.g. a keyer)
- You may need more specialized components. (e.g. a higher frequency response)
- You may want to use another type of PIC microcontroller.
- You may have several applications that you want to use simultaneously.

PIC-EL Components

Figure 1 shows the schematic diagram of the PIC-EL.

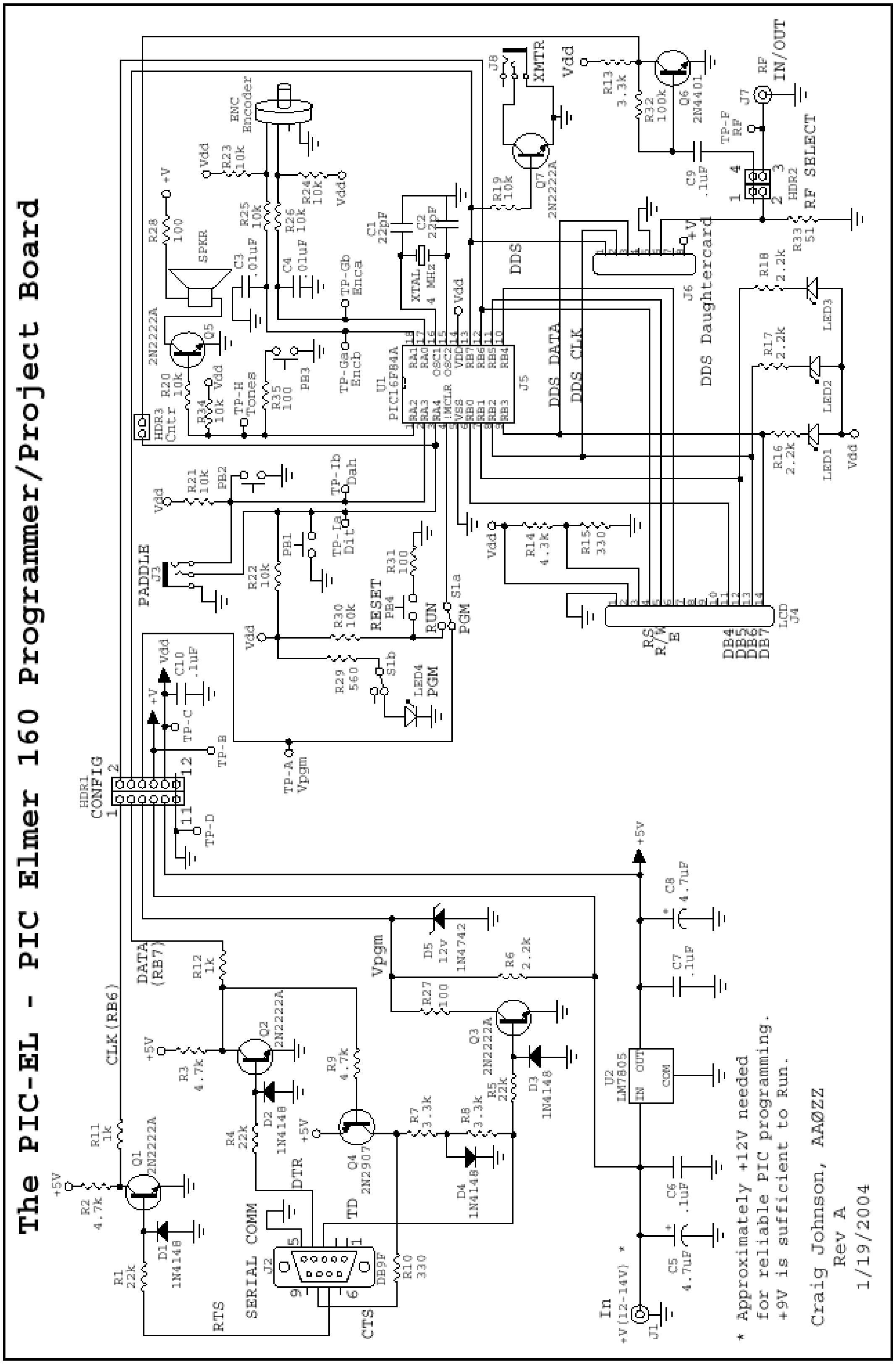

The PIC-EL - PIC Elmer 160 Programmer/Project Board
* Approximately +12V needed
for reliable PIC programming.
+9V is sufficient to Run.
Craig Johnson, AAØZZ
Rev A
1/19/2004

Figure 1

Programmer (RS232 serial port)

The PIC-EL board interfaces to the computer via a 9-pin RS232 (serial port) connection. Why was a serial port selected? Because it is the most commonly available computer port on virtually all computers until very recently. Computers used serial ports for connections to modems and other peripheral devices, so they were standard equipment on every PC.

Serial ports are not as popular on new computers these days, being replaced by the Universal Serial Bus (USB). While the lack of a serial port may be a problem for some people, there are some alternatives (discussed later) for them too. For most people, however, computers with serial ports are readily available so the single type of interface to the PIC-EL is not a big hindrance.

The PIC-EL board could have been designed to include a parallel port and/or USB interfaces in addition the RS232 serial interface. These options were discussed at the beginning of the design phase, but because of development time and cost constraints, we decided to limit this project to a serial port only.

Many people have wondered about why the 16F84A PIC was selected, instead of, for example, the 16F628. The simple answer is the simplicity of the PIC architecture.

The board's two major sections are divided by a 2 x 6 CONFIG header (HDR1). The user can use this header to chose between the following options:

1. Use the PIC-EL serial port programmer and the PIC-EL project board PIC and associated components. Program and use the on-board PIC (U1) in socket J5.

   In this case, the user connects a jumper block on HDR1 which shorts the six IN pins (pins 1, 3, 5, 7, 9 and 11) to the six OUT pins (pins 2, 4, 6, 8, 10 and 12).

2. Use an external programmer (e.g. USB or parallel port) and connect it to header HDR1. The external programmer may draw 12v and/or 5v power from the IN side of HDR1, pins 4 and 5 respectively. Whether or not the external programmer draws power from the IN side, it must always pass 12v and 5v power to the OUT side of HDR1, pins 8 and 10 respectively. Simply shorting from the IN side power connections to the OUT side is fine. The external programmer is then used to program the on-board PIC (U1) in socket J5.

   In this case, the user connects the external programmer to HDR1. The programmer supplies Clock, Data Out, and Vpgm to output pins 2, 4 and 6 of HDR1. Data In is passed from the PIC microcontroller to the external programmer via the same data line (HDR1, pin 4).

3. Use the internal programmer and connect to a foreign project board containing a PIC microcontroller. Any type of PIC microcontroller can be programmed in this manner.

In this case, the user connects the external project board to HDR1. The external board draws 5v and possibly 12v power from the IN side of HDR1. The external project board receives Clock, Data Out and Vpgm on pins 1, 3, and 5 of HDR1.

PIC Programmer Description

The PIC programmer has an RS232 (DB9F) serial port connection. Pin assignments are as follows:

Data Out is on RS232 pin 4 (DTR)
Clock is on RS232 pin 7 (RTS)
Data In is on RS232 pin 8 (CTS)
MCLR is on RS232 pin 3 (TD)

The RS232 lines representing Data Out and Clock are inverted and converted to PIC signal levels via NPN (2N2222A) transistor switches (Q1 and Q2) before going to the PIC microcontroller. Thus, for these two computer output signals passed via the serial port's DTR and RTS lines, low serial port signal levels (–12v) get converted to high PIC signal levels (+5v) and high serial port signal levels (+12v) get converted to low PIC signal levels (0v).

The MCLR signal is another PC output signal and it is sent to the programmer via the serial port's TD line. This signal is generated by the PC programming software in order to put the PIC in high-voltage programming mode. In this case, the PIC needs the two levels to be zero and approximately +12v. Transistor Q3 operates in a manner that is very similar to Q1 and Q2, except its collector voltage is higher. As before, it inverts the serial port signal levels but this time the low level (–12v) results in a MCLR signal of approximately 12.5v (depending on the power supply voltage) and the serial port high level (+12v) results in a MCLR signal of approximately zero volts.

One 2N2907 (PNP) transistor switch (Q4) is used in the programmer. It brings the Data In signal from the PIC microcontroller to the serial port connector. Again, its high and low levels are inverted. There is some additional circuitry associated with this signal to change the PIC levels to RS232 levels.

Project / Demonstration Board

The PIC-EL was designed to demonstrate the usage of components that are of interest to hams. Starting with the very simple and getting more complex, each of the components has a unique reason for being used in a ham's projects. However, the intent is that the principles learned in the Elmer 160 course and demonstrated in the PIC-EL board will stimulate experimenters to build follow-on projects. With this in mind, as we look at the various components of the PIC-EL we will discuss how the principles can be used to a stand-alone project.

1. Pushbuttons

A pushbutton is one of the most useful and easy to understand components to use in a PIC project. Nearly every PIC project will use some type of “user interface”, and a pushbutton is one of the most basic. Once a pushbutton usage is understood, the concept is very easily expandable to keypad.

The PIC-EL has four normally-open SPST pushbuttons. Three (PB1, PB2 and PB3) are used as “general purpose” pushbuttons while one (PB4) is used as the PIC Master Reset.

A pushbutton can be directly connected to a PIC I/O pin without a pull-up resistor as illustrated in Figure 2. In some cases, the PICs internal “weak pull-ups” can be enabled via software.

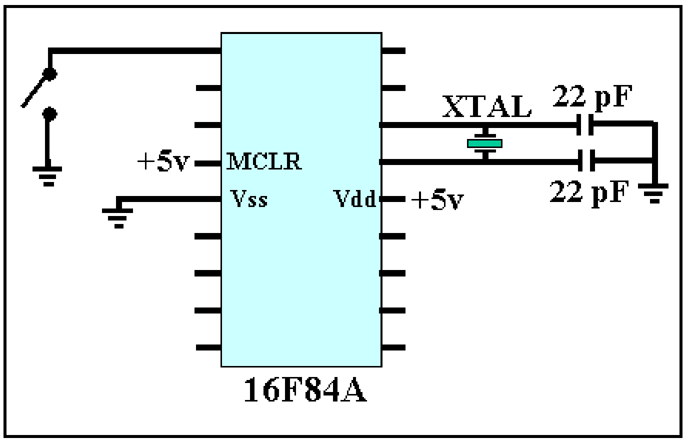


Figure 2

However, it is generally advisable to use a pull-up resistor for each pushbutton, as shown in Figure 3. This insures the voltage on the I/O pin goes to its logical high level (+5v) when the pushbutton is released.

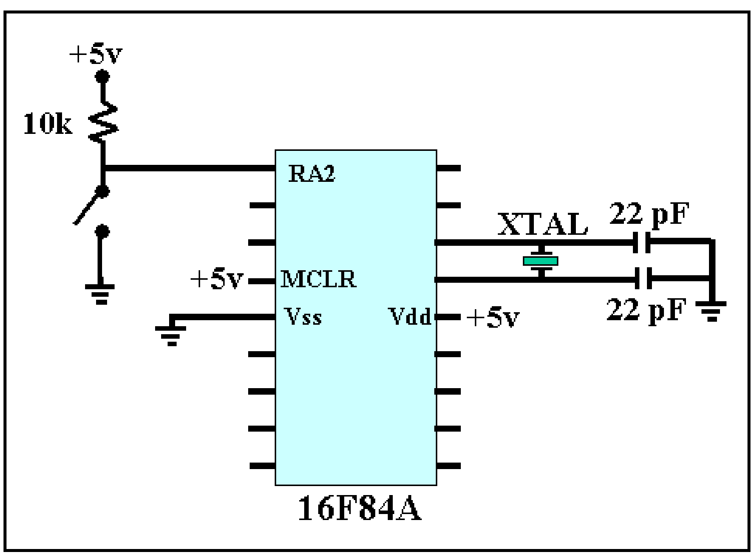


Figure 3

Figure 4 shows the suggested method for using a pushbutton for a PIC Master Reset. The resistor is required in this case so the power supply is not shorted to ground when the switch is closed to perform the reset. The MCLR pin needs +5v for normal operation. A momentary low level on the MCLR pin causes the PIC program to start from the beginning.

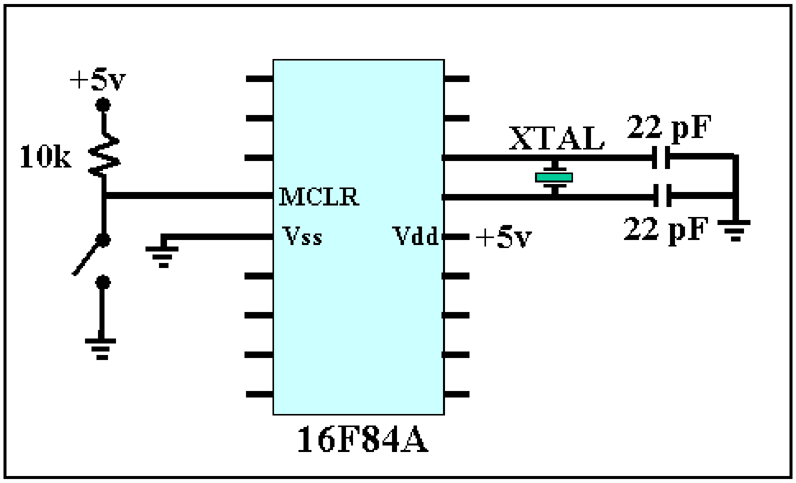


Figure 4

PIC code to determine whether or not a pushbutton is being pressed can be done with a single instruction in the PIC code. Additional code may be used to check for “bounce” (switch noise).

2. LEDs

LEDs are also very easy to implement and are very useful. LEDs have typically been used as power indicators. In the PIC-EL, LED4 is used to indicate whether switch S1 is in the Programming (PGM) or in Run position. However, when an LED is connected to a PIC I/O pin, it can be used as an indicator that some event took place. LED1, LED2 and LED3 in the PIC-EL are general purpose indicators.

There are two direct ways to light an LED from a PIC microcontroller. The first is to connect a PIC output pin to the anode of the LED, with the cathode connected to a resistor and then to ground. To light the PIC, the program needs to assert a logical high (+5v nominal) on the output PIC pin. The PIC “sources” the current to light the LED.

The other way is to connect a PIC output pin to the cathode of the LED, with the anode connected to a resistor and then to connected to +5v. In this case, to illuminate an LED from the PIC, the PIC pin needs to be brought to a low level. The PIC is a current “sink”. One minor drawback of this method is that the PIC programmer must remember that the logic is reversed; i.e., the LED is illuminated when the PIC pin is set to a logical low, and it is dark when the PIC pin is logical high.

Figure 5 shows two ways in which an LED can be connected to PIC I/O pins.

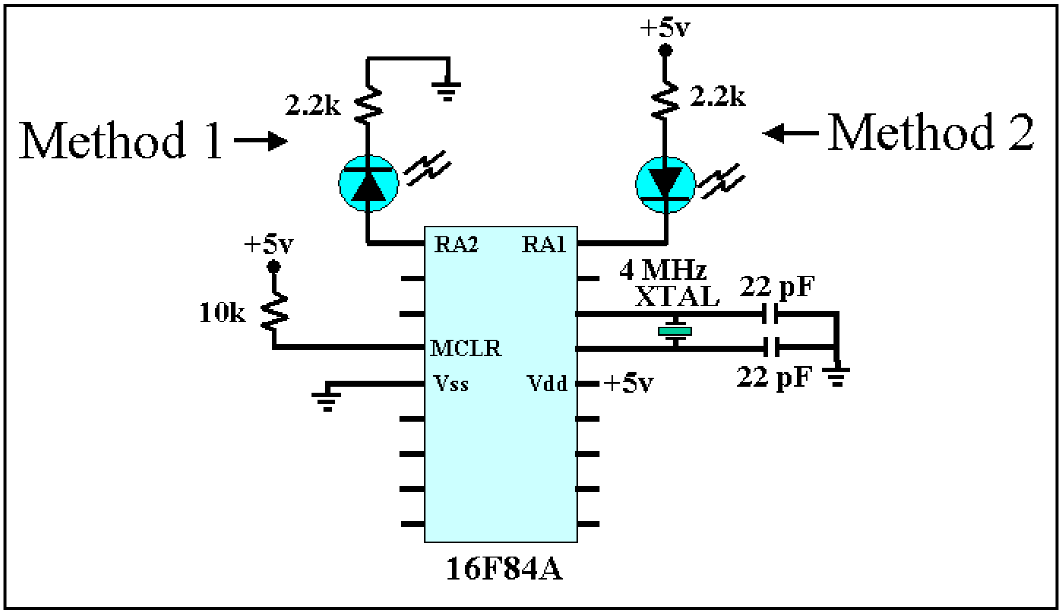


Figure 5

In Method 1, shown on the left side, the LED is activated by putting a high signal (5v) on the PIC pin. The specs say that an LED can handle up to 20 ma or but most will light adequately with about 1 ma. My experiments with the PIC-EL prototypes indicated that the LEDs being used in the PIC-EL were bright enough with a 2.2k series resistor. With the 2.2k resistor, as shown, the PIC "sources" approximately 1.5 ma. (The LED drops approximately 1.8v, so the voltage drop across the 2.2k resistor is approximately 3.2v. This means the current is 1.5 ma.)

In Method 2, on the right side, the LED is activated by putting a low signal (zero) on the PIC pin. When the PIC pin is driven high (5v) the LED is goes out. Once again, when the LED is lit, approximately 1.5 ma of current flows through the LED. However, this time the current flows from the power supply to the PIC.

Method 2 was used in the PIC-EL. However, either method will work if you are careful about the total amount of current flow. In the 16F84, the total current that all pins of Port A can source is 50 ma, while Port A can "sink" 80 ma. Port B can source 100 ma but can sink 150 ma. Obviously we are nowhere near these limits in the PIC-El design, but it is a factor to keep in mind when you design your projects.

3. Speaker

A miniature speaker (SPKR) is attached to a PIC pin by way of a simple transistor (Q5) driver. The transistor driver gives more "punch" to the speaker than could be attained by directly attaching it to the PIC pin to the speaker. Figure 6 illustrates how the speaker is connected to the PIC.

Note that a speaker is different than a piezo element which is often used in PIC projects. The difference is that a piezo element makes a tone at a set frequency when a DC voltage is applied. On the other hand, the speaker in the PIC-EL responds to pulses generated by the

PIC microcontroller, so the frequency is determined by the frequency of the waveform. The frequency response of this speaker is approximately 500 Hz to 3000 Hz.

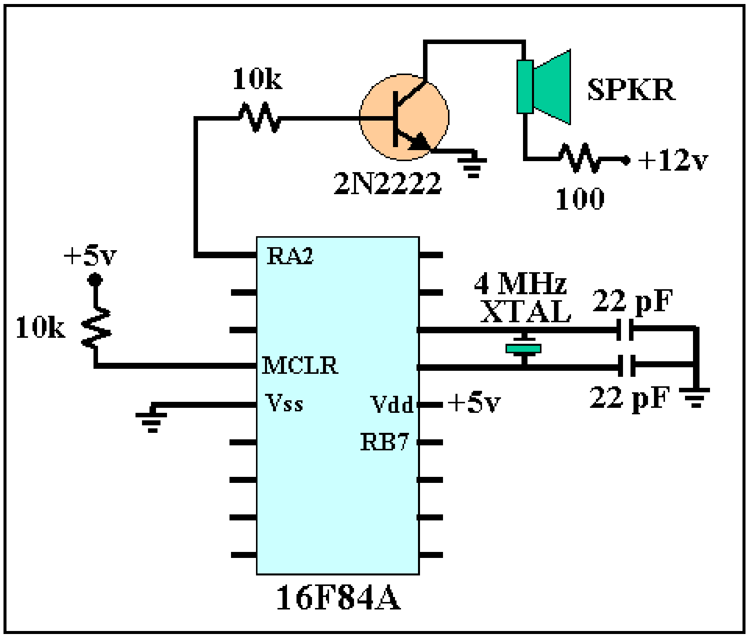


Figure 6

4. CW Paddles (CW Keyer)

The CW paddles are connected to the PIC-EL via a 1/8" stereo jack, J3. The two paddle connections are considered exactly the same as pushbuttons by the PIC code.

The jack connects one of the paddle connections to the tip and the other to the ring. Both pins have pull-up resistors (R21 and R22) attached to +5v. The two paddle inputs are connected to the same PIC pins that PB1 and PB2 are connected to. This means that you can use PB1 ("Dit") and PB2 ("Dah") for sending CW instead of using paddles. (Probably not a good idea for serious contesting!)

Note that the two pins of HDR3 must not be shorted together when using the paddle inputs to the PIC. If the pins are shorted together, the frequency counter "conditioner" circuitry puts a load on the pins such that a logical high cannot be achieved with the pull-up resistor R22.

5. Transmitter Keying

To key a transmitter with the output of the demonstration keyer (see Figure 7), another 1/8" stereo jack is provided. The output of a PIC pin goes to a transistor driver which then goes to the tip connection of the stereo jack. When keyed (by putting a logical high on RB7), the transistor driver changes the voltage at the tip from approximately 5v down to "near ground" potential. When the PIC pin is not keyed the tip-to-ground connection looks like an open circuit so the tip remains at approximately 5v. This keying mechanism will work for most modern rigs because they are positive-keyed transmitters. Positive keying means that the radio has approximately +3 to 5 volts on the tip connection and the radio is keyed when this pin is “shorted” to ground. Some older style transmitters (tube style in particular) used negative keying. Negative keying transmitters often had something on the order of –30v on the tip connection and are keyed when this connection is shorted to ground. The keying circuit shown here is for positive keying only, but if your radio requires a negative keying scheme, it can be done by adding a few extra components.

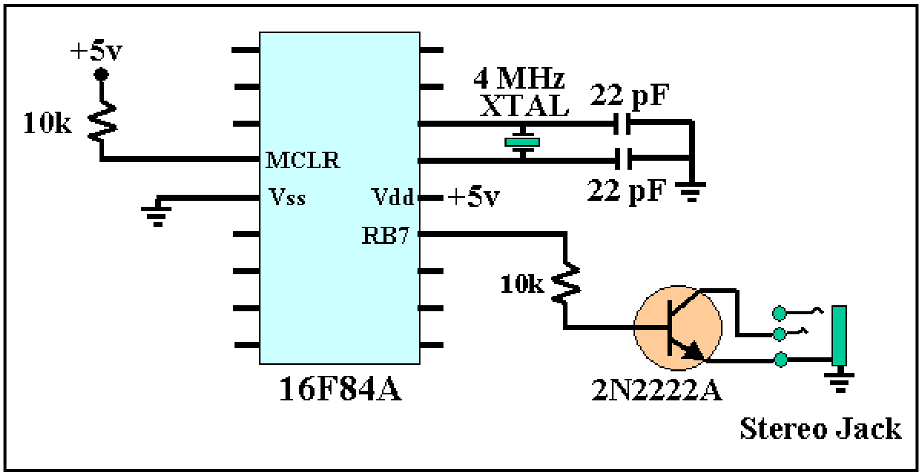


Figure 7

6. LCD

The LCD used in the PIC-EL demonstration board is has a single row of eight characters. It is a standard 5x10 dot matrix LCD that has a standard Hitachi 44780 controller. It is attached in such a way (Figure 8) that it minimizes interaction with other functions of the PIC-EL. In particular, the PIC programmer (using RB6 and RB7) still works properly when the LCD is connected in this manner. (Other LCD connection configurations were found to interfere with PIC programming.)

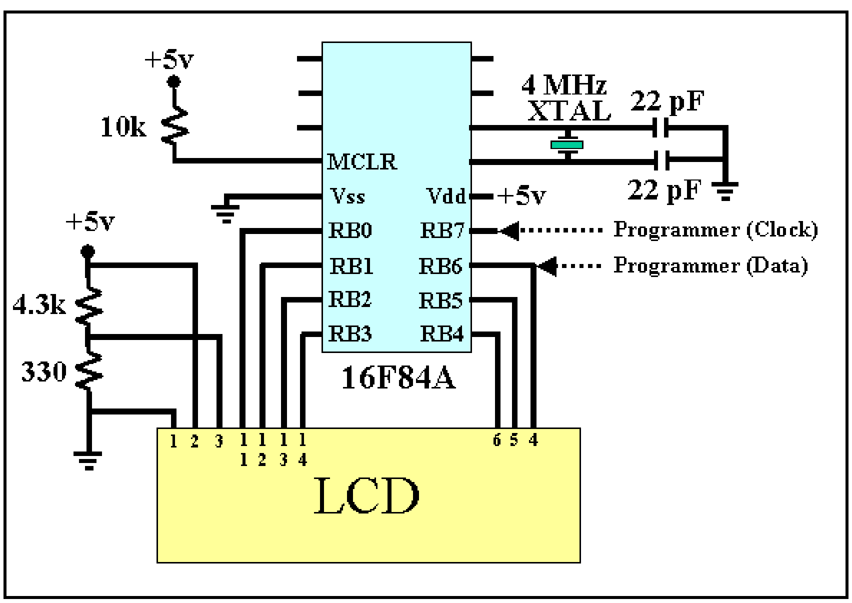


Figure 8

The values of the voltage divider resistors (4.3k and 330 ohms) were selected to put the proper voltage on the LCD's contrast pin (pin 3). These values were determined experimentally for the LCD used in the PIC-EL kit. Other LCDs may require different resistor values. (For many LCDs, pin 3 may be grounded, eliminating the need for the second resistor.)

7. Shaft Encoder

Both of the encoder's data lines use pull-up resistors as well as series resistors. The capacitors attached to the data lines prevent excessive switch noise (bounce). Try it without the capacitors and see the difference.

The encoder's shaft also has a normally-open SPST pushbutton (PB-4) which is connected to a PIC pin.

A shaft encoder is useful for many projects that the ham may want to build. It may be the method of tuning a VFO, or it may be the method of selecting the speed in a keyer, or countless other examples.

The simple shaft encoder that we use in the PIC-EL project is a mechanical encoder. This is much cheaper than the typical optical encoders and illustrates the principles. Each of the mechanical encoder's signal lines produce 15 pulses per revolution, so a total of 60 transitions per revolution can be detected by the PIC microcontroller. If more pulses per revolution are needed, you may need an optical encoder.

Think of a shaft encoder as two SPST switches that open and close many times during a single revolution of the shaft. The two switches are connected to two PIC pins. Both of the encoder's data lines use pull-up resistors as well as series resistors. The capacitors attached to the data lines prevent excessive switch noise (bounce). Try it without the capacitors and see the difference.

How does the PIC code determine whether the rotation is "UP" or "DOWN"? Here is a simplified explanation. The two encoder lines go to PIC pins RA0 and RA1. The two bits, A and B are "gray code" - 90 degrees out of phase (quadrature) .

Here (Figure 9) is an illustration of the two encoder signals, A and B:

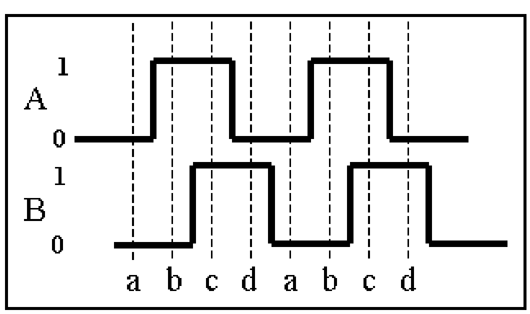


Figure 9

At the various times shown above, the voltage levels for lines A and B are as follows:

	A	B
Time a:	0	0
Time b:	1	0
Time c:	1	1
Time d:	0	1

Going UP (turning clockwise), the sequence is a,b,c,d,a,b,c,d, etc., so the signal sequence is:
00, 10, 11, 01, 00, 10, 11, 01, etc.

Going DOWN (turning counterclockwise), the sequence is d,c,b,a,d,c,b,a, etc., so the signal sequence is:
01, 11, 10, 00, 01, 11, 10, 00, etc.

To determine if the sequence is UP or DOWN, follow this algorithm:

1. Take the "Right-Bit" of any pair.
2. XOR (Exclusive- OR) it with the "Left-Bit" of the next pair in the sequence.
3. If the result is 1 it is UP.
4. If the result is 0 it is DOWN

That's it! You simply write a few lines of code to implement this algorithm and now you can tell if the encoder is turning clockwise (UP) or counterclockwise (DOWN).

If your application needs more than 60 transitions per revolution, to get less "backlash", for example, you may need an optical encoder instead of a mechanical encoder. Connections are very similar, although you need to supply 5v to the encoder as well. An optical encoder does not need the "debounce" capacitors. Optical encoders that give 512 transitions per revolution are quite common. They are more expensive.

8. Signal "Conditioner"

A signal "conditioner" shown in Figure 10 is provided to increase small amplitude signals to levels which are appropriate as an input into a PIC pin. This "conditioner" is good up to about 7 MHz.

The output amplitude of the NJQRP DDS Daughtercard is about 600 mv. This is too low to be fed directly back into a PIC pin for the frequency counting demonstration. To make this work, the amplitude is increased by the signal "conditioner" circuitry. Notice that this is different than an amplifier in that it does not attempt to keep the sine-wave output. For purposes of frequency measurement, a square wave would be just as good as a sine wave.

Note that a Header (HDR2) is used to select the source of the signal which goes into the "conditioner". In one position, the output of the DDS Daughtercard is fed into the “conditioner”. In another configuration a signal from an external source can be brought into the PIC-EL board via the BNC connector (J7) and routed through the “conditioner” before going to the PIC.

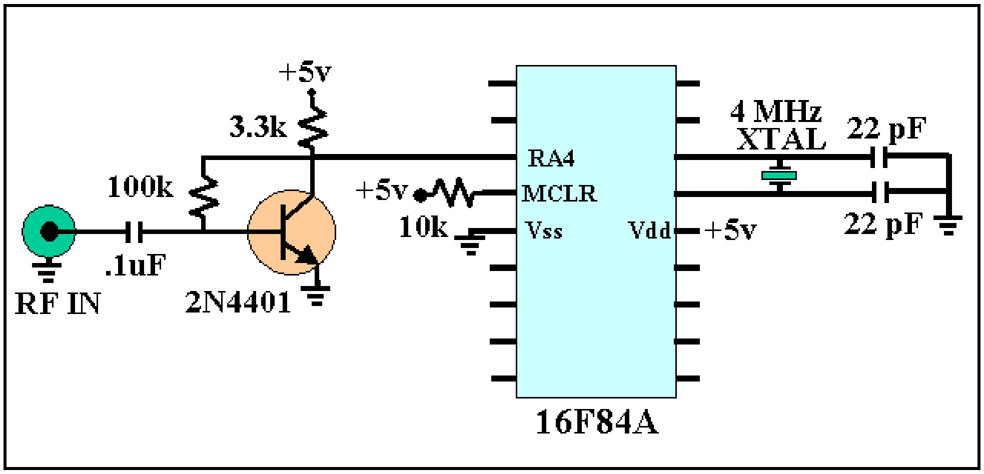


Figure 10

9. Frequency Counter

To demonstrate how a frequency counter can be implemented, the PIC-EL uses the output of the signal “conditioner” and feeds it into PIC pin 3 (RA4/T0CKI). This PIC pin may be used as a general purpose input/output pin but also has the unique characteristic of being able to bring a signal in for the PIC’s TMR0 counter. This counter is used by the frequency counter.

Remember that the frequency response of the “conditioner” is limited to approximately 7 MHz. To measure higher frequencies you need to use a different kind of signal conditioner.

Note that the two pins of HDR3 must be shorted together when using the frequency counter.

10. NJQRP Daughtercard connection

The NJQRP DDS Daughtercard is a small, 1” x 2” board that contains the essential elements to make a fully functional DDS signal generator. It contains an Analog Devices AD9850 DDS chip, a 100 MHz clock oscillator, a 5th order elliptic filter, and a MMIC RF amplifier. The three control lines, power supply inputs, and the output signal are available on a pin header at the board edge.

The NJQRP DDS Daughtercard can be plugged into the PIC-EL board by way of a socket (J6).

Appropriate PIC connections are made and the required +12v is also supplied to the socket for the Daughtercard. Details of how the Daughtercard operates can be found on the NJQRP web page at: http://www.njqrp.org/dds/index.html

The output of the Daughtercard is supplied back to the socket (J6) at pin 6. The PIC microcontroller can drive the DDS Daughtercard to produce an amplitude is approximately 600 mV with a frequency within the range of zero to 30 MHz.

See my Web site for the latest version of my signal generator code, PICELgen, that drives the NJQRP Daughtercard on the PIC-EL. This code is a modification of the popular SIGGEN3a code that many amateurs have found useful in the past.

Handy Debugging Hints

LEDs come in very handy when you are trying to debug PIC code. Sometimes you will want to know if you are ever executing a certain set of instruction in your code. It is often very helpful to temporarily commandeer a "spare" LED for this purpose. With just a couple of instructions in the code in question, you can set up and light the LED. Then, it is advisable to force a delay for at least a second or two before going on. Sometimes you may want to just "hang" after lighting the LED.

Similarly, a pushbutton may be used to "trigger" a particular event in your code. Once again, you can set up to check for a pushbutton with just a couple of instructions. You can check for the pushbutton being pushed in your "main path" and if it is, you have it jump into a particular piece of code that you want to exercise. Very handy.

Options

USB Interface To PIC-EL

Do you want to use the PIC-EL board but only have a USB port on your computer? The PIC-EL has only a RS232 port for use with a serial (COM) port on the computer, but there still is a way, albeit not quite as convenient to use. This method is to use a "foreign" programmer which has a USB port, and to bring the pertinent signals into the PIC-EL via a cable connected to the PIC-EL's configuration header (HDR1).

One example of a USB programmer that works well is K149 from DIY Electronics of Hong Kong (www.kitsrus.com). The DIY kits are available from several US distributors listed on the KITSRUS web page. I got mine from Carl's Electronics (www.electronickits.com). It has a serial port as well as a USB port. Cost was reasonable - about $35 for the programmer and an additional $10 for an 18-volt power supply.

How does the K149 programmer differ from a simple USB to RS232 cable adapter? It has some special components and circuitry.

Hardware

The instructions say that the K149 programmer requires an 18 volt power supply input. The power supply is not supplied with the kit but is available for $10 with the kit. It is a fairly large "wall wart" with a slide switch to select the output voltages - 6, 9, 12, 15, 18 or 20v at 500 ma. The output cable has alligator clips as well as a connector into which you insert one of the 6 removable tips. The largest tip in the set (note – it is larger than 2.5 mm ID) works with the jack supplied for the programmer. The jack is standard size, so it could easily be replaced with a more standard 5.5 / 2.1 or 5.5 / 2.5 jack.

The board has a 8-v (78L08) regulator and a 5-v (7805) regulator. The 5v regulator has a big heat sink screwed on to it. To get the "programming voltage", Vpgm, they stack the two together to get approximately 13v.

Question - why do they say they require a 18v power supply? I don't know! According to the PIC specification sheets, to program a PIC with the high voltage method, the voltage applied to MCLR (Pin 4 in a 16F84,. 16F84A or 16F628) needs to be suddenly brought from zero up to 4v higher than Vdd (5v). Usually 12v is recommended as a safety factor, but approximately 9v will work.

I measured the voltage at Pin 4 (MCLR) to measure Vpgm with various input power supply voltages and found these results:

Power Supply Voltage	**Pin 4 (Vpgm)**	**Pin 14 (Vdd)**
18	**13.0**	**4.95**
15	**12.8**	**4.95**
12	**9.5**	**4.95**

This indicates (and I confirm) that a common 12 – 13 volt power supply will work.

To solve PIC programmer timing issues, DIY Electronics has a 16F628 PIC on the board. The FTDI chip interprets the USB signals or RS232 signals and supplies inputs to the 16F628 which generates the appropriate Clock and Data for the PIC being programmed.

To support the RS232 connection, the board uses an ICL232 transceiver chip. Signals come directly from the RS232 connector to the ICL232 and from there to a 16F628 PIC. This PIC contains a lot of control logic. The programmer's data and clock are generated by an output from this PIC controller.

The board feeds it's USB connector into an FT232BM FTDI chip. This chip requires its own 6 MHz crystal. The output of the FTDI chip goes to the same 16F628 PIC controller, which again generates the DATA and CLOCK signals for the programmer.

A 78LS06 hex inverter chip in used on the board as well as a number of discrete transistors for signals. It uses several BC558's (PNP's) and one BC547 (NPN) in the logic that generates the programming voltage for MCLR.

The 16F628 control PIC supplied with the board is copy protected. They say they removed the protection because it caused too many problems, but you cannot Read or Write the 16F628 PIC with another PIC programmer, so it IS copy protected. However, they do supply a HEX file which contains the code if you want to program another PIC. (They supply updates this way.) There is no source code for this PIC, of course.

The programmer has provisions to mount an optional 40-pin ZIF socket, so it can program all sizes and varieties of PICs. This is a good idea. It is a bit tricky to find ways to insert various size PICs in the 40-pin socket to make it work, but they all do work.

Software

The K149 kit comes with its own software package. Actually, it just has a 2-page flyer with it pointing to the web page for all software as well as the 18 page manual (PDF format).

To drive the programmer board, you need to use special computer software. Actually it is a pretty slick package, but you MUST use this one to talk to the K149. In fact, the software "recognizes" the K149 programmer and "connects" with it.

The serial interface can be used with no additional drivers in the computer. However, before you can use the USB interface, you must load TWO drivers. They both come from FTDI, which means they are kept very current. Drivers are available for Windows 98 as well as Windows 2000 / Windows XP. The first USB driver maps the USB to an unused COM port. Then it also installs a port driver.

Interface Cable to PIC-EL

You need to make an interface cable that connects the K149 programmer to the configuration header (HDR1) of the PIC-El. The cable is a length of 5-conductor cable with an 18-pin DIP socket (such as a Digkey WM403AE-ND) on one end and a 6-pin header (e.g. DigiKey WM4004-ND) on the other end. Figure 11 shows the connections required, while Figure 12 shows the K149 to PIC-EL cable.

A machine pin socket is preferable, since you need to solder wires to it. Insert each of the wires into the sockets (as if inserting a component) and apply a bit of solder to hold them in.

On the header side, simply wrap each wire around the appropriate header pin and solder.

How does this interface work? The signals required at the header of the PIC-EL are all available within the 18-pins of the interface socket when inserted in the K149 PIC socket. The 6-pin header is inserted in the right side of the PIC-EL Header (HDR1). This means they connect to HDR1 pins 2, 4, 6, 8, 10 and 12.

Proper alignment of an 18-pin socket in the K149's 40-pin PIC programmer socket has Pin 1 of the 18-pin socket inserted in Pin 2 of the 40 pin socket. See the K149 instruction sheet.

K149 Interface socket pin 12 supplies the CLOCK signal to PIC-EL header (HDR1) Pin 2
K149 Interface socket pin 13 supplies the DATA signal to PIC-EL header (HDR1) Pin 4
K149 Interface socket pin 4 (MCLR) supplies 12v to PIC-EL header (HDR1) Pins 6 and 8
K149 Interface socket pin 14 supplies the Vdd (5v) to PIC-EL header (HDR1) Pin 10
K149 Interface socket pin 5 (GND) supplies the ground to PIC-EL header (HDR1) Pin 12

You may wonder why the 12v is connected to Pin 6 as well as Pin 8. Only Pin 6 is really required, since it supplies Vpgm to the PIC. However, if you have the NJQRP DDS daughtercard installed on your PIC-EL board, it needs to be powered up with 12v in order for the programming to work. The daughtercard puts a load on RB7, since it is dual-usage between the daughtercard load signal and the programming CLOCK signal, and prevents the programming function from working if the daughtercard is not powered up. Of course, if you don't have a daughtercard connected, the jumper to pin 6 is not required.

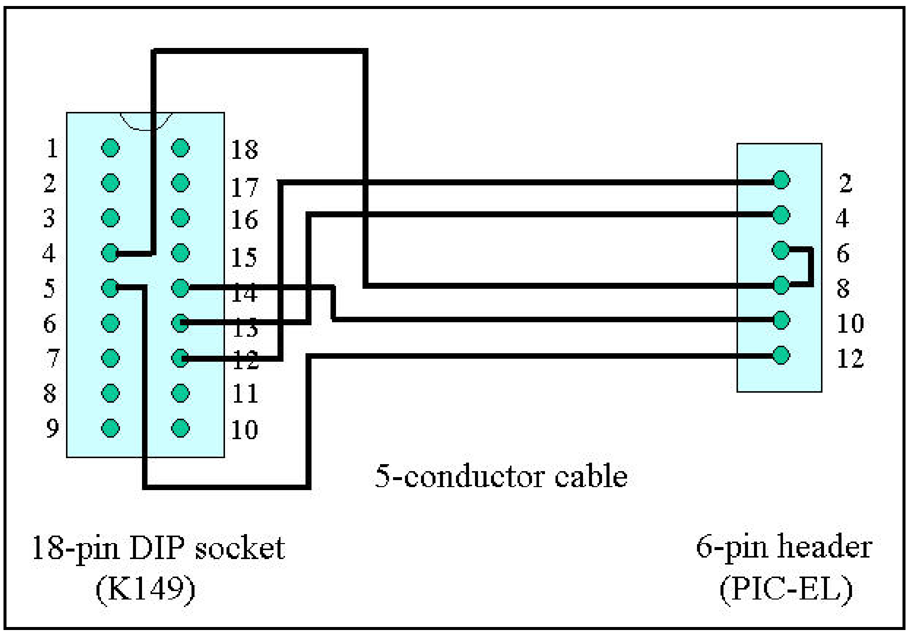


Figure 11

K149 to PIC-EL Cable and Connections

Figure 12
K149 to PIC-EL cable

Operational Considerations

To run the PIC-EL via a USB-connected K149, you must use the MicroPro software that is supplied with K149. Note that there is a switch on the board in which you select which interface (RS232 or USB) you will use. Similarly, in MicroPro you select the port that you will use. You select either the serial (COM) port that you are using or, if you are using the USB, you select the COM port that has been mapped to the USB port by the driver software installation.

With the interface cable connected properly, the MicroPro software operates exactly like the PIC being programmed is in the K149 board.

You can run the program in the PIC-EL with the power supply connected to the K149 and the interface cable supplying power to the PIC-EL. However, please note that in order to run the PIC-EL in this manner, you need to shut down the MicroPro software or disconnect the USB cable from the computer to the K149. (The 5v signal is held at zero when MicroPro is active and the USB cable is connected.) When the MicroPro is shut down, the 5v power is again supplied via the cable. Of course, after you are through programming the PIC in the PIC-EL, you can disconnect the interface cable, replace the header with HDR1 jumpers, and use the power supply connected to the PIC-EL.

Modifying the PIC-EL Rev A board to work with a 16F628 PIC

Two minor hardware changes are needed in the PIC-EL board (Rev A) to make it work with a 16F628 PIC.

1. Some PIC-EL boards will not program a 16F628 with the LCD in place. The 16F628 (unlike the 16F84) is very sensitive to current flow into PIC Pin 10 (RB4) when programming. The 16F628 uses this pin for "low voltage programming", a function which is not implemented in the PIC-EL because it doesn't apply to a 16F84. This pin (RB4) is used in the PIC-EL as the "Enable" signal for the LCD. However, when the 16F628 goes into programming mode, RB4 is configured as an Input, and the LCD can source a bit of current into the pin. This can be enough to make the 16F628 fail to program.

Since the LCD is not used in all projects, you could decide to remove the LCD and this change would not be necessary. However, you will probably want to use the 16F628 in future projects that use the LCD so you do not want to remove it. This means you need to make this simple modification:

FIX: Add a 10K resistor from PIC Pin 10 to ground. This can be done easily on the bottom of the PIC-EL board by soldering one end of a 10k resistor to PIC pin 10 and the other end to the ground side of capacitor C10. No shrink wrap necessary since it is very close. As an alternative, you could solder the resistor between the LCD socket pins 1 and 6.

2. Another modification to the PIC-EL board is needed to make it work reliably with a 16F628. With the current configuration, PIC Pin 1 is used for two purposes. It can be an output (feeding the speaker via transistor Q5) or it could be used as an input, making Pushbutton 3 usable. A pull-up resistor, R34, is used to make the pin HIGH when configured as an input. Unfortunately, because of the speaker circuitry connected to this pin as well, the 10k R34 pull-up resistor only pulls the pin up to 2.75v or so. This is high enough to be recognized as a "HIGH" by a 16F84, but unfortunately, a 16F628 will still see this as a "LOW", making it look like the pushbutton is always being pressed.

FIX: We need to make the pull-up resistor, R34, smaller. There are two easy options here.

a) Remove R34 and replace it with a 5.6k resistor, or
b) On the bottom of the PIC-EL board, solder another 10K resistor across the R34 connectors, making the resistance equivalent to 5k.

With these hardware modifications, the PIC-EL will program the 16F628 and the PIC-EL is able to use the 16F628 for your projects.

Summary

The PIC-EL is meant to be a learning tool. Hopefully we have accomplished our goals of introducing people to the world of PIC programming. PIC microcontrollers are powerful devices, but yet they can be used in simple as well as complex applications.

The next step is up to you. Try it and then tell us all about it. As we have seen in the past, one good idea tends to spur on another, and yours may be just the spark that someone else needs. We will all learn together as we proceed with these fun applications.

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March 27, 2004
(Updated March 5, 2005)

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The JUMA-RX1

2005 SRAL RX Design Contest Winner

With a little time on the homebrewing bench, you too can reproduce this small and inexpensive DDS-based receiver suitable for listening to AM, SSB and CW transmissions from 100 kHz to 8 MHz!

The Finnish Amateur Radio League (SRAL) launched a RX construction contest in the November 2004 issue of their magazine ”Radioamatööri”. The purpose was to design and make a receiver intended primarily for beginners in the radio hobby. The participating constructions were judged according to the following criteria:

1. The clearness, usability and repeatability
2. Functional reliability and technical quality
3. Creative solutions
4. Operation in the bands
5. The cost and availability of the parts
6. Documentation for construction and other necessary instructions

Further, the cost of the parts was not allowed to exceed 60 Euros (about US$75).

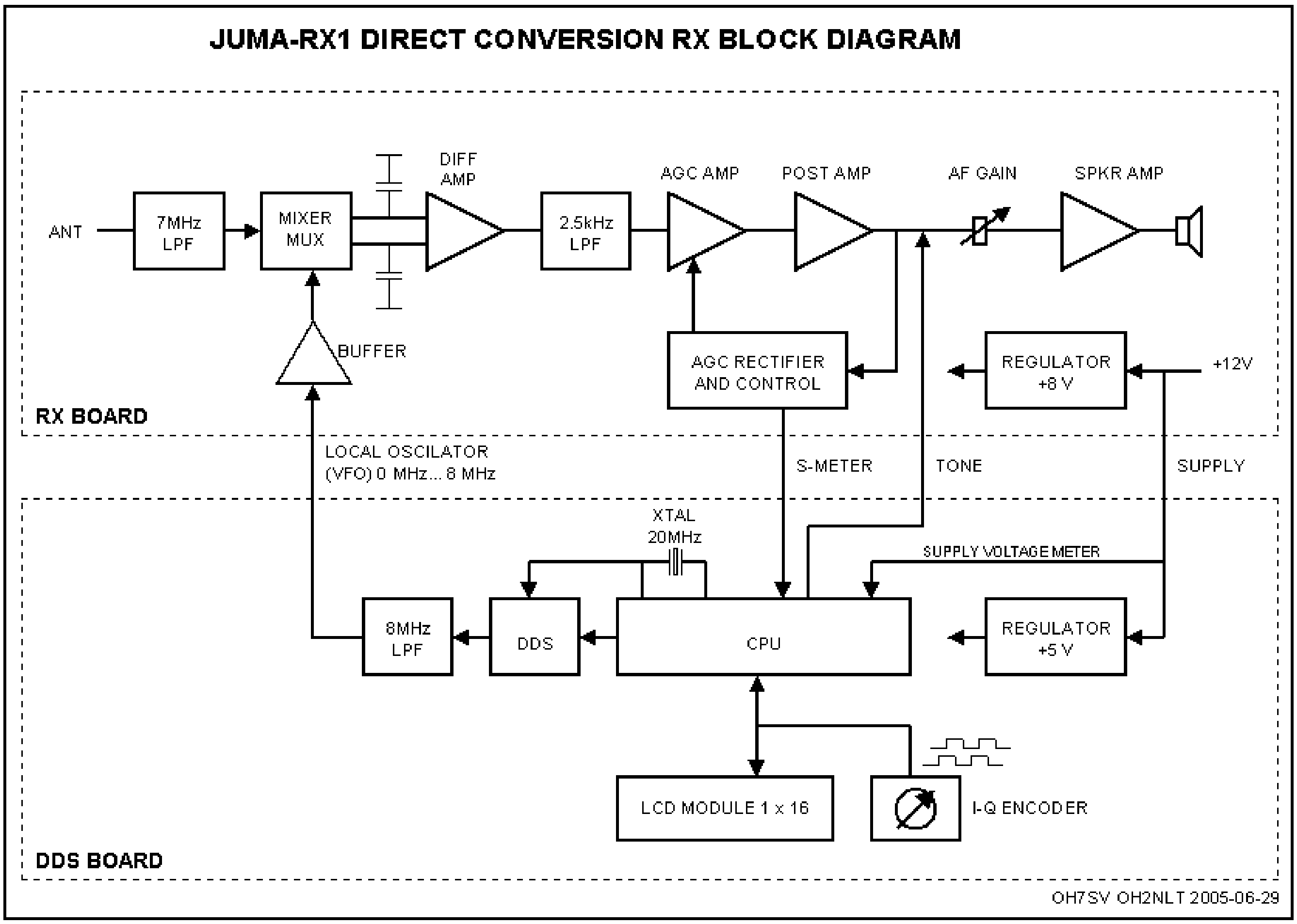
The project was judged by three technical experts, namely OH2GF, Jukka Vermasvuori, OH2BCW, Elja Ahti and OH2DT, Antti Huhtala. This article is a summary of their comments and judgment of this tiny receiver, which soon can be obtained as a kit from the SRAL. A related TX is in the planning phase.

The detailed schematics for the receiver board and DDS display board are located at the end of this article. We’ve recorded some audio files of the receiver performance during SSB and CW reception – these audio files are contained in the Audio section of this Homebrewer issue #6 CD, and links to the files are in the Reference section at the end of the article. Similarly, the full source code for the RX1 control processor (PIC16F819) is located in the Software section of the CD, with a link also provided in the Reference section of the article.

The Receiver

This is a project that doesn't need winding of a single coil! The band filter in the front end of the receiver is made of standard surface mount inductor components. Despite that, the filter is surprisingly good.

The frequency range of the synthesis circuit is 0 - 8 MHz. The practical actual working range of the receiver is 3.5 - 7.5 MHz, but it will also work for listening of AM stations on MF, although it isn't intended for it. It will function all the way down to 100 kHz, however with limited performance due to the input filter. The receiver is a double sideband design and is suited for both SSB and CW reception. Power consumption is less than 50 mA and the usable supply voltage is 9-15 V DC.

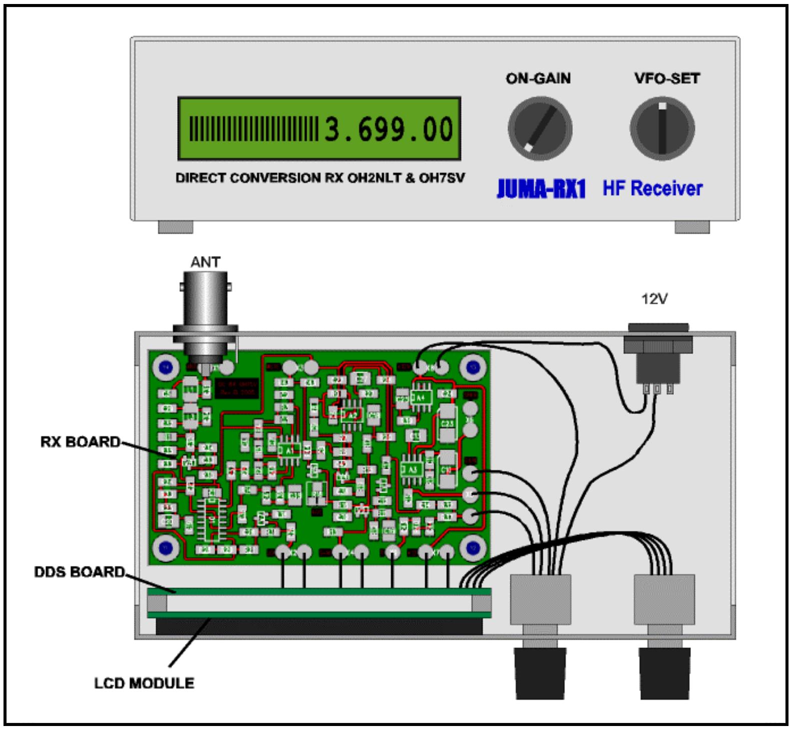


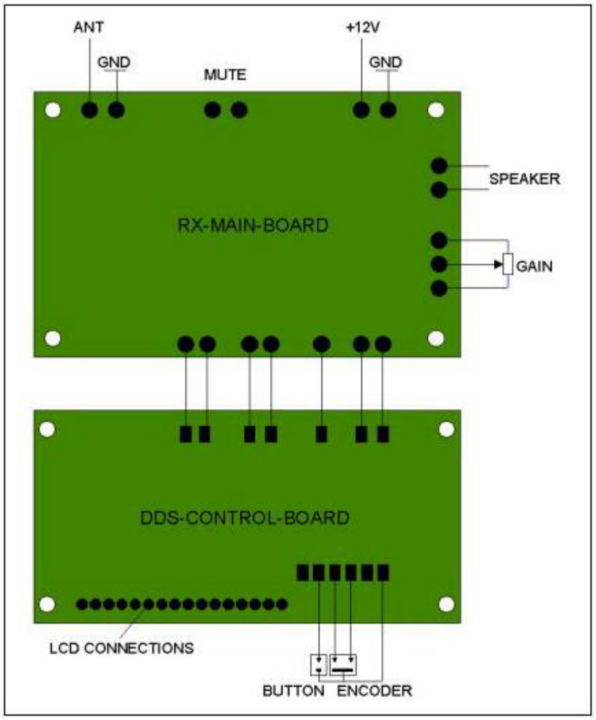
It is important that the receiver not generate interference signals by itself. At the beginning of the frequency range, below 100 kHz, a small amount of interference occurs, as well as two stronger spurs at 4 and 6,666 MHz, which raises the S-meter somewhat. Otherwise the digital interference is kept at a negligible level. Notably the hum, which normally is present in a DC (Direct Conversion) receiver, is completely nonexistent.

The sensitivity is chosen so that the receiver requires a full size antenna; for example, a dipole. Good dynamic characteristics and excellent AGC function provide smooth reception.

The sensitivity is good enough if you use a correctly-tuned antenna. The receiver ”hears” the same signals as a commercial reference receiver. A greater sensitivity would have caused worse intermodulation characteristics; therefore the designers wanted to permit the use of a proper (good) antenna. Otherwise they would have had to design an attenuator with additional controls and higher costs.

The RX1 can tolerate high level signals extremely well. According to the measurements, the receiver can handle 20 dBm signals without choking. The bandwidth is 300 Hz – 2.5 kHz at the -6 dB points. In reality it is still 5 kHz, since the double side detector. The selectivity when receiving DSB isn’t the very best, but that is a price one has to pay with this kind of technical solution. Third order Intercept Point (IP3) is at a very good level +23 dBm. The AF output of the receiver is 1 watt.

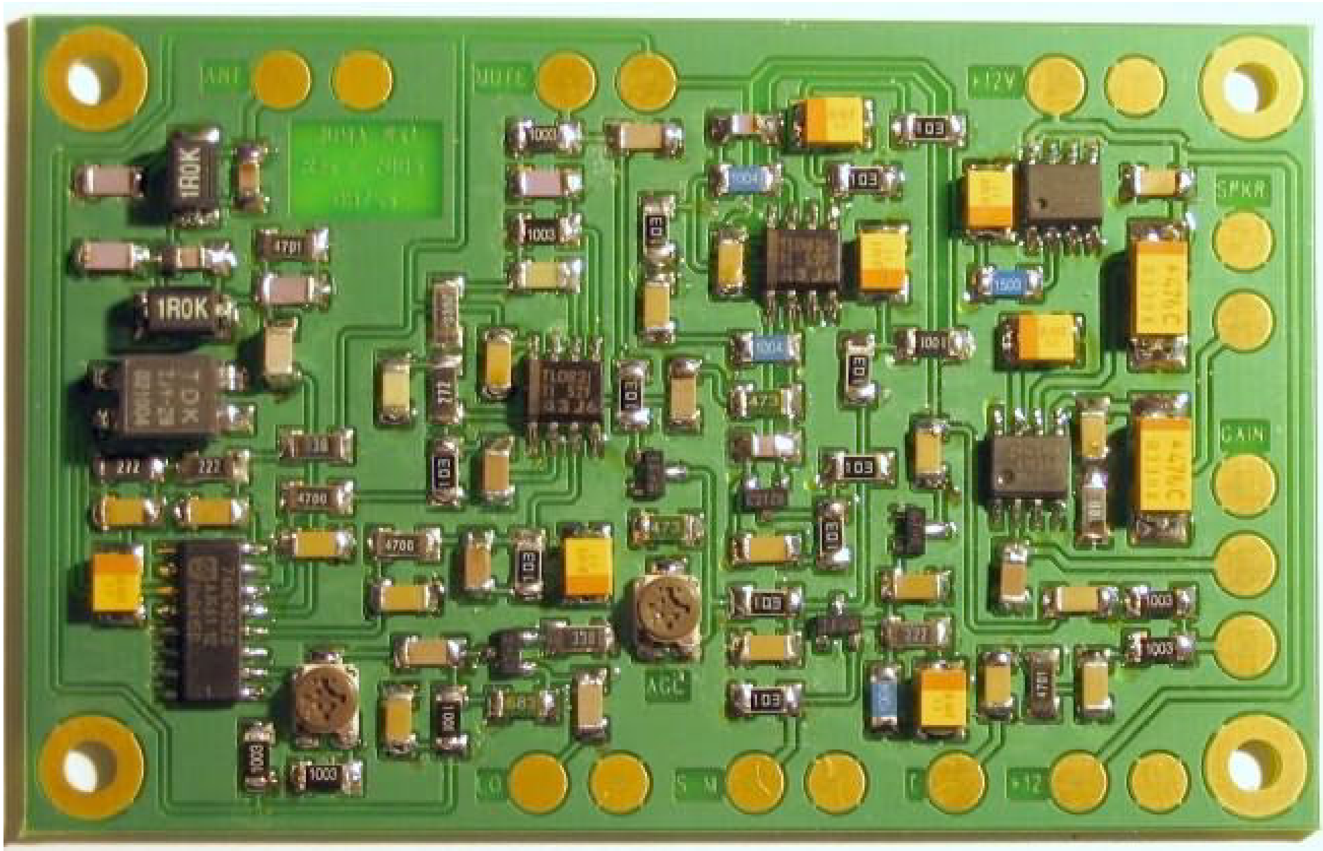




The design

The receiver is based on direct conversion. The local oscillator (the VFO) is made with an Analog Devices AD9833 DDS (Direct Digital Synthesizer) chip which is controlled by a PIUC16F819 microcontroller. A commercial LCD module is used as a display. In this way a compact and yet simple construction with excellent frequency stability, and wide working range is achieved.

The receiver consists of two printed circuit boards, the RX-main and DDS-control board. The mixer, necessary amplifiers, the (DSB) audio filter, AGC-stage and voltage regulator are located on the RX-board. It also supplies 12 VDC and the S-meter voltage to the DDS card. The local oscillator signal and the acknowledgement tones are generated on the DDS board.
The DDS board contains the digital local oscillator, which is controlled by a microcontroller. Frequency setting is done by a rotary encoder which is read by the microcontroller. The microcontroller also drives the LCD display. The display shows the operating frequency, the S-meter or optionally the operating voltage.


Assembled Receiver Board

The modular approach makes it possible to either build only the RX part or the DDS part, and make the rest by own constructions.

It should be pointed out that this project is not a toy, but a serious basic general coverage receiver for amateur radio use, with an accuracy of 10 Hz over the whole frequency range. It differs from the receiver in a modern transceiver mostly by using only one mixer stage (the detector) and lacking a CW or SSB filter. Also the frequency coverage is smaller.

Working Principles of the Receiver Circuit

The signal coming from the antenna is filtered in a two stage, 7 MHz low pass filter which attenuates the 3f signals which are due to the working principle.

After the low pass filter, there is a wideband transformer which balances the signal to the mixer stage. The balancing prevents the local oscillator signal from leaking to the antenna, since the VFO frequency is the same as the listening frequency.

An analog CMOS switch, the HEF74HC4052 (D1) is used as mixer. It connects the antenna signal in turns to two sampling capacitors (C36 and C37). A mixer of this kind was chosen for its exceptionally good dynamics, which in turn makes it possible to use only a wideband low pass filter and no RF amplifier in the front end. The sampling principle used in the mixer, together with the VFO, forms a narrow band filter which follows the frequency. The width of this filter is ± 16 kHz and it attenuates frequencies outside of the listening range with

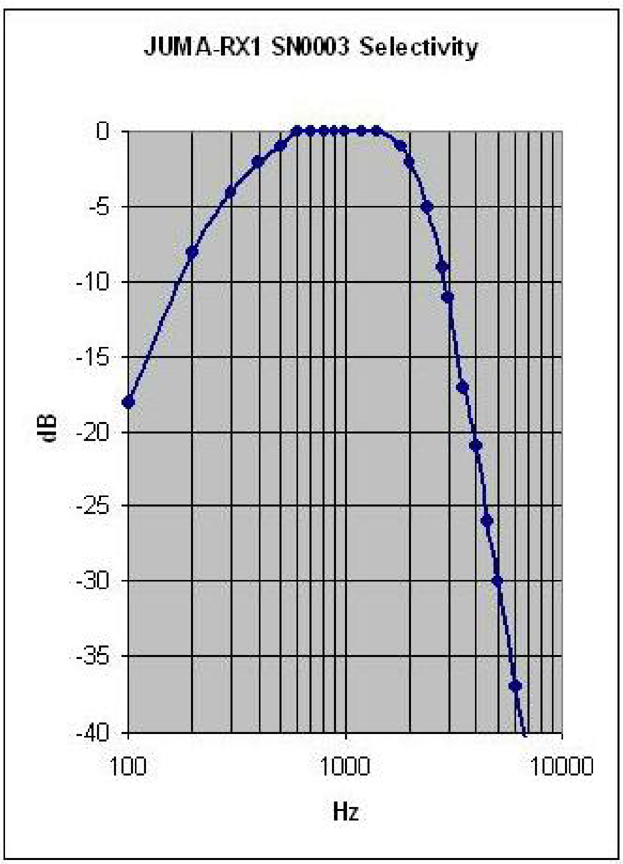
6 dB/octave already in the mixer. For example a station on 100 kHz distance is attenuated in the mixer by 16 dB, and if the distance is 1 MHz, the attenuation will be about 35 dB!

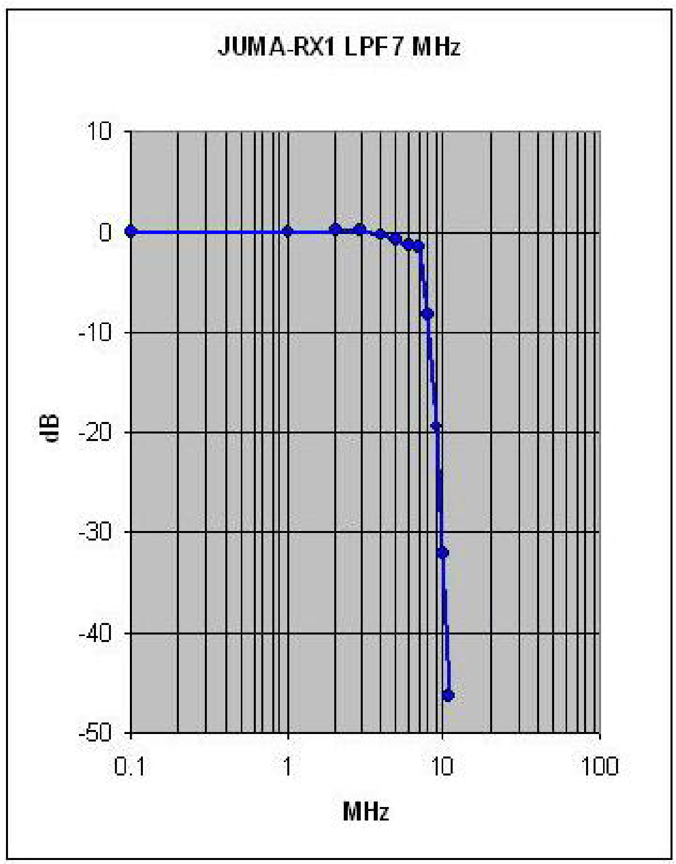
Following the mixer there is a differential preamplifier (A1-A), made of a JFET op amp TL082. The gain is moderate not to clip strong signals on its output but sufficient enough so that this stage determines the signal-to-noise ratio. The noise characteristics of this amplifier are sufficient for the 80 and 40 meter bands.

Next stage is the 2.5 kHz SSB audio filter. It is an active low pass filter with the op amp (A1-B). The gain of the filter in the pass band is 0 dB. In this way the good dynamic range is maintained. The filter is designed for SSB reception and it is also usable on CW. The low frequency attenuation, 0-300 Hz, is achieved by selecting suitable coupling capacitor values in the amplifier chain.

JUMA-RX1 has a good automatic gain control (AGC). It consists of a controllable amplifier (A2-A and V4), post amplifier (A2-B), signal rectifier (V1) and a controlling circuit (V2). When the antenna signal grows, the resistance of the JFET decreases when the control reduces the gate voltage of the FET towards the source. The FET works as the feedback resistance for the op amp, and in that way the gain is changed according to need.

An LM386 integrated amplifier is used as the AF amplifier, and it can drive a low impedance loudspeaker with about 1 watt.



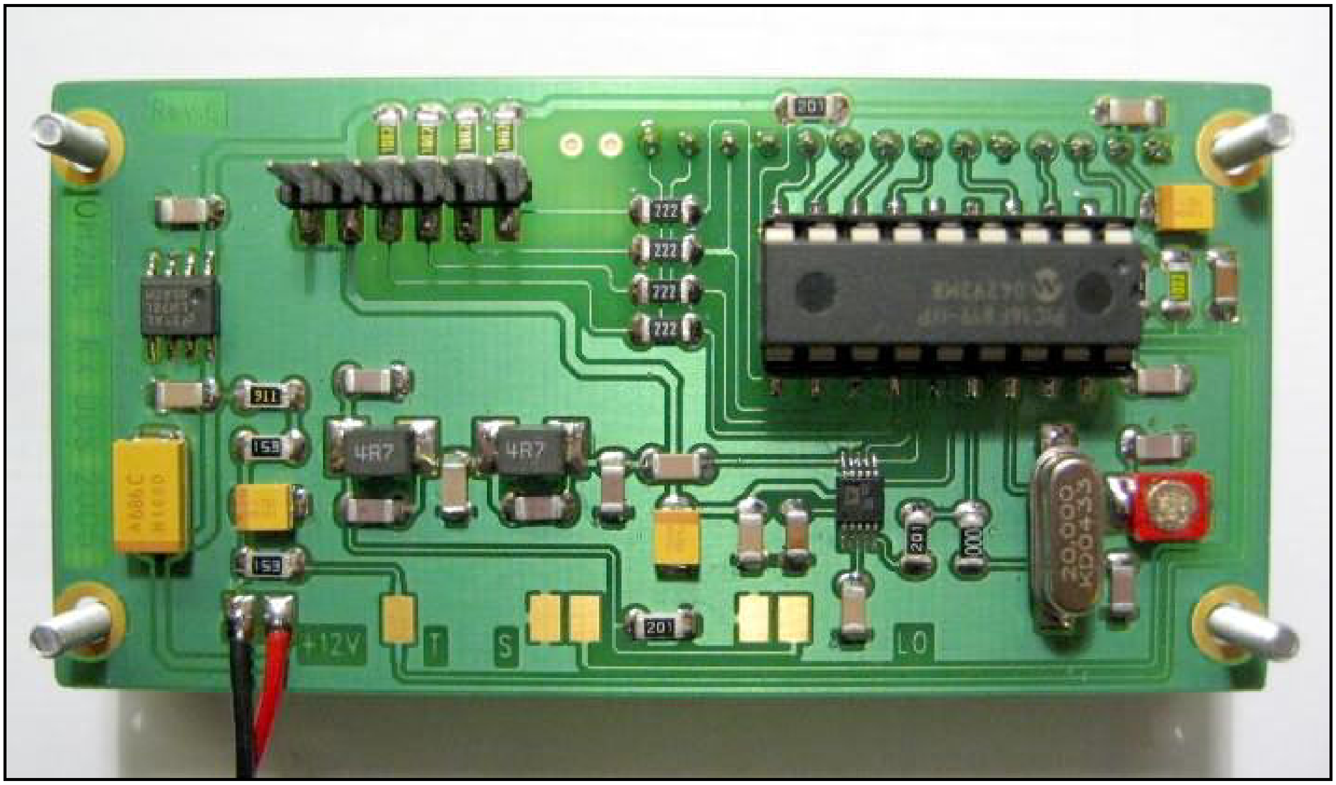


Functions of the DDS Circuit

The DDS consists of one chip from Analog Devices, the AD9833, and the following low pass filter. The DDS circuit is in the JUMA-RX1 case controlled by a microcontroller, the PIC16F819 from Microchip. The same controller also performs all other functions in the user interface of the receiver.

The DDS board takes care of the following functions:

- Generation of the local oscillator frequency
- Tuning of the frequency by the rotary encoder
- Displaying the frequency on the LCD display.
- Selection of the tuning step by the encoder step switch.
- Display of the settings made on the LCD display.
- Storing used frequency and step size in the EEPROM
- Graphic display of the S-meter on the LCD display.
- Measurement and display of the supply voltage on the LCD display.
- Generation of the acknowledgement tones for the user interface.



DDS Board

The oscillator is designed with a low cost 20 MHz crystal which supplies the clock signal to the microcontroller chip and generates a reference frequency for the DDS chip. Use of the DDS principle also generates a series of harmonic frequencies, which are dependent of the base frequency. These are filtered off by an 8 MHz low pass filter before the signal is routed to the buffer amplifier controlling the mixer on the RX board.

Using the Receiver

On the front there are only two knobs. How is it possible to control everything with just these? One of the knobs is used only as power switch and for AF gain. The other one is the VFO-SET knob, and it has several functions. Most important, of course, is the frequency tuning, which is done by turning the knob.

The tuning can be made in steps of different size. The step size is chosen by pushing the knob and simultaneously turn it, clockwise for bigger steps, and counterclockwise for smaller steps. The step size are 100 kHz, 100 Hz or 10 Hz. The selection is acknowledged by a beep in the loudspeaker with the pitch of the tone indicating the selected step size, low pitch for small step, higher for bigger step. The step size and actual frequency are stored in the non-volatile memory by pushing the knob for more than two seconds. These values will be default the next time the receiver is powered up until they are changed. The step size can be changed anytime without actually storing it.

Just a short push on the setting knob changes the display to show the supply voltage instead of the S-meter. The six digit part of the display always shows the frequency when the receiver is turned on.

When the receiver is turned on, it identifies itself and states its readiness on moderate speed CW. This is a funny characteristic, but also useful for those visually impaired, who then will know the state of the receiver.

Mechanical design

The box is a commercial aluminum box measuring 142 x 42 x 72 mm consisting of a bottom part and a cover part. The holes needed for display, control knobs and connections are drilled in the front and back. Below the cover there is a small loudspeaker. The antenna is connected to the receiver by a BNC connector at the back. Also on the back is a 3.5 mm jack for earphones or external speaker, and a DC jack for power supply.

Is it possible to build?

Very good documentation is available currently on Finnish and Swedish.English translation is under way.

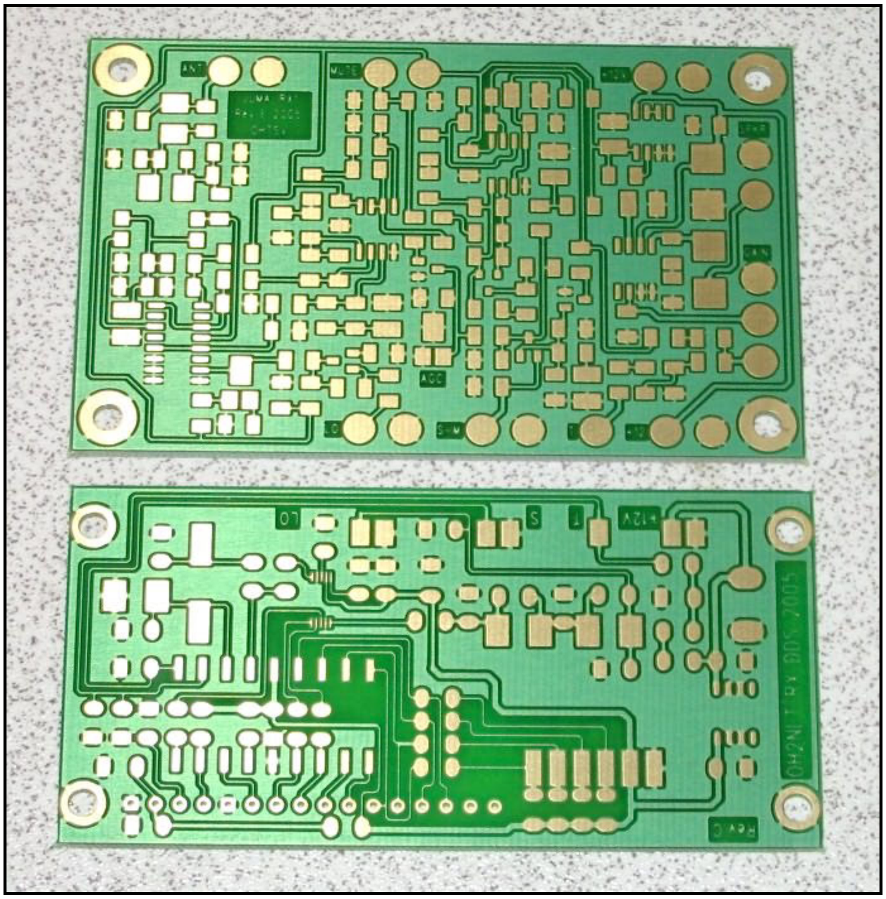
DDS technology and surface mounting is the trend today. One cannot rely only on conventional technology like VFO/VXO solutions because some components, for example tuning capacitors, are big, expensive and hard to get. DDS is the solution which further gives increased flexibility. The use of surface mounted components yields a small and lightweight receiver which almost fits in the pocket of your jacket. The components used in the receiver are easy to get at your normal supplier.

Conclusion

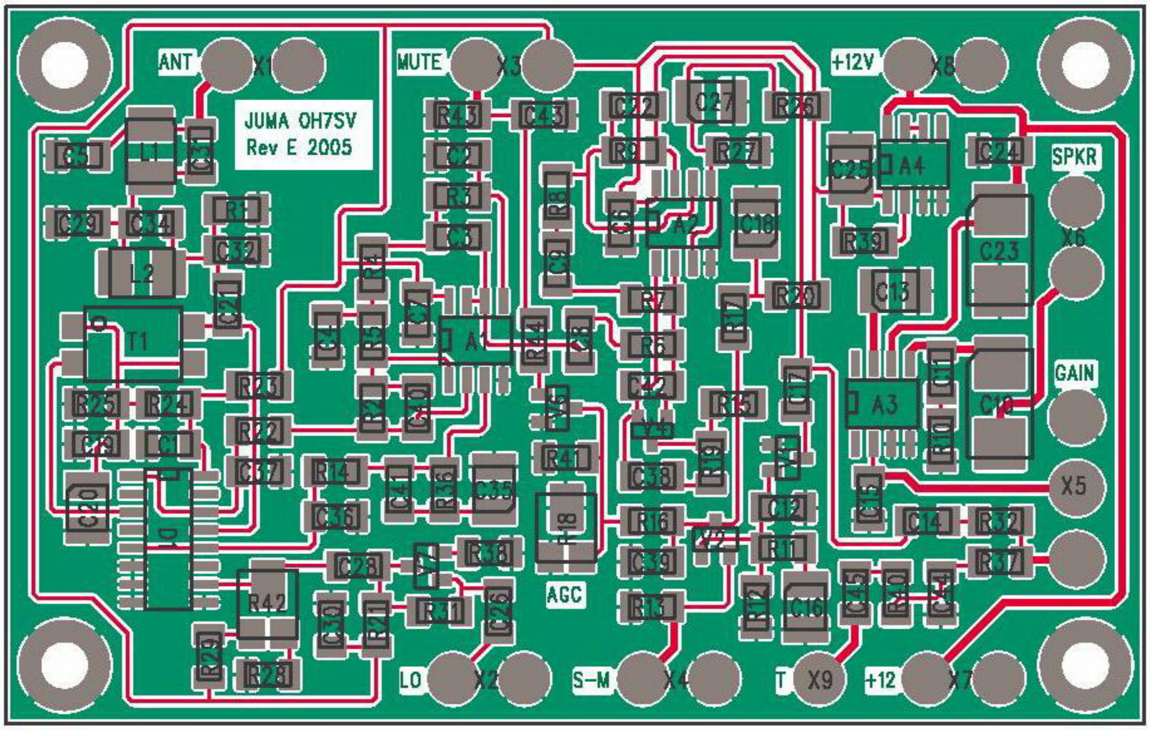
The receiver is small, lightweight and inexpensive to build. It needs some skill in soldering, especially in handling the surface mounted parts. The characteristics of the receiver is in many aspects comparable with those of commercially made receivers. The receiver is very suitable as the first receiver for a newcomer, or for anyone who wants to learn how such a receiver works. It is also suitable as a summer cottage or camper receiver for the more experienced ham.

The designers may be reached at:
oh7sv@sral.fi (Matti) and oh2nlt@sral.fi (Juha)

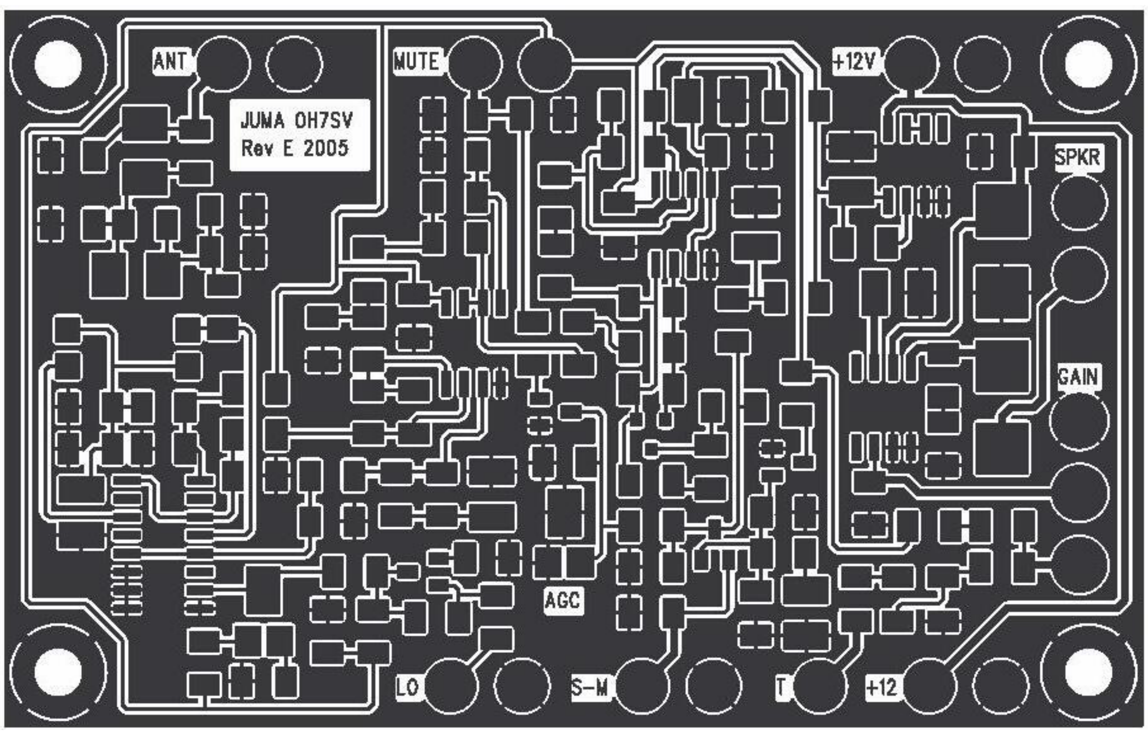
This article was translated by Thomas, oh6nt@sral.fi



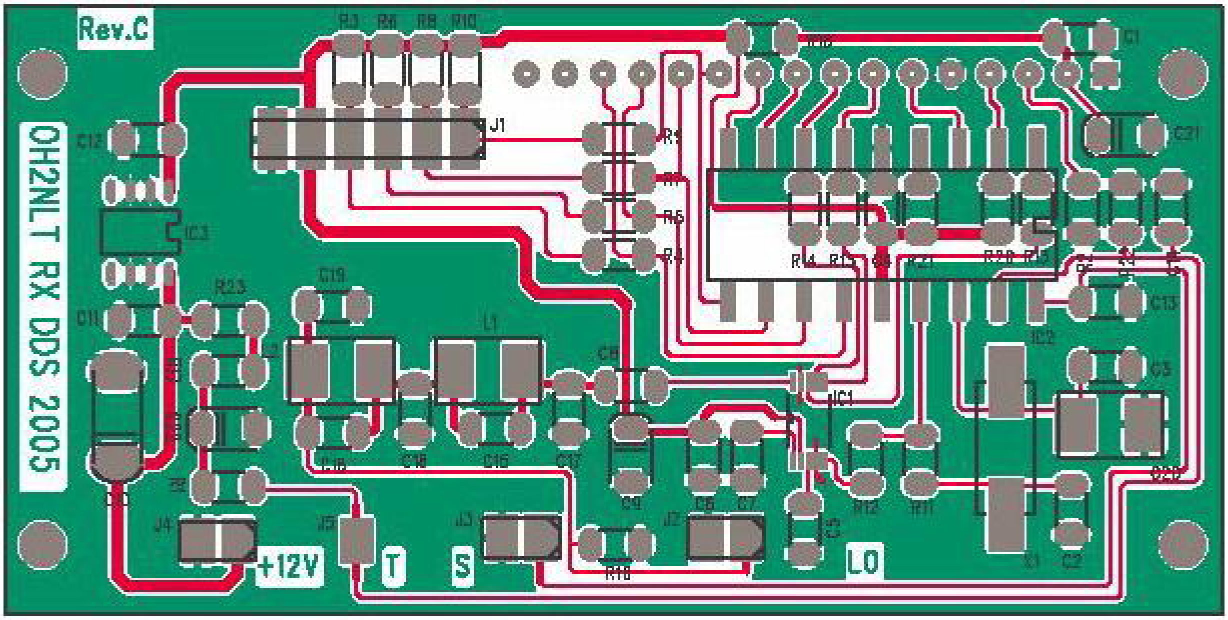
Single-sided SMT pc boards for the Receiver (upper) and the DDS/Display (lower)



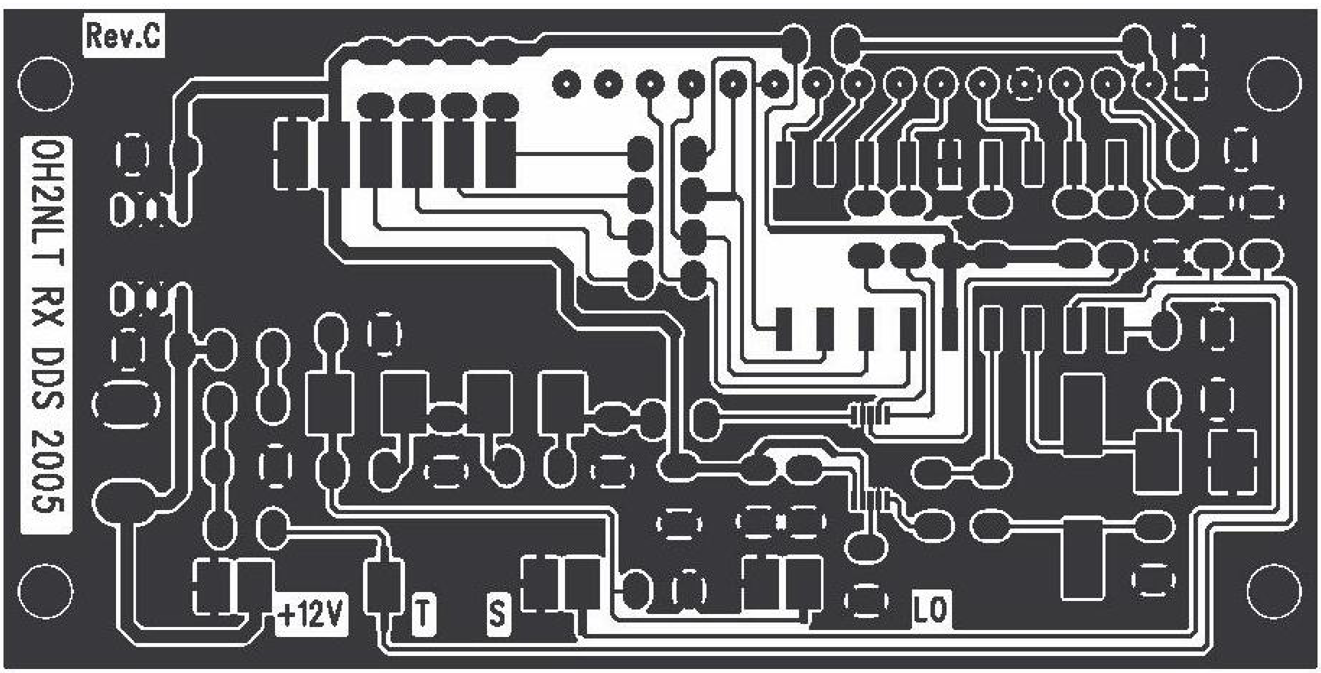
Receiver Board Layout



Receiver Board Artwork

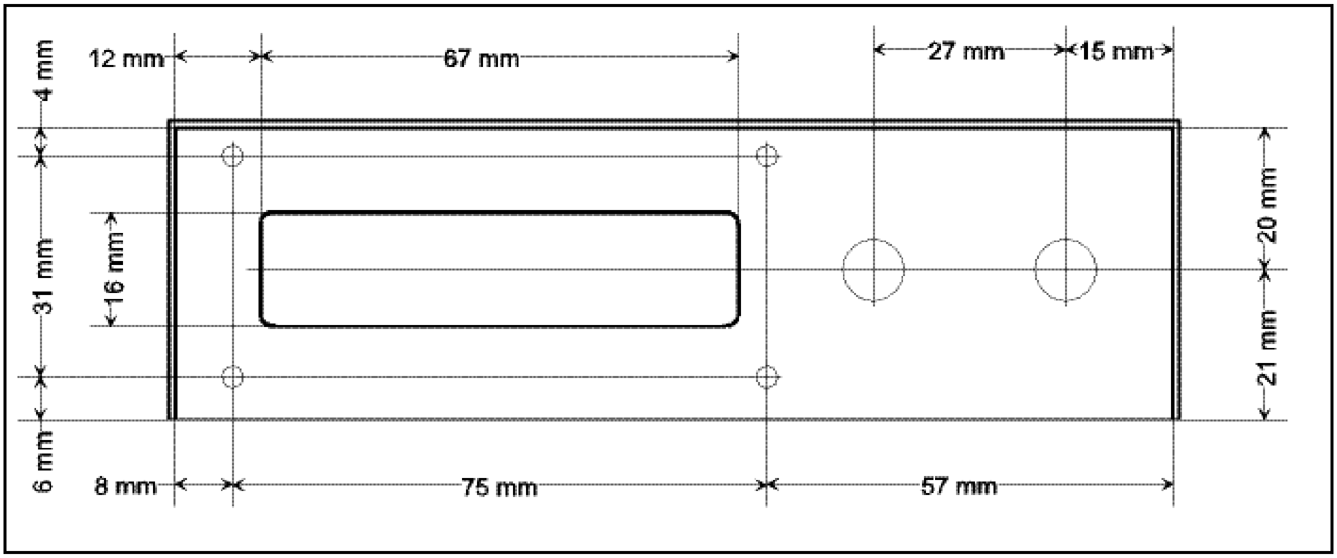


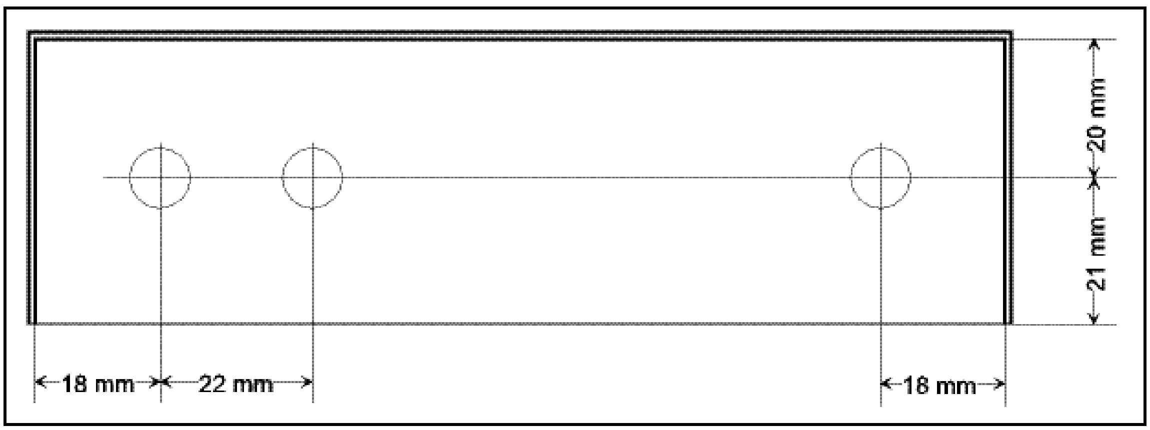
DDS Board Layout

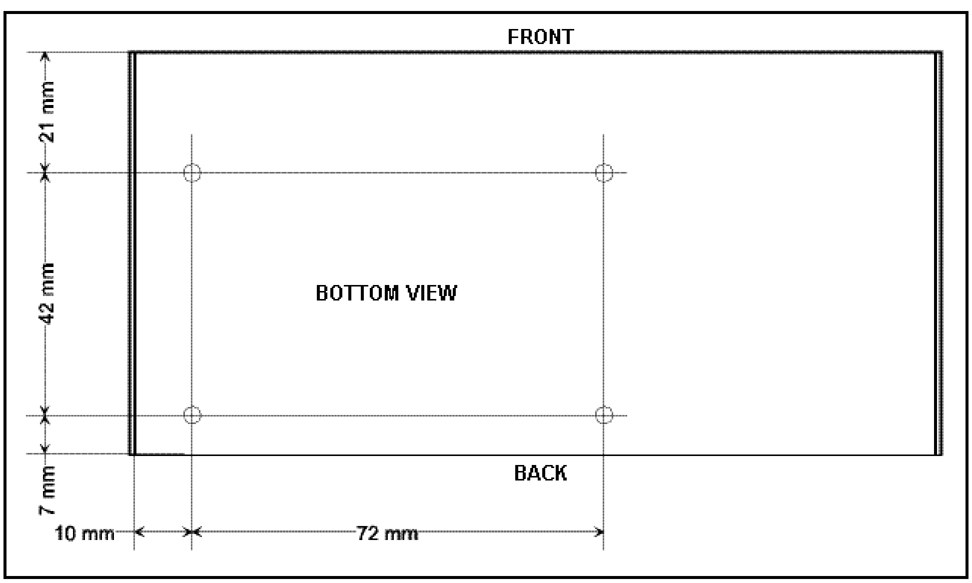


DDS Board Artwork

Enclosure Panel Dimensions







PARTS LISTS

Display Board

Selite	Arvo / tyyppi	kpl	Huom	Toimittaja	a hinta	Hinta yht
Ruuvi	2,5 * 20 mm	4		Wurth	0.05	0.20
Mutteri	2,5 mm	16		Wurth	0.05	0.80
Ruuvi	3 * 5 mm	4		Wurth	0.05	0.20
Mutteri	3 mm	4		Wurth	0.05	0.20
Alumiinikotelo 44x72x140	Teko 4/B	1		Yleiselektroniikka Oy	5.25	5.25
Potentiometri	47k, log, kytkimellä P6M	1		Partco Oy	1.90	1.90
ANT-liitin BNC	BNC JR	1	Mutterikiinn. + juotosk.	Partco Oy	0.65	0.65
Kaiutin	8...10 ohm, halk 45...50 mm	1		Partco Oy	0.95	0.95
Rotary encoder	Piher CI-11CT-V1Y22-LFACF	1	Farnell koodi 445-2446	Farnell => Parco Oy	5.55	5.55
Nuppi	NUP3, muovia, 6mm akselille	2		SP-elektroniikka	0.80	1.60
DC-runkoliitin	Keskitappi 2.1 mm, muovia halk 12.5 mm	1		SP-elektroniikka	1.20	1.20
					Elektromekaniikka yhteensä	18.50

Receiver Board

Osa no	Selite	Arvo / tyyppi	kpl	Huom	Toimittaja	a hinta	Hinta yht
R10	Vastus SMD 1206	10R	1		SP - Elektroniikka	0.05	0.05
R23, R38		33R	2		SP - Elektroniikka	0.05	0.10
R14, R22		470R	2		SP - Elektroniikka	0.05	0.10
R21, R20		1k	2		SP - Elektroniikka	0.05	0.10
R11, R24		2k2	2		SP - Elektroniikka	0.05	0.10
R5, R25		2k7	2		SP - Elektroniikka	0.05	0.10
R1, R40		4k7	2		SP - Elektroniikka	0.05	0.10
R2, R8, R13, R15, R16, R17, R19, R26, R27, R36, R44		10k	11		SP - Elektroniikka	0.05	0.55
R4		33k	1		SP - Elektroniikka	0.05	0.05
R6, R41		47k	2		SP - Elektroniikka	0.05	0.10
R31		68k	1		SP - Elektroniikka	0.05	0.05
R3, R28, R29, R32, R37, R43		100k	6	R32:n ja R37:n arvo riippuu potentiometristä, katso skema	SP - Elektroniikka	0.05	0.30
R39		150k	1		SP - Elektroniikka	0.05	0.05
R7, R9, R12		1M	3		SP - Elektroniikka	0.05	0.15
C22, C42	Ker.kondensaattori SMD 1206	47p	2		SP - Elektroniikka	0.08	0.16
C34		100p	1		SP - Elektroniikka	0.08	0.08
C31		180p	1		SP - Elektroniikka	0.08	0.08
C2		330p	1		SP - Elektroniikka	0.08	0.08
C5, C32		470p	2		SP - Elektroniikka	0.08	0.16
C29		820p	1		SP - Elektroniikka	0.08	0.08
C15, C40, C41		1n	3		SP - Elektroniikka	0.08	0.24
C3, C21		4n7	2		SP - Elektroniikka	0.08	0.16
C8, C26, C28, C43		10n	4		SP - Elektroniikka	0.08	0.32
C4		47n	1		SP - Elektroniikka	0.08	0.08
C1, C6, C7, C9, C11, C12, C14, C17, C19, C24, C30, C36, C37, C38, C39, C44, C45		100n	17		SP - Elektroniikka	0.08	1.36
C13, C16, C18, C20, C25, C27, C35	Tantaalikondensaattori SMD	4u7-22u/16V koko B	7	tai "tippa-tantaali"	SP - Elektroniikka	0.35	2.45
C10, C23		47u/16V koko D	2	tai elko 47u tai suurempi	SP - Elektroniikka	0.35	0.70
R18, R42	Trimmeri potentiometri SMD	100k Bourns 3314J	2	Muutkin SMD tyypit käyvät	SP - Elektroniikka	0.50	1.00
L1, L2	Kuristin SMD 1206 tai 1210	1uH	2	Isommatkin SMD tyypit käyvät	SP - Elektroniikka	0.30	0.60
T1	Ferriittirunko	Amidon BN-43-2402	1	Tai TDK:n data-filtter ZJYS51R5-2PB	SRAT, TDK:n filtteri Farnell => Parco Oy	1.50	1.50
V1	Diodi Double-serial SMD	BAV99 SOT-23	1	tai vast Si-diodi	SP - Elektroniikka	0.15	0.15
V2, V6	NPN AF transistori	BC848B SOT-23	2	tai BC846B, BC847B	SP - Elektroniikka	0.15	0.30
V7	NPN RF transistori	BFR93A SOT-23	1	tai vast. Ft>500MHz	SP - Elektroniikka	0.30	0.30
V4	Transistori P-JFET SMD	SST177	1	tai PMBFJ177 (Vgs-off 0.5-3V)	Farnell => Parco Oy	1.20	1.20
A1, A2	Operaatiovahvistin SMD	TL082 SO-8	2	(tai low noise LT1113)	Parco Oy	1.15	2.30
A3	Kaiutinvahvistin SMD	LM386 SO-8	1		Parco Oy	1.20	1.20
A4	Jänniteregualaattori SMD	LP2951ACM SO-8	1	tai 78L08 SO-8, katso käsikirja	Farnell => Parco Oy	1.00	1.00
D1	Analogia Muxer IC	HEF74HC4052 SO-16	1	Vain Philips käy!	Parco Oy	0.50	0.50
-	Valoherkkä piirilevy-materiaali	PCB single side FR4 1.6mm	1	Valotetaan ja syövytetään	SP - Elektroniikka	2.00	2.00
						RX-MAIN-board yhteensä	19.90

DDS Board

Osa no	Selite	Arvo / tyyppi	kpl	Huom	Toimittaja	a hinta	Hinta yht
R11	Vastus SMD 1206	0R	1	Tai langan pätkä	SP - Elektroniikka	0.05	0.05
R12, R16, R18		200R	3		SP - Elektroniikka	0.05	0.15
R23		910R	1		SP - Elektroniikka	0.05	0.05
R13, R14, R15, R21		1k	4		SP - Elektroniikka	0.05	0.20
R2		1k8	1	LCD kontrastisäätö	SP - Elektroniikka	0.05	0.05
R4, R5, R7, R9		2k2	4		SP - Elektroniikka	0.05	0.20
R3, R6, R8, R10, R20, R22		10k	6		SP - Elektroniikka	0.05	0.30
R1, R17		15k	2		SP - Elektroniikka	0.05	0.10
C2, C3, C16	Ker.cap SMD 1206	22p	3		SP - Elektroniikka	0.08	0.24
C15		33p	1		SP - Elektroniikka	0.08	0.08
C17, C19		100p	2		SP - Elektroniikka	0.08	0.16
C18		180p	1		SP - Elektroniikka	0.08	0.08
C13		1n	1		SP - Elektroniikka	0.08	0.08
C7, C14		10n	2		SP - Elektroniikka	0.08	0.16
C1, C4, C5, C6, C8, C11, C12		100n	7		SP - Elektroniikka	0.08	0.56
C9, C21, C22	Tantaalikondensaattori SMD	4u7-22u/ 16V-6V koko B	3	tai "tippa-tantaali"	SP - Elektroniikka	0.35	1.05
C10		47u/16V koko C	1	tai elko 47u tai suurempi	SP - Elektroniikka	0.35	0.35
							0.00
C20	Trimmerikondensaattori SMD	5.5 - 20 pF	1	Jalallinenkin käy	SP - Elektroniikka	0.50	0.50
L1, L2	Kuristin SMD 1206 tai 1210	4u7H	2		SP - Elektroniikka	0.30	0.60
X1	Kide HC49	20MHz	1	myös SMD versio käy	Partco	0.85	0.85
IC1	DDS	AD9833BRM	1	Farnell 9,54		5.00	5.00
IC2	Mikrokontrolleri 18pin DIP	PIC16F819-I/P	1	Farnell 4,93		3.00	3.00
IC3	Regulaattori 5V SO8	LM78L05ACM	1		SP - Elektroniikka	0.50	0.50
LCD1	LCD Display 1*16 character	TM161ABA6	1	Muutkin käyvät	Bebek	5.50	5.50
- IC2 kanta	IC jousikanta	18-pin DIL 0,3"	1	Jalat taivutetaan ja lyhennet.	SP - Elektroniikka	0.30	0.30
-	Valoherkkä piirilevy-materiaali	PCB single side FR4 1.6mm	1	Valotetaan ja syövytetään	SP - Elektroniikka	2.00	2.00
						DDS- ja ohjausosa yhteensä	22.11

REFERENCE

1) Original (untranslated) material for this article can be found at the author's website: http://www.nikkemedia.fi/juma-rx1. Intererested homebrewers should occasionally check this location for updated schematics and software.
2) Audio files demonstrating performance can be found in the Audio section of this issue's CD: CW1, CW2, SSB1, SSB2, SSB3, SSTV1, SSTV2, SSTV3, SSTV4.
3) 'C' Source code for the PIC16F819 microcontroller can be found in the Software section of this issue's CD: jumarx1v2_01.ZIP

Sources for Parts

DDS-kortin komponentteja

LCD moduuli TM161ABA6 http://www.tianma.com/comparative_table/tm161a.html
Kontrolleri PIC16F819 http://ww1.microchip.com/downloads/en/DeviceDoc/39598e.pdf
DDS piiri AD9833 http://www.analog.com/en/prod/0%2C2877%2CAD9833%2C00.html
Regulaattori 78L05 http://www.national.com/ds.cgi/LM/LM78L05.pdf
Encooderi Piher CI-11 http://www.piher-nacesa.com/pdf/04-CI-11v04.pdf
Kide 20MHz http://www.cmac.com/mt/databook/

RX-kortin komponentteja

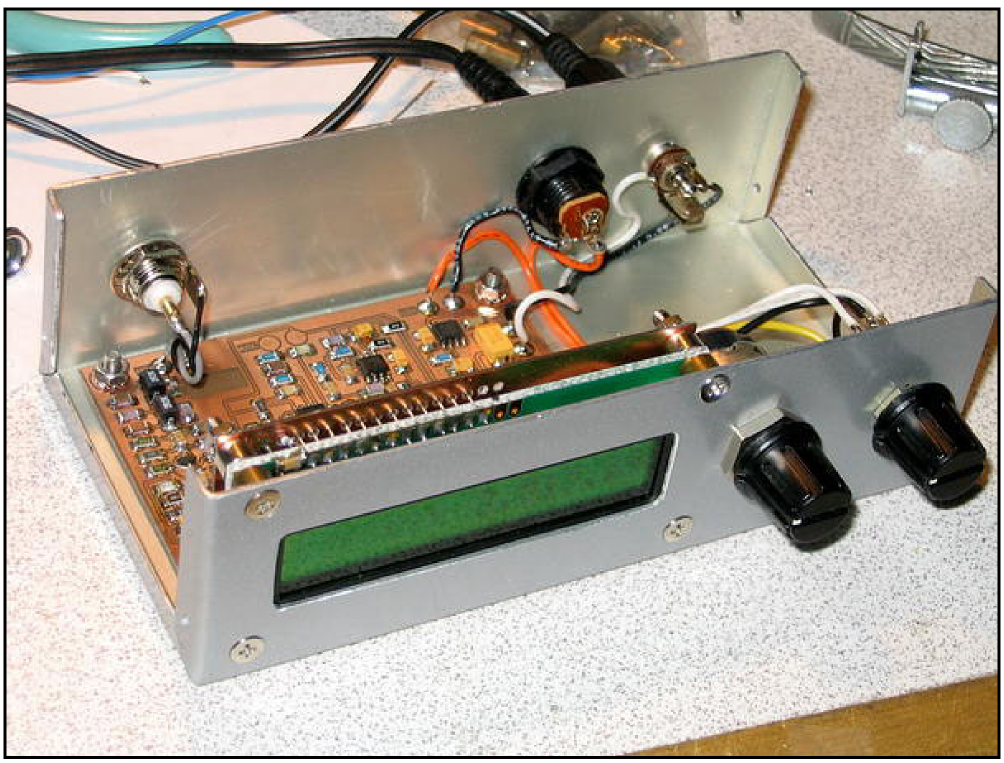
CMOS MUX Philips HEF74HC4052
http://www.semiconductors.philips.com/acrobat/datasheets/74HC_HCT4052_4.pdf
Operaatiovahvistin TL082 http://www-s.ti.com/sc/ds/tl082.pdf
Operaatiovahvistin low noice LT1113
http://www.linear.com/pc/downloadDocument.do?navId=H0,C1,C1154,C1009,C1026,P1366,D3177
Audiovahvistin LM386 http://www.national.com/ds.cgi/LM/LM386.pdf
Regulaattori LP2951 http://www.national.com/ds.cgi/LP/LP2950.pdf
JFET SST177 http://www.vishay.com/docs/70257/70257.pdf

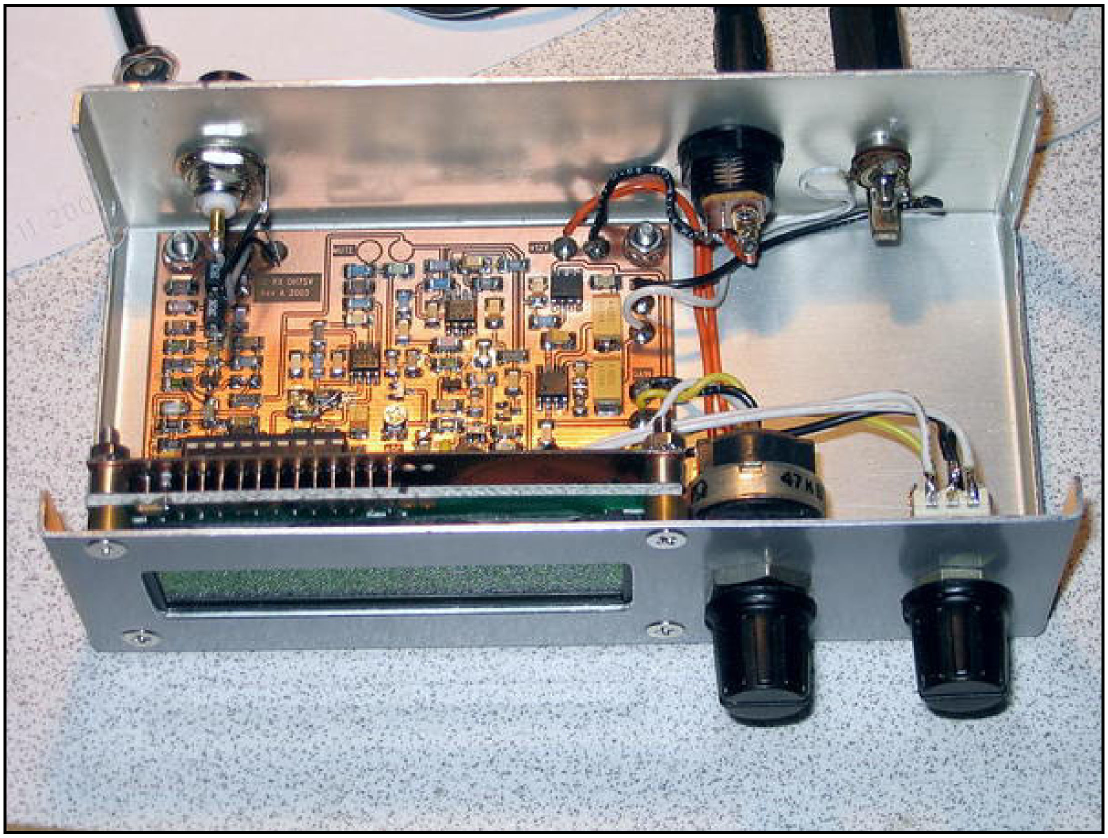
JFET PMBFJ177
http://www.semiconductors.philips.com/acrobat/datasheets/PMBFJ174_175_176_177_CNV_2.pdf
Transistori BFR93A http://www.semiconductors.philips.com/acrobat/datasheets/BFR93A_2.pdf
Transistori BC848B http://www.semiconductors.philips.com/acrobat/datasheets/BC846_BC847_BC848_5.pdf
Diodi BAV99 www.fairchildsemi.com/ds/BA/BAV99.pdf
Filttereiden kelat (kuristimet) http://industrial.panasonic.com/www-data/pdf/AGA0000/AGA0000CE33.pdf
Laajakaistamuuntaja (data filter) http://www.tdk.co.jp/tefe02/e971_zjys.pdf

Muita linkkejä
Kotelo Teko 4B http://www.teko.it/Eng/ENCLOSURES/frame.htm
Microchip kehitysympäristö
http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en019469&part=SW007002
Hi-Tech c kääntäjä http://www.htsoft.com/products/picccompiler.php

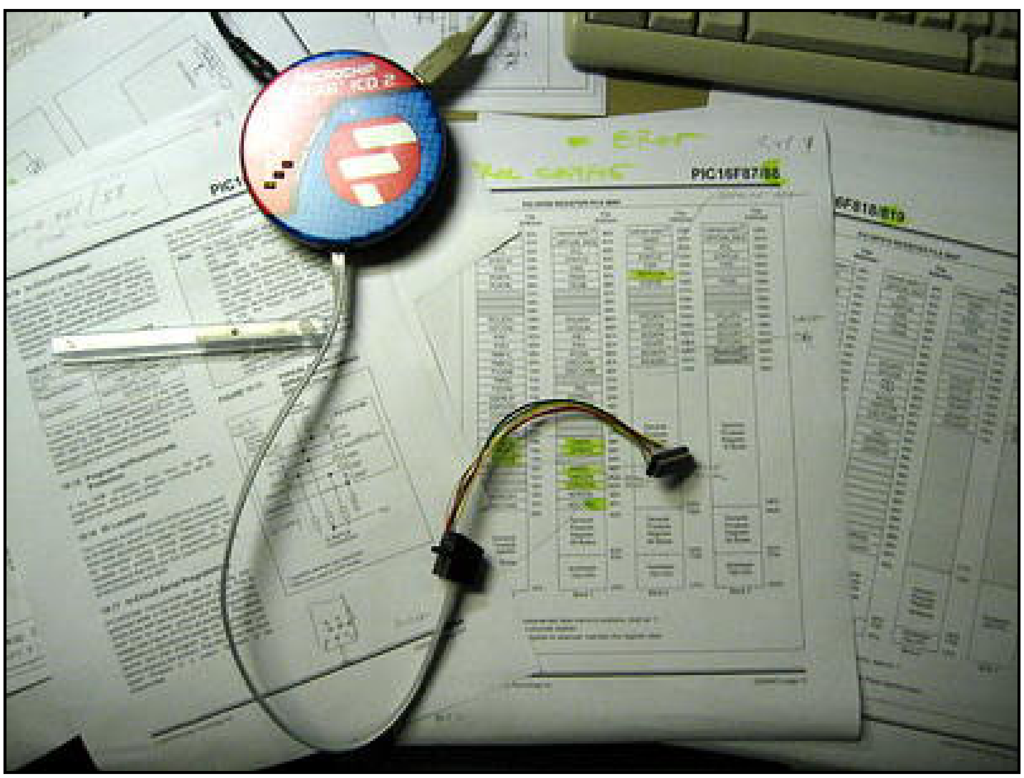
Komponenttien hankintapaikkoja
SP-Elektroniikka http://www.spelektroniikka.fi
Partco http://www.partco.fi
Yleiselektroniikka http://www.yeoy.fi
Bebek http://www.bebek.fi/

PHOTO OVERVIEW OF THE JUMA-RX1






FINLAND
Phone: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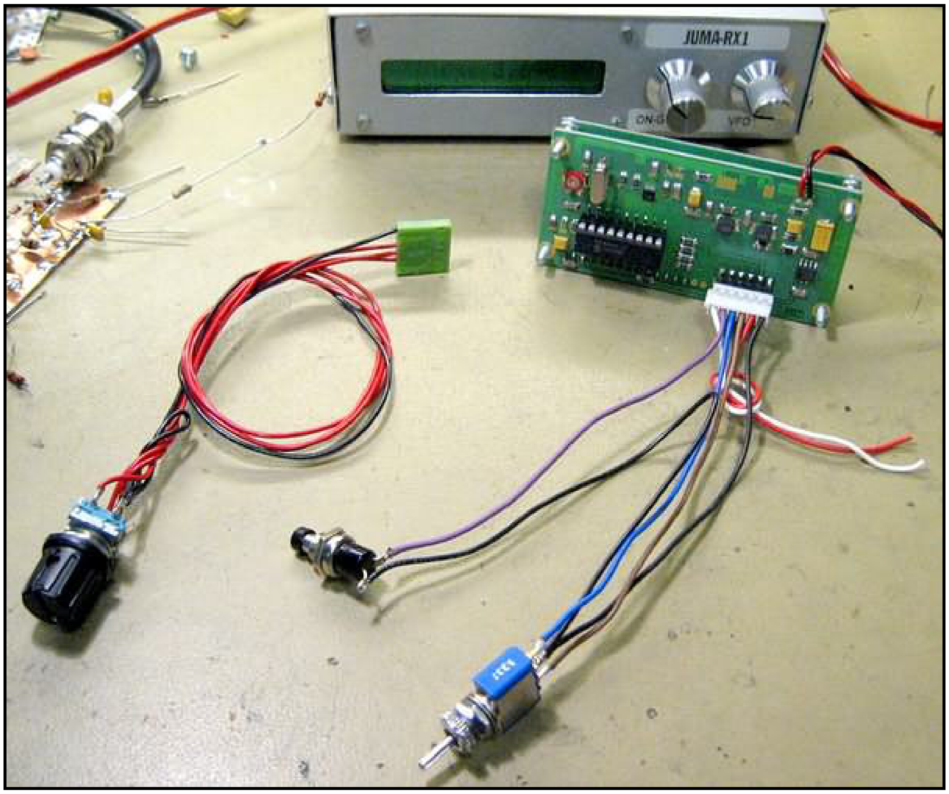
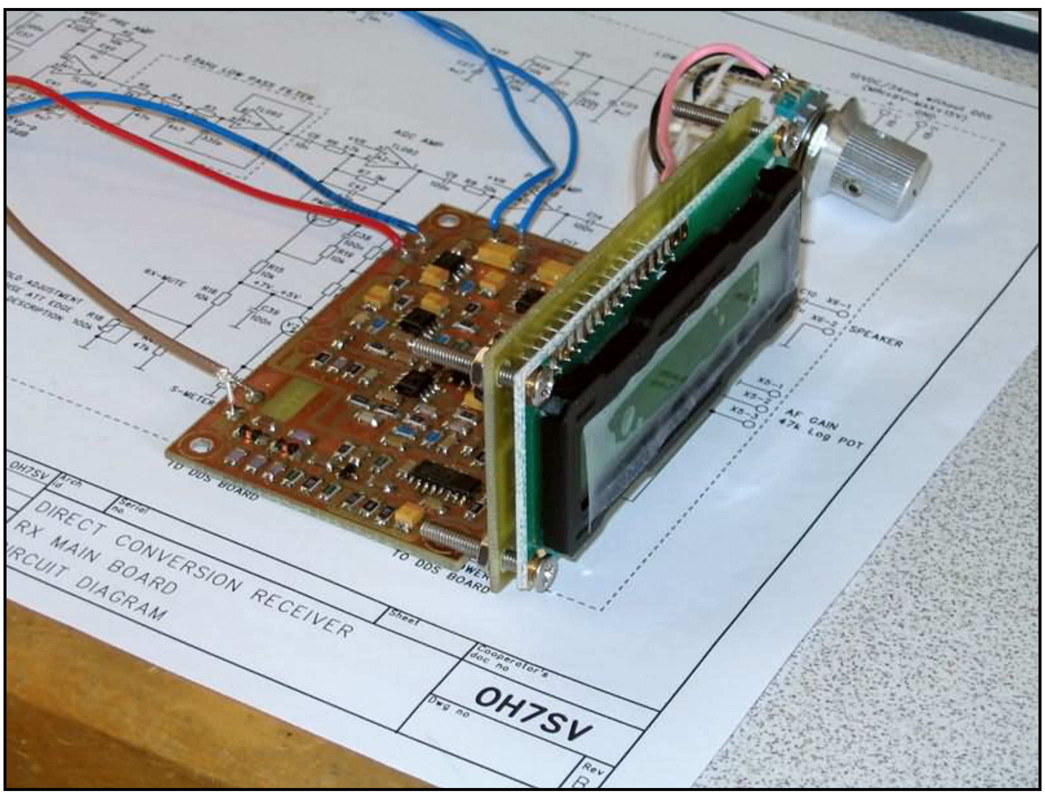
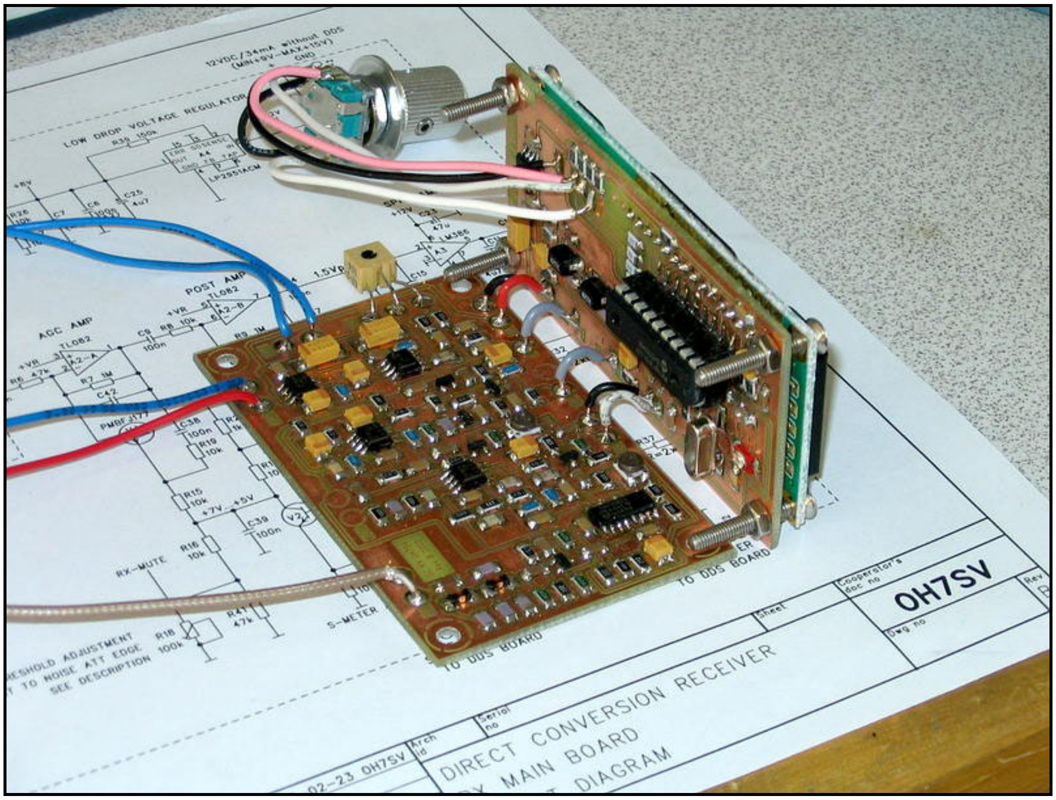
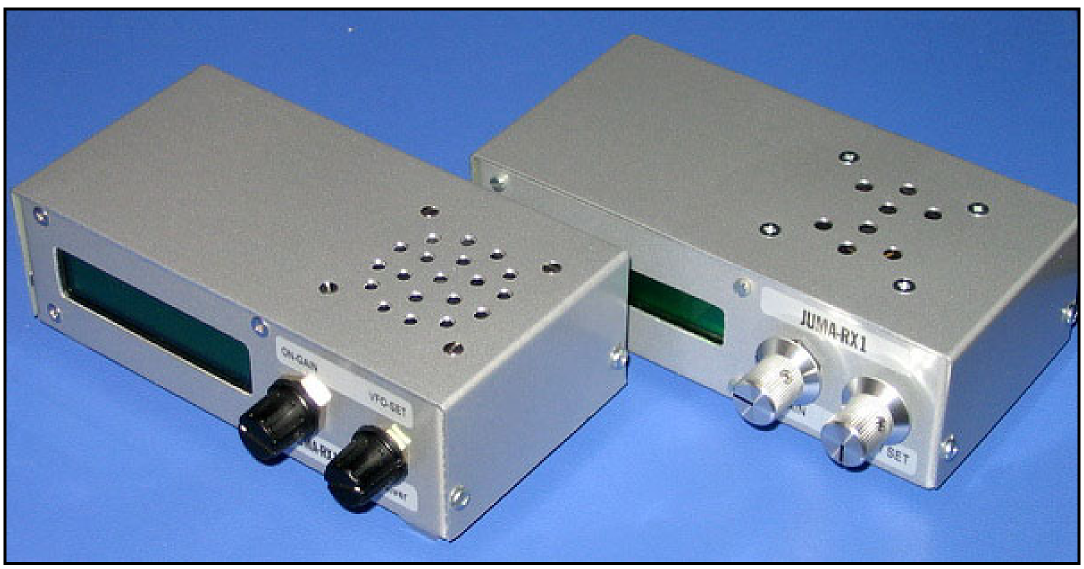

JUMA-RX1
VFO

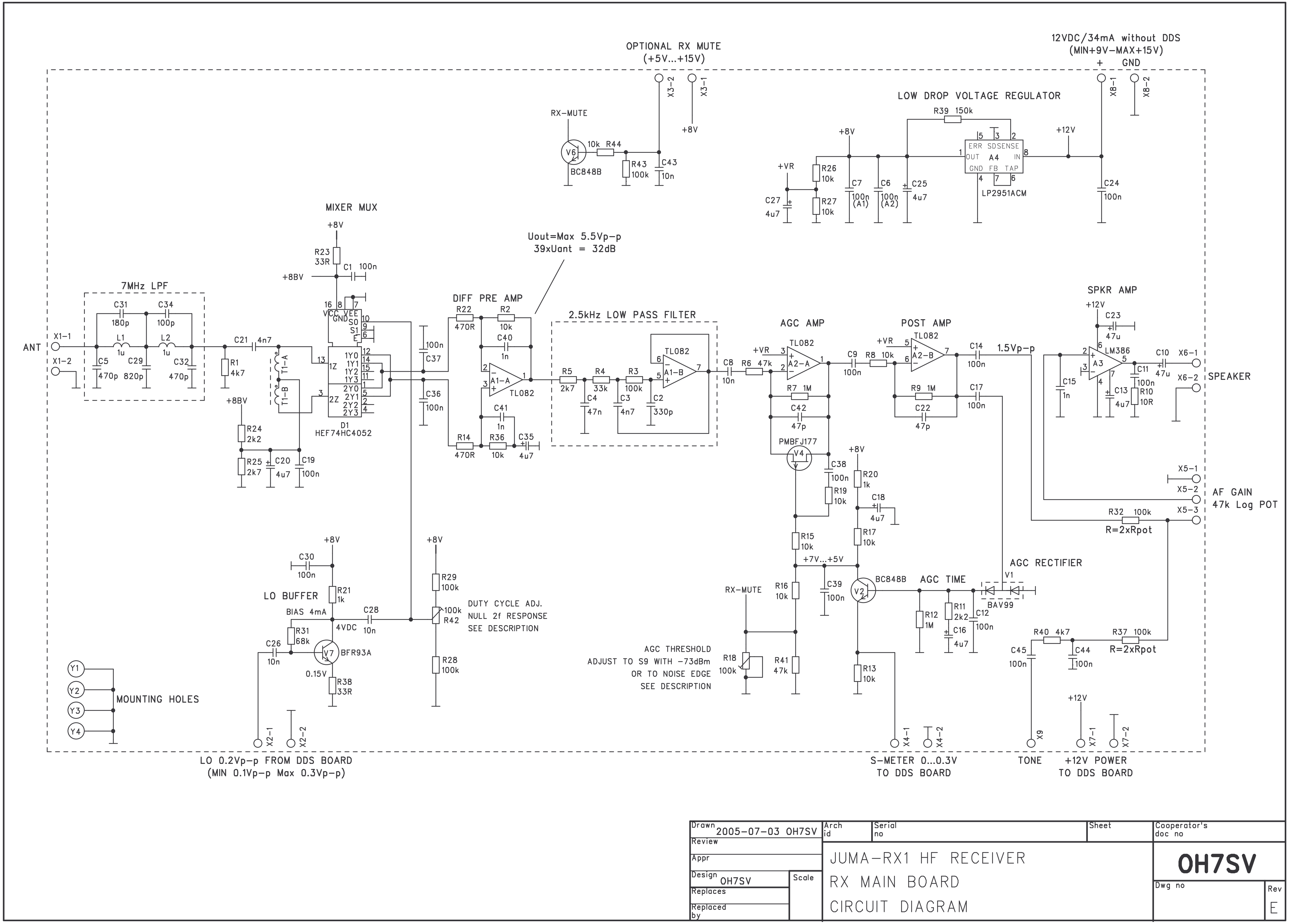

DIRECT CONVERSION RECEIVER
RX MAIN BOARD
CIRCUIT DIAGRAM
OH7SV
SPEAKER
AF GAIN
47k Log POT
TO DDS BOARD


DIRECT CONVERSION RECEIVER
MAIN BOARD
OH7SV
TO DDS BOARD
S-METER
RX-MUTE
POST AMP
AGC AMP
LOW DROP VOLTAGE REGULATOR

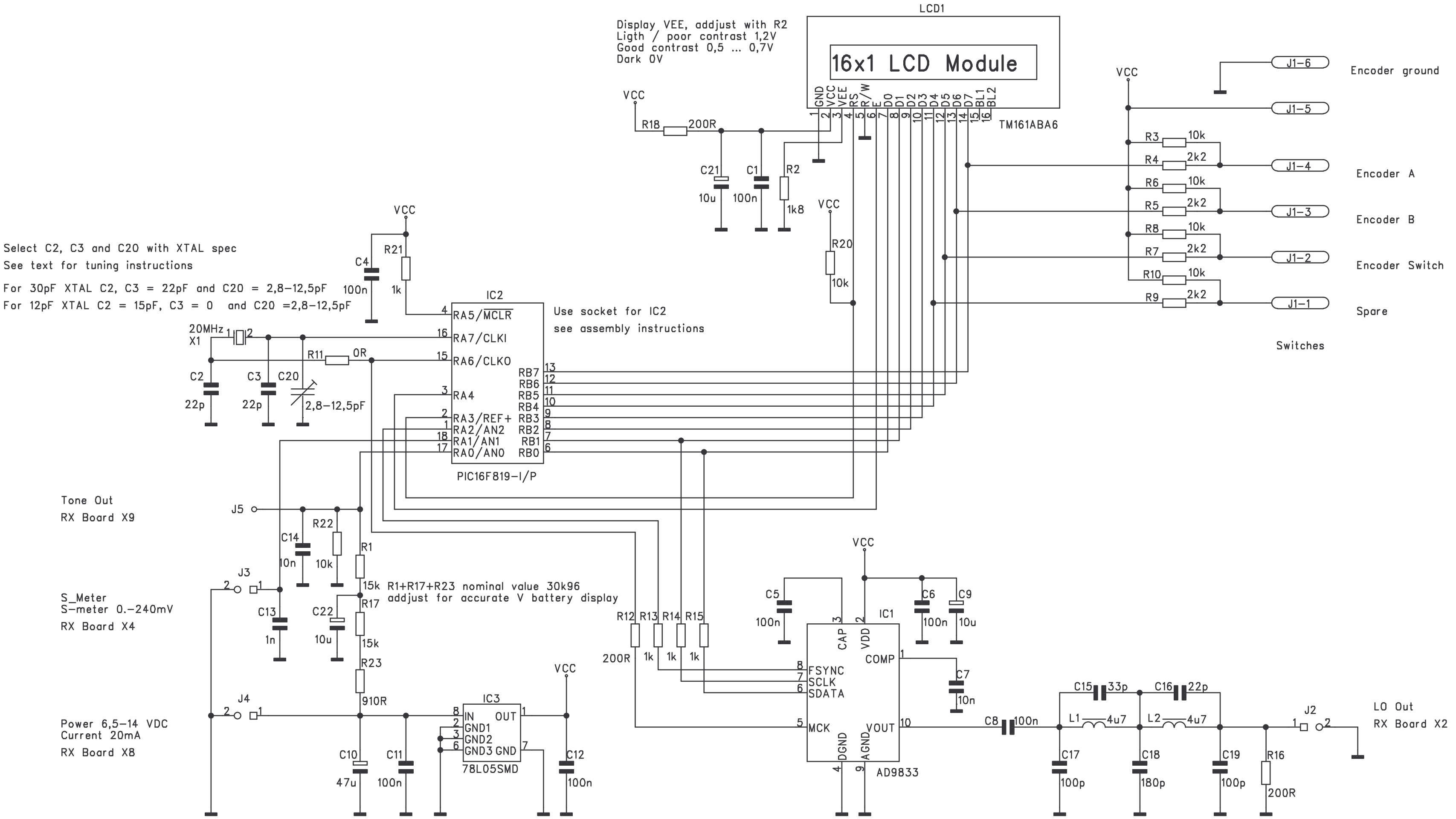

JUMA-RX1
OH2NLT
OH7SV
+9...+15 VDC / 50mA (peak 200mA)
S/N 0002-2005
+12 VDC
SPEAKER
PHONES
ANT
SPEAKER
+12 VDC
JUMA-RX1 HF Receiver
OH2NLT & OH7SV
+9 V...+15 VDC / 50mA, peak 200mA
S/N 0001-2005
ANT


JUMA-RX1
HF Receiver
ON-GAIN
VFO / SET
JUMA-RX1
ON-GAIN
VFO / SET
JUMA-RX1
HF Receiver


ON-GAIN
VFO-SET
JUMA-RX1
SET



OPTIONAL RX MUTE
(+5V...+15V)
12VDC/34mA without DDS
(MIN+9V-MAX+15V)
+ GND
LOW DROP VOLTAGE REGULATOR
LP2951ACM
MIXER MUX
HEF74HC4052
Uout=Max 5.5Vp-p
39xUant = 32dB
DIFF PRE AMP
2.5kHz LOW PASS FILTER
AGC AMP
POST AMP
SPKR AMP
LM386
7MHz LPF
ANT
SPEAKER
1.5Vp-p
AF GAIN
47k Log POT
R=2xRpot
AGC RECTIFIER
BAV99
AGC TIME
PMBFJ177
BC848B
+7V...+5V
RX-MUTE
AGC THRESHOLD
ADJUST TO S9 WITH -73dBm
OR TO NOISE EDGE
SEE DESCRIPTION
LO BUFFER
BIAS 4mA
4VDC
0.15V
BFR93A
DUTY CYCLE ADJ.
NULL 2f RESPONSE
SEE DESCRIPTION
MOUNTING HOLES
LO 0.2Vp-p FROM DDS BOARD
(MIN 0.1Vp-p Max 0.3Vp-p)
S-METER 0...0.3V
TO DDS BOARD
TONE
+12V POWER
TO DDS BOARD
Drawn 2005-07-03 OH7SV
Review
Appr
Design OH7SV
Replaces
Replaced by
Arch id
Serial no
Scale
Sheet
Cooperator's doc no
JUMA-RX1 HF RECEIVER
RX MAIN BOARD
CIRCUIT DIAGRAM
OH7SV
Dwg no
Rev
E



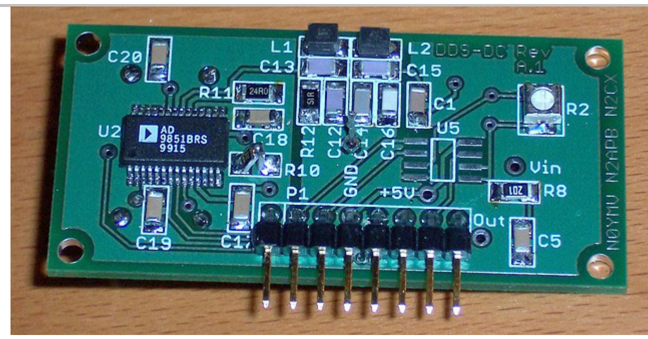
JUMA-RX1 HF Receiver DDS & Control board	OH2NLT	Drawn	08.04.2005	OH2NLT Jni
	DRAWING No. Rev. C / 25.08.2005	Appr.		Page 1

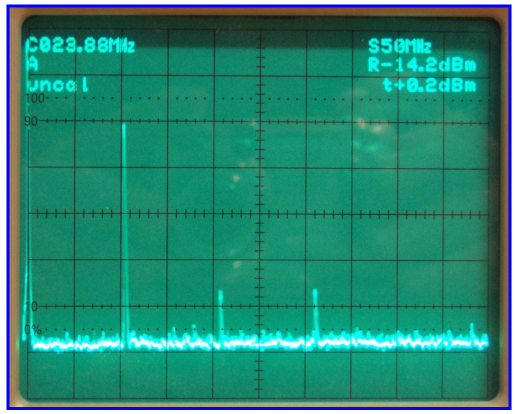
AmQRP.ORG HOMEBREWER

George Heron, N2APB
Joe Everhart, N2CX
David Willmore, N0YMV

DDS-60 ... a modular way to add stable signal generation to your next transceiver or VFO project

How many ways can you use a self-contained, high-precision dc-60 MHz signal source contained on a 1" x 2" plug-in circuit board? How about as a stand-alone VFO, a signal generator for your bench, a replacement LO for your Sierra or NC40 transceiver, or perhaps as the heart of an antenna analyzer! Control it with your favorite microcontroller, or even hang it off the parallel port of your PC. Any way you do it, you'll be generating quality signals for about $30





Direct Digital Synthesis (DDS) captures the experimenter's imagination and excites him like no other technology these days. Exceptional signal precision, accuracy, stability, programmability and signal quality are all easily and inexpensively achieved. But two quite formidable problems still remain.

The first problem is that these surface mount DDS chips are so tiny, with lead pitches as fine as 0.65 mm, that it is nearly impossible to homebrew with them using conventional techniques. It is quite difficult to tack-solder a fine wire onto one of these small SOIC package leads, let alone putting 16 wires to the chip!

The second problem is that these DDS chips must be interfaced to a microcontroller that provides that frequency programmability. A 40-bit control word must be loaded into the DDS chip to command it to generate a specific frequency. There are many projects around that control a DDS chip with a PIC, an Atmel controller, a BASIC Stamp, an SX chip, and so on. I don't know about you, but the VFO I will ultimately need is likely to use some controller that I don't technically "know" and cannot program. This makes it tough to use that controller for anything but commanding the DDS, thus raising the cost of the entire project, increasing the amount of board real estate needed, and raising the power needs for the entire project.

The Solution

To get past these two problems, we designed a self-contained functional module that generates a top-notch RF signal by using a small pc board to contain just the bare DDS essentials – an Analog Devices AD9851 DDS chip, a clock oscillator, a 5^{th}-order elliptic filter and an adjustable-level RF amplifier. Additionally, an onboard 5V regulator is provided so you only need provide a single 12V battery or power supply ranging anywhere from 8-16V DC. The three digital control lines, the power supply, and the output signal are all available on a pin header at the board edge. The schematic is shown on page 3.

The 8-position pin header at the board edge serves to allow DDS Daughtercard to be plugged into and used in any project you might have on your bench, regardless of which microcontroller is employed. Just provide a single strip socket (e.g., a 16-pin IC socket split lengthwise) on the project board and plug in the DDS Daughtercard. Heck, you don't even need a dedicated microcontroller – use a cable connected to the parallel printer port of your PC and use public domain PC software to control the DDS board! See the Controller section later in this article for a number of custom solutions for you to easily control your DDS Daughtercard.

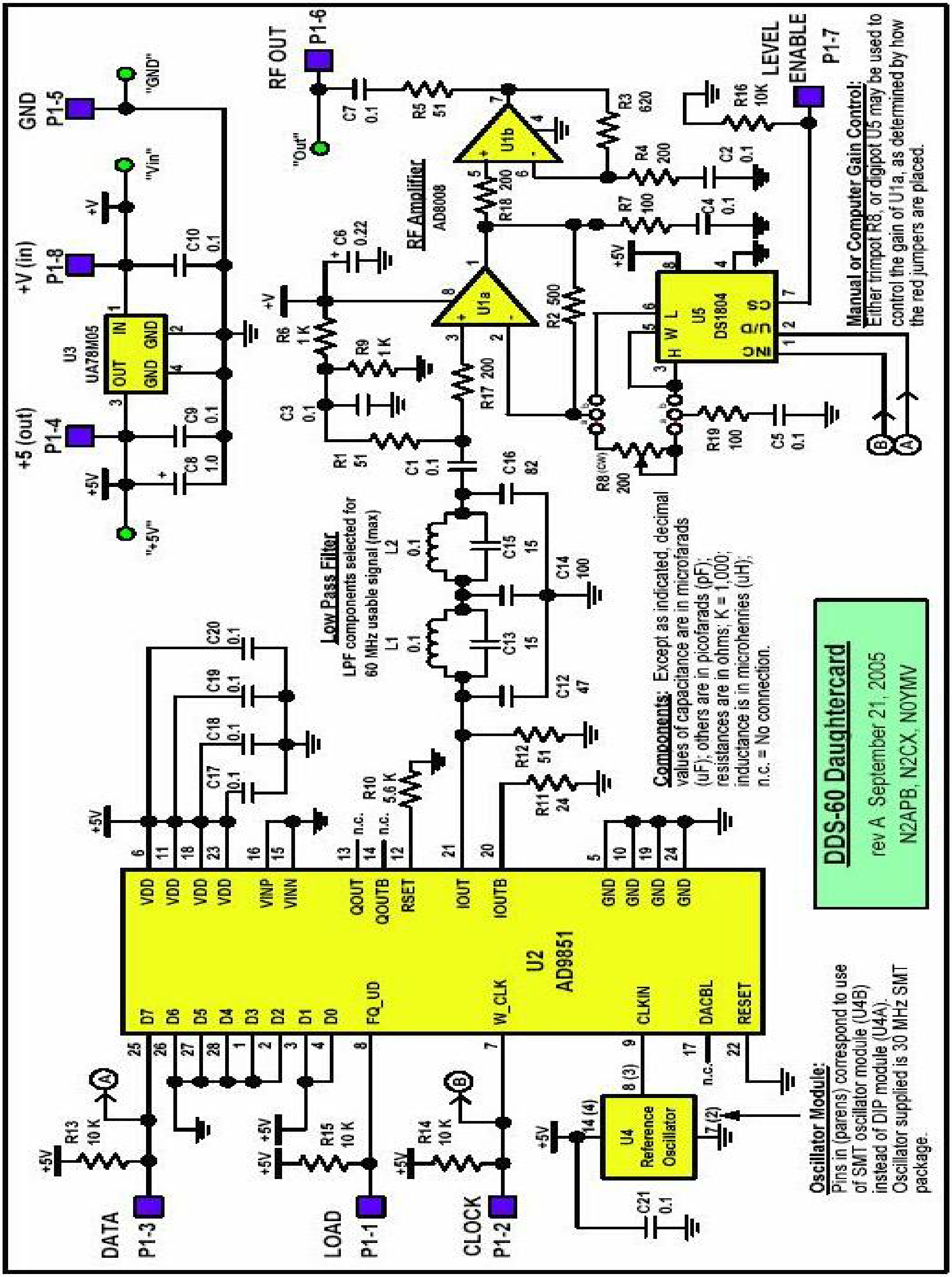
Once your controller-of-choice serially loads the 40-bit control word into the DDS, the raw waveform is presented to an elliptic filter that removes unwanted high-end frequency components, resulting in a signal of sufficient quality to serve as a local oscillator for a transceiver. We regularly see great signal quality, with harmonic content of –40 dB.

The signal generated by the DDS is quite small so we use an AD8008 low power amplifier to provide about 18 dB of gain to boost the signal to about 2V p-p, which is quite usable in a variety of applications. This amplifier chip replaces the single-chip MMIC amps used in earlier versions of the DDS Daughtercard. Our new amp is much improved compared to the previous design by offering unconditionally stability (k>1) and yielding spectrally-clean signals with harmonics down more than 40 dB. It is an ideal signal source for making impedance measurements in the Micro908 Antenna Analyst and other demanding designs. A trimpot allows precise setting of desired output levels. Alternately, a DS-1804 "digi-pot" is provided in the design to allow the external microntroller to set the output level under software control. The design provides a good signal using supply voltages from 16V all the way down to 8V, thus conveniently allowing for battery operation.

The amplified signal is then presented to P1 pin 6 on the pin header where it can be used as a 50-ohm source input signal. If not used as an input to any other component or module, the output should be terminated with a 50-ohm resistor in order for the stated specifications to be realized.

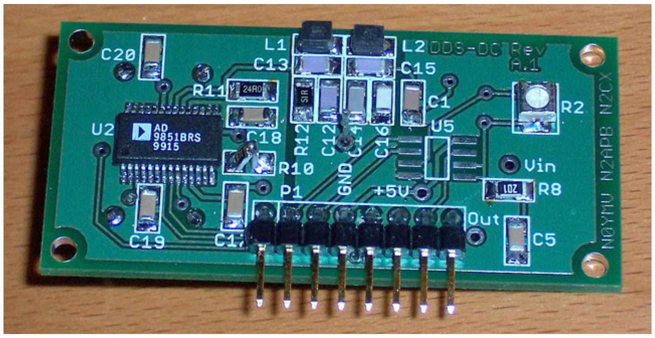
Specifications

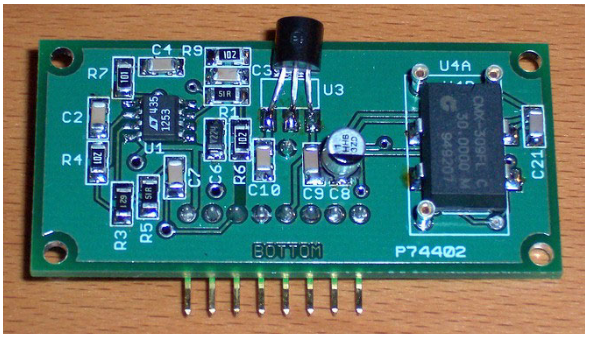
- Power requirements: 8-16V DC at 180 ma (max).
- RF Output – fully adjustable to +10 dBm, or about 3V pp.
- Output signal unaffected by varying +V supply voltage – great for battery operation.
- Near-constant output level from 1-60 MHz
- Good signal purity – harmonics down approximately 40 dB from the fundamental.


DDS-60 Daughtercard
rev A September 21, 2005
N2APB, N2CX, N0YMV
Components: Except as indicated, decimal values of capacitance are in microfarads (uF); others are in picofarads (pF); resistance are in ohms; K = 1,000; inductance is in microhenries (uH); n.c. = No connection.
Low Pass Filter
LPF components selected for 60 MHz usable signal (max)
RF Amplifier
AD8008
Manual or Computer Gain Control:
Either trimpot R8, or digipot U5 may be used to control the gain of U1a, as determined by how the red jumpers are placed.
Oscillator Module:
Pins in (parens) correspond to use of SMT oscillator module (U4B) instead of DIP module (U4A). Oscillator supplied is 30 MHz SMT package.
U2
AD9851
U3
UA78M05
U5
DS1804
U4
Reference Oscillator
DATA
P1-3
LOAD
P1-1
CLOCK
P1-2
+5 (out)
P1-4
+V (in)
P1-8
GND
P1-5
RF OUT
P1-6
LEVEL ENABLE
P1-7
"+5V"
"Vin"
"GND"
"Out"

DDS-60 Daughtercard Parts List:

QTY	Designator	Description
3	R1, R5, R12	Resistor, 51, 1206 SMD
1	R2	Resistor, 510, 1206 SMD
1	R8	Trimpot, 200, SMD
1	R3	Resistor, 620, SMD 1206
3	R4, R17, R18	Resistor, 200, SMD 1206
2	R6, R9	Resistor, 1K, SMD 1206
2	R7, R19	Resistor, 100, SMD 1206
1	R10	Resistor, 5.6K, SMT, 1206
1	R11	Resistor, 24, 1206 SMD
4	R13, R14, R15, R16	Resistor, 10K, 1206 SMT
13	C1, C2, C3, C4, C5, C7, C9, C10, C17, C18, C19, C20, C21	Capacitor, 1206 SMD, 0.1uF 25V
1	C6	Capacitor, 0.22 uF, tantalum, SMD 1206
2	C8, C11	Capacitor, electrolytic, SMD, 1.0uF, 50V
2		Capacitor, 1206 SMD, 15pF 25V
1		Capacitor, 1206 SMD, 47pF 25V
1		Capacitor, 1206 SMD, 82pF 25V
1		Capacitor, 1206 SMD, 100pF 25V
2	L1, L2	Inductor, 0.10uH, 1206 SMD
1	U1	Integrated circuit, op amp, AD8008
1	U2	DDS integrated circuit, 28 pin SSOP
1	U3	Integrated circuit, 5V voltage reg, SOT-223
1	U4	Oscillator, 30 MHz, SMT
1	U5	DS1804 "digi-pot"
1	P1	Pin Header, 0.1", 8 pin
1	PCB	PC Board
1	Manual	Assy Manual





Top side of DDS-60 Daughtercard ……………… and the bottom side. .

Controlling the DDS

It won't be too long before you consider ways to use the DDS Daughtercard. Well, you are in for a real treat as there are a whole bunch of convenient and powerful techniques already developed that can be employed to provide a user interface and controller for this RF signal generator module.

In general, the DDS chip needs to be sent a control word by an external controller before the Daughtercard is capable of generating a signal. No matter what controller you use, it must serially send a 40-bit control word to the DDS Daughtercard on the DATA line (P1 pin 3). The controller clocks each bit into the DDS by the toggling the CLK control line (P1 pin 2). To complete the sequence, the accumulated control word is loaded into another internal DDS register by a toggling of the LOAD line (P1 pin 1), thus instructing the DDS chip to generate the frequency just loaded. Then *bingo*, the new frequency appears at the RF Output of the DDS board (P1 pin 6).

The AD9851 data sheet, and an Interactive Design Tool applet on the Analog Devices website:

(http://www.analog.com/Analog_Root/static/techSupport/designTools/interactiveTools/dds/ad9851.html)

provide all the details on how to construct the five byte, 40-bit control word with your microcontroller-of-choice. Just enter 100 MHz in the reference clock field and the desired operating frequency, and the applet will display the five control bytes that you need to send serially to the DDS Daughtercard in order for it to generate that frequency.

There are many software programs available that already accomplish sending the control words to the DDS card, thus enabling it to serve as a general purpose VFO. Any of the techniques outlined in the next section may be adopted if you plan on using the specific processors in your project. They are also great examples on which you can model a software program using a different microcontroller.

Many Uses!

Here are some great ways for you to build up a project using the DDS Daughtercard to generate AF and RF signals.

QuickieLab

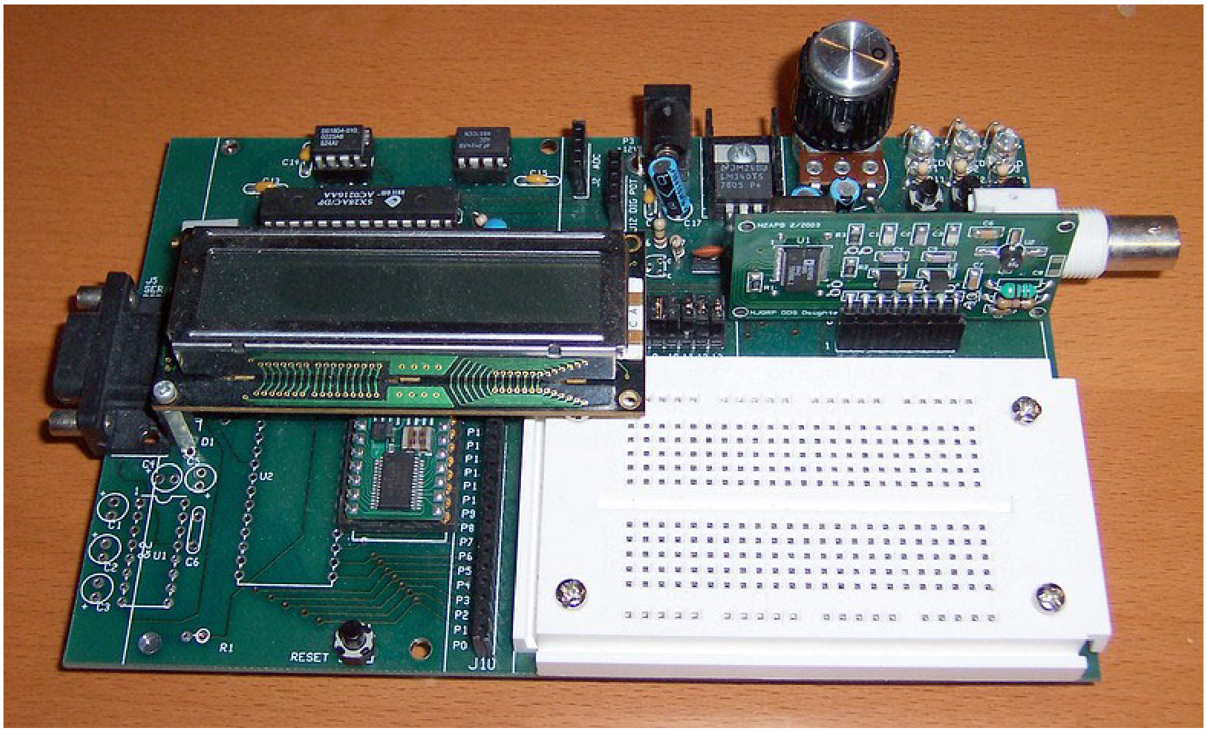
The DDS Daughtercard is ready-made for plugging into the NJQRP "QuickieLab", which is an experimenter's platform provided several years ago in kit for hobbyists to easily build up circuits on a plugboard and connect them into various standard circuits provided on the board for audio amplification, A/D conversion and LCD display. So all you need to do is plug the DDS Daughtercard into the appropriate socket on the QuickieLab and use some of the canned software that's provided to have the hardware serve as a basic VFO.

The programming sequence is easily accomplished. In one of his renowned "Joe's Quickies" columns in QRP Quarterly magazine, N2CX uses the following three lines to instruct the BASIC Stamp controller to produce a 7.040 MHz signal with the DDS Daughtercard plugged into the QuickieLab:

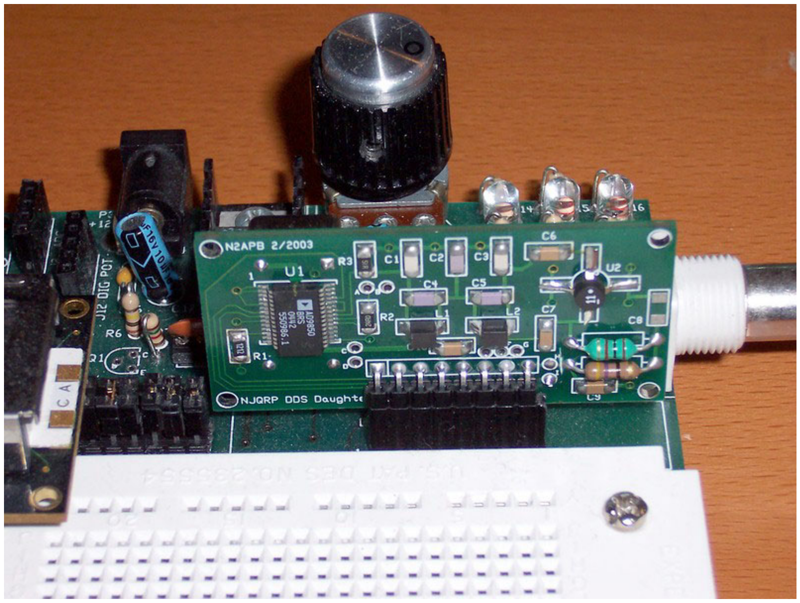

```
shiftout 7,8,0,[$02,$BC,$05,$12,$00]
out9 = 1
out9 = 0
```

The first instruction line shifts out the 40-bit (5-byte) value on port P7, using P8 as the clock. The second and third instruction lines toggle the LOAD pin going to the DDS, at which point the RF signal is generated at the output of the DDS Daughtercard.

(If you do use the DDS Daughtercard with the NJQRP QuickieLab, remember to cut the +5V trace on the bottom of the QuickieLab pc board that leads to P1 pin 4 on the DDS Daughtercard socket. This is because the DDS Daughtercard produces its own internal 5-V supply and doesn't require that the QuickieLab supply it.)



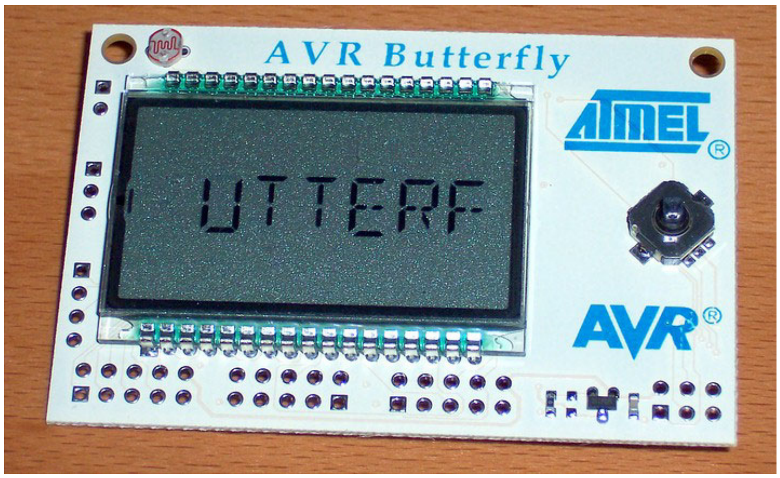
Here's the QuickieLab set up with the DDS Daughtercard in the socket located just above the white plugboard. The BASIC Stamp processor, located on the main board beneath the LCD, commands the DDS chip on the daughtercard in order to generate RF signals that are pumped out the BNC connector on the right side of the board.



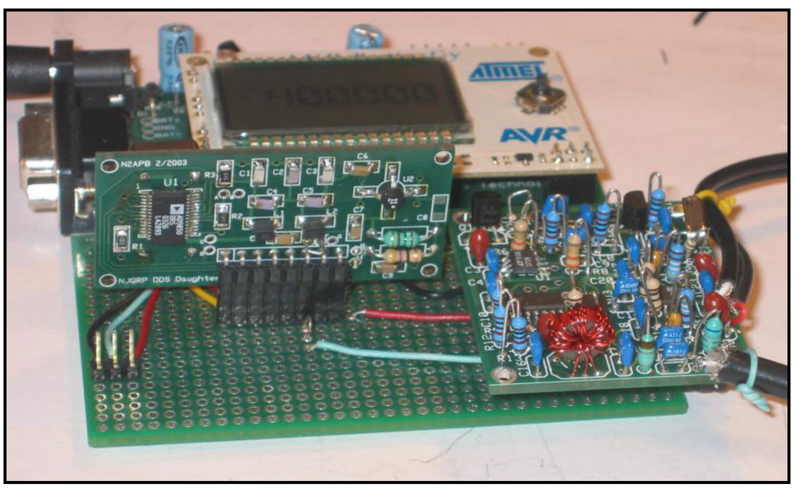
Closeup of the DDS Daughtercard plugged into the QuickieLab.
Note that DDS card used here is one of the original ones that used the MMIC amplifier on the right side fo the card. (The MMIC amplifier has been replaced by the addition of the DDS Amp "grand-daughtercard in the current design.

Butterfly Controller Board

Software currently exists for the AVR Butterfly card to present a simple user interface for frequency entry and display and to command the DDS Daughtercard to generate those frequencies. See http://www.atmel.com/dyn/products/tools_card.asp?tool_id=3146) for more information on the Butterfly controller card. Steve Weber, KD1JV developed the DDS card driver software and has it on his website, located at http://www.qsl.net/kd1jv/bfydds.HTM.



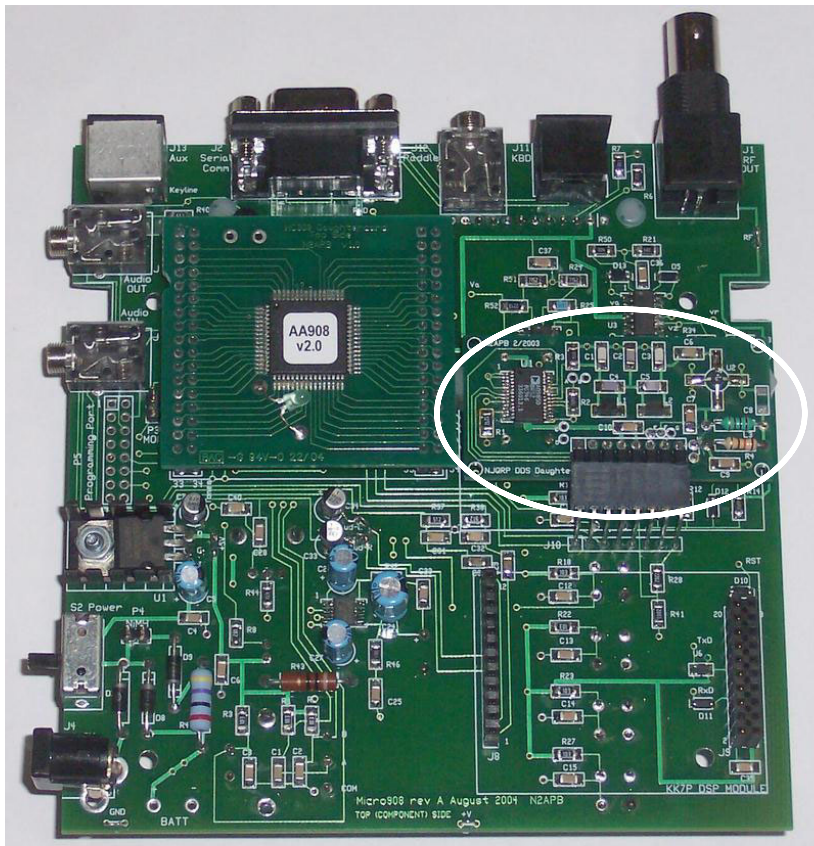
The "Butterfly" controller card from Atmel is a convenient and inexpensive way to get a fairly powerful processor on a card with some universal I/O of an LCD and "joystick/pushbutton" being used to navigate.



Here is pictured the DDS Daughtercard plugged into an ERCOS Butterfly Carrier board, which allows the Atmel processor to control circuits interfaced to the Butterfly board. The additional circuit card on the right is an earlier version of the SoftRock40 SDR receiver project described elsewhere in this issue of Homebrewer. In this application, the Butterfly controller board controls the DDS Daughtercard to generate RF being used as the local oscillator for the little receiver card. (The ERCOS Carrier Kit can be found at http://www.ecrostech.com/Products/Butterfly/Intro.htm)

Micro908

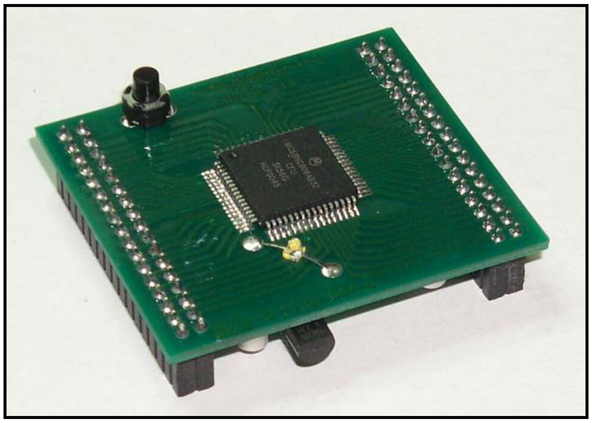
The DDS Daughtercard is already incorporated into the Micro908 kit from the AmQRP Club and is integrally used to make the instrument function as an antenna analyzer. So if you are able to write a specific VFO program for the Micro908, or perhaps just use the VFO function provided with the AA-908 software load on the Micro908, you can use the instrument to generate signals “right out of the box”.

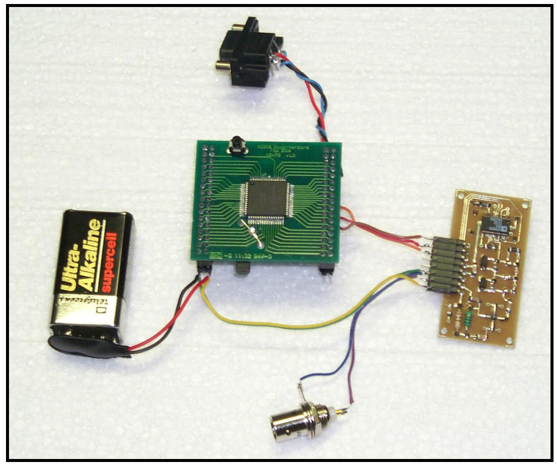


The DDS Daughtercard (identified by the white circle in the photo above) Is controlled by the HC908 Daughtercard on the Micro908 motherboard. It plugs into an 8-pin right-angle connector that holds the DDS card up off the motherboard, above the reflectometer circuits of the Micro908.

HC908 Daughtercard

You may also plug the daughtercard into the HC908 Excerciser board described in the Digital QRP Breadboard project and use the software provided with that project to have it serve as a programmable VFO.

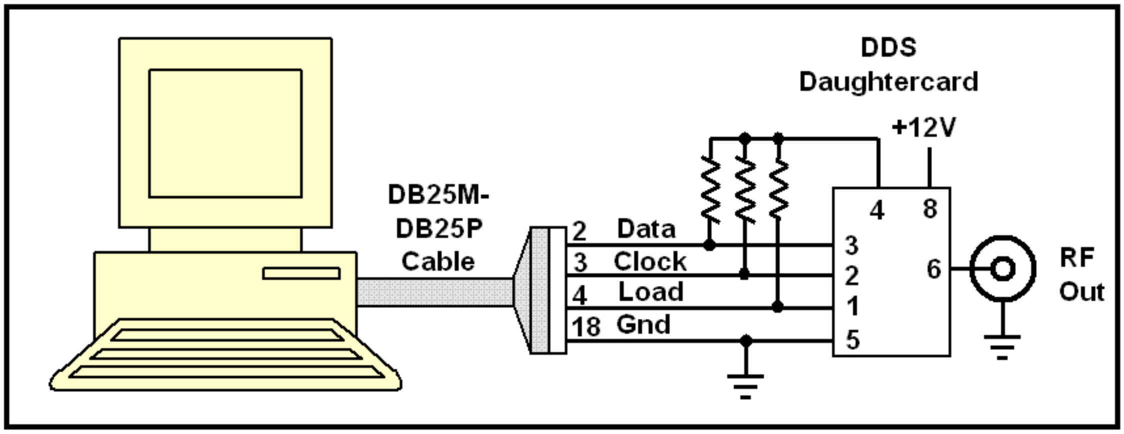




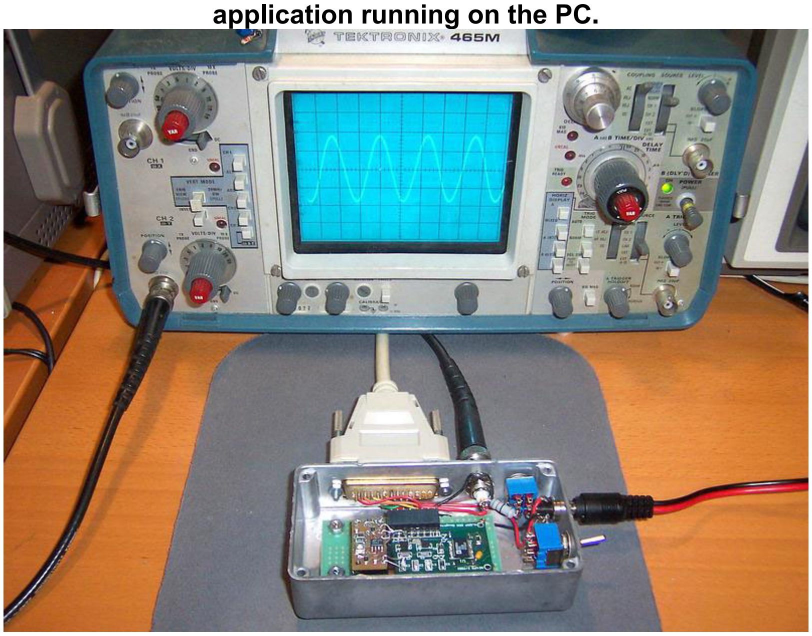
The HC908 Daughtercard controller is a popular and recurring component with the DDS Daughtercard. Together they make a flexible combination of modules that can be used in many different applications, using a common set of software libraries (subroutines). The configuration of the two modules shown in the right photo is the minimal hardware arrangement needed for a "dumb terminal" (like HyperTerm on a Windows PC or ProComm on a handheld computer) to command the HC908 to generate frequencies … in effect, the HC908 and DDS daughtercards become a remotely-controlled signal generator!

Parallel port control from your PC

You can even control the DDS Daughtercard directly from your PC. All that's needed is to wire the daughtercard to the printer port cable and run one of several public domain custom software programs to have the PC serve as VFO controller. The programs from KA2UPW, or WA6UFW and WA6FXT (located on the project website) each have an attractive display screen that offers specific frequency entry, phase settings, and even scanning controls!



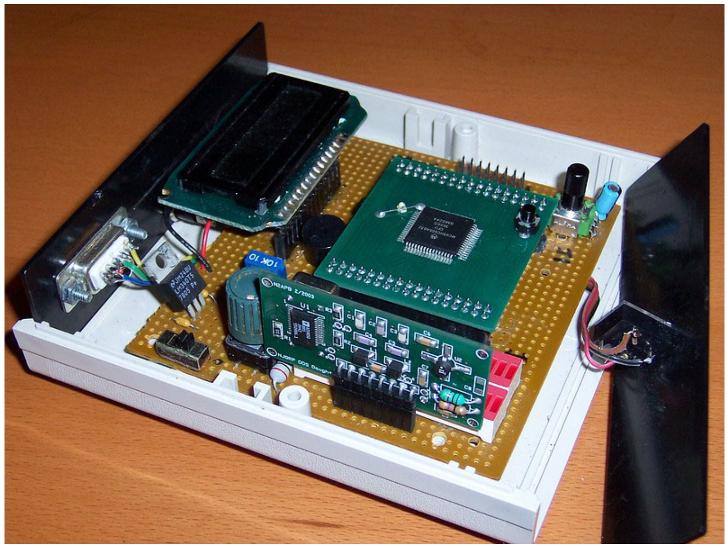
If you wire the DDS Daughtercard to the PC's parallel port connector and a power supply, as shown in this diagram, any signal from 0.1 Hz to 30 MHz may be generated by the software application running on the PC.



Here is shown the "PC VFO" assembly being controlled by a PC over its parallel printer port. The DDS Daughtercard is housed in a rugged die-cast aluminum enclosure with connectors for the parallel port control lines, RF output on a BNC, and power input on a coaxial power connector. Switches provide power control and the ability to switch a 50-ohm load resistor in/out of the circuit. The oscilloscope display in the background shows the nice and clean 10 MHz signal currently being generated by the DDS card, as commanded from the PC screen.

Custom Controller

Of course you can also design the DDS Daughtercard into your own custom project, using your favorite microcontroller chip as the “brains”, be it a PIC, Atmel, Ubicom, or 8051-derivative processor. The possibilities are limitless!



This photo shows the DDS Daughtercard included in a circuit I call the Exerciser … which is a test fixture that all HC908 Daughtercards get plugged into in order to get tested and qualified before being programmed with the appropriate software before shipping. (The Exerciser schematic and software program are located in the HC908 Daughtercard manual.)

Conclusion

This simple DDS Daughtercard solves both of the problems described at the beginning of this article. It enables the homebrewer to easily take advantage of the positive attributes of the DDS chip to produce a high quality homebrew variable-frequency signal source. Let us know how you end up using your DDS 'card!

Notes

1) The DDS-60 Kit may be purchased from the AmQRP Club. Refer to the DDS-60 project web page for all current technical and ordering details: http://www.njqrp.org/dds60.

2) The AD9851BRS DDS chip is not provided because homebrewers can obtain a free sample from the Analog Devices website at: http://products.analog.com/products/info.asp?product=AD9851 . Just go to this Internet location, register with Analog Devices (i.e., give them your mailing address), and within a week or so you will receive a free sample of the DDS chip by mail.

3) The NJQRP has lined up a great resource to assist in soldering the DDS chip onto the printed circuit board. Once you've acquired your free AD9851BRS DDS chip from Analog Device, send the chip and your DDS Daughtercard circuit board, to Mike, WA6OUW, at "KitBuilders". For $10 he will attach this surface mount chip to the pc board and return it promptly by mail. It's not tested because at that point it's only the DDS chip on a bare pc board, but Mike does excellent work. (The NJQRP uses KitBuilders for assembly of the HC908 Daughtercard product, so we know the quality is there!) Just place your DDS chip, pc boards and a $10 check or M.O. payable to "KitBuilders" into a padded envelope and send to: KitBuilders, 6361 Berrybush Ct, Gilroy, Ca. 95020. You can contact Mike by email at wa6ouw@aol.com if you have further questions.

4) Details of the NJQRP QuickieLab project can be found at www.njqrp.org/quickielab .

5) Details of the HC908 Daughtercard project can be found at www.njqrp.org/hc908 .

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Joe Everhart, N2CX *may be contacted at n2cx@verizon.net,*
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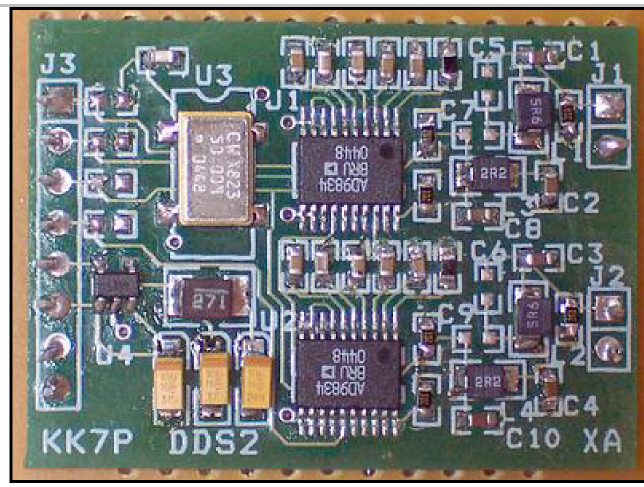
David Willmore, N0YMV *may be contacted at willmore@optonline.net*
or by mail at 12 Country Lane, Hamilton, NJ 08690

Lyle Johnson, KK7P
George Heron, N2APB

Portable Software Defined Radio … Part 1: The DDS2 Card

Here is a working dual-DDS prototype that can serve as the timing heart of a digital radio system. Add a few increasingly-common modules – quadrature sampler & DSP – and you have yourself a small, standalone "Software Defined Radio" with terrific performance.



Background

In his "Digital Building Blocks for Analog Radios" presentation at the Atlanticon 2005 QRP Forum, KK7P explained how radios have long been constructed of tangible parts that we all know and love: tubes, transistors, resistors, capacitors, and so on. Lyle pointed out that increasingly all sorts of integrated circuits have been creeping into our radios – some, like the NE602, we embrace and utilize to the fullest.

Others, however, have tended to be "black boxes" that show little resemblance to the components we used to understand, but provide astounding degrees of functional value in our radios. He presented a series of sketches showing how some of these modern digital modules could be used to provide correspondingly superior performance in radio designs.

One of the sketches described a concept for a dual-DDS (Direct Digital Synthesis) RF generator. That "DDS2" module is the focus for our first paper here in Homebrewer Mag describing the evolution and design of a portable, low-cost transceiver consisting of digital building blocks with features and capabilities contained in software running on those modules. This type of radio is also known as Software Defined Radio (SDR) because the function and characteristics of that digital radio (e.g., changing from SSB to AM demodulation) may be changed simply by loading new software into its onboard computers.

This article describes the design of the DDS2, and overviews some of the other modules coming downstream in our quest for a Portable SDR radio.

DDS2 – Circuit Description

The DDS2 is a dual-DDS card that can output two independent frequencies, such as the HFO and BFO in a superhet receiver or transceiver. It can also output accurate quadrature RF at a particular frequency and serve as an I+Q VFO for an image rejecting direct-conversion radio. Such a radio might resemble Rick Campbell's R2 or T2, or a quadrature sampling detector (*aka* Tayloe detector) like that used in the SDR-1000 from Flex Radio Systems.

So, given that the DDS2 is ideal for generating two precision RF signals, with control over both frequency and phase, let's next walk through a description of the simple circuit diagram, shown at the end of the article.

The DDS2 card contains two DDS chips and the design contains a good deal of symmetry, so we'll first start with one of the DDS sections.

U1 is an AD9834 Direct Digital Synthesis (DDS) chip made by Analog Devices. This part can be driven with a clock up to 50 MHz, and it can create a reasonably pure output signal from under 1 Hz to more than 1/3 the clock frequency. We say reasonably, because DDS techniques have some drawbacks, which we'll explain later.

The output of the DDS is filtered by a 5-section low-pass filter, L1, L3 and associated capacitors. This LPF is a very necessary part of a DDS-generated RF signal, as it removes much of the spurs and other digital artifacts in the signal above the its maximum usable frequency – again, about 1/3 the clock frequency.

U2 is an identical DDS with another low pass filter of the same design as that used for U1.

U3 is a clock oscillator. The prototype uses one selected for minimum jitter, or phase noise, and it runs at the maximum published rate the DDS can accept, 50 MHz. This is the same clock speed that is used in the Elecraft KX-1. Steve Weber's ATS-3 uses a 40 MHz clock to save a little current.

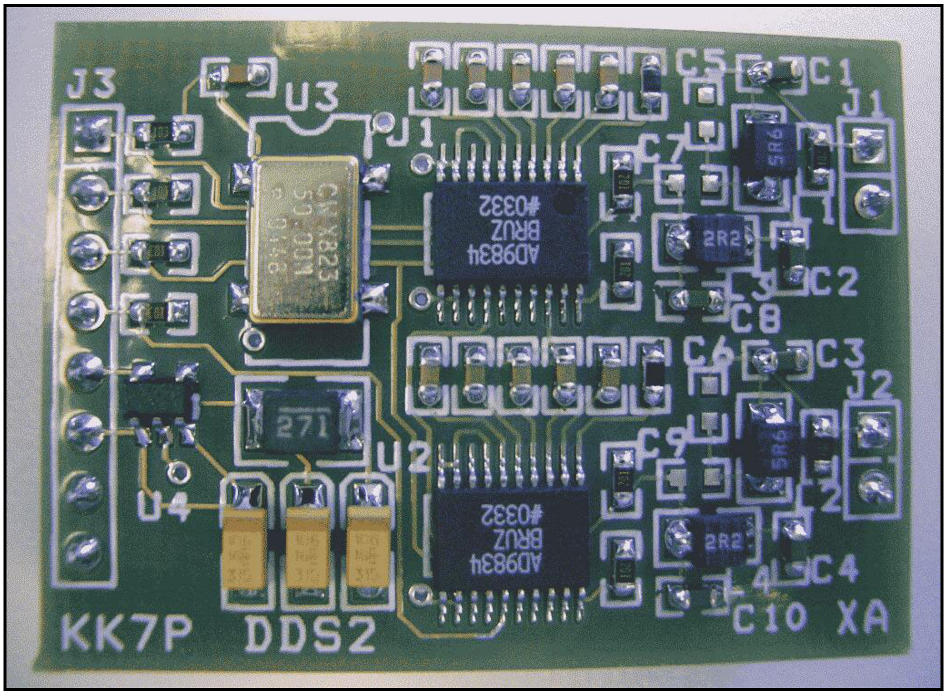
The DDS accepts control signals from an off-board microprocessor, such as the Micro908 from AmQRP, or a PIC or any controller that has a SPI (Serial Peripheral Interface) port. The control signal lines are pulled up by 10K resistors to protect the DDS chip from floating inputs. However, the DDS2 card runs on 3.3 volts and cannot be driven with a 5-volt signal, so some simple voltage dividers can be used on the four digital input lines controlling the card, as shown in Figure 2.

U4 is a 5V-to-3.3V regulator. It can be left out if the project has an available, filtered 3.3V source.

Notice that there are two kinds of grounds shown on the schematic, joined together in one place. This is to keep the digital and analog signals separate, primarily to keep digital noise out of the RF! However, the board is very small and it was impractical to keep the ground areas separate without going to multi-layer PCB technology. This was deemed overkill for the intended uses.

DDS2 – Physical

The DDS2 is shown below. This photo shows how very compact the design is, measuring only 1.1” x 1.5” (2.8 cm x 3.8 cm). The passive components are all surface mount with the majority (everything except the tantalum capacitors) being of 0603 size. These parts measure 0.060” x 0.030” in size. The board is too small to put silkscreen legends near all the parts, so only the parts in the output filter are labeled, along with connectors and ICs.



J3 is the digital control header and power input, while RF is taken at J1 and J2. The header pins are on 0.1” centers to make it easy to plug into various circuits.

DDS2 Improvements

The second version of the DDS2 will likely migrate to 0805 passive parts and larger PC board to make it more practical to kit. If it were to be an assembled module, like the KK7P DSPx, then use of 0603 components is not a problem.

However, the PC board needs to be enlarged anyway, because it is necessary to add an IC buffer chip that can withstand and accept 5V control signals.

The alignment of J1 and J2 with respect to J3 will be slightly altered as well, to ensure all pins fall in a 0.1” grid.

Applying the DDS2

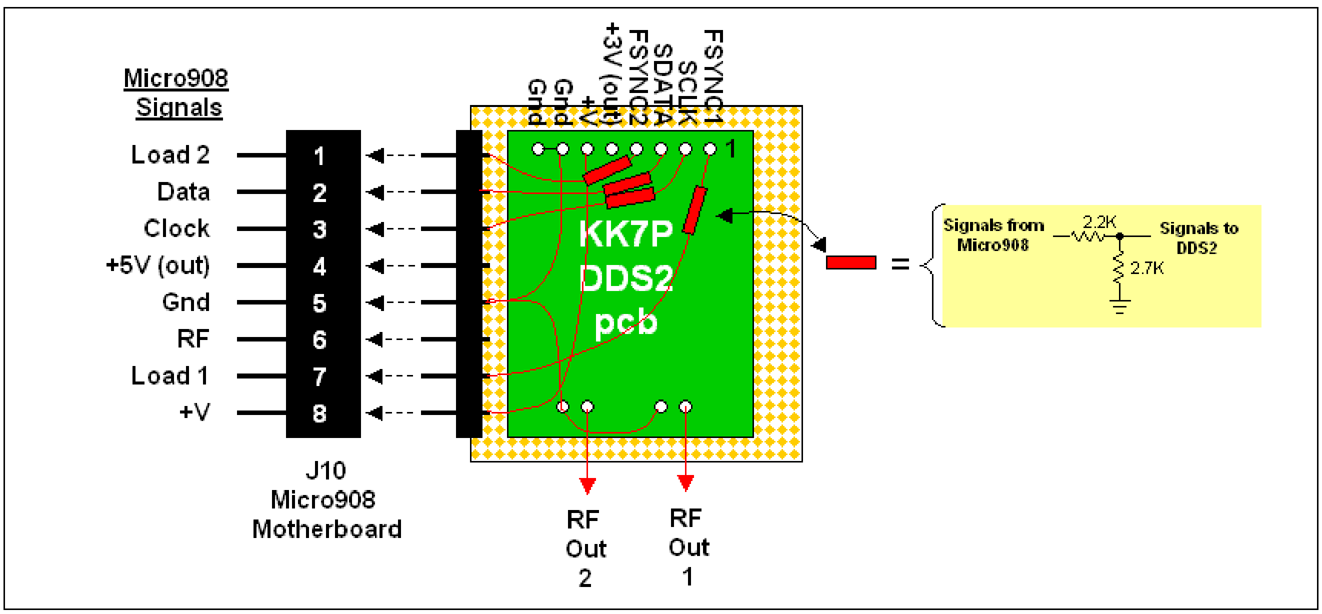
The authors are excited by the possibilities of applying the DDS2 to a quadrature sampling detector (QSD) and exciter (QSE), such as are used in the SDR-1000 software defined radio.

The SoftRock-40 is such an example of a simple 40-meter QSD receiver, and is also presented in this issue of Homebrewer Magazine. We saw the immediate opportunity of integrating the DDS2 card with the SoftRock-40 as a fully programmable, quadrature LO for that little receiver. By coupling the two clock signals directly to the QSD circuit on the SoftRock-40, we are able to operate anywhere with in the 40-meter band, unlike the stock SoftRock-40 design which is locked to a 48 kHz swath of RF centered at its built-in clock of 7.056 MHz. Ultimately, all that would be needed to operate the DDS2+SoftRock on other bands is a modified bandpass filter on the RF input of the SoftRock card.

The DDS2 card is completely “dumb” and incapable of doing anything until a controller is connected to its Clock, Data and Load input control lines. The Micro908 controller from the AmQRP Club ideally serves as that controller in our current prototype, providing full user interface through its use of LCD, pushbuttons and rotary encoder, and electrical interface by means of the existing DDS Daughtercard interface.

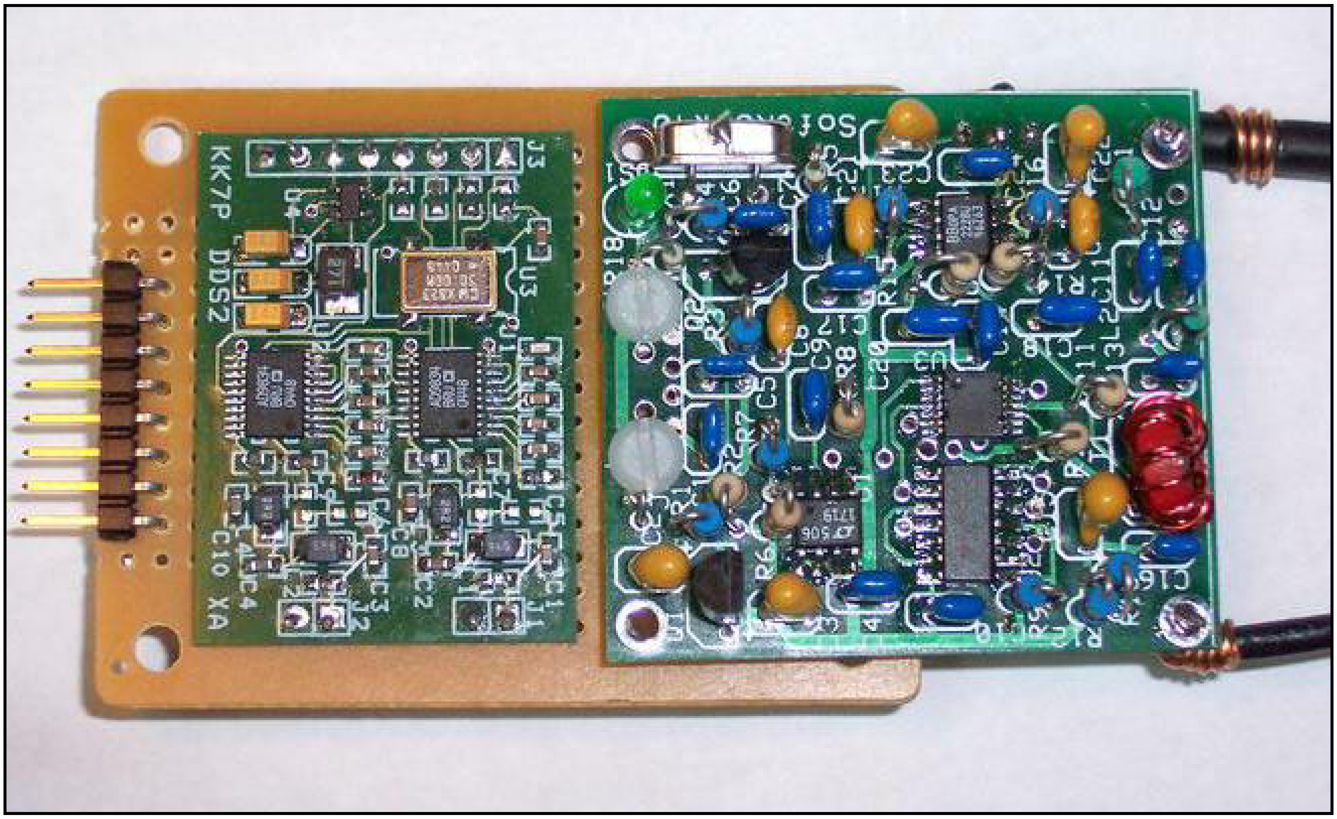
In fact, this DDS Daughtercard electrical interface in the Micro908 served perfectly for our use. We built a small perf board “base board” to hold the DDS2 card and the SoftRock-40 card, and this perf board plugged right into the connector that normally holds the DDS Daughtercard. Only one extra signal needed to be brought to the DDS Daughtercard connector, the Load control signal for the second DDS chip on the DDS2 card; otherwise, all other signals that we needed were already presented at that connector.

The diagram below shows the interconnection of signals from the J10 connector on the Micro908 motherboard, to the DDS2 card sitting on the perf board.



KK7P DDS2 card electrical interface to the Micro908 controller. Note the red “rectangles” denoting the voltage divider resistors needed to match the 0-5V control signals in the Micro908 to the 0-3.3V components on the DDS2 card.

In practice, the photo below shows the DDS2 card coupled with the SoftRock-40 card on the perf board that plugs into the J10 connector on the Micro908 motherboard. The wiring and interface resistors are located on the bottom of the perf board.



KK7P "DDS2" card (card on left) serving as an extremely flexible and precise dual local oscillator for a prototype of the SoftRock-40 receiver (card on right), making multi-band operation possible. This sub-assembly can be plugged into the AmQRP Micro908 motherboard in place of its current (single) DDS Daughtercard. With a new software driver for this DDS2 card, the Micro908 rotary encoder and LCD serve as the "front panel" for controlling the SoftRock-40 receiver operation anywhere on the 40m ham band.

The photo on the next page shows how the prototype clock & QSD card plug into the Micro908. Granted, at this point it does not fit within the space provided by the enclosure, but such is the life of prototypes! Perhaps we'll get there in the next round of the project.

Once the clock card (DDS2) & QSD card (SoftRock-40) combination was plugged into the Micro908, the next challenge for this project began – software to control it all.

DDS2+SoftRock board in position inside the Micro908 instrument. The Micro908's user interface and built-in nature of the DSP card (daughtercard in the lower right corner) make a standalone Software Defined Radio quite possible. In this prototype, the SoftRock audio signal cable is plugged into the input jack of the Micro908 enclosure (cable input at upper left of diagram), which then routes the audio signals over to the DSPx Daughtercard on the motherboard.

Portable SDR Software

Software for our Portable SDR prototype consists of two main components: the control software and the signal processing software.

Control software is designed to run on the Motorola 68HC908AB32 processor, which is on the HC908 Daughtercard heart of the Micro908 platform. Using the AA908 Antenna Analyst software as a starting point proved to be very convenient, as that software already provides a great deal of the user interface control for the rotary encoder and LCD display. Further, the entire architecture of the AA908's "VFO" mode of operating serves perfectly as the starting point for a radio controller. The basic operations needed by a radio controller ("move frequency" and "select bands") are augmented by the supporting framework (user-settable configuration, field-upgradable software updates, backlight control, scanning rates, et al.)

The only major new software that was needed for this prototype was a new driver module to handle control of the two AD9834 DDS chips, instead of the single AD9850 chip used in the stock DDS Daughtercard of the Micro908. This ultimately proved quite straightforward and the "SDR-908" software application running on the Micro908 now can control the DDS2 card. Experimenters may obtain the binary loadable SDR-908 code for loading into their Micro908; or they can get the source code for this too, as the project is completely Open Source and freely available.

The **signal processing code** is the other software component of this project. Here again, we were extremely fortunate for having an architecture in the Micro908 that provided convenient use of a digital signal processing board used in several other notable products. The KK7P DSPx card is a small daughtercard containing a powerful Analog Devices ADSP2185N signal processor, CODEC and supporting circuits that is simply ideal for our use in our Portable SDR project. The DSPx card has been successfully used in the DSP-10 product, the Elecraft K2 transceiver, and *(ta da!)* in the Micro908 controller as a programmable audio filter. So again, the architecture of the Micro908 served us very well by providing the mechanism to get new DSP code into the DSPx Daughtercard, as well as handle routing of the stereo input and output signals to/from the DSPx card.

The actual DSP code that runs on the DSPx card is used to demodulate the IQ audio signals being presented to the card from the SoftRock-40 module. It is the 18 MHz transceiver code from EMRFD, which is an I+Q demodulator with filters. This code has an SSB bandwidth mode and a CW bandwidth mode, as well as volume control – all handled by having the Micro908 pulse a couple of IO lines on the DSPx. Lyle helped modify this code for VK6APH and VK6VZ for their Buccaneer 160m receiver article in the July 2005 issue of RadCom, and it will serve us just as well right here in our Portable SDR prototype. We are working through integrating and testing with this code right now in the Micro908.

Conclusions *… so far!*

We are showing that with a DDS2, a QSD and a DSPx module, and a simple microcontroller, an all-mode, self-contained, portable receiver could be constructed. Such a receiver would provide high sensitivity, good strong signal characteristics, plenty of appropriate selectivity, rock-solid stability and be capable of all mode operation. It could also incorporate typical DSP features like denoisers, notch filters, and decent AGC.

We intend to continue refining the project and describing the digital modules comprising our "analog radio". We hope that you'll follow along … and perhaps you'll even get some ideas that you too can build upon!

Lyle KK7P, and George N2APB

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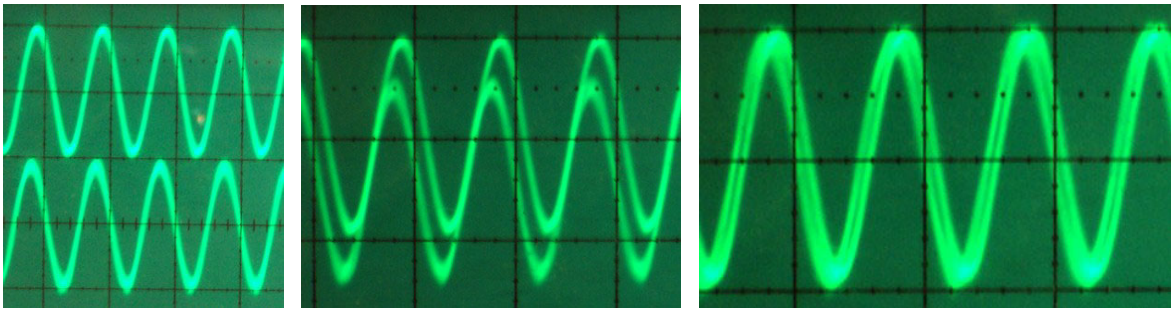
SIDEBAR: DDS Limitations

As mentioned earlier, a DDS is not necessarily the best solution for all radio designs.

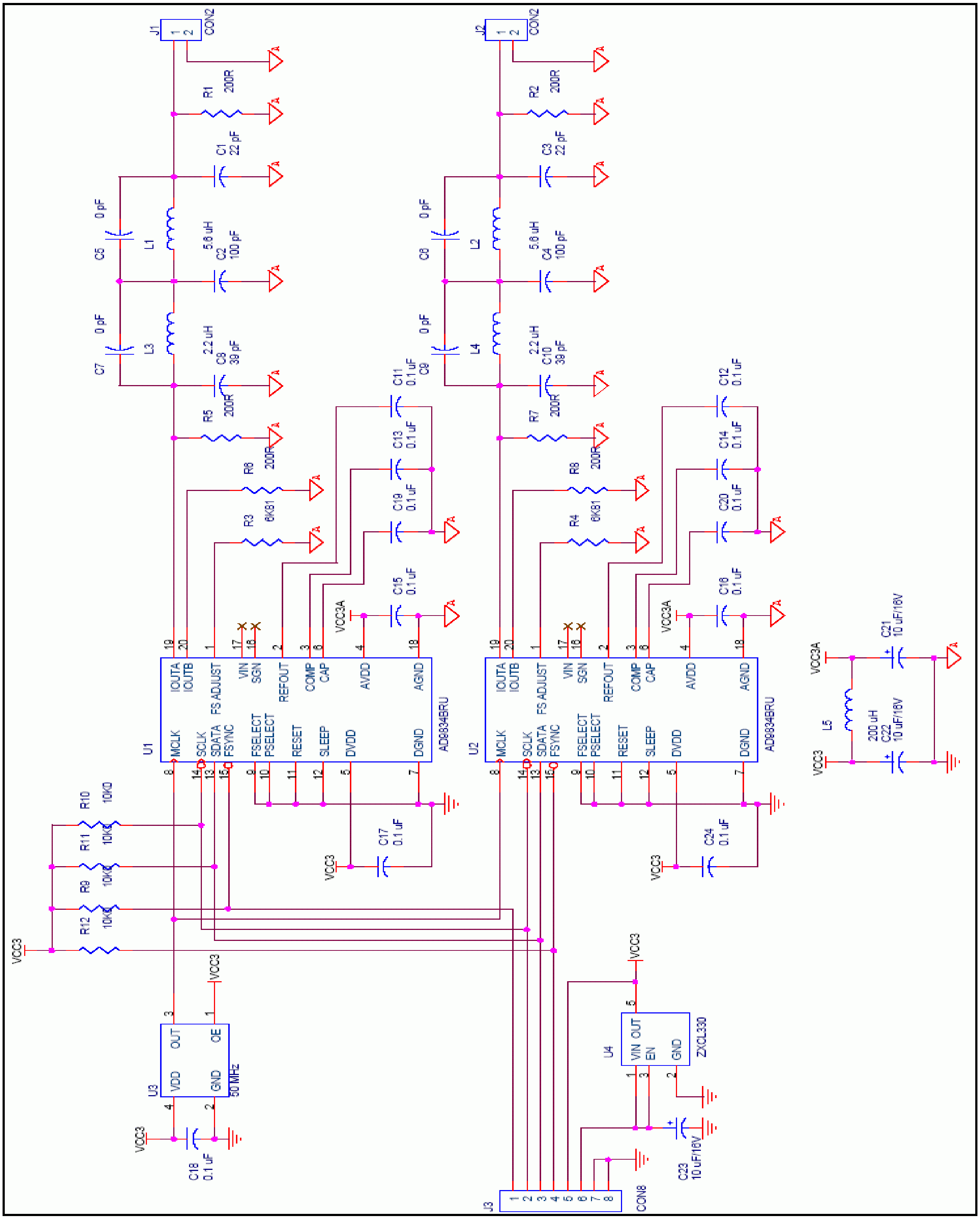
DDS outputs often have spurs, which cause howls and whistles and other annoying manifestations. There are ways to work around some of these, of course, but simple filtering isn't enough. And some spurs can be quite prominent, so you have to be very careful if you want to amplify and transmit a CW signal directly from a DDS chip.

A DDS system can consume a lot of power. The DDS2 prototype with the low jitter oscillator draws around 40mA. A low-power oscillator can cut this down to perhaps 10 or 15 mA, but with increased phase noise and an increase in material cost.

Many receiver and transmitter mixers are happiest when fed with a square wave. This means more parts to make a good clipper/limiter, and more power consumption. Some DDS chips include a comparator for this purpose, but they are designed for microprocessor clocking, not local oscillators, and are typically very noisy. Some care must be used when making a wave shaper for a mixer that doesn't want clean sine wave injection.



DDS2 waveforms showing (L-R): Separate (identical) signals from U1 and U2, scope images partially overlayed to show (adjustable) phase control, and fully overlayed scope images.


J1
CON2
R1
200R
C1
22 pF
C5
0 pF
L1
5.6 uH
C2
100 pF
C7
0 pF
L3
2.2 uH
C8
39 pF
R5
200R
R6
200R
R3
6K81
C11
0.1 uF
C13
0.1 uF
C19
0.1 uF
C15
0.1 uF
VCC3A
U1
IOUTA
IOUTB
FS ADJUST
VIN
SGN
REFOUT
COMP
CAP
AVDD
AGND
MCLK
SCLK
SDATA
FSYNC
FSELECT
PSELECT
RESET
SLEEP
DVDD
DGND
AD9834BRU
C17
0.1 uF
VCC3
R10
10K0
R11
10K0
R9
10K0
R12
10K0
J2
CON2
R2
200R
C3
22 pF
C6
0 pF
L2
5.6 uH
C4
100 pF
C9
0 pF
L4
2.2 uH
C10
39 pF
R7
200R
R8
200R
R4
6K81
C12
0.1 uF
C14
0.1 uF
C20
0.1 uF
C16
0.1 uF
U2
AD9834BRU
C24
0.1 uF
L5
200 uH
C21
10 uF/16V
C22
10 uF/16V
U3
VDD
GND
OUT
OE
50 MHz
C18
0.1 uF
U4
VIN
OUT
EN
GND
ZXCL330
C23
10 uF/16V
J3
CON8

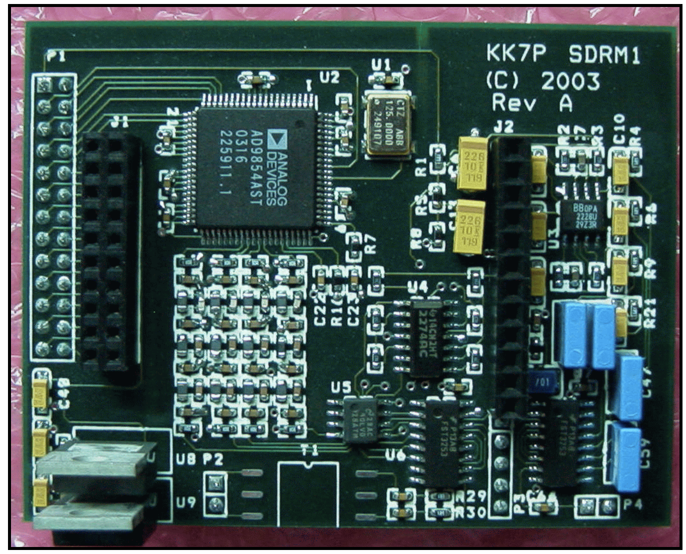
AmQRP.ORG HOMEBREWER

Lyle Johnson, KK7P

Digital Building Blocks for Analog Radios

(or, The Natural Evolution of the Iambic Keyer)

Over the years, hams and especially QRPers have developed a serious curiosity about radios and how they work. Especially HF radios. Especially HF radios that operate CW. Especially HF radios that operate CW and are very portable. That curiosity leads to interest in home construction of such radios.



Introduction

If you go back a few years -- OK decades! – and look at the construction articles in various magazines and handbooks, it is clear that radios used to be made out of parts. Tubes, transistors, resistors, capacitors. Radios had knobs and switches and schematics that revealed how they worked

Fast forward to the last decade or so, and we find all sorts of integrated circuits have crept into our radios. Some, like the NE602, we accept. We may even like them. Others are simply little black boxes whose internal functions are secret.

Often, the ones we like get discontinued by their manufacturers as the competitive world of mass produced electronics abandons repairable devices in favor of highly integrated disposable devices, like cell phones and video games.

Along the way, parts have become more friendly to machines and less friendly to humans – or so we like to think. Integrated circuits are more integrated and complex, and have tiny little leads that are hard to see. If they have leads at all…

How is a homebrew radio aficionado to cope?

How can we turn this apparent problem into a resource to be applied?

In short, how can we use these tiny, sophisticated parts in our home built HF radios that operate CW and are highly portable?

In this paper, I'll focus on receiver design simplification. Of course, the same techniques can be applied to the transmit side.

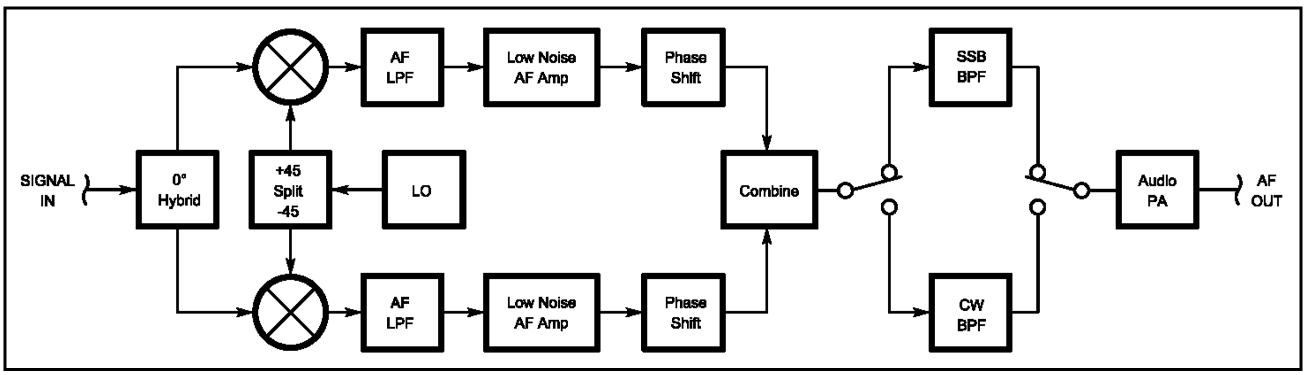
Approaches to Receiver Design

There was a landmark article in November, 1968 by Hayward and Bingham on Direct Conversion Receivers. Such receivers briefly caught on, epitomized by the Ten Tec Power Mites of the late 60s and early 70s. We still occasionally use such receivers.

But in our crowded bands of the 21st century, we often need better performance. At a minimum we want “single signal” selectivity, so we only hear one side of “zero beat.”

There are two fundamental approaches to this requirement: image rejecting direct conversion and the superhet.

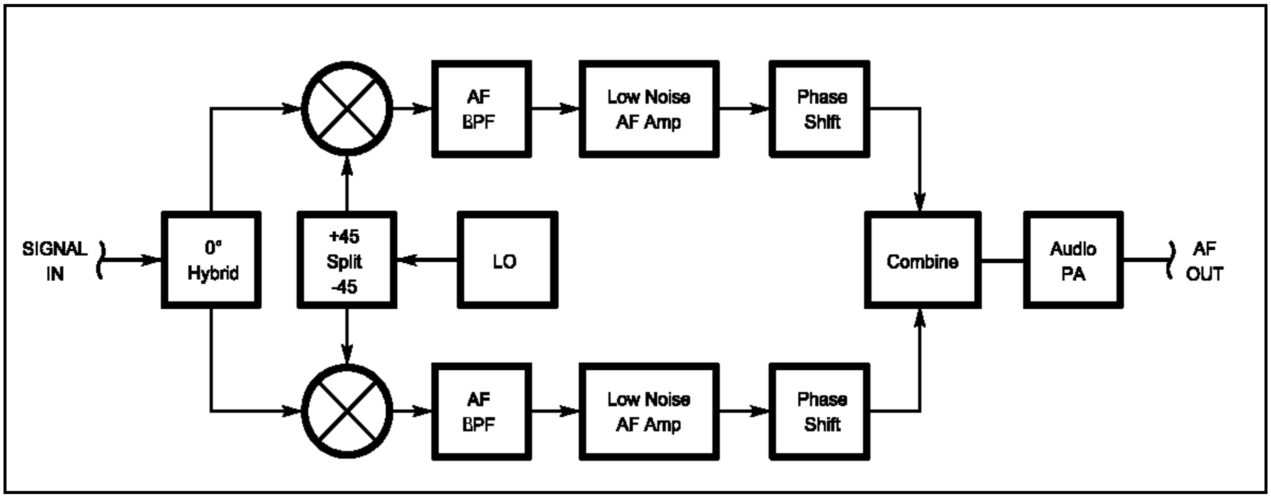
Image Rejecting Direct Conversion



Block diagram of a typical image rejection direct conversion receiver.
(From 2005 Edition of the ARRL Handbook.)

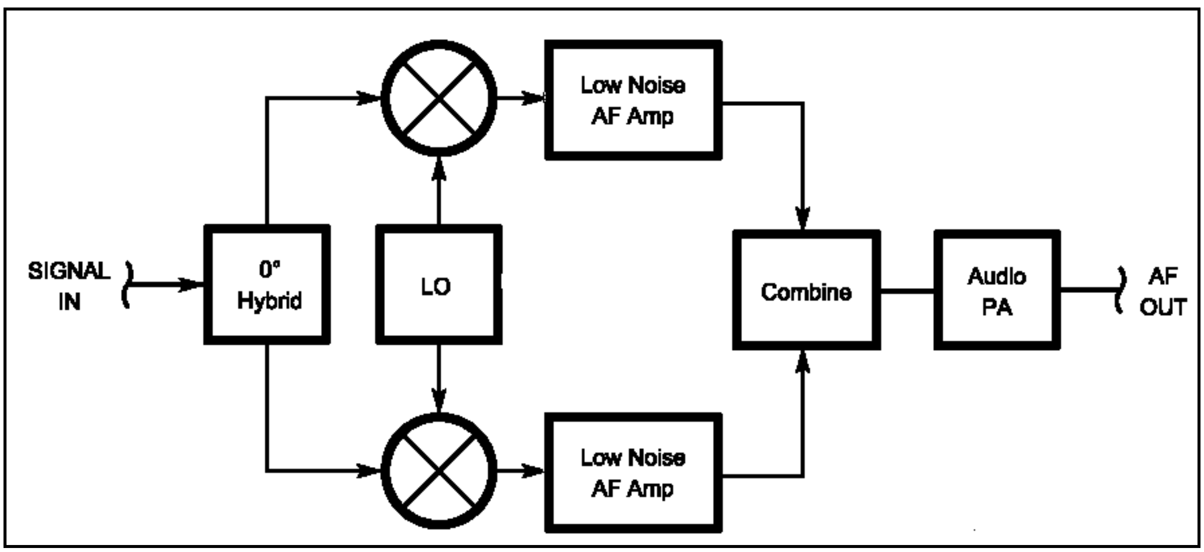
Rick Campbell, KK7B, popularized this type of receiver with his series of articles on the R2. For the homebrew radio constructor, challenging areas are the LO with +/- 45 degree phase splitter, the matched AF LP Filters, the audio phase shift networks and perhaps the band pass filters.

A variant of this approach deals with the mixer, and is variously called the Quadrature sampling detector (QSD) or the Tayloe detector. In this design, filtering is part of the mixer itself. The block diagram looks like this:



Quadrature sampling (QSD) detector, aka the "Tayloe detector"

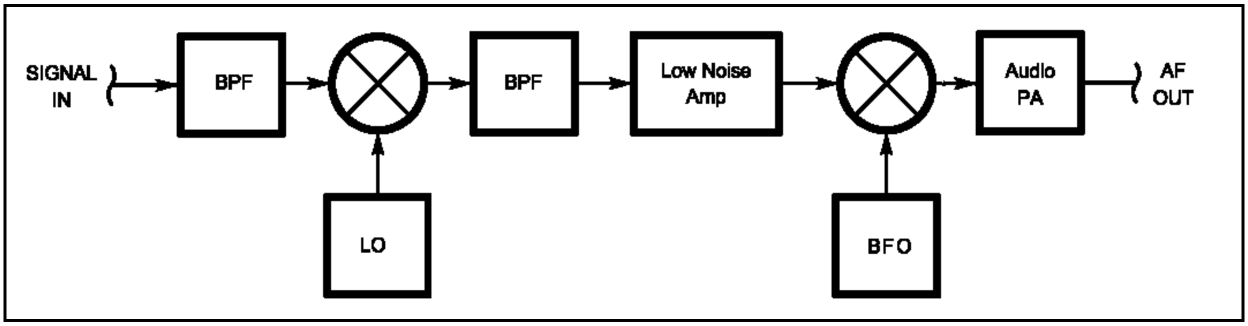
Our goal is to make the block diagram look like this:



We'll examine how to do this after we quickly review the superhet!

Superhet

The tried and true mainstay of most radios is the superheterodyne receiver. A typical block diagram of a simplified superhet is:



Block diagram of a simplified superhet

Of course, we can add all sorts of filters, AGC and so forth.

Our goal with the superhet is to combine the LO and BFO and add a lot of flexibility into the block marked Audio PA.

On to Digital…

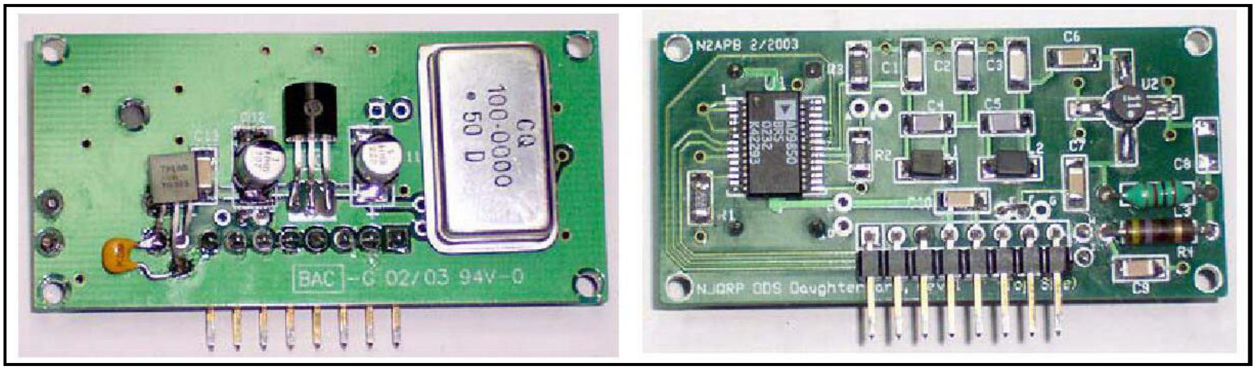
Many QRpers' eyes glaze over at the mention of anything digital. Direct digital synthesis and digital signal processing are often considered too complex for the average person to grasp or apply – especially digital signal processing (DSP).

This paper is not a theoretical tutorial on what these techniques are; it is a guide to help you apply these technologies as "black boxes" in your homebrew radio designs.

DDS

The techniques of Direct Digital Synthesis (DDS) have been brought to the world of QRP by such groups as NJQRP, AmQRP, Elecraft, KD1JV and others. The idea is to use a crystal controlled source to create a precision sinewave. The advantages are excellent stability, precise control, and low phase noise (broadband noise). The disadvantages are lots of (usually small) spurs, complexity and power consumption.

Fortunately, Analog Devices (www.analog.com) has focused on DDS products for several years and reduced an entire DDS to a single chip. This eliminates complexity from the list of disadvantages. NJQRP has created a simple **DDS Daughtercard**:



DDS Daughtercard by the AmQRP uses AD9850 DDS chip to produce simple-but-effective 1-30 MHz signal generator in modular form-factor

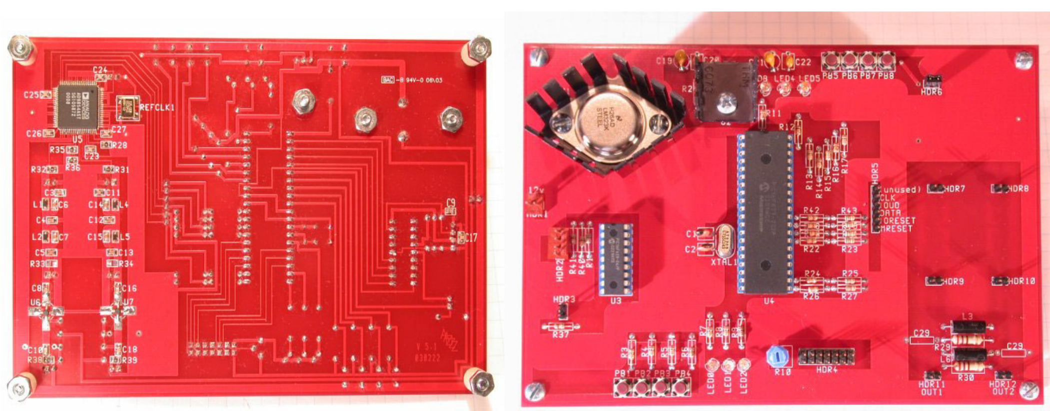
Two features are here that I call to your attention.

- The tiny, surface mount DDS chip can be soldered onto a PCB by hand
- The entire module can be treated as a single, large component for various construction projects.

The DDS Daughtercard measures 1” x 2” (2.5 x 5 cm) and is based on the Analog Devices AD9850 or AD9851 chip. It provides an output signal in the range of audio to about 30 MHz. It consumes a few hundred milliwatts.

For our image rejection direct conversion receiver, we need two LO signals that are matched in amplitude and differ in phase by 90degrees. This is called phase quadrature, and you often see the two signals list as I and Q for in-phase and quadrature. We might use a pair of DDS boards to get these signals, or we could use a special DDS that provides the required two signals.

Analog Devices makes a specialized DDS, the AD9854. It provides quadrature signals. AmQRP offers a kit designed by Craig Johnson using this chip, the **IQ-VFO**.

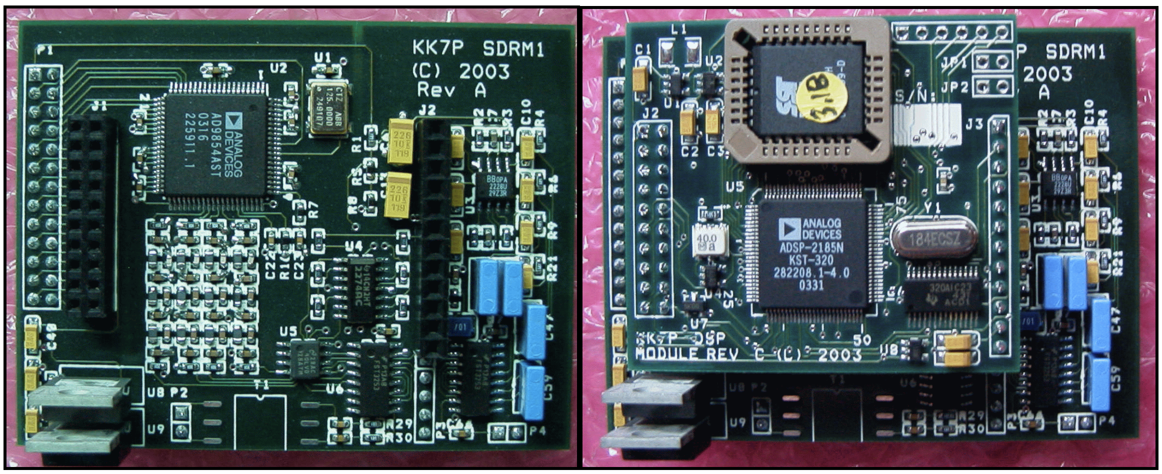


IQ-VFO project by AA0ZZ uses AD9854 DDS chip to produce high-performance quadrature output signals

The DDS chip is the small square device in the upper left corner of the left photo. The rest of the board is mostly control circuitry provided by a pair of PIC processors. This project is useful as a standalone signal source, but may be impractical to embed in a small, portable receiver.

The **SDR-1000 Software Defined Radio** by Gerald Youngblood uses the AD9854 as the quadrature LO for a quadrature sampling detector style radio. This product was reviewed in the April, 2005 issue of QST.

In late 2003, I became interested in applying the AD9854 and created a small module, pictured below. This particular module also incorporates a quadrature sampling detector with low-noise post-amp as well as a quadrature sampling exciter. It should be good over the entire HF range. All it needs is a decent amplifier/filter system on the RF side and…



Custom-design AD9854 DDS card by the author … and same board with his DSP module plugged in

What are the connectors on the top of the board for? An associated DSP module, of course!

This is a complete image rejection DDS/DSP based transceiver core. Just add the RF amplifiers/filters, a power supply and a suitable microcontroller, like the AmQRP HC908 Daughtercard, and you have a very versatile radio!

The AD9854 is an excellent DDS chip, but it does have the drawback that it consumes a watt or more. OK in the shack; not OK in the field.

In the area of low-power DDS, Analog Devices once again makes the part we need. The AD9834 can provide output to 15 or 20 MHz, and consumes only a few mA at 3V. Two popular radios based on this DDS chip are the Elecraft KX1 and Steve Weber's ATS-3.

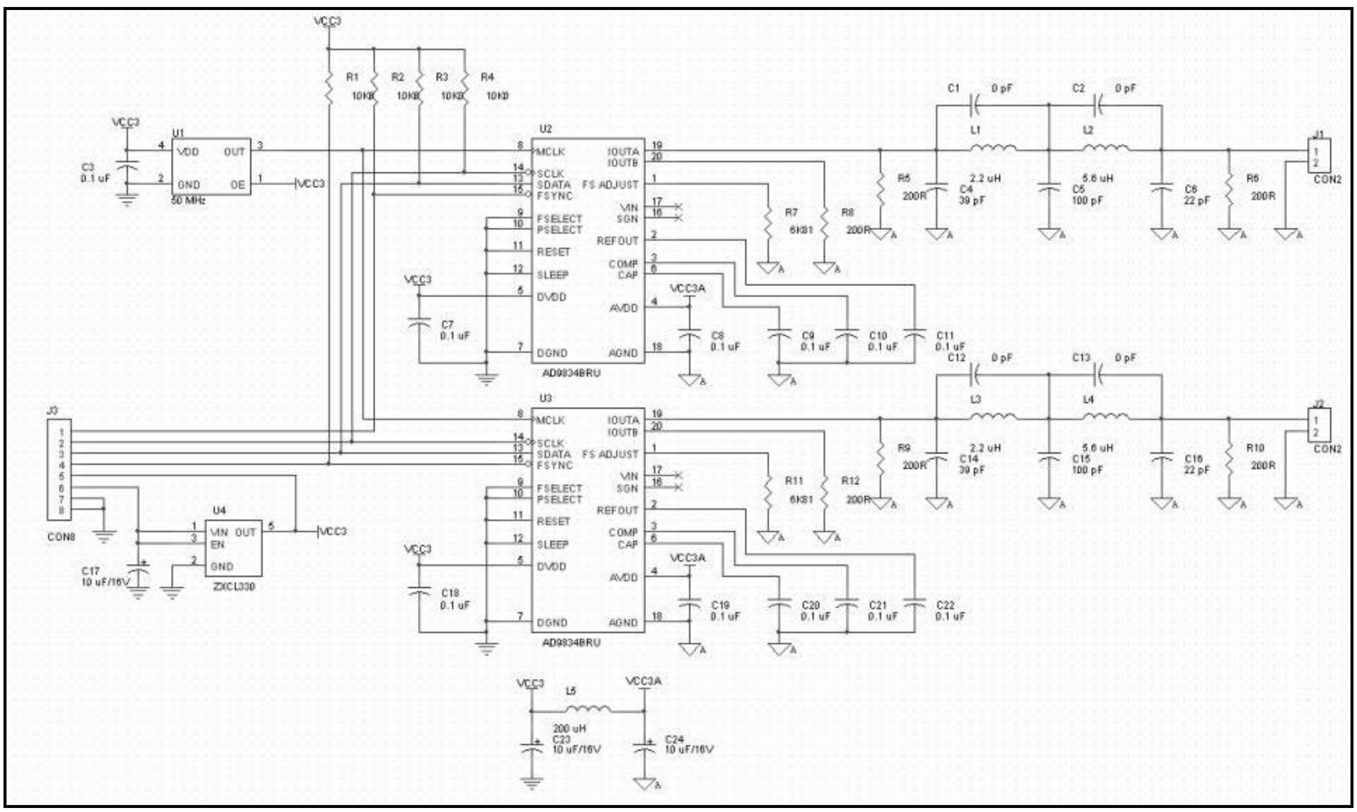
Too bad the AD9834 doesn't offer a quadrature option… or does it?

It turns out that a pair of AD9834 chips can be driven from a common clock oscillator and have their programming control lines set up in such a way that the pair can in fact provide quadrature output! Hhhhmmmm…

KX1 transceiver by Elecraft

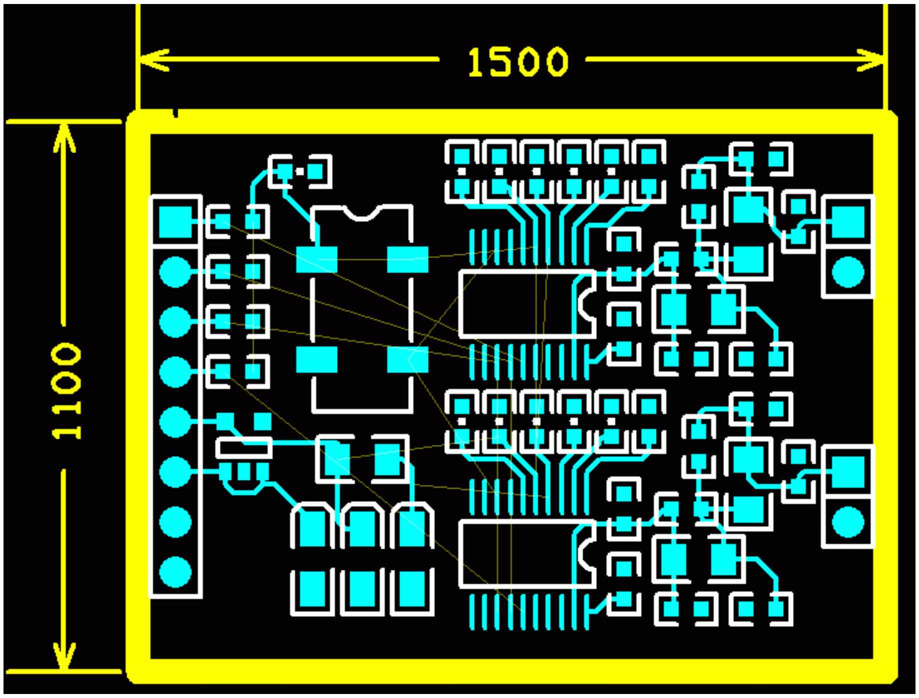
ATS-3 transceiver by KD1JV

Another home project I am working on is a small dual-DDS card based on a pair of AD9834 chips. Here is a schematic:



Schematic for KK7P dual-DDS design based on AD9834 DDS chips, producing two coupled signal generators capable up to 20 MHz

The PCB layout, nearly complete is here:



Prototype pcb layout for the dual-AD9834 DDS project

The board measures only 1.1" x 1.5" (2.8 x 3.8 cm) and offers two quadrature, tracking outputs or two independent outputs at frequencies up to about 20 MHz. The quadrature mode is for experimentation with image rejection direct conversion receivers and transmitters. The independent output mode is intended for use in superhet receivers and transceivers.

DSP

Have you ever used a keyer to send CW?

If so, you have probably used transmit side digital signal processing (DSP)! That's right, DSP! In this case, you used a sampling filter. The input is your paddle and the output is the keying signal to your transmitter.

How else might you apply DSP to a homebrew radio?

For more than a decade, manufacturers of digital signal processor chips have made evaluation boards. These are intended for engineers to quickly get familiar with a particular DSP chip in the hope that they will then design it into high-volume products, resulting in increased integrated circuit sales by the DSP chip maker.

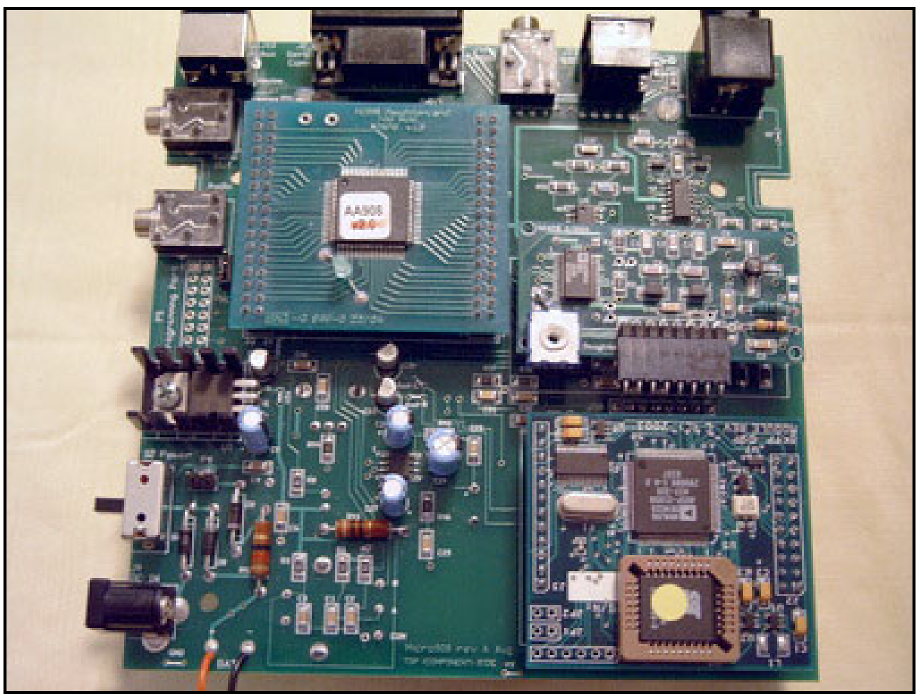
Enterprising hams saw these as an opportunity for experimentation, and in the early 90s there were all sorts of projects published using DSP evaluation boards as the core. Unfortunately, the DSP chip makers were selling these evaluation boards at cost or even less, and never intended that they be produce din volume. They have since raised the prices, and most evaluation boards are in the $300 to $500 range – out of reach for most experimenters.

In fact, PSK-31, a very popular QRP digital communications mode from Peter Martinez, was developed using a Motorola 56002 evaluation board!

One of the more popular boards was the EZ-Kit Lite from Analog Devices. When it sold for $89, it was a great value and many interesting Amateur projects were based on it, including the DSP-10 2-meter Software Defined Radio by Bob Larkin. Sadly, this evaluation board has been discontinued.

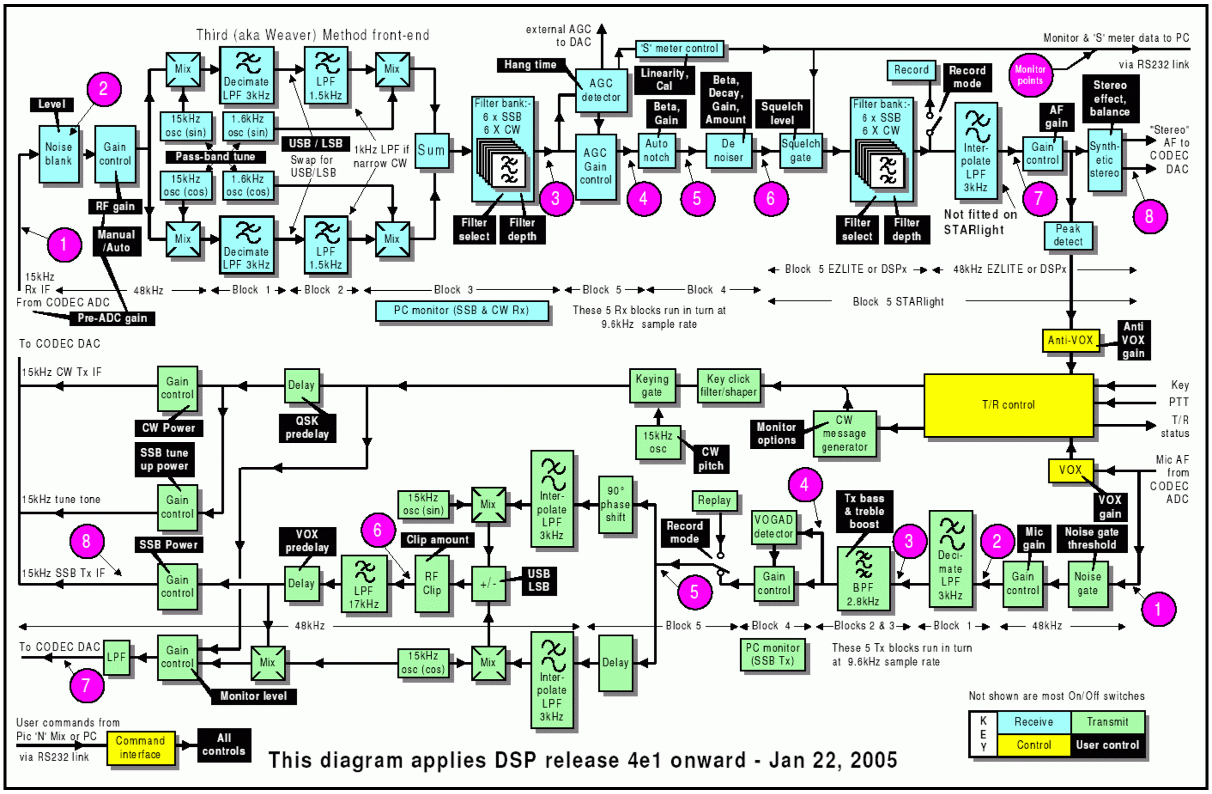
In early 2003, I created a small DSP module based on the Analog Devices ADSP-2185N DSP and a Texas Instruments two-channel analog-to-digital (ADC) and digital-to-analog (DAC) chip. A chip that incorporates both an ADC and a DAC is commonly referred to as a CODEC, for COder-DECoder. The American QRP Club integrated this module into their popular Micro908 platform and offers it at a very low cost to encourage experimentation.

Shown below is the Micro908 with the DDS card and the DSP card:



KK7P DSP Daughtercard shown mounted on bottom right corner of Micro908

What can such a DSP do in a radio? Here is a block diagram of the DSP functionality in the Pic A Star project by Peter Rhodes:



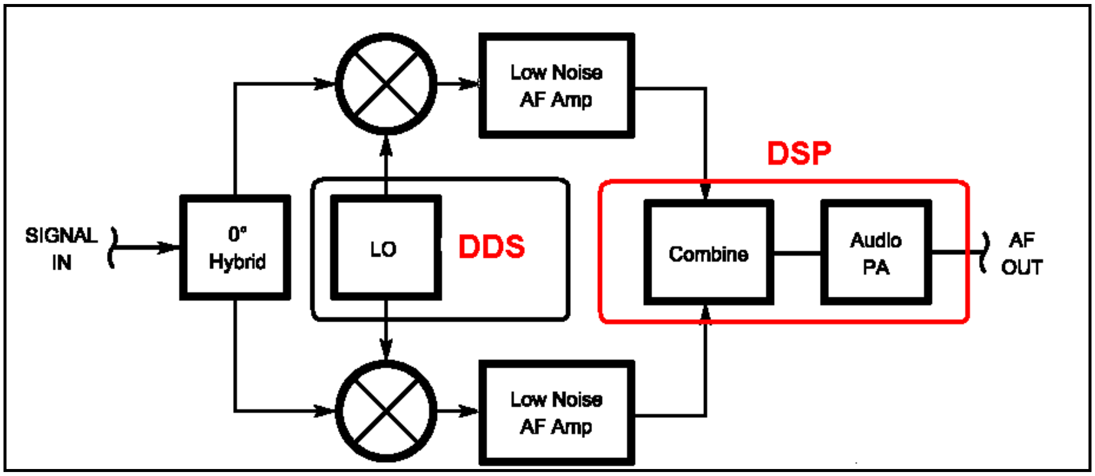
PicAStar DSP functionality

As you can see, a module less than 2" square can provide a huge amount of functionality! And as a bonus, the software tools for this DSP are freely available for DOS/Windows PCs from the Analog Devices ftp site on the web, as well as on the Micro908 CD-ROM.

Putting it All Together

Let's re-examine our earlier radio architecture block diagrams and see how we might enhance performance of our homebrew radios while leaving ourselves plenty of room for individual design and experimentation in the area we particularly love: RF!

Here is the image rejecting direct conversion receiver with DDS and DSP building blocks:

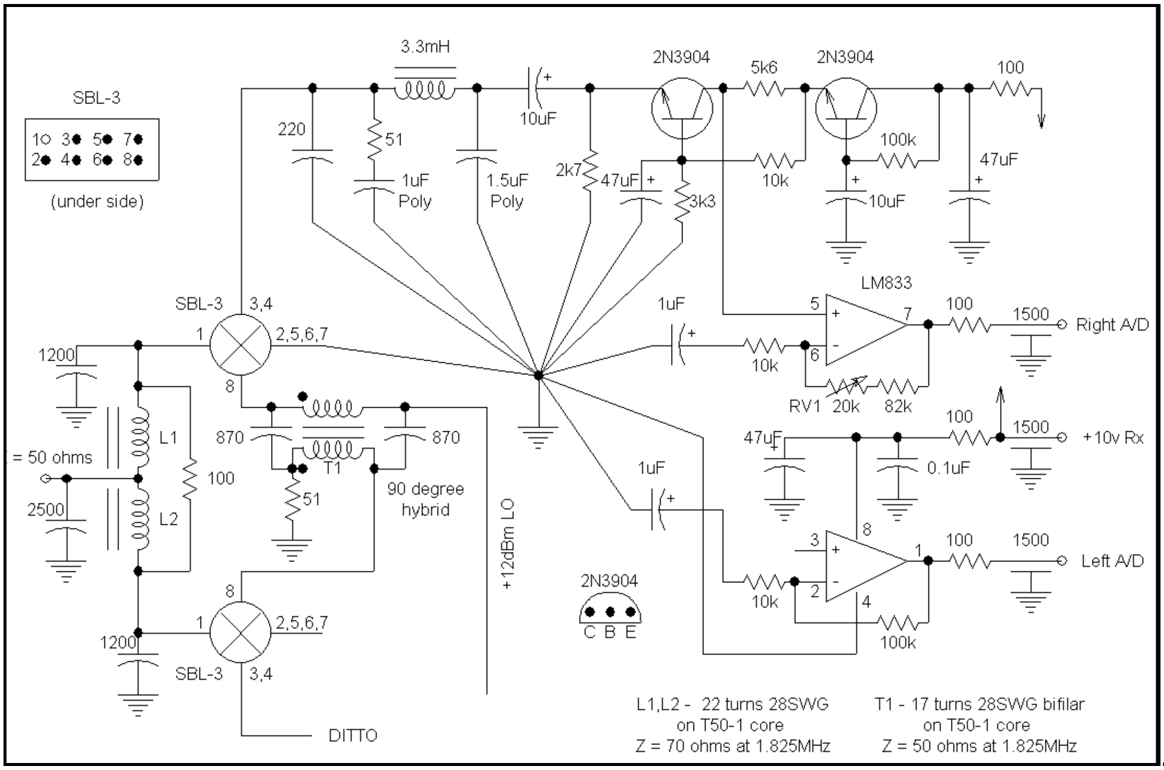


This gives us a receiver capable of operation from VLF through 17 meters or so. These are some of the features it could have, courtesy of the digital building blocks: low power consumption, drawing perhaps 200 mW; all mode operation, including USB/LSB/CW/FM; denoiser; manual and automatic notch filters; AGC; greater than 90 dB dynamic range. On transmit, or transceive, it could provide full QSK and include the keyer.

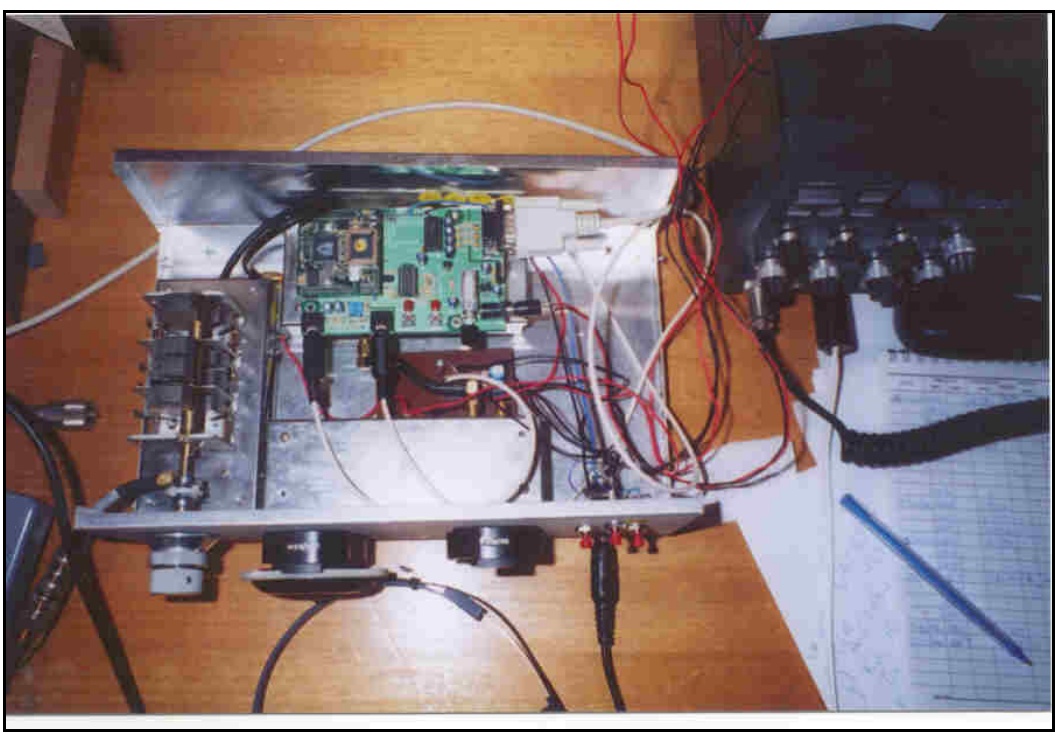
As the experimenter, you still get to wind the toroids and tinker with all the RF stages! Want smoother AGC? Use a QSD/Tayloe arrangement in the mixers and run the DSP as an IF DSP at 15 kHz or so. This is exactly what the SDR-1000 does!

Enough paper design, what about a real world example?

A couple of VK6 Amateurs in the Perth, Australia area decided to make a contest-class 160m radio. It doesn't use DDS. They wanted to avoid the spurs that a DDS unit might have, and since they only needed to cover a small frequency range, they elected to make a dual VXO, mixing the outputs to get enough coverage at 18 MHz. A simple LC network provides the quadrature phase shift. This is a portion of the radio design by Steve Ireland and Phil Harmon, showing the mixer and low noise AF preamp:



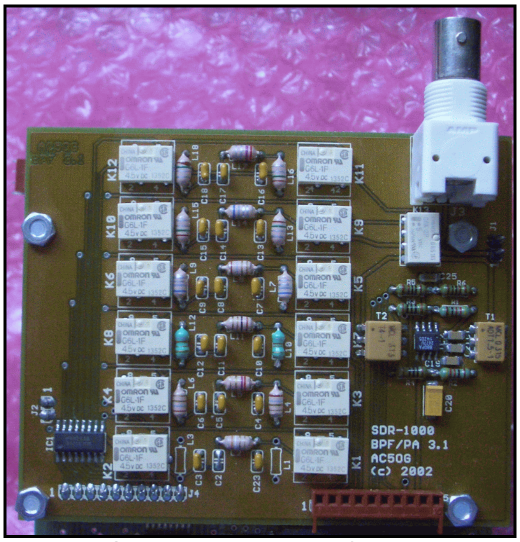
VXO by VK6 amateurs uses LC network to achieve 90-degree phase shifted outputs to drive these mixers



A view inside the completed VK6 160m radio

Note that this design was inspired by the 18 MHz transceiver in Experimental Methods in RF Design. It is also interesting to note that the EMRFD code was ported to the DSPx by a ham in the UK, which the hams in VK6 then applied. They wanted the filter response improved, which I did for them. A three-continent effort of cooperative experimentation!

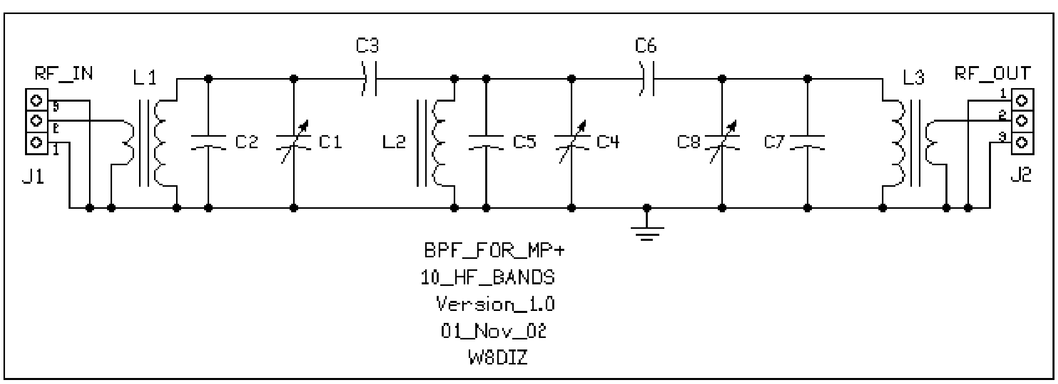
What if you want wider coverage? A set of bandpass filters can be built to cover the amateur bands, or even half-octave filters for general coverage. Here is a shot of the latter from the SDR-1000, which then drives mixers and a DSP not too unlike that shown above.



SDR-1000 bandpass filters

Kanga US offers modules for the KK7B R2 Pro receiver. LNA modules (RF amplifiers/filters) for various bands are available, along with the "Downconverter" which is a dual mixer board optimized for image rejecting direct conversion receiver operation.

What about other RF modules? W8DIZ offers kit modules for low pass filters, bandpass filters and receiver sections. Full schematics and PCB information is on his website, www.partsandkits.com. The design appears to be based somewhat on the Elecraft K2, and offers an interesting basis for experimentation. The bandpass filter board, for example, has 10 filters to cover all the HF amateur bands on a single PCB.



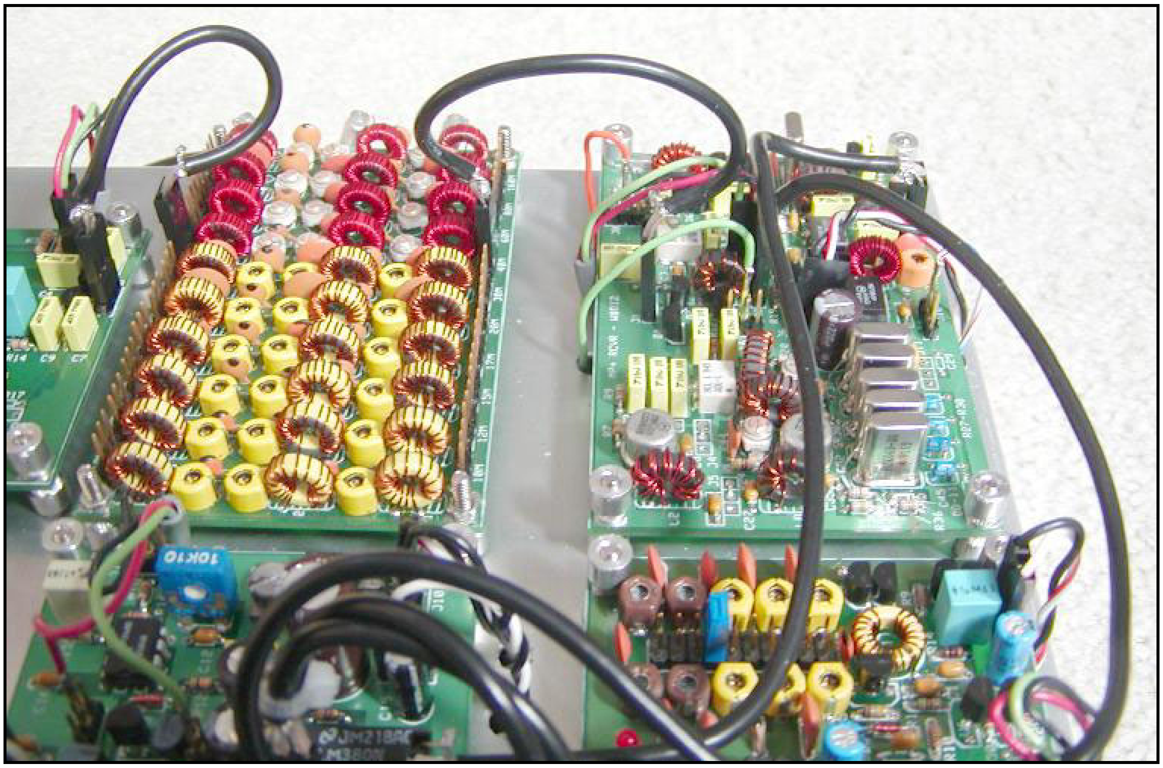
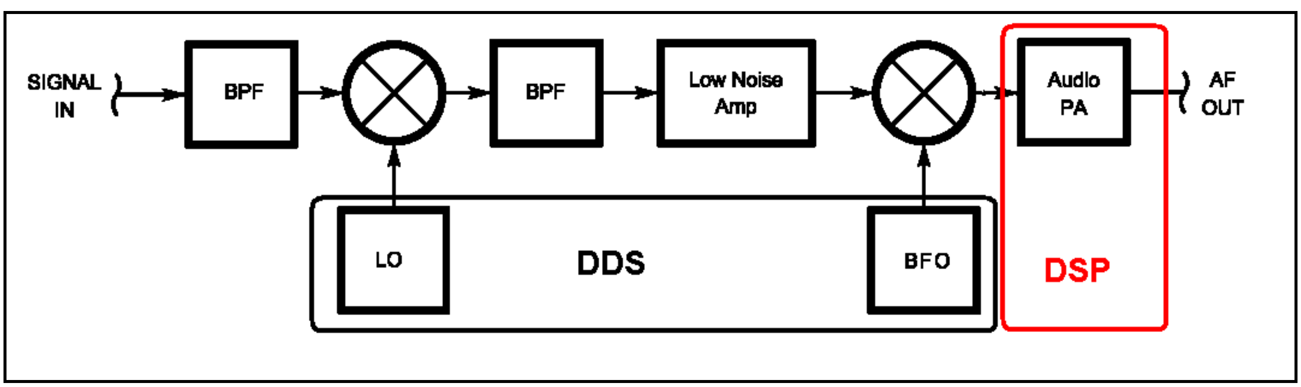


Photo from W8DIZ website showing the bandpass filter and receiver boards

The receiver board appears easily modifiable to accept DDS inputs for the LO and BFO.

The receiver board is a superhet.

Let's see what a superhet design based on the same digital building blocks might look like:



Superhet block diagram shown using DDS and DSP

This looks deceptively simple because I have not shown the AGC and various features that make such designs interesting…

If we pick a high enough IF, say 10 MHz or so, we can make the IF crystal filter from cheap microprocessor crystals. The IF amp can be simple, perhaps a single transistor stage or, if you want a really nice one capable of very smooth AGC action, consider an Analog Devices AD603. With low-side injection for the higher bands, we can now cover VLF through 30 MHz. Our LO would run from 11 to 20 MHz, coupled with our 10 MHz IF, to cover 21-30 MHz. We use combinations of high- and low-side injection to cover the frequencies below 21 MHz.

Oh, one more important thing. With this design, and a BFO under DDS control, we can convert the output of the product detector to a range of 15 to 20 kHz or so and get IF DSP!

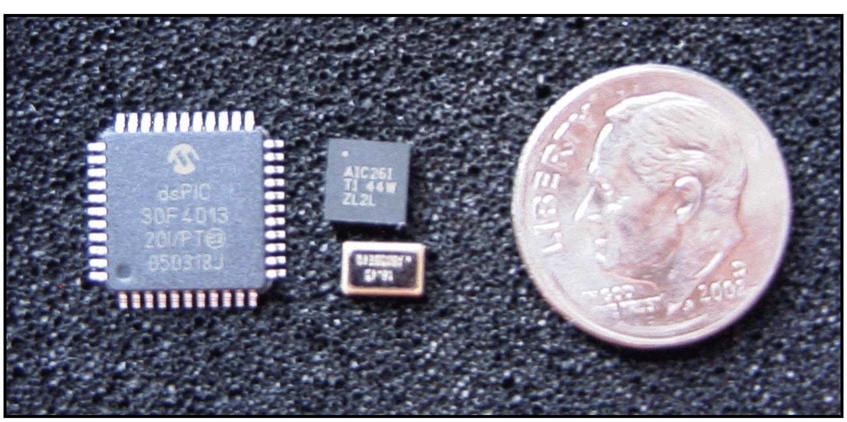
If you look carefully at the block diagram from the Pic A Star shown above, you will see that it is in fact an IF DSP system.

MiniDSP

Just for fun, I have also been designing a miniDSP module. The intent is to make an accessory that could be used in my KX1 or ATS3!

The key to this project is the new dsPIC from Microchip. Microchip has created a series of DSP chips that also include much of the functionality of their ubiquitous PIC processors. By using internal flash memory, a really tiny DSP system is possible. Texas Instruments makes a very small and low power CODEC which can be hooked directly to the dsPIC. Adding a miniature surface mount crystal and not much else and we have an AF DSP processor that can give improved selectivity, denoiser, notch filters, and simulated stereo effects!

The photo below shows the components alongside a dime. To the left is the dsPIC, the upper center is the CODEC with stereo headphone amplifier, and lower center is an 18.432 MHz crystal. The PCB could be not much larger than the dime if we use both sides of it… Hopefully, you will be inspired to do this before I do!



dsPIC, CODEC and 18 MHz crystal … compared to the size of a dime!

With the PIC features of the dsPIC, the unit could, for example, read the voltage of the WIDTH control on the KX1 to create a tracking audio filter. If WIDTH is set wider than, say, 1 kHz it would automatically activate the denoiser. A setting of maximum width would assume phone operation and cut in the automatic notch filter, too. AGC could be monitored to throttle back the denoiser as signal strength increased.

Keys to Successful Experimentation

As QRP homebrew radio experimenters, present day devices look intimidating and difficult to apply. I hope this paper has shown you that you can in fact use modern devices in your projects and take advantage of the features and convenience they provide.

In closing, I'd like to offer some observations on keys to successful experimentation.

First, consider using small modules as plug-in platforms for your projects. This allows you to re-use the modules in multiple projects. It also enables you to use proper grounding and shielding techniques that are often necessary, such as multiple-layer PC boards, for these components.

Second, subscribe to email reflectors and other internet groups that are based on or using the modules you apply. This gives you feedback from others, and allows sharing of design tricks, software, and so forth.

Third, recognize that these are just building blocks. Think of them as super-ICs. The ultimate creativity is in your hands. Freed from the need to deal with tiny parts, you can realize their advantages in your designs while you focus on the radio itself.

Fourth, don't be afraid to try! If you exercise reasonable precautions, these sorts of modules are extremely rugged and reliable.

Happy Experimenting!

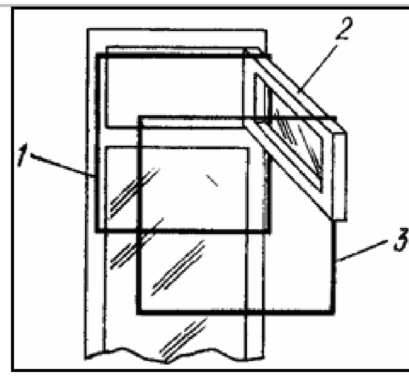
Lyle Johnson, KK7P kk7p@wavecable.com

AmQRP.ORG HOMEBREWER

Victor Besedin, UA9LAQ

145 MHz Experimental Antenna for Outdoor Use

The experimental antenna described here is light weight, can be easily taken to any place you like, and is put to operating position in short period of time.



Some words about the fact why to start for portable antenna from classic quad. First of all, the quad is two times shorter than a dipole. The second fact (the most important one) is that such antennas can be operated on smaller heights and are not sensitive to, for instance, hands which are situated at a distance more than 150-200 mm from the quad's side. The third fact is that such antennas as quad suppress noise and impulse character QRNs. The fourth fact is that this variant of quad has the DC short-circuit driver.

The cubical quad with 75-Ohm coax feeder [1] was taken as basic for the Experimental Antenna ("EA"). The distance between driver and reflector is equal to 0.2λ as shown in Figure 1, elements of basic quad: driver (1),reflector (3) were put onto casement window (2) inside the room. Such a construction can be situated outside fastened to the wall. Such antenna can be rotatable but only in sector of 120-150°. To stabilize the position of antenna hooks are a great help. Such antennas will be helpful for amateur radio and for TV reception too.

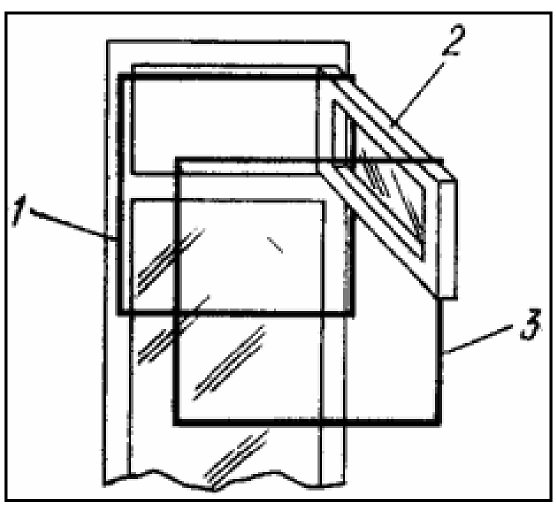


Figure 1

To start with, the test matrix for VHF-antennas was made of two parallel 1 mm dia. thick fishing-lines (some 250-300 mm in between) fastened to the walls inside of a wooden chamber some 10 cm from the ceiling. Elements of future antennas were fastened to the lines with the help of rings made of the same fishing-line material, wire-rings or plastic clamps (Figure 2): first of all there were two elements, then other were added one by one until they are 13 in number (max. for the room).

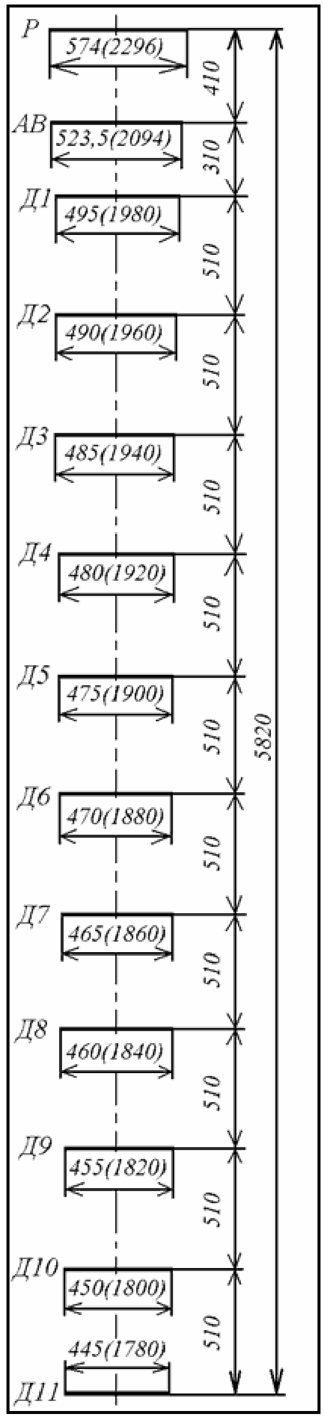


Figure 2

The element lengths of driver and reflector were designed according to the formula from [1] and checked after that on practice with the help of characteristics-meter X1-48. Directors were made by decreasing the length of every following element by 5 mm pro side. Elements were made from aluminum wires (3 mm dia. to metal) in isolation taken from 3-phase supply voltage cables (better will go the copper-plated aluminum in isolation – it is light weight and good for soldering). The isolation is not taken off and it is good for mounting purposes because wires with isolation of white, black and red color can be put in turn and the difference in size between the elements of the same color after two elements will be more visible. The lengths of sides of EA- elements and distances between them are seen in Figure 2, besides, there are their perimeters.

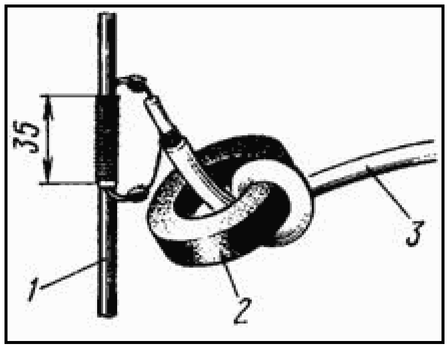


Figure 3

The input impedance of EA is about 45 Ohm. This antenna was fed through 50-Ohm (OD (outer dia)=4 mm) coax, its length was about 1 meter (Figure 3). At connection to driver element (1) there was a 20 mm-ferrite toroid (2) with μ = 20 put to the cable (3) with one winding on it. You can apply the γ – matching (Figure 4) to match the EA more close to the optimum either to 50- or to 75-Ohm coax cable. You can also come to the optimal match by increasing and decreasing the distance between the driver and first director.

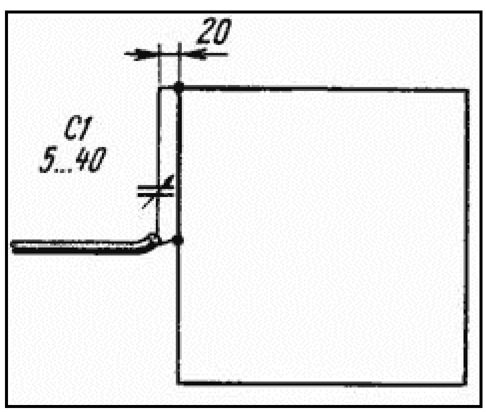


Figure 4

It must be taken into account that multi-element antennas would better have a stable construction – the distances between the elements on operation must be unchanged. As some experiments in the field conditions show two fishing lines are not enough – the antenna is “playing” in the wind like underwear when put to air. The best variant for these antennas is the rigid boom, but it is not good for the out - door operation. I suggest the project of an antenna without the boom (Figure 5). Now there are four lines of fishing-line or of tennis-string (1) they are bound each to its corner inside of the element (2) and this way to all the elements to set the distances according to Figure 2. The lines must be 3…4 m longer than (at each side) the EA axial length to have the opportunity to tie the antenna to posts, trees and so on.

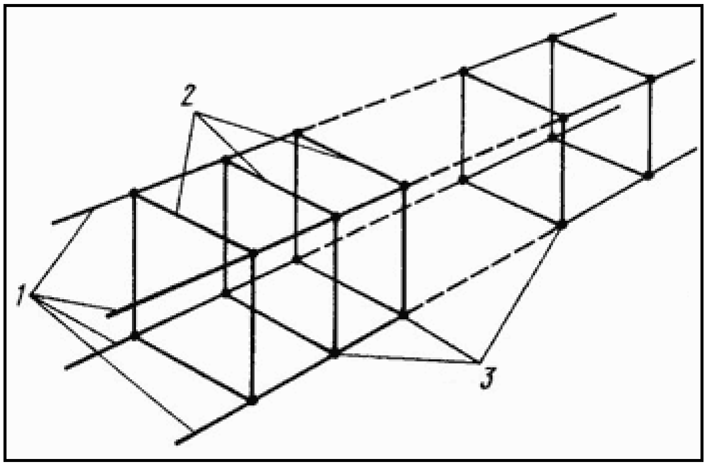


Figure 5

For proving the constructive reliability You can put a pair of supporting frames (2) made from wood protected against moisture (Figure 6) at the ends of lines (5) which are fastened to frames in their corners.

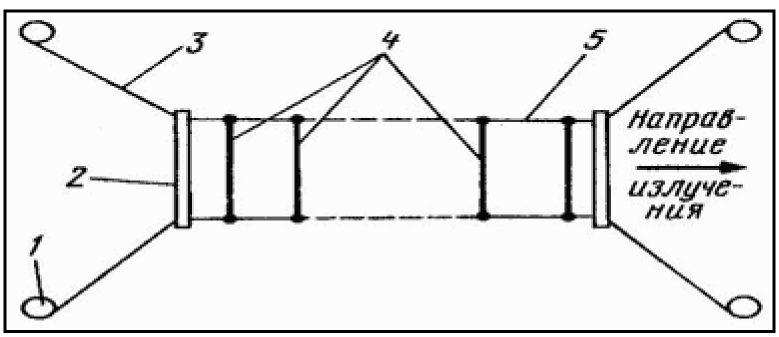


Figure 6

The EA is then spined out with the help of supplementary ropes (3) (here: 1 – posts, poles, supports; 4 – EA-elements). If one would like to install the small wooden bars (4) to the frames (Figure 7), he can get a groove to hide EA-elements (3) and ropes with lines in such compact position EA can live its shelf-life and be taken to any place You like. To fasten the parts of enclosure (frame 1 to frame 4) You can use hooks, clamps or isolation (or scotch) band. The feeding coax can be wound along with the elements or put off if there is a connector.

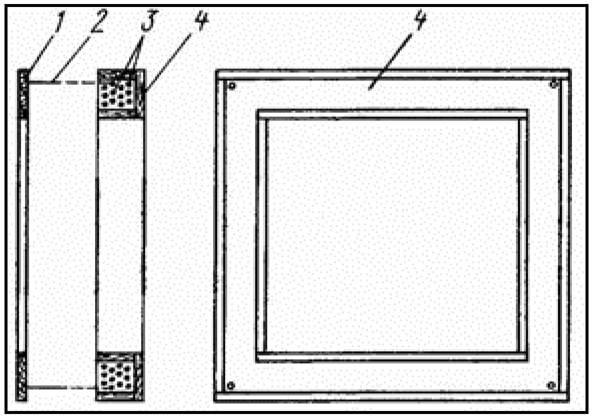
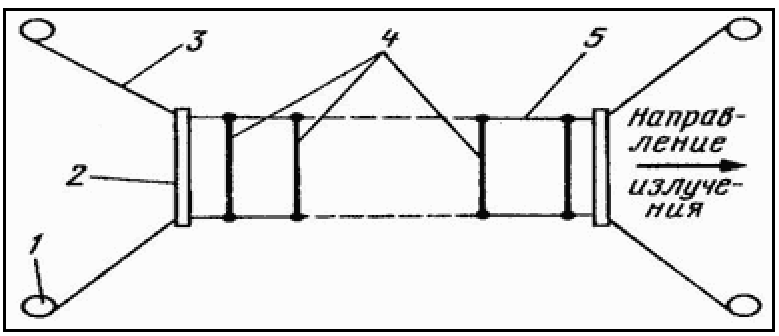
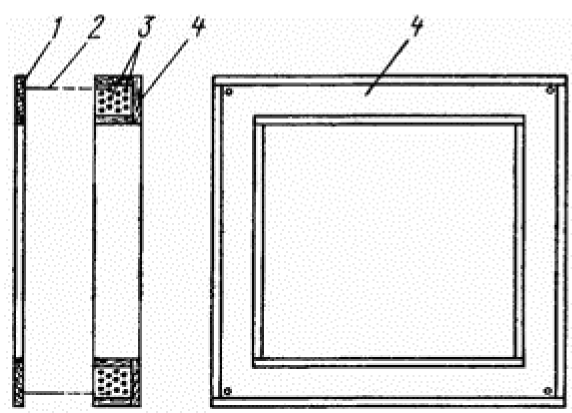


Figure 7

EA-elements are to produce from the straight pulled (tensioned) wire. Cutting the fragments to element lengths do not forget about reserves for connecting the de-insulated ends by means of welding, soldering or simple twisting (the last can be the means of adjusting elements to their frequencies if desired).



The small tail has no influence on EA-parameters, it is more important to observe element dimensions. The connecting tails are better to put to the same position for instance the right bottom corner for all elements. The elements must be strict flat, situated strict parallel to each other and look coax (concentric) from the reflector's side.



Pointing to the desired station signal can be done according to Figure 8 holding EA by hand at the frame (5) or rope (6) behind the reflector for minimum body influence on EA.

Rope (2) fastened to the frame (3) at the directors (4) side is to fasten to trees (1). After finding the right direction EA is to fasten at frame corners - EA will not be rotated in the wind.

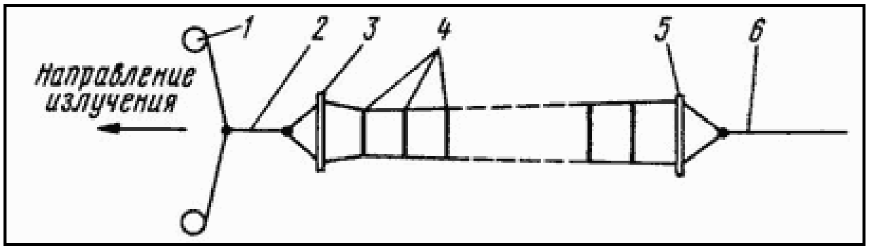


Figure 8

Further EA testing was held low at the ground surface in drainaged marsh at my "dacha" (fazenda, rancho are synonymous to dacha but with national colourite). The highest point of EA was situated at height of 1,8 m above the ground. EA was spined out between the shed's wall and a board (plank) diged into the ground and strengthend. The distance between my fazenda and friends in the city was 22...24 km. Of course, no straight sight as it were if there was the hill slope. No hills here, only marshes low plain land covered with woods and bushes. The fore lap of EA goes through the road (at 200 m distance from EA) on dam dividing the aperture of EA in two equal parts, there are forest and bushes behind the road (at 350…500 m distance from EA) - the situation to be seen from Figure 9.

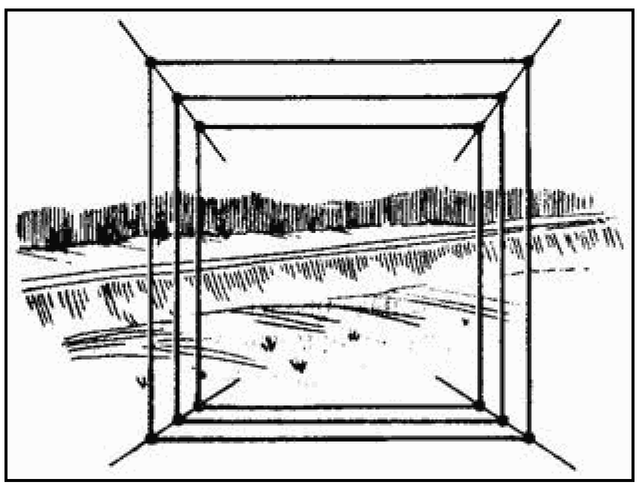


Figure 9

At good production the "spot" radiated from EA at 0,7 – level will be 25…30˚ x 25…30˚ and the gain is above 16 dBd. At not thorough production the spot is dispersed and the gain decreases. If there is no possibility to make mechanically stable construction (EA is stable on 4 lines) You can make the portable 5-element variant of EA with the given dimensions and thicker wire, but the fewer element antennas have to be situated higher referred to ground to omit the reflections from the ground near EA according to broader fore lap. Still the elements are to be stable in this variant, too. When You operate in woods, special in vertical polarization, take better not thick places but opened to desired stations (better elevated ones). Spin out Your antenna in between the trees but let no trees be near EA in the fore lap.

So, EA can be collapsed like harmonica or fishing tools. It is the advantage of this antenna. Now the QRP station can be powerful presented in local nets and repeaters being out-doors. The disadvantage of this antenna is a bit longer time for spinning it out for changing the direction, but if You prepare all the hooks beforehand it would not take You more than a minute.

13-element version was set to 145,5 MHz. With slight modification and even without it EA can be explored through all European 2m amateur band. EA gain is more than 15-16 dBm, the 0,7-level fore lap (vertical and horiz.) is less than 30°, the input impedance is 45 Ohm, SWR (145.5 MHz) is 1,8 with 50-Ohm coax and toroid shown in Figure 3.

Though there are applied the amateur methods of investigating the EA (and getting punishment from wife for the mole hollow outs in vegetable rows) it is worth the attention. May be one would like to model it in some antenna soft and show us the hidden draw-backs. My sides there was Yeasu FT-11, my friends use IC-706 Magyar FM-164 and Yeasu FT-270. At distances 24..-25 km with low spined out EA and 0.3 watts out, my friends tell me my sigs to be 3 to 4 S-points according to S-meters (rather coarse ones: squelch works perfectly and readability is 100% at no indications of S-meters at all). According to the regulations 1 point means the reception is impossible, thus the level of my 0.3 watts TX there was strong enough for good quality receiving and traffics. After I had switched to max. pwr. out - a bit more than 4 watts, - my friends reported the signal growth to 59, 59+10 and 59+20 dB QSB. The test was in FM mode. Friends use vertical dipole, collinear antenna and 5-el vertical Yagi fixed pointing a bit aside of me, all were situated on the roofs of 5-storried (collinear on 9-st) houses in the far corner (from me) of the city.

I've noticed the influence of moisture on leaves and grass to the propagation near the ground. The rain has fallen the sun is shining again and 2 points of signal strength were gone. There was another test to compare the rubby of FT-11 to EA: the only changed spectra of noise no reception is possible to 59 with dB - both at 4 wtts output level. That's grand for a QRP!

The Yagi antennas so low above the ground will be completely detuned and mismatched. The longer elements of such antennas are to be treated with more care and put higher, but this is not always possible in field conditions, though the multi-band Yagi [2] is comfortable for carrying.

Experimentation with VHF antennas is comfortable to do on two fishing lines as it is mentioned at the start of this article. Elements of dipole antennas are simple to put down on lines and push them adjusting. Some specified clamps will be applied for protection from dislodge. For signal source can be used a mini-bacon [3] situated in the antenna aperture fore lap at distance over 10 "boom" lengths from antenna. The coax from antenna is led to RX input for adjustment (to max.) measure purposes. This method can be applied for constructing of TV antennas.

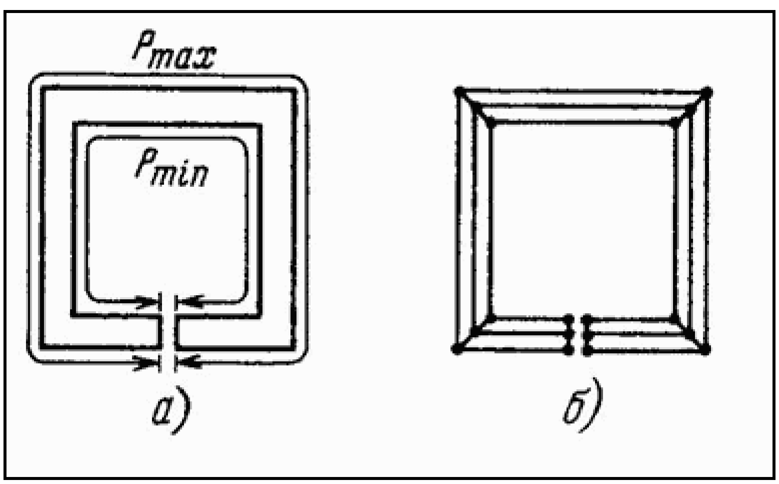
Some words about the coax connection to driver element of EA. Between the points of connection there must be an insulator insertion on which the feeding coax is to be fastened or it is the place to install a RF socket (BNC or other). The fast production of EA can permit the other method: the terminations of driver wire are bent (90˚) to the driver's side, flattened to better fixation of the coax wires, element wire is put one onto another (isolation upon isolation) and are fastened by thread-bandage protected from moisture (by isolation band or plastic clamps), - wire is not used here for it gives parasitic resonances in electro-magnetic field. The driver's shape is a bit collapsed but it is not important when (if only) the driver is adjusted to the desired frequency. The coax (put through ferrite toroid 16-20 mm dia. (Figure 3). The other coax termination is adopted to station output connector.

Polarization of EA can be easily changed by turning the driver to 90˚ other elements are untouched. Some discomfort comes with lack of coax weight compensation (the long and thick coax can be supported by Y-shaped branch or stand). The shorter coax is supported (along with the talky) by operator himself standing nearby. Coax is situated strict parallel to the ground (at vertical polarization).

The good antenna means not only the low output power of rig but also small batteries enough to DX QSO (as for VHF and QRP) as an equal partner. The difference between the antenna of a portable station and EA is grand!

The antenna was named as experimental. The home-brewer will decide by himself to better produce this project from available materials. The portable simplest version without long cable and wooden frames weight less then 1 kg. All the fishing-lines can be fastened with the help of plastic clamps, isolation or scotch band for transportation purposes. Other things to carry can be held with the same hand inside of the elements.

EA permits the operator to be close to its elements: minimal distance is 150…200 mm this fact permits to have the short coax. Important is the fact that EA can work on minimal heights (to 1 m above the ground), still, the higher the better. As for practice the upper side of EA must be situated not lower than 1 m (1,5…2,0 m are better). Distances between the elements are chosen to not forget them when experimenting or at corrections in mechanically unstable construction of antenna. Done to the dimensions EA works full or diminished to 12-5 elements as a minimum. The more elements the lower it can be mount.



It must be taken into account that at application of the uneven wire for the elements there can be a mistake – the elements will be too long. On the other hand by driver's adjustments it can be that it will become shorter than desired. Do not change the driver, do not try to pull the wire, - the wires coming out of the coax-braid are associated with driver element, so You can easily make them longer to make driver be adjusted to the desired frequency. IF You use the thicker wire for elements You introduce to them more capacitance and have to shorten the elements' wires. The bandwidth of the driver element is to be designed according to formula [1]:

$$\mathbf{F\Delta = Fmax - Fmin = 304635/Pmin - 304635/Pmax,}$$

where Fmax and Fmin are the highest and the lowest frequency of the passband according to minimal (internal) and max, (outer) perimeters of driver element (Figure 10a).

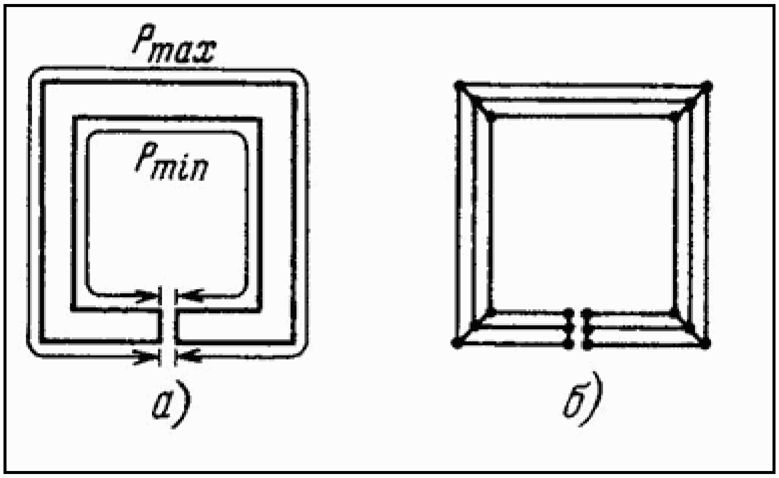


Figure 10a & 10б

The driver made out of the metal band (a broad-band one) can be modeled with the help of a number of wires connected with each other electrically (Figure 10б). This method is used at TV-antennas production. For to be not out of the band it is sometimes useful to use the thicker wire for elements but this slightly decreases the gain of antenna.

Some words about the experiments with other quad-antennas. Two element quad will work good inside the city like the undirected antenna according to the reflections, vertical polarization and 1…5 wtts rig is enough to be used for the local net. Set high above the roof, the quad takes care to reach anyone until the very ground, any direction, TX or RX. At city's random the broader lap (60˚ at 0,7 level, 8 dBd gain for 75 impedance with distance between elements equal to 0,2λ) of 2-element quad will help You to QSO. If You go away from the city You have to increase the element number, the gain will also increase, the lap then will go narrower but it is of use because the city will be situated then in narrower sector. All the things come good together. Moreover You need not rotate the antenna to have the traffic with Your friends when You are in the fields and friends are in the urban circumstances.

EA was tested in its 7-element version being situated inside of wooden shed about 1,5 m (centre) above the ground. The -3dB-width of transmission here was about 40°, at about 12 dBd gain.

As it was cleared out the influence of the fourth and the following directors on resonance frequency and impedance is not fatal it can not be taken into account and the number of elements in EA can be to one's desire. Do not forget that the high concentration of RF energy at multi-element antennas can serve to miss the target in plane of azimuth and in plane of elevation. At the same time the multi-element antennas can work at lower heights. EA can work at the lower heights as the most of antennas it improves the signal if situated higher: the signal was improved by S1 when it was raised only by 300 mm. At polarization change at one side the signal level decreases by S4. The more precise match coax to antenna can be done by means of shuffle of ferrite toroid along the coax (the direction of EA is then slightly changed).

The middle elements of EA are a bit lower to the ground than elements at the ends of EA. This fact (and aconcentric situated elements) helps to prevent the reflection of RF energy from the ground just at the last director when EA is low to the ground.

EA was made many times by many home-brewers. They note the low noise level, high gain and directivity. There were some modifications of EA: for example: 20 element portable antenna and 2 stacked 13 element EA with boom for EME-communication.

At the very end of my article I suggest You to refresh the things: this is a small program in GW-BASIC for designing the EA to frequency You like. (Line 240 in listing is to be written as one line).

```
10 DIM A(20)
20 CLS
30 PRINT "     UA9LAQ VHF ANTENNA DESIGN"
40 INPUT " Antenna design frequency, kc"; F; PRINT
50 PRINT " Element-perimeters, m         Element side's length, m"
60 DW = 300000 / F
70 PR = DW * 1.1133333#
80 PA = DW * 1.01545
90 PRINT " R ", PR, "------------", PR / 4
100 PRINT " A", PA, "==========", PA / 4
110 FOR I = 0 TO 10
120 READ A(I)
130 PD(I) = DW * A(I)
140 PRINT " D "; I + 1, PD(I), "--------", PD(I) / 4
150 DL= PD(0)+PD(1)+PD(2)+PD(3)+PD(4)+PD(5)+PD(6)+PD(7)+PD(8)+PD(9)+PD(10)
160 NEXT I
170 PRINT " Distances between elements, m"
180 RA = DW * .19885
190 PRINT "RA", RA; " reflector - driver "
200 AD = DW * .15035
210 PRINT "AD", AD; " driver – first director"
220 DD = DW * . 24735
230 PRINT "DD", DD; " between directors (all distances are equal)"
240 DATA 0.96030003,0.95060003,0.94090003,0.93120003,0.92150003,0.91180003,
  0.90210003,0.89240003,0.88270003,0.87300002,0.86330002
250 OD = PR + PA + DL
260 PRINT" The sum of all element-perimeters (without constructives, m)";OD
```

The Result

```
 UA9LAQ VHF ANTENNA DESIGN
Antenna design frequency, kc? 145500
```


Element-perimeters, m   Element side's length, m
R   2.295533 ------------   .5738831
A   2.093711 ==========   .5234278
D1   1.98   --------   .495
D2   1.96   --------   .49
D3   1.94   --------   .485
D4   1.92   --------   .48
D5   1.9   --------   .475
D6   1.88   --------   .47
D7   1.86   --------   .465
D8   1.84   --------   .46
D9   1.82   --------   .455
D10   1.8   --------   .45
D11   1.78   --------   .445
Distances between elements, m
RA   .41 – reflector - driver
AD   .31 – driver – first director
DD   .51 – between directors (all distances are equal)
The sum of all element-perimeters (without constructives, m) 25.06925
Ok

After letting the program to go by RUN, input the antenna design frequency. The result will appear immediately after You press "Enter". If all PRINT in listing will be converted to LPRINT, we'll get the printed copy of antenna design. You can use "Print Screen" - the result is only one screen – page.

References:

1. Ротхаммель К. Антенны. М.: Энергия, 1979, стр.267,268.
2. Ротхаммель К. Антенны. М.: Энергия, 1979, стр. 232, 233.
3. Беседин В. УКВ Маячок. — КВ журнал, 1998, № 2, стр. 46, 47.
4 Беседин В. Адаптация радиостанций промышленного применения к любительским условиям. — Радиолюбитель. КВ и УКВ., 1996, № 6, стр. 26.
5. Беседин В. Экспериментальная антенна на 145 МГц. КВ журнал, 1998, № 3, стр. 22…30
6. Беседин В. Экспериментальная антенна на 145 МГц. Радиолюбитель. КВ и УКВ., 1998, № 5, стр. 31.

73! Victor Besedin, UA9LAQ, ua9laq@mail.ru

AmQRP.ORG HOMEBREWER

Jim Kortge, K8IQY

Build a "Precision Variable Crystal Oscillator"

The Precision Variable Crystal Oscillator provides a precise and stable frequency source for crystal parameter analysis, and also serves as an instrument for accurately sorting crystals for use as filter elements.

Further, it may be used in any application where a stable frequency source is needed, and for which a crystal is available on or near the required frequency. Suggested uses include a receiver alignment source, DC receiver local oscillator, or the first stage of a QRP transmitter. Read about further use of the PVXO in the Crystal Measurement Fixture companion article.

Introduction

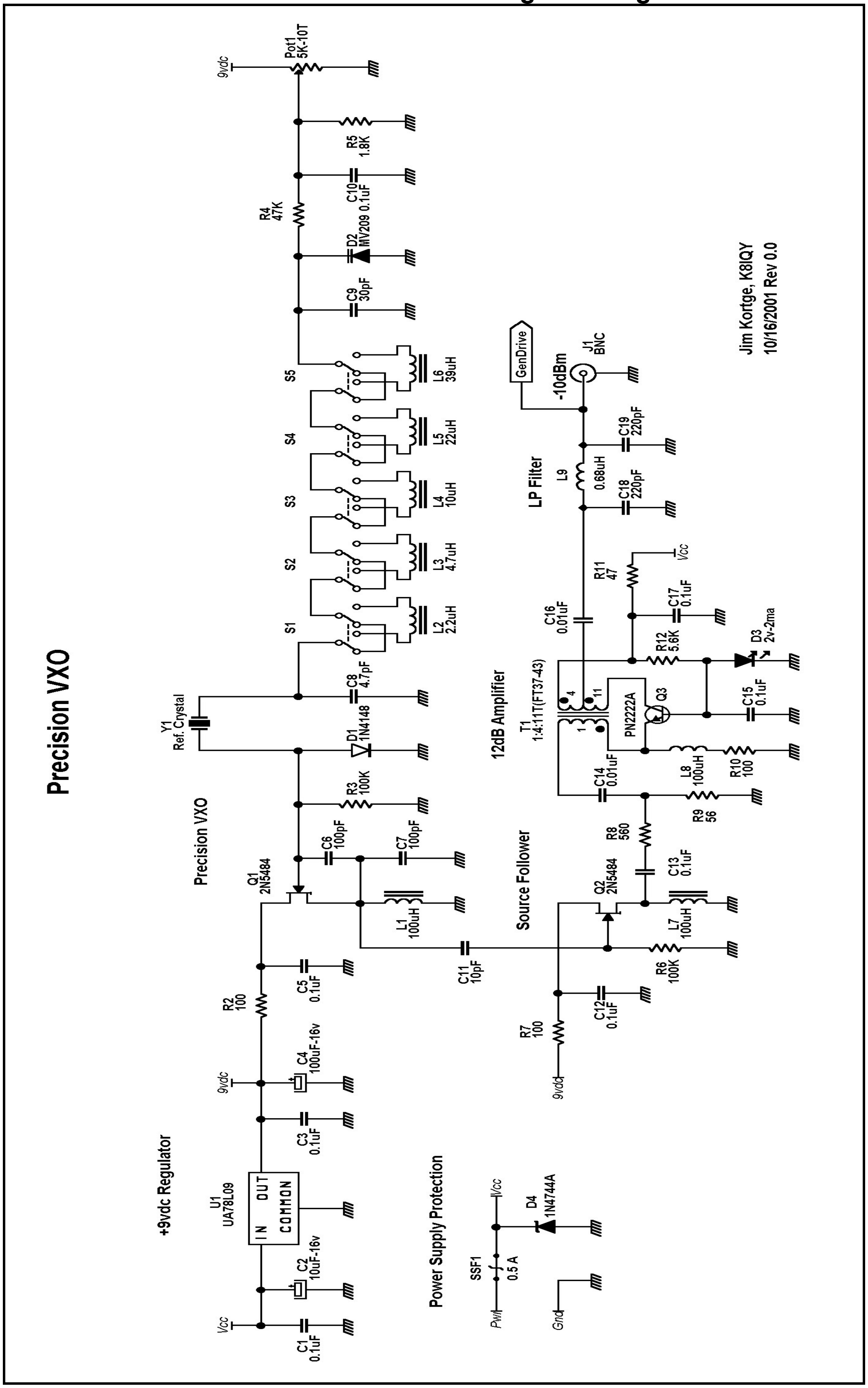
A variable crystal oscillator (or VXO) is one way to generate a stable signal for crystal testing. The one that I am presenting fills the need for a precise and stable source that is capable of providing measurement results comparable to those obtained with a high end, commercial signal generator. Over the past several years, I have suggested this approach to several experimenters but am not aware that any actually tried it. I wasn't sure the idea was sound until a prototype was built and several sets of crystals had been tested. The results using this generator were comparable to those obtained using my Racal-Dana 9087.

This article will describe the design and construction of my Precision Crystal Oscillator. Actual use of this piece of test equipment is described in the companion article that follows in this issue wherein I overview and detail crystal parameter measurement.

Theory of Operation

As shown in the schematic (Fig 1), the PVXO employs a Colpitts oscillator, Q1, using a 2N5484 junction FET. The crystal is usually one from a set that will be used for building a filter or for Local Oscillator service. However if the Precision VXO is being used for receiver alignment, the crystal might be one whose frequency is inside one of the lower ham bands. Controlling the frequency of oscillation is accomplished with an MV209 varicap diode and a set of five molded inductors configured as a binary weighted set. The inductance needed to

Precision *VXO* Schematic Diagram – Figure 1



force the crystal to oscillate at its marked case frequency is experimentally determined by selecting the desired total inductance using switches S1 through S5. When no inductors are selected the minimum inductance is that of the leads going to S1 and S5. Under those conditions, the crystal will oscillate at its highest frequency. As more inductance is added, the crystal's oscillating frequency is lowered. Maximum inductance is obtained when all of the inductors are selected and are connected in series. Under these conditions many higher frequency crystals may cease to oscillate. The minimum inductance change is 2.2 uH, provided by the setting of S1.

The tuning range of the varicap diode can provide the overlap needed to make the digitally controlled inductance work seamlessly with most crystals. Sufficient frequency span is also achievable so that the resonant frequency of another crystal under test can be determined. Frequency precision is obtained by using a 10-turn potentiometer. Stability is achieved through the use of an internal regulated supply and by minimizing the RF levels in the oscillator circuit.

A second 2N5484 transistor, Q2, is used as a source follower to further isolate the oscillator from any changes reflected back from the output load. The stage is also set up, by way of a voltage divider (R8 and R9), to provide an output impedance of 50 ohms. This impedance properly drives the fixed input impedance of the Norton amplifier used in the output stage. Both Q1 and Q2 are supplied with 9 volts from a regulator. Using a regulated supply helps maintain frequency and amplitude stability.

The output stage, a PN2222 (Q3), provides a gain of +12 dB and amplifies the generated signal to a level of approximately –10 dBm, or 250 millivolts peak-to-peak. This stage is a noiseless Norton amplifier design. Downstream of this amplifier is a low pass filter, to reduce harmonic content above 20 MHz. A spectrum plot of the generator's output is shown in Figure 2.

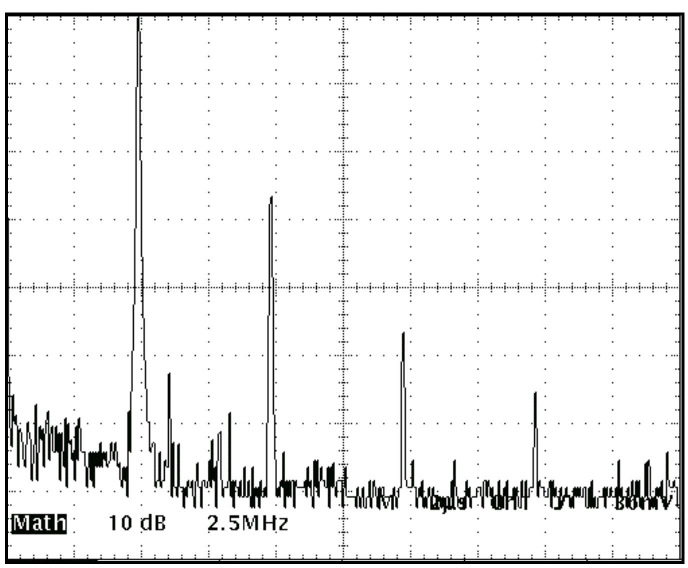


Figure 2

Overall this Precision VXO generator is designed to work with the commonly-available HC49 and HC49U style computer crystals often used in IF filter service. It will operate with crystals in the frequency range of 3.5 through 13.5 MHz but is optimized for crystals at 9 MHz and below.

Besides having a clean output spectrum, this low cost generator also has excellent frequency stability. Its warm-up drift is a few Hz, and the stability over a 24-hour period is within 20 Hz. Short-term stability is not measurable with the equipment in the K8IQY laboratory.

The typical tuning range with a 4.9152 MHz crystal is plus and minus 250 Hz, which is more than adequate for covering the series resonant frequency of crystals being characterized or matched. More importantly, with the wide range of inductance available, the oscillating frequency of the VXO crystal can be moved over a considerably wider range, thus assuring that one can find the series resonant frequency of a crystal under test.

Construction

Although a complete kit of parts is available (see Note 1 at the end of the article for ordering details), the PVXO may easily be constructed in a Manhattan-style homebrew manner. I've presented the layout of the PC board from the kit as a layout guide for this homebrew approach if you decide not to obtain the kit.

Assembly of the PVXO is broken up into logical steps. Regardless of how you decided to construct the PVXO, each section can be sequentially built and then tested. While that approach is recommended, it is not necessary – the layout is logical and component locations are well identified. No alignment operations are required after assembly.

Our assembly approach will be to follow the schematic diagram of the Precision VXO, and essentially build from it in terms of which parts are installed and the order in which they are installed. While this method isn't as detailed as the old "Heathkit process" of calling out a part, installing it and then checking off a box, it is more than sufficient for this simple kit. The schematic is included as Figure 1.

Start by adding the Power Supply Protection components – the solid-state fuse (SSF1) and the Zener diode (D4). Take care to properly orient the diode.
Next, install the +9-volt Regulator components – capacitors C1, C3, C5, C2, and C4; resistor R2; and regulator U1.

If you want to test the assembly at this point, apply 12-to-13.8 volts DC to the "Pwr" and "Gnd" input to the Power Supply circuit. Making sure you have the polarity of the applied voltage correct, verify that the voltage at the junction of R2 and C4 is 9 volts.

Next install all of the components that comprise the VXO part of the circuit in the following order. GROUP 1: capacitors C6, C7, C8, C9, and C10. GROUP 2: inductors L1, L2, L3, L4, L5, and L6. GROUP 3: resistors R3, R4, R5. GROUP 4: transistor Q1, diodes D1 and D2. Install the 3-pin crystal socket Y1 "standing up" or perpendicular to the surface of the board. Install DPDT switches S1-S5, making sure each switch is in contact with the surface of the board and perpendicular to the top surface before soldering its pins. Install one switch at a time and work slowly. Removing a switch or attempting to reorient it after several of its pins are soldered will be difficult.

If you want to test the assembly at this point, apply DC power again to the board. Using a DVM, verify the voltage at the junction of R2 and C5 is 8.6 volts. If you have an RF probe or oscilloscope, plug a 3.5-to-9 MHz crystal into socket Y1. Place the handle of all five switches toward the rear of the board and place the RF probe or oscilloscope probe on the junction of L1, C6, and C7. There should be several volts of peak-to-peak RF signal present. Remove the crystal, and verify the RF voltage drops to near zero. It may not completely drop to zero as the circuit may continue to oscillate at 300+ MHz at a lower amplitude.

Continue the assembly by installing the components for the Source Follower. GROUP 1: capacitors C11, C12 and C13. GROUP 2: resistors R7, R6, R8, and R9. GROUP 3: inductor L7 and transistor Q2. Make sure Q2 is oriented correctly, and elevated above the board surface about ¼ inch.

If you want to test the assembly at this point, apply DC power to the board again and ensure the voltage at the junction of R7 and C12 is 8.6 volts. If you have an RF probe or oscilloscope, plug a 3.5-to-9 MHz crystal into socket Y1 and place the handle of all 5 switches toward the rear of the PC board. Place the RF probe or oscilloscope probe on the junction of R8 and R9. There should be approximately 100 millivolts of peak-to-peak RF signal present. Remove the crystal and verify that the RF voltage drops to near zero.

Transformer T1 in the output amplifier should next be constructed. This transformer is wound with a total of 15 turns, tapped at the 4th turn from the beginning of the winding. Start this winding using about 12 inches of #26 or #28 wire. Bring an end through the toroid core from the backside and bend it over the top edge of the core in the 1 o'clock position with about 1½ inches of the free end beyond the edge of the core. Next, grab the free end that is sticking back through the core and bring it forward, pushing it through the core hole and pulling it tight. The turn just wound should be below, or clockwise around the core from the free end at the 1 o'clock position. This is the 2nd turn, as one turn is counted each time the wire passes through the center of the core. Wind two more turns in the same manner as before. The wire that has the "working end" should now be behind the back edge of the core. Pull it off to the right at the 3 o'clock position, and make a loop that is about 1½ inch out and another 1½ inch back, with the two wires parallel to each other. Twist the loop several times to hold these two wires until the twists come up to the back (outside) edge of the core. This loop will be the tap at the 4th turn. Continue winding in the same direction until another 11 turns has been placed on the core. The exiting wire will be at the 7 o'clock position on the backside of the core. Cut the remaining wire off leaving a 1½-inch end. Save the cut off wire, as it will be used for the one turn link when the transformer is installed. Scrape or burn off the insulation from the 3 ends and tin with solder. A photo is provided on the next page, illustrating these steps of winding the transformer.

Form the leads of the core so that the 4- and 11-turn windings will line up with their respective pads on the board layout. Place the core on the board with the three leads to the correct pads, and solder them in position.

Take the remaining scrap of wire used for winding and remove the insulation from one end for about ½ inch. Skip the next 1 inch, and remove the insulation from the next one inch, and cut the wire there creating a piece 2½ inches in length. Tin the bare areas, and solder the ½ inch end onto the pad that also connects to the emitter of Q3 and inductor L8. Route this wire up over the left edge of the toroid core, down through center of the core, and under the right edge with the remaining end going to the pad which is also connected to capacitor C14. The core will likely be slightly elevated, enabling the wire to make it through to through the pad. Pull the remaining end of the one turn link taut, and solder it.

The remaining parts for the 12 dB Amplifier can now be installed. GROUP 1: capacitors C14, C16, C15, C17, C18 and C19. GROUP 2: resistors R10, 5.6 K resistor R12, and 47 ohm resistor R11. Group 3: 100 uH inductor L8, and 0.68 uH inductor L9. Group 4: PN2222A transistor Q3, and green LED D3. D3 is installed with the longer lead, the anode, going to the pad that is also connected to the junction of Q3's base, C15, and R12. Place Q3 and D3 above the board surface ¼ inch.

If you want to test the assembly at this point, apply 12-13.8 volts DC to the "Pwr" and "Gnd" pads on the board. Make sure you have the polarity of the applied voltage correct. Using a DVM, verify the voltage at the junction of R11 and C17 is 13.1 volts with 13.8 volts applied to the PWR pad. If you have an RF probe or oscilloscope, plug a 3.5 to 9 MHz crystal into socket Y1. Place the handle of all 5 switches toward the rear of the PC board. Place the RF probe or oscilloscope probe on the junction of L9 and C19. There should be about 500 millivolts p-p (510 millivolts p-p for reference) of RF signal present. Remove the crystal, and verify the RF voltage drops to near zero.

The output voltage will drop when the generator is driving a 50-ohm load. Its output under that load should be about 250 millivolts p-p, or 90 millivolts RMS, or –8 dBm, or 160 microwatts, should you decide to use it as a transmitter.

The last two components can now be installed - the 5 K, 10-turn potentiometer, Pot1, and the BNC output connector, J1.

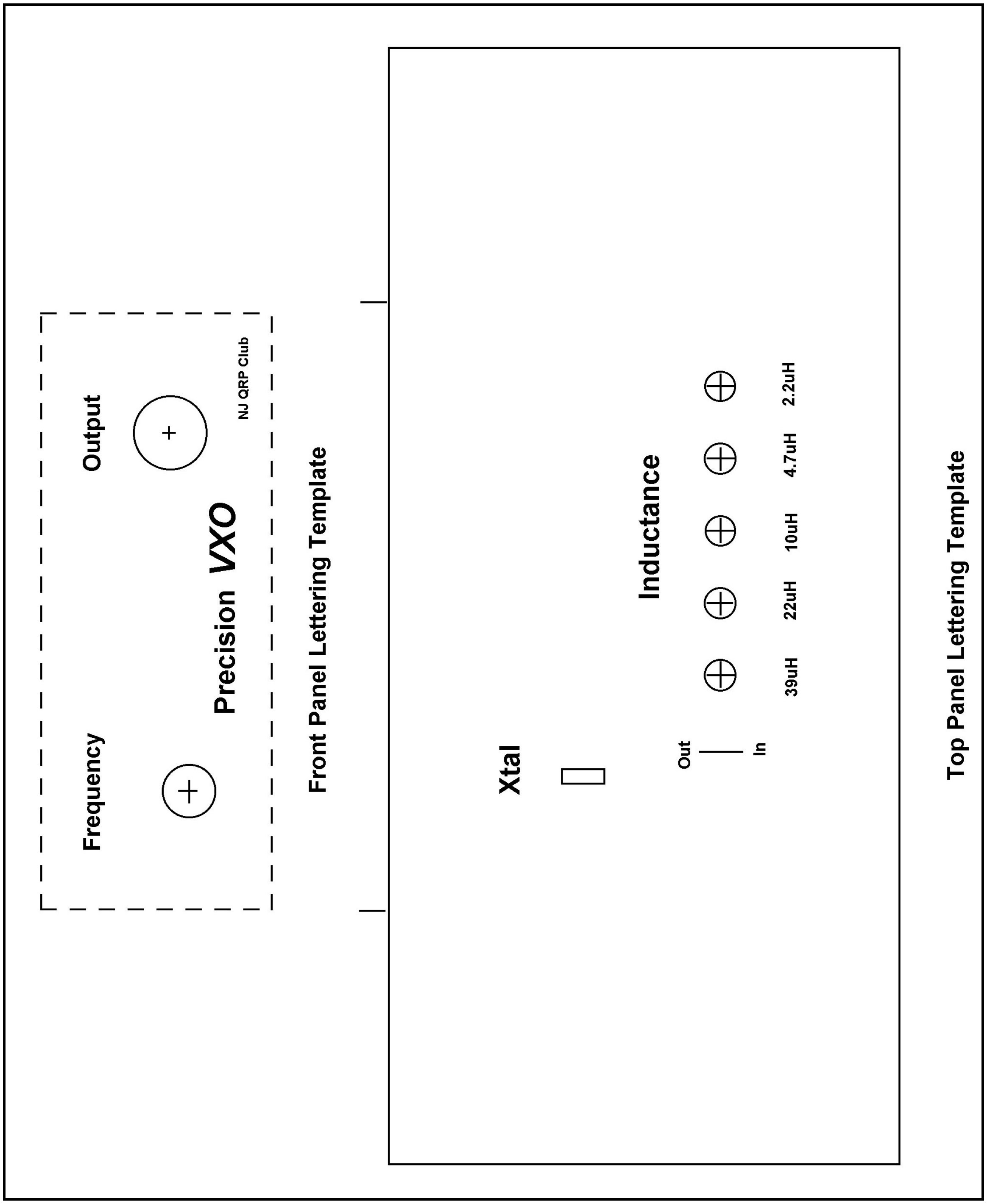
Congratulations! Assembly of the PVXO circuit is now complete! If you have done the interim testing along the way and that was successful, your Precision VXO is fully functional.

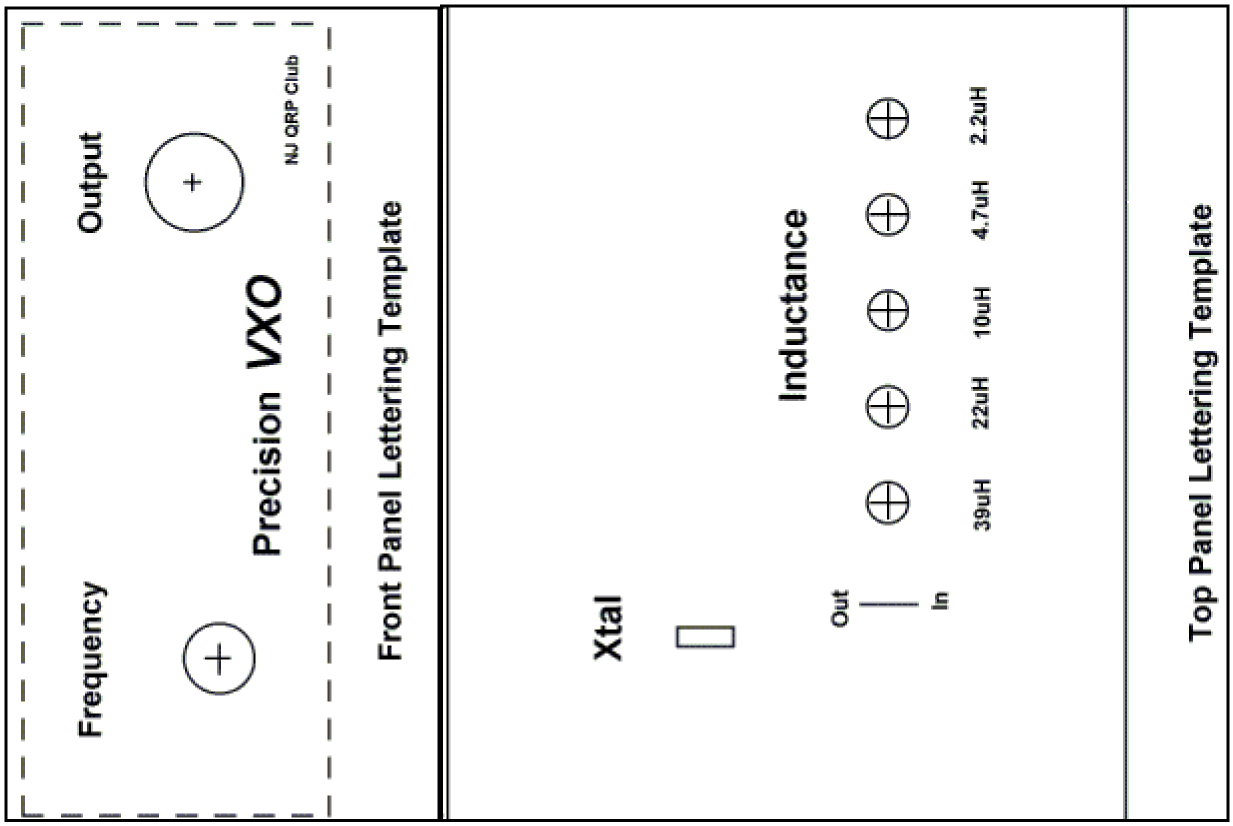
Labeling the Enclosure

Full-scale label templates are provided in the following pages. Photostatic copy these graphics (so you don't mess up your issue of Homebrewer), cut them out and past them onto the top and front surfaces of the enclosure. Carefully drill the enclosure according to the hole positions and insert the controls/jacks into their respective positions. Many other options can be followed, of course, when it comes to finishing the outside of the enclosure ... use your imagination.

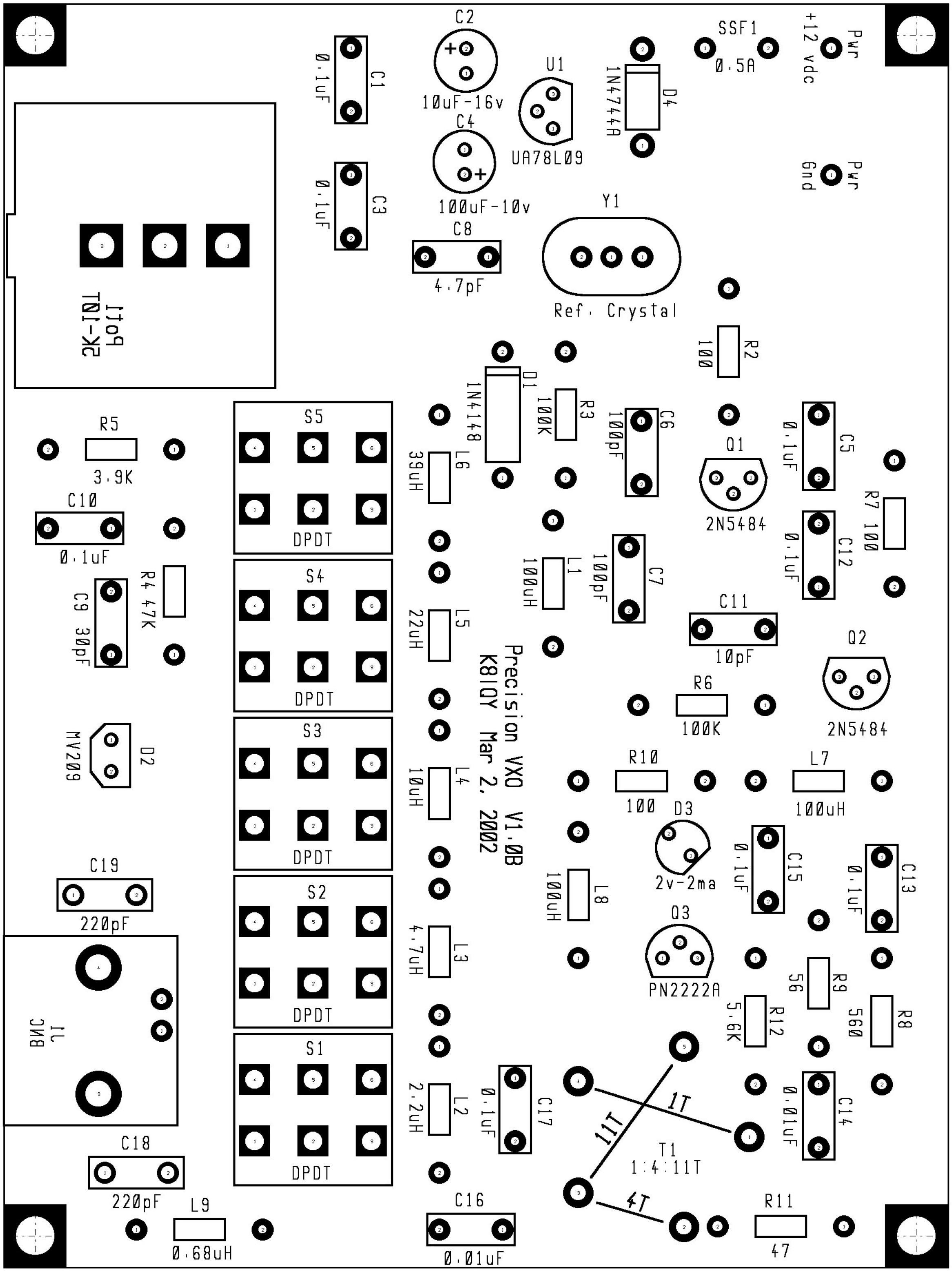
Wrapping Up

That's it…your Precision VXO is finished! You now have a precision piece of test equipment that can be used in a variety of ways. In the next article I'll show how to use the PVXO with a "crystal test fixture" to measure crystal parameters.


Frequency
Output
Precision VXO
NJ QRP Club
Front Panel Lettering Template
Xtal
Out
In
Inductance
39uH
22uH
10uH
4.7uH
2.2uH
Top Panel Lettering Template


Frequency
Output
Precision VXO
NJ QRP Club
Front Panel Lettering Template
Xtal
Out
In
Inductance
39uH
22uH
10uH
4.7uH
2.2uH
Top Panel Lettering Template

PC Board Layout



Parts List

Item	Qty	References	Value	Description
Capacitors				
01	1	C8	4.7pF	NPO cap (4.7)
02	1	C11	10pF	NPO cap (10)
03	1	C9	30pF	NPO cap (30)
04	2	C6,C7	100pF	NPO cap (101)
05	2	C18,C19	220pF	Disc cap (221)
06	2	C14,C16	0.01uF	Disc cap (103)
07	8	C1,C3,C5,C10,C12,C13,C15,C17	0.1uF	Mono cap (104)
08	1	C2	10uF-16v	Electrolytic cap
09	1	C4	100uF-16v	Electrolytic cap
Resistors				
10	1	R11	47 ohm	Res (Yel Vio Blk)
11	1	R9	56 ohm	Res (Grn Blu Blk)
12	3	R2,R7,R10	100 ohm	Res (Brn Blk Brn)
13	1	R8	560 ohm	Res (Brn Blu Brn)
14	1	R5	3.9K	Res (Org Wht Red)
15	1	R12	5.6K	Res (Grn Blu Red)
16	1	R4	47K	Res (Yel Vio Org)
17	2	R3,R6	100K	Res (Brn Blk Yel)
18	1	Pot1	5K-10T	10 turn pot (Blu)
Inductors				
19	1	L9	0.68uH	Ind (Blu Gry Sil)
20	1	L2	2.2uH	Ind (Red Red Gld)
21	1	L3	4.7uH	Ind (Yel Vio Gld)
22	1	L4	10uH	Ind (Brn Blk Blk)
23	1	L5	22uH	Ind (Red Red Blk)
24	1	L6	39uH	Ind (Org Wht Blk)
25	3	L1,L7,L8	100uH	Ind (Brn Blk Brn)
26	1	T1	1:4:11 T	FT37-43 toroid
Diodes/transistors/regulator				
27	1	D1	1N4148	Signal diode
28	1	D2	MV209	Varicap diode
29	1	D3	2v-2ma	LED (Grn)
30	1	D4	1N4744A	Zener diode
31	2	Q1,Q2	2N5484	FET transistor
32	1	Q3	PN2222A	Bipolar transistor
33	1	U1	UA78L09	Voltage regulator
Miscellaneous				
34	1	SSF1	0.5 A	Fuse (Yel, marked B050)
35	1	J1	BNC	Connector (Blk)
36	5	S1,S2,S3,S4,S5	DPDT	Switch (Blu)
37	1	Y1	Crystal	3 pin socket
38	1	--	------	Precision *VXO* PC board


Xtal
Inductance
Out
In
39uH
22uH
10uH
4.7uH
2.2uH
Output
Frequency
Precision VXO


Frequency
Output
Precision VXO
NJ QRP Club

PVXO News, App Notes, etc:

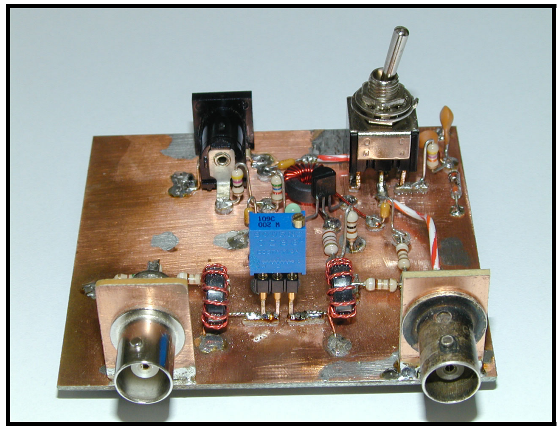
NJQRP Website: www.njqrp.org/pvxo

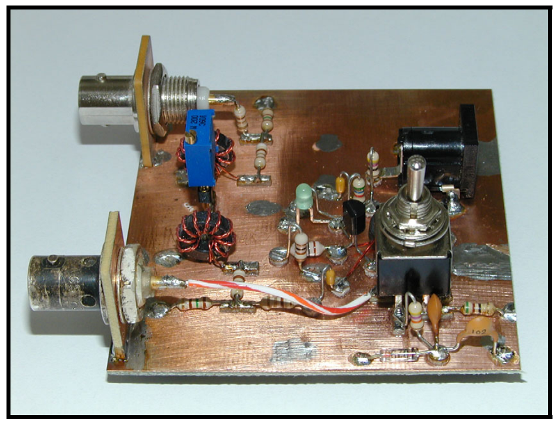
Jim Kortge, K8IQY

k8iqy@k8iqy.com

Jim Kortge, K8IQY

Simplified Tools and Methods for Measuring Crystal Parameters





Here's an excellent primer in crystal parameters that also describes an approach for measuring crystal parameters using the Precision Crystal Oscillator (PVXO) described in the previous article. K8IQY extends the usefulness of his PVXO by designing a "crystal test fixture" that can be easily built Manhattan-style.

With careful use, the crystal parameter values derived from this test setup are comparable in accuracy to those measured with instruments costing thousands of dollars. The same instruments and setup can also be used for measuring crystals for use in multi-pole filters.

Background

One of the common elements in all modern superheterodyne receivers is at least one crystal filter. A contest grade receiver may employ more than one filter for improved performance. One can obtain a crystal filter essentially two ways; either purchase a commercial unit on the required IF frequency or build the filter from easily obtained components.

Purchasing the filter requires little effort, but the cost is high, on the order of $150.00, and may be much more than this amount for a high performance filter. On the other hand, the components to build a filter will probably cost one-tenth of the commercial unit, but effort is required to build the filter. Most of that effort is embodied in determining the characteristics of the crystals that will be used. The remainder is in assembling and testing the constructed filter.

What are the benefits of building a filter? First, one can tailor the filter's characteristics to exactly those desired. For example, the filter could be built for CW use with a pass band of 350 Hz. Obtaining a commercial filter with that bandwidth is prohibitively expensive, since it is not a standard. Another reason for building our own filter is the ability to choose the number of elements needed to achieve the performance desired. If a 4-pole filter is needed, that's what is built. On the other hand, if a 7-pole filter is desired for enhanced performance, it too can be built with little additional effort. We can even build a filter with an adjustable pass band; try to find one of those commercially. Finally, by building our own filters, we have many more options available in deciding the RF mixing schemes used. With commercial filters, most of those decisions are dictated by the offerings of the various manufacturers, which are limited unless a custom filters is ordered.

Crystal Parameters

Before we can build a crystal filter, we have to know the properties of the crystals that will go into it. If the filter is built without that knowledge, two important deficiencies will occur. First, the filter will probably be far from optimum in performance. There will most likely be artifacts in the pass band amplitude and phase characteristics, and the insertion loss will not be minimized. Second, our ability to reproduce the filter, regardless of its performance, or lack of, will be compromised. A second unit built from the same kind of parts will most likely be markedly different in performance. Notice that I used the term "most likely" since by chance, one may end up with a good filter, with reproducible characteristics, without knowing anything about the crystal elements used. However, the probability of that actually happening is very, very small. The remainder of this paper will concentrate on the equipment and test setups required to ascertain this vital information

Crystals are characterized by the following parameters:

Fs = this is the series resonant frequency of the crystal, and represents the point where the series inductive and capacitive reactance terms cancel.

Rs = this term is the equivalent series resistance of the crystal at resonance (Fs), and represents the energy loss in the quartz element.

Lm = this term is the motional inductance of the crystal, and represents the vibrating mass of the quartz element.

Cm = this term is the motional capacitance of the crystal, and represents the elasticity of the quartz element

Co = this term is the holder capacitance of the crystal, and is the capacitance of the plated contact areas on the quartz element, the connecting lead wires, and the parasitic capacitance to the surrounding case.

Q = this term represents the overall energy loss in the crystal when it is being driven by an external source. It is equivalent to the Q of a capacitor or inductor.

Figure 1 shows a typical electrical schematic for a crystal, with the various parameters identified.

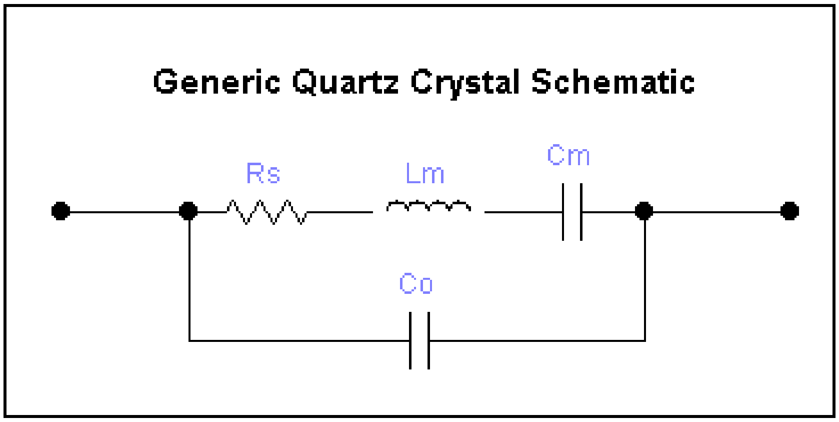


Figure 1

As can be seen, the basic structure is a series RLC circuit comprised of Rs, Lm, and Cm, with Co in parallel with the RLC elements. This might suggest that the crystal will behave differently depending on the frequency exciting it, and that's exactly what happens. Figure 2 is a frequency response, or Bode plot for a 4.9152 MHz crystal, typical of the crystal element used in the 2N2/40+ IF filter, or the IF filter in a K1 or K2.

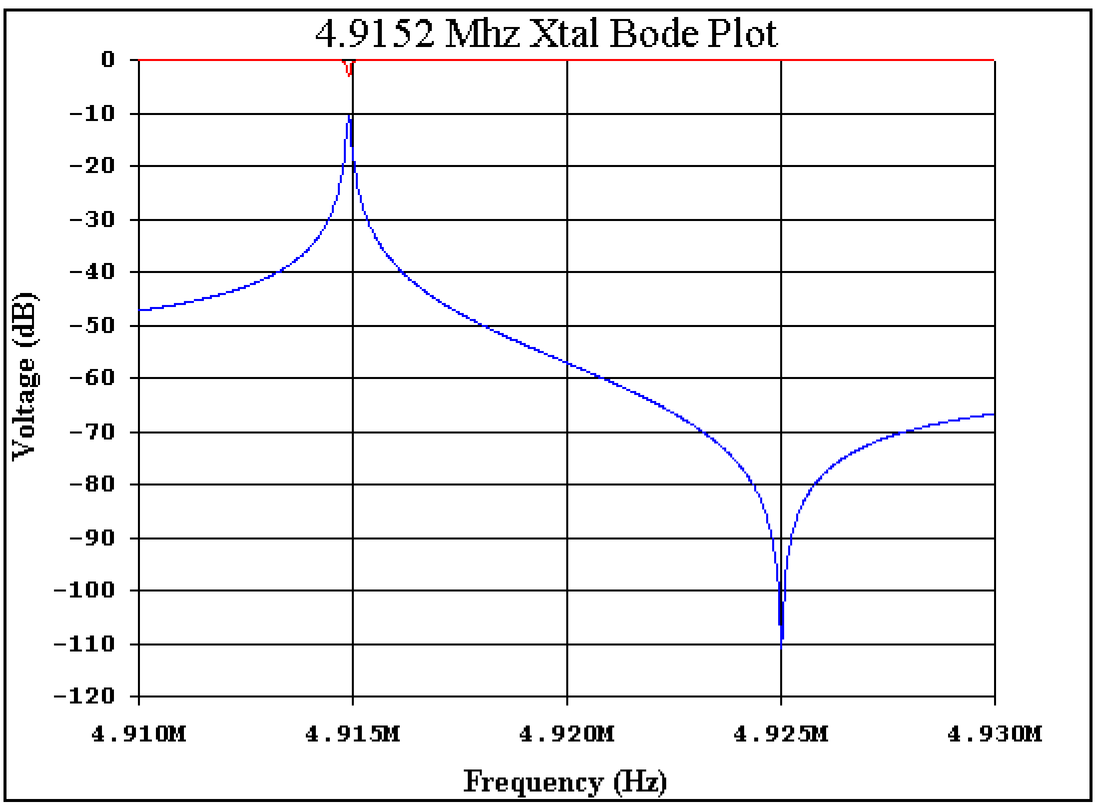


Figure 2

As suggested, we see a very sharp response peak from the series RLC part of the circuit at nominally the frequency marked on the case. However, there is also a very deep null about 10 KHz higher in frequency, at the parallel resonance point. This is where the “series” motional capacitance is absorbed into the motional inductance, and the “parallel” holder capacitance term, Co now prevails. Notice that the difference in amplitude between the series resonant peak and the parallel resonant null is about 100 dB. This very large dynamic range makes it difficult to see or measure the parallel resonance of a crystal unless one has access to an instrument with a corresponding very wide dynamic range. A spectrum analyzer, or similar instrument is typically required to make this measurement.

Here are the parameters for this crystal:

Fs = 4.9152 MHz
Rs = 13.0 Ohms
Lm = 0.070 Henry
Cm = 1.50E-14 Farad
Co = 3.64E-12 Farad
Q = 167,500

Crystal Parameter Measurements - Overview

Figure 3 is a block diagram of the basic setup used to measure the crystal parameters.
This arrangement employs a signal generator with good short-term stability and precision, a counter to measure the signal generator frequency if the generator does not have its own readout, a fixture to hold the crystal under test, and a suitable RF detector.

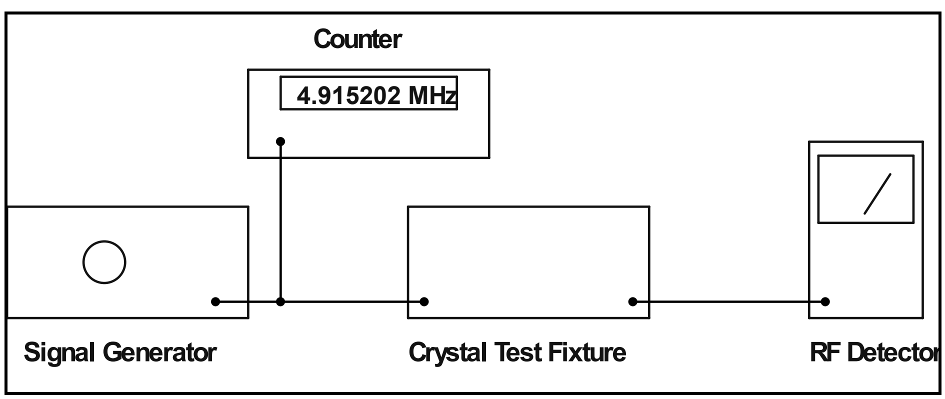


Figure 3

Some details on each of the blocks in this diagram are appropriate. The signal generator can vary widely in terms of its capability. It can be a highly accurate, digitally synthesized, low phase noise, mega-dollar unit from Agilent or Rhode & Schwartz. It could be a lower cost, older unit from Racal, Fluke, or HP, such as an 8640B. Or it could be a very low cost, rather simple but highly stable, VXO based generator, built Manhattan-style that utilizes one of the crystals that will eventually be incorporated into a filter. We’ll see details of this generator type later on.

The counter may or may not be needed, depending on the design of the generator. Whichever way it is implemented, it must be capable of resolving 1 Hz at the crystal's resonant frequency, and have both good short term and long term stability. Almost any crystal base counter will suffice if the resolution requirement is met. The Arizona QRP Club's "Stinger Singer" would be suitable as a low cost choice.

A special crystal test fixture is required as part of this system. It must mechanically hold the crystal, and more importantly, provide appropriately conditioned signals to the crystal under test, and to the downstream detector. This element is also rather simple in design, and can be constructed Manhattan-style, using readily available parts. We'll see details of this test fixture later on too.

The final element in the system is some kind of RF detector. This could be something as simple as an RF probe, used with a digital voltmeter, or analog VOM. It could also take the form of a low bandwidth oscilloscope, with or without the RF probe used as a demodulator. My favorite is a HP 400EL AC voltmeter. These are available on the used equipment market, typically for under $50, and provide detection and an analog display in dB up to 10 MHz. A suitable alternative is a used HP 3400A. It has the same basic capabilities as the 400EL, but its primary scale is linear.

Of those crystal parameters shown earlier, only Fs, Rs, and Co are directly measured. The remaining are obtained by way of additional measurements, and a set of equations to compute them. Here are those equations:

Lm = (25+Rs/(2*PI*DeltaF) where DeltaF is the frequency difference between the –3 dB points on the response curve

Cm = 1/(4*PI^2*Fs^2*Lm)

Q = (2*PI*Fs*Lm)/Rs

The actual crystal characterization is done a piece at a time, with the next parameter being derived from previous information in most cases. After we look at the details of the signal generator and crystal test fixture, we'll come back to these equations and see in detail how they are used.

Crystal Test Fixture – A Crystal Drive Circuit

Figure 4 show the schematic for a Crystal Test Fixture.

The driving signal from the generator is first attenuated by 3 dB before being applied to the crystal. Some attenuation is desirable to reduce the load variations the generator sees as the crystal is driven at various frequencies. As the attenuation is increased, the variations decrease. As in all designs, there are tradeoffs. If more attenuation is used, more generator power must be provided to achieve a drive level sufficiently large that we can accurately measure the crystal. The 3 dB value is a reasonable choice, but 6 dB would also work, and provide a bit more isolation.

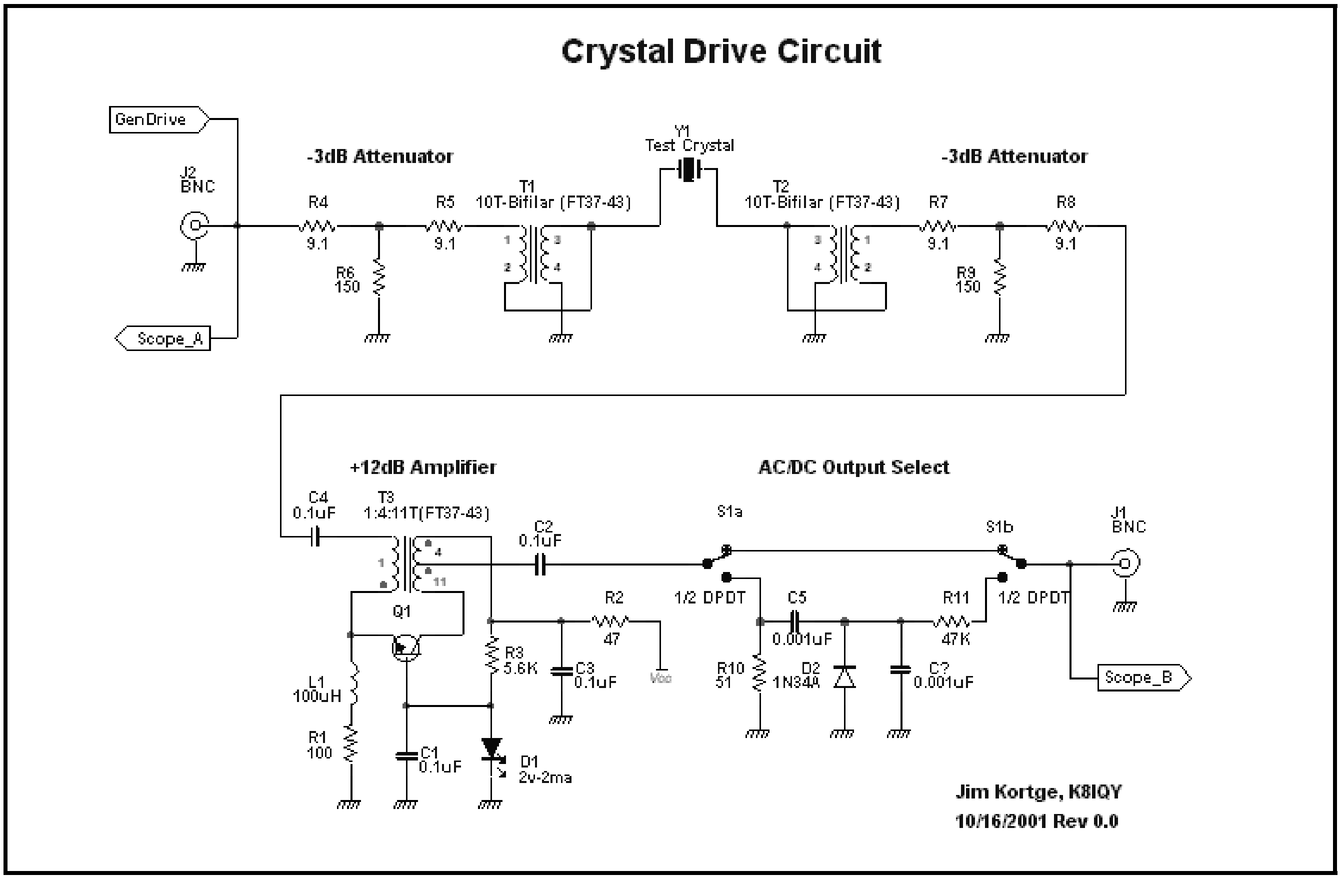


Figure 4

After the first attenuator, the drive is applied to a 4:1 step down transformer, T1. This transformer uses bifilar construction, and is wound with 10 turns. While wire size isn't critical, #28 or #30 are the preferred sizes for ease in winding. The output impedance of T1 is 12.5 ohms, which is a reasonable approximation to the Rs values for the crystals being tested.
The drive signal next passes through the crystal being tested, and on to another transformer, T2. This transformer is identical to T1, and is connected to provide an impedance step up back to 50 ohms. Another 3 dB attenuator follows T2, again, to help keep the 50-ohm impedance constant into the output amplifier, as the crystal impedance varies during testing.

The output amplifier, Q1, is a Norton configuration, identical to the output amplifier used in the Precision VXO. It uses a PN2222 transistor, provides 12 dB of gain, and has an output impedance of 50 ohms. The output signal is then routed to the output connector either directly, or through a built-in RF detector. With either output configuration, a 50-ohm load is provided to the output amplifier.

When the test crystal is replaced with a short circuit, the net gain of the test fixture itself is 6 dB. The test fixture, as designed, should be driven with a signal generator having an output impedance of 50 ohms. In like manner, the output should be connected to a detector with an input impedance of 50 ohms. When using the RF detector setting, an internal 50-ohm load is provided to the output amplifier.

Measuring Crystal Parameters – Details

Now that we have seen the details of the measuring system, let's go back and walk through the measurement of a crystal, and see how each of the parameters is obtained. Once that is done, we'll also take a look at using the system for measuring a group of crystals for use in a crystal filter.

We start with perhaps the most important aspect of the process – getting the equipment ready to do the measuring. First, connect everything together, and make sure it follows the setup diagram. Next, and this is the important part, turn everything on, and let it warm up for at least 4 hours, longer if at all possible, and overnight if you can plan your measurement session that far ahead. The reason is that we are going to be making measurements down to one Hz out of several million, and temperature drift is our worst enemy.

Next, decide how many crystals will be tested, and get them out on the bench so they can warm up to ambient temperature also. You'll quickly find out how sensitive crystals are to temperature changes when you start doing these measurements. You can see the temperature drift induced by picking up a crystal and plugging it into the test fixture. Once plugged in, you can see it change again due to heating caused by the drive signal. And finally, you'll discover that crystals measured in one session will not be the same if measured again several hours later, the next day, or the next week. This caveat is especially important if you are only finding the resonant frequency of each unit for matching purposes. Do them all in one batch, or you will end up with confusing, inaccurate, and inconclusive results. I'd also suggest that at least 5 crystals be measured and that an average of each parameter be used as the characteristics for the batch.

OK, let's measure a crystal. We'll assume that all of the equipment is warmed up and stable.

Step 1

Put a crystal into the Precision VXO socket, if you are using that kind of signal generator. If not, skip this step. Adjust the Precision VXO tuning pot to the center of its range, that is, at 5 turns from one end. Remove all of the inductance by setting S1 through S5 to the bypass position. Measure the frequency of the VXO crystal. If it is above its case marked frequency, start adding inductance. Keep adding inductance until the measured frequency is below that marked on the case. Reconfigure the inductance switches a final time to make sure you are as close as you can get to the frequency marked on the crystal case. Above or below is acceptable, but below is preferred.

Step 2

Insert a crystal into the Crystal Test Fixture. Let it stabilize for at least a minute, maybe two. Start increasing the frequency of the generator being used, looking for a change in the detector signal level. If none is noted, increase the detector sensitivity until an increase or decrease is noted. If the signal is increasing with increasing frequency, keep going in that direction until a peak is found. If the signal is decreasing with increasing frequency, reverse the frequency direction, and find a peak. Vary the frequency back and forth through the peak several times until you are sure you've found the best peak you can get. Measure the frequency of the generator and write it down. Also, write down the reading shown on the detector, as we'll need this value later. The frequency we noted where the peak occurred is our first parameter, Fs, the resonant frequency of the crystal.

Step 3

Remove the crystal, and replace it with a 25-ohm, cermet, or other non-inductive trim potentiometer, and don't change the generator frequency setting. Adjust the trim potentiometer to the same reading that was recorded when the crystal was in the test fixture. Remove the trim potentiometer, and replace it with the crystal being characterized. Measure the trim potentiometer with a DMM, set on its lowest ohm scale. Be sure to compensate the reading for lead length errors if a non-zero reading occurs when the test leads are shorted together. Record this resistance value. This is our second parameter, Rs, the equivalent series resistance of the crystal.

Step 4

Readjust the signal generator to assure it is still set on the resonance peak of the crystal under test. Record the detector setting. Adjust the signal generator higher in frequency until the detector setting decreases by 3 dB, or 0.707 times its peak reading. Record the generator frequency of this point. In a like manner, retune the signal generator lower in frequency until the resonance peak is passed, and the detector is again lower by 3 dB, or 0.707 times the peak reading. Record this generator frequency. Subtract the lower reading from the higher, and record the difference. This is the DeltaF term in the Lm equation. For those who are curious about the Lm equation, the "25" constant in the numerator is the sum of the impedances driving the crystal, in our example test fixture, 2 times 12.5 ohms, or 25 ohms total. Plug the Rs and DeltaF values into the Lm equation and do the math. The numerical result is our third parameter, Lm, the motional inductance of the crystal.

Step 5

We're done with the measurements on this first crystal, so replace it with another crystal in the test fixture, and return the signal generator frequency control to the 5-turn position.
This will allow the next crystal to stabilize while we complete the remaining calculations. Continuing on, plug in the Fs and just computed Lm values into the Cm equation, and turn the crank. The resulting value is our fourth parameter, Cm, the motional capacitance of the crystal.

Step 6

After removing the crystal from the test fixture, plug it in to whatever apparatus you have for measuring low capacitance values. My preferred instrument is an AADE L/C Meter. However, companies such as B & K Instruments also make an L/C meter. There are other choices too, including using an MFJ 274B Antenna Analyzer or the RF-1 antenna analyzer made by Autek Research. If an instrument is not available, use a value of 3.5 pF as the estimated Co for HC-49 style crystals in the 3.5 to 9 MHz range. This measurement or estimate yields the fifth parameter, Co, the holder capacitance.

Step 7

Almost done, plug in the Fs, Rs, and Lm values into the equation for Q, and do the math. The result is our sixth, and last parameter, Q, the Q of the crystal. The higher the Q value, the better the crystal will be for use as a filter. The higher the Q, the lower the insertion loss. Values above 150,000 are really good, those above 100,000 are more than adequate, and those above 50,000 are useable, but the filters will be about as lossy as can be tolerated.

Step 8

Measure at least another 4 more crystals using the previous steps. Compute the average value for each of the parameters and record these in your logbook along with other relevant information, such as manufacturer, measurement date, etc. As you accumulate crystals, and measurement information, these records become very important in deciding who makes good crystals for filters, and who does not. There is much variation among manufacturers.

Matching Crystals for Filter Elements

Now that we know the characteristics of a batch of crystals from the previous steps, using the test setup for matching crystals for filter use is a natural extension. It’s really quite simple. The basic process is this: Insert a crystal in the test fixture. Let it “soak” for a fixed time period. A minute is suggested as the minimum. Adjust the signal generator for a peak reading on the output detector. Write the last 4 digits of the frequency readout on the crystal with an indelible marker. Put another crystal in the test fixture, and repeat the process until all of them are done. As you are measuring your batch, look for crystals that show excessive drift, or which result in very low readings on the output detector. Mark these with an “X”, and don’t use them in your filter. Those that tend to drift will result in a less than optimal filter, and those producing low detector outputs have abnormally high equivalent series resistance values. Using those in a filter will raise its insertion loss, sometimes by a significant amount. All of these rejects will work fine as Local Oscillator crystals, so don’t throw them away, just don’t use them in a filter.

Once all of the crystals are measured, select the set that has the tightest frequency grouping for use in your filter. With a group of 20 or more crystals, sets of 4 or more are often within a range of 20-25 Hz. The “rule of thumb” is to have the crystals matched within 10% of the filters bandwidth. So for a 500 Hz filter, the crystals should all be within a span of 50 Hz, quite easy to do with crystals from a known source.

Final Comments

I hope you have found the information within to be enlightening and more importantly, useful. Measuring crystal parameters can be done accurately, with relatively simple equipment if you don't mind building some of it. Matching crystals is also easy to accomplish when using the equipment and methods shown. Your efforts can result in home-built filters that are remarkably good and very inexpensive compared to commercial units.

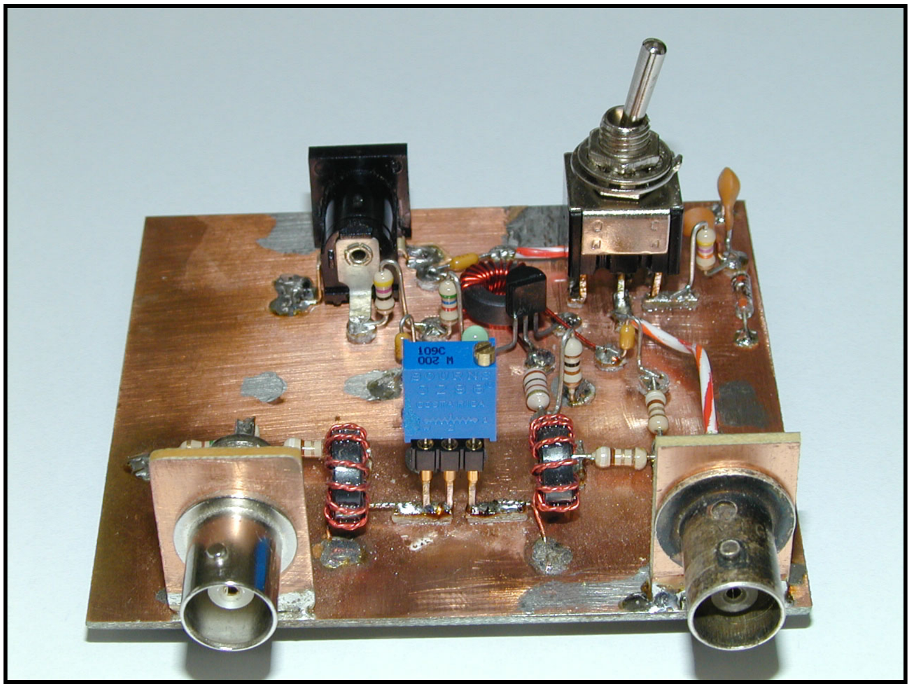


Figure 5

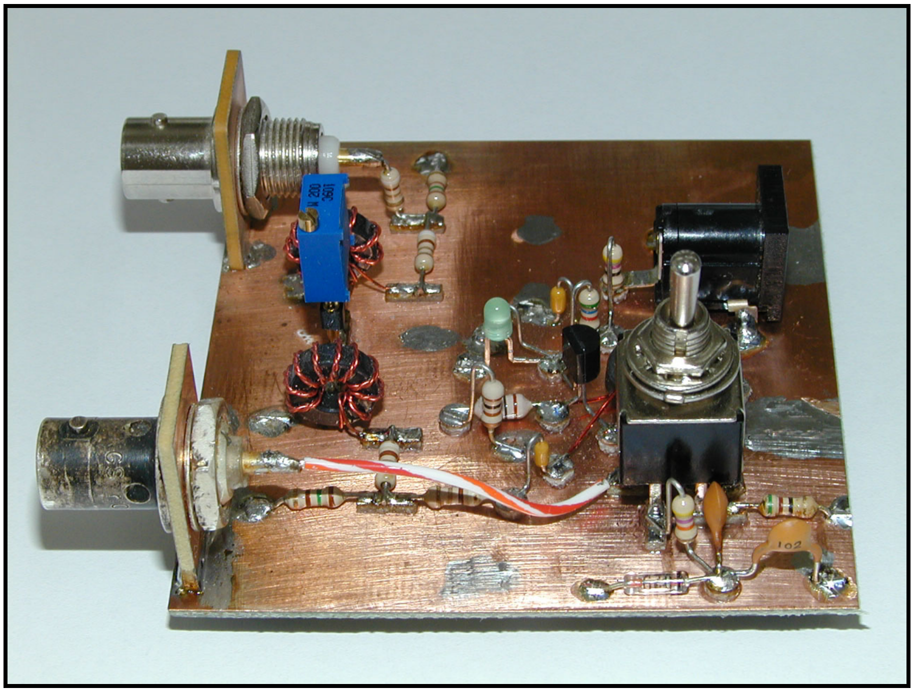


Figure 6

Jim Kortge, K8IQY

k8iqy@k8iqy.com

AmQRP.ORG HOMEBREWER

Rich Arland, K7SZ

TUNING UP!

"The Argonaut from Hell"

The Saga Continues…

A demonically-possessed Argonaut 509 captures K7SZ's attention far longer than he expected!

Was ***The Homebrewer #5*** terrific or what?!?!?!? Man, what an issue. I knew that George was going to attempt something really spectacular, but I had NO idea that it would be this good! Well done, George!

Well, let's see……we have Dayton and FDIM behind us. It was nice to go there after an eight year hiatus and meet new friends and renew old acquaintances. It was especially nice to see some of my old G-QRP cronies again after so many years. The presentations were top notch, as expected. The Buildathon was a great experience and I came away with a neat little semiconductor tester, courtesy of M3 Electronics (pronounced "M Cubed"). This is a one-of device but relax, M3 has a neat little piece of test gear on the immediate horizon that will be a must-have for your shack. More on this next issue.

Field Day has come and gone. This year I spent the weekend at French Creek State Park near Reading, PA, with the Eastern Pennsylvania QRP Group. We used the N3EPA callsign to run a 3A battery powered QRP entry this year. Ron, WB3AAL, the A-Trail Ninja, was on the CW station (an Elecraft K2) and Jon, N3ZIL and Craig, WB3GCD, worked the phone station (an other K2….what else?....***AND*** I brought my K2 as a back up…just in case) while I provided the V/UHF station consisting of a trio of 25+ year old Icom "Bookshelf" radios: IC-202, 402, 502 (2M, 70cms, & 6M respectively). These cute little radios are capable of producing a massive 3W PEP on SSB and about 1.5W on CW. My antennas consisted of a 3 element 6M yagi from MFJ, an Arrow 4 element 2M yagi and another Arrow 7 element 70cms yagi. Craig, K1CRA, (www.k1cra.com) provided a 6VDC rotor (cute little thing but extremely light duty) that turned the small array quite easily. He also furnished a 4 element 2M/70cms Log Periodic Antenna (LPA) that we tested during the FD event. This tiny antenna does not have the performance needed for a dyed-in-the-wool V/UHF contester when compared to a set of small yagis for the same bands. However, it does serve to offer the backpacker a convenient two band array that collapses into a very small package for easy transport. It is a novel antenna that deserves some serious consideration for any QRP VHFer or for those interested in a low profile rover mobile, provided you get to high ground.

Lobstercon is also over and done. Unfortunately Pat and I could not attend this year do to work related conflicts in Pat's schedule. However, we are looking hard at next year. This QRP gathering is the antipathy of Atlanticon: emphasis is placed on hanging antennas and time-in-front-of-the-radio and, eating lobster, of course. This is a "must-do" event that is now on the K7SZ/KB3MCT 2006 calendar.

Now, I know you've all been waiting with baited breath (you can actually get rid of that with some mouthwash…) for the latest in the saga of "***The Argonaut 509 from Hell***" so lets re-visit some old business!

"*The Argonaut 509 from Hell*": The Saga Continues…

After having spent quite a few hours inside this little beastie my repertoire, as far as troubleshooting electronic gear is concerned, has been greatly expanded. The dead 10M band problem still plagued me. Short of completely stripping the little Argo down to bare chassis and replacing both switch wafers, which would probably entail between 10 and 15 hours of work, I was at a loss as to how to restore 10M operation on this radio.

In addition, while I was tweaking the oscillator coils to align the bands, I managed to break one so I called Garland Jenkins…..again….and there was a couple of new coils on their way to me post haste. Once replaced, the alignment went as expected…..tweak one slug, retune the VFO to the opposite end of the band, tweak the other slug…repeat until you had a fairly linear response across the dial. This, by the way is almost impossible to get completely linear….therefore, a good crystal calibrator is in order to insure that you are where you should be on the band. Hey, we're talking about 30+ year old technology here, folks, not frequency synthesized or DDS VFOs!

I managed to obtain another Argo 509 from a missionary friend in Mexico….boy, did it look like it came from a Tijuana flea market! No kidding, it was really rough, but all I needed was a source of parts and this old Argo made the supreme sacrifice. Not only did I acquire a spare PTO, I also had a complete spare set of PC boards (well, almost) and meter, bandswitch linkages, etc. My little "Mexican Cutie" provided me with a wealth of spare parts for future Argonaut adventures.

Armed with all this stuff, I proceeded to complete the **"*The Argonaut 509 from Hell*"** restoration. One of the problems that I kept encountering was that the doubler/tripler stage in the Oscillator board was intermittent. I tried replacing all the NPN transistors with 2N2222 in metal cans, but that still did not cure the problem. After reheating many of the solder connections on the bottom of the board several times, the problem disappeared, but to this day, I still don't know what really cured that particular problem.

With **"*The Argonaut 509 from Hell*"** limping along on 4 out of 5 bands, and all else being equal, I decided that the most appropriate course of action was to procure yet another 509 in working condition and let this little beastie sit on the bench as a reminder that: "sometimes you're the windshield, and sometimes you're the bug".

I located another Argonaut 509 just down the road near Lancaster, PA. This particular radio actually worked on all 5 bands and, although it was in good mechanical and electrical condition, it was one of the very early 509s that featured a mechanical relay on the control board for T/R switching. According to Garland Jenkins from Ten-Tec, there were only a couple of hundred of these units made prior to converting the Argonaut control boards over to solid state T/R switching. Mechanical relay or not, the CW keying is still the buttery smooth Ten-Tec full QSK we have all come to expect from our Sevierville radios.

About the only draw back to this rig was that it belonged to a chain smoker and the exterior and interior of the radio was caked with nicotine and tar from countless cigarettes. It was a smelly mess to clean up, however, after a thorough washing of the front panel, top, bottom and end panels, coupled with a good dose of alcohol, rubbing compound/polish and some polymer wax the exterior finish was brought up to original luster. The knobs were caked with crud, as well, and these were soaked overnight in a solution of dishpan detergent and water. While the crud came off the knobs, the silver inserts in the center of each knob became discolored, so the entire knob set, except for the main tuning knob, band selector knob and the dial skirt were rendered unusable for my restoration of **"*The Argonaut 509 from Hell*"**. That's OK I had the knobs off of "***Radio Free Tijuana***" and the original knobs from **"The Argo from Hell"**, plenty of knobs to go around!

I did the obligatory rebuild of the PTO along with a dial restringing (big surprise there) and a re-cal of the oscillator board to restore the dial calibration, which was between 15 and 20 kHz off depending upon which band was being used. Calibration holds up pretty well until you get about 200 kHz up from the low end on each band, then the linearity starts to get a little squirrelly.

Since I had **"The Argonaut 509 from Hell",** and the Tijuana Rig, I ended up with two "spare" SSB Generator subassemblies that I could experiment with. When I bought **"The Argo from Hell" it** came with an International Radio (InRad) 2.1 kHz 8 pole crystal filter that a previous owner had procured for the modification to the SSB generator board but it had not been installed. I decided to pirate the SSB Gen board from **"The Argonaut 509 from Hell"** (I knew this board worked whereas the Tijuana Rig's SSB gen board I was a little leery of) and change out the stock 4-pole crystal filter with the narrower 8-pole InRad unit. The plan then called for me to install this modified SSB Gen board into my newly acquired 509 (you know, the one from Lancaster…..Is it me or are all these Argonauts starting to become confusing to you, too?) and check out the performance. In the event I could not realize any improvement over the stock filter or the InRad filter modification would not work properly, I could always go back to the original SSB Gen board.

The InRad filter was almost a perfect fit. Although I had previously referred to this mod as a "drop-in", I would not really call it that since there were some leads to be extended and connected, and a couple of parts on the existing filter board had to be removed prior to mounting the InRad filter on the generator board with some double sided sticky tape. As luck would have it, the InRad filter, being smaller than the optional Ten-Tec filters normally used for this mod, fit on the SSB Gen board like it was made for it

Once the mod was completed and installed in the Lancaster Argo, adjustment of the IF was quickly done using Spectrogram and the sound card on my laptop. The improvement was phenomenal! The receiver IF passband was a lot tighter and you could actually hear the difference. All in all, this InRad filter conversion was definitely worth the time and effort to accomplish because now I had an Argonaut with a receiver capable of being used for some serious QRP contesting.

I recently removed the front panel, and end panels on **"The Argonaut 509 from Hell"** and replaced the similar items on the Lancaster Argo 509. I now have a fully functional, pristine looking, QRP Contesting Argonaut 509 that will be a lot of fun to use. The other two Argo chassis will be good for spare parts for years to come. While it was not a complete "win", I did manage to prevail and I learned a lot in the interim. Now, if I could just find an Argosy 525-D…………

QRP and "The Last Frontier"

Those who know me personally will agree that my one fondness outside of QRP Contesting and DXing is my love of V/UHF experimentation. While I am not a microwave "plumber", I do enjoy playing with novel antenna designs and experimenting with QRP on the VHF+ bands. While many hams will tell you frankly that QRP and VHF/UHF operations are mutually exclusive terms, I don't believe that one bit.

Bob Witte, K0NR, a good friend and contributor to my 2nd edition of the ARRL QRP book, and I have been communicating via the internet regarding the need for QRPers to get away from the HF stereotype and get active on the VHF+ bands. With nothing more than a Yaesu FT-817 and a small yagi mounted on a camera tripod, any able bodied QRPer can climb a hill or bluff, fire up their gear and have a blast working grid squares like mad! Do this during a V/UHF contest and select your ground carefully (like a rare grid square) and you will literally become the hit of the party!

Old Farts with Old Radios

"Back in the day" (1979-1984), while stationed in the UK courtesy of the USAF, I became quite attached to a set of Icom "Bookshelf" radios: the IC-202S and the IC-402. The 202 was a 2M SSB/CW rig and the 402 was it's 70cms cousin. The "S" designation on the 202 indicated that it featured both USB and LSB whereas the original 202 model was USB only. Much later, I added an IC-502 to cover 6M SSB/CW.

All these rigs had a 3W PEP output on SSB and ran about 1.5W on CW. Keying was rather cumbersome on CW, as you had to flip a front panel switch and then key the radio with a straight key or keyer and paddle set. Not exactly contest oriented full QSK, huh? However, these two rigs (the 202S and the 402) provided me with countless hours of fun and excitement working all over the UK, western Europe and down into "The Med", upon occasion, using nothing more exotic that a 13 element yagi on 2M and a 19 element yagi on 70cms. Using a simple turnstile antenna for 2M and adding the appropriate crystal to the IC-202S, I was able to copy OSCAR mode J signals from my UK QTH in East Anglia. Although I never tried communicating via any of the OSCARs of the day using the pair of Icoms, no doubt it could have been done, although I might have had to have added an amplifier on my uplink signal in order to hit the birds.

In short, these two rigs were some of the best fun I ever had on VHF/UHF since becoming a ham in 1963. Unfortunately, these two radios, along with my first IC-502 went by the wayside, having been sold or traded off sometime in the late 1980s.

Recently, in late 2004, I decided to become active on the high bands once again and, while I had a FT-817, I really wanted to revisit the old days by procuring a full set of Icom “Bookshelf” radios. “A hunting we will go, a hunting we will go, onward to e-bay, a hunting we will go”.

It didn’t take long: I had a IC-502 on the way direct from Japan for a total of about $125. Dave Benson, K1SWL, sold me his old IC-202 for a paltry $75. Two down, one to go. I finally found a mint condition (as in brand new, still in the original box) IC-402 from a farmer out in the mid west. Cost: $135. So, for slightly over $300 not counting shipping and handling costs, I had my trio of Icoms. It took only about a month or so to amass all this stuff, too. Not bad, really.

The IC-502 and 402 radios were immaculate. They worked fine and were utterly stunning cosmetically. Unfortunately, Dave’s IC-202 had been stored in a garage for many, many years, and needed some cosmetic refurbishing. After a good clean up, it, too, looked like it came right off the shelf at AES!

A good friend of mine in upstate New York, WB2VUO, had been following my antics and wanted to know if I needed the IC-215, 2M FM “Bookshelf” rig to round out my collection? The price was right: trade straight across for an old MFJ tuner I had kicking around in the basement for 20 years. It came complete with telescoping antenna, rubber-ducky antenna along with most of the15 channels full of crystals: several on local repeaters in my area! Done deal!

In the mean time a person I had never met out in Las Cruses, NM sent me his old IC-202 that he use to contest with as a gift. He said it sounded like I would provide it with a good home, so he offered it to me in exchange for the shipping costs. One nice thing about this radio, it had the LSB mod done to it AND it came with a Janel 2M receive preamp! 20-25 years ago, this bipolar preamp was one of the hotter offerings for the serious VHFer.

So, a dear reader, that is how this ***Old Fart*** accumulated a shack full of 25+ year old Icom V/UHF gear with which to amuse himself on the high bands. Now the neat thing about this type of set up is that you can monitor three bands or modes simultaneously, which is impossible using only one FT-817. For contesting, it is a simple matter to set each station up with its own antenna and listen for band openings or new stations on the two other bands while working on one band. There is no lag time for band switching, just grab the mic or key the rig and make a QSO. Life is good.

Many of you are probably wondering how well 3W PEP works on VHF+. Allow me to share a true story. “There I was at 30,000 feet, a Mig 25 on my tail……” ooops, not that story!

In February 2005 I was sitting in my easy chair monitoring 6M (50.125 MHz) with the IC-502 quietly perking along in the background, when I heard a scratchy signal calling “CQ Six”. I quickly adjusted the VFO (it’s actually a VXO, since they warp the crystal in the IC-X02 series of rigs using a front panel mounted capacitor driven with a large reduction drive), and tuned the station in. I answered his call. No luck. After he made a QSO, I tried again, and again, no joy. This went on several more times and finally we made contact! We swapped signal reports and grid squares (he was in northern Florida) and I told him what I was running for a radio. He stated that he hadn't heard one of them on the air in ages. Things got a lot more interesting when I told him that my 6M antenna was a scanner discone mounted only 3 feet off the roof and that it was not resonant at 50.125 MHz!

This QSO started a string of contacts that went on for several hours which enabled me to work 11 grids all down south in North and South Carolina, and Florida! All with 3W PEP from a 25 year old rig feeding a non-resonant omni directional scanner antenna mounted just above roofs edge! No, I didn't bust any pile ups (yes, pile ups do occur during 6M openings) and it always took me several attempts to make it into the other Ops log, but I did manage to do quite well despite only running 3W. So, make draw your own conclusions: does 3W PEP work on VHF+? By my standards it certainly does. I would like to get the RF output up to the accepted QRP SSB levels of 10W PEP, and I am working on that project.

Antenna improvements at K7SZ/KB3MCT this year call for adding a 6M Cushcraft vertical omni on a chimney mount, moving the scanner discone to the side of the tower, about 40 feet up, adding a 2M Cushcraft vertical omni on the pole that previously held the discone, and finally adding a "short stack" of 5 over 5 yagis for 2M with a 19 element yagi for 70cms on a rotor on the end of the house. Ultimately, I will acquire a 5 element 6M yagi for mounting above the TH7DX on the main tower, but I doubt that this will occur this year.

The Old Fart and Friends do an Antenna Project

In talking with George Burt, GM3OXX, my interests in hill topping using a small 2M rig like an IC-202 or a FT-817 were rekindled. I have had an Arrow 4 element yagi for many years. This unique little antenna is made using aluminum arrow blanks for elements and all these elements break down and they store inside the one inch square aluminum boom. End caps on each end of the boom transform this antenna into a walking stick, of sorts. Short for me, but maybe not for you.

My next door neighbor, Dave Carey, N3PBV, is an adjunct professor of electrical engineering at Wilkes University in downtown Wilkes-Barre, PA. About the time I was talking to George about hilltopping, Dave approached me wanting some ideas for an undergrad engineering antenna project for some of his students. Oh, Davie, you should never have tempted me with something like that!

Dave and I discussed the Arrow antenna (he has a couple himself) and I brought up the idea of a five or six element 2M yagi design using the take-apart antenna elements ala Arrow. Being an avid outdoorsman and Boy Scout leader, Dave liked the idea, especially the part about the walking stick. There is nothing like a good six foot walking stick for making your way through the woods or along the Appalachian Trail. After you stop for a rest or to spend the night, assemble the 2M yagi and you are on the air from your campsite in fine style with a gain antenna. Before long we had roughed out an undergrad antenna project for his students which would include not only designing the antenna but ordering parts for six of them, fabricating, testing and evaluating these antennas on the newly refurbished antenna test range at Wilkes.

Once completed, I am to receive a complimentary 5 element “Wilkes Walking Stick” for my humble input to the project. The long term spin off is that I have whetted Dave’s appetite for continuing on and having his next class expand on the original project with a workable design for a 70cms walking stick antenna or, better yet, a cross polarized 2M/70cms OSCAR walking stick antenna for the adventurous QRP VHFer. The latter design has some promise since you can use it for terrestrial weak signal hill topping by simply orienting the respective elements in the horizontal polarization position for working either 2M or 70cms. It’s so nice to have a university professor and a class of eager undergrads handy to do some antenna experimentation (not to mention a fully stocked lab and antenna test range). Actually, Dave and I are co-writing a piece for QEX regarding this antennas design and fabrication. Credit for the project will go, of course, to Dave’s class of newly graduated electrical engineers. Man, I love this hobby!

That’s it for this issue of ***The Homebrewer***. Next issue I hope to have some empirical data regarding the Wilkes Walking Stick 2M yagi and some other topics of interest. Until the, get out of the shack, enjoy the great weather, have fun with ham radio ala QRP!

72, Rich K7SZ

AmQRP.ORG HOMEBREWER

Joe Everhart, N2CX

TEST TOPICS … and More!

Using a 75-ohm attenuator, series and parallel circuits, and power attenuators.

TTAM this time around shows some basic electronics that are relevant for more than just test equipment. Designed for Test shows how to use a 75-ohm attenuator with other equipment and cables designed for a 50-ohm impedance using a so-called minimum loss pad. Coming to Terms deals with series and parallel equivalent circuits, a topic that comes up now and again, particularly in conjunction with impedance matching. Stimulus and Response talks about power attenuators – how to design them and how to size the components that make them up.

Never fear, calculations are needed for most of the topics; but in addition to the formulas used, this column also presents some spreadsheets to automate the process. Since the Homebrewer journal is distributed in CD form, two spreadsheets (PowerAtten.xls and ImpCon.xls) are easily provided for your use. By the way, using spreadsheets to do repetitive computing tasks for "what if" comparisons is something I use quite a bit. I generally design the spreadsheets on my "big" computer then keep a copy on my PDA as well so that I always have them with me.

Designed For Test

Lab-grade step attenuators are very convenient on the measurement bench. In a later column we may give some examples of ways to employ them. You can even roll your own and I've certainly built my share. However it is hard to pass up the opportunity when someone gives you a good commercial grade step attenuator, as my friend Dave Ottenberg, WA2DJN did recently. As you can see in Figure 1, it goes up to 102 dB in 1 dB steps. And being a good grade commercial product, it is ruggedly built and I expect it to have accurate and repeatable operation. There is one handicap though – it is designed to be operated in a 75-ohm system and the RF equipment and cabling I use is the more common 50-ohm variety.

Figure1: Commercial-grade 75-ohm step attenuator

Fortunately there is a fairly simple solution to this dilemma – something called a "minimum loss pad" (Ref 1). The idea is really quite simple and is implemented with two resistors, as shown in Figure 2. Looking from the left side, the impedance is 50 ohms when the right-hand side is terminated in 75 ohms. Similarly when a 50-ohm load is connected to the left-hand side, the impedance seen looking into the right-hand end is 75 ohms.

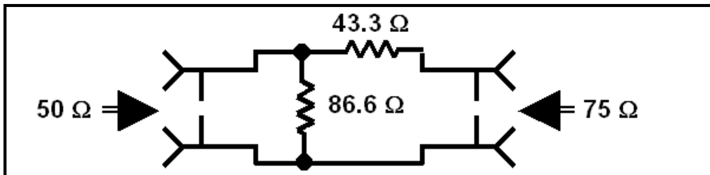


Figure 2 – Minimum Loss Pad for 50/75 ohms

There is a price to pay, however since there is loss in the minimum loss pad. In this case, the loss is 5.72 dB. To use the original 75-ohm step attenuator in a 50-ohm system you have to add a minimum loss pad on either end as shown in Figure 3. Theoretically, the total added loss is 11.44 dB but you may want to round this off to 11.5 or even 12 dB, depending on how precisely you have your system calibrated and how close to exact the net attenuation needs to be.

Figure 3 – Min-Loss Pads Match 75 Ω Attenuator to 50 Ω

Construction can be as simple as you want or as exacting as you need. For precision you can use 1% resistors with values of 43.2 and 86.6 ohms. Alternatively, you can obtain a quantity of 43-ohm 5% carbon film resistors and sort as needed. Using a digital multimeter, pick one close to 43.3 ohms and a series combination close to 86.6 ohms. For "proof of concept" I lashed up a couple of BNC connectors and the resistors shown in the photo at Figure 4. Eventually I'll build something more rugged with better shielding and shorter leads to preserve bandwidth. Dave Ottenberg suggests using a small "Pomona" box with BNC females on either end and a double-male BNC adaptor to connect to the step attenuator. To be precise, the double male adaptor and BNC female on the "75Ω" side of the pad should be 75-ohm types. However except at VHF, using 50-ohm BNCs should only add a negligible impedance bump to the system.

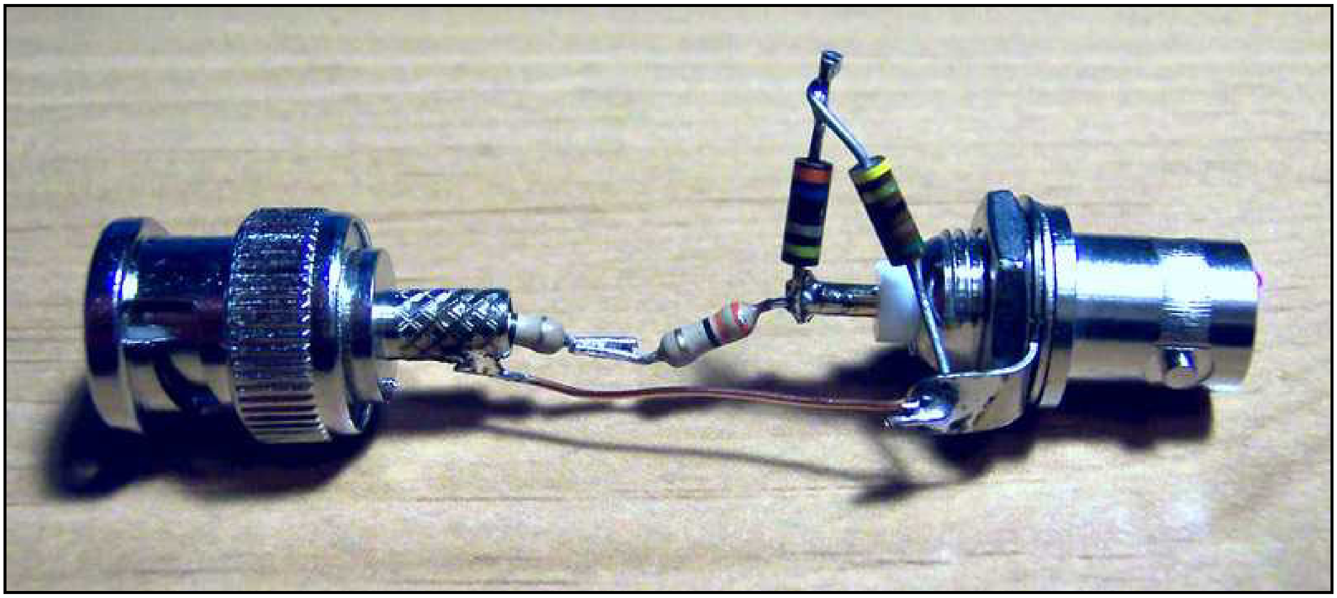


Figure 4: Minimum Loss Pad "proof of concept"

Coming To Terms

When we talk about RF circuits and antennas, we always need to consider circuit impedances. For much RF work involving coaxial cable, the nominal impedance level is 50 ohms, except for cable TV applications which instead use 75 ohms. However, impedances more generally have a more complex nature (pun intended). There are several ways of describing complex impedances. See any recent edition of the ARRL Radio Amateur's Handbook or Wes Hayward's Introduction to RF Design for much more detail.

The most common way of expressing an impedance is to talk about the magnitude of the impedance represented by the letter Z. This is what we use day-to-day when we talk about transmission lines, filters, dummy loads and other RF blocks. To be completely precise you also need to add the effect of reactance by adding something called the phase angle Θ. The expression then becomes Z with an angle of Θ, or $Z\angle\Theta$. This mathematical notation called the polar form of the impedance is really clumsy, so there are still other ways to represent impedance.

The second method is one often seen in amateur literature and in measurements made by the familiar antenna analyzers. It is called the series form of impedance where the resistance R and reactance X are expressed as if they were series components, as shown in Figure 5. The impedance is written as R ± jX. The "j" indicates that the reactance is indeed a reactance and the sign associated with it indicates where the reactance is inductive (+) or capacitive(-). For example an impedance with a 50-ohm resistive component and 10 ohms inductive is 50 + j10 while 50 ohms resistive and 10 ohms capacitive is written as 50 – j10.

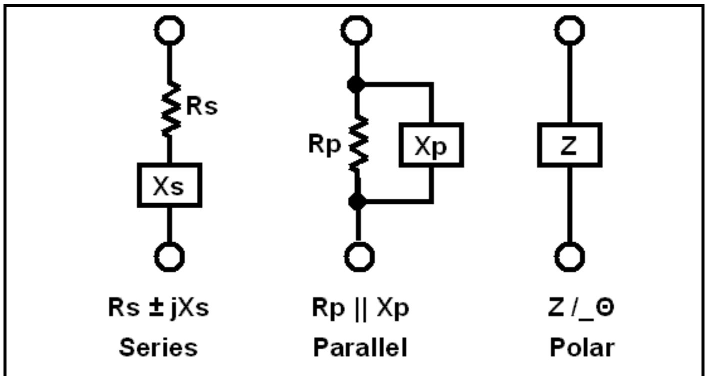


Figure 5 – Equivalent Impedance Forms

There is yet another way to express complex impedances: the parallel form of notation. It becomes handy sometimes when designing matching networks for antennas or RF components. Circuit-wise, the parallel form is also shown in Figure 5.

It may seem surprising, but when you are measuring an impedance using only RF measurements at a single frequency, you cannot tell if a given circuit is comprised of a resistor in series with a reactive element or different valued components in parallel. But it really doesn't matter since it is equivalent and can also be expressed in the polar form. This is likewise illustrated in Figure 5.

For easy reference, the formulas to do these conversions are given in Appendix A. However if math is not your bag don't panic. An Excel spreadsheet is included with this column that does all the heavy lifting for you. The file name is Impcon.xls When you open the file you will see a series of boxed-in areas, each corresponding to a type of conversion. Conversions presented are:

- Series to parallel conversion
- Parallel to series conversion
- Series to polar conversion
- Polar to series conversion

For convenience, the spreadsheet also provides conversions between inductance/capacitance and reactance, and vice versa.

Note that some boxes in each section have a yellow background. These are boxes where data is to be entered. When the appropriate data is entered, the results are automatically displayed in each section. Sample data is already entered but the reader is encouraged to try some of his own data to see how the process works.

Stimulus and Response

Back to the main topic, I have been queried on the design of power attenuators. These have a number of uses for hams:

- Reducing transmitter power to drive a transverter,
- Knocking down a transmitter output to use it as a signal generator
- Protecting a low-level signal generator from inadvertent transmitter keying during transceiver testing
- Achieving QRPp and below transmit power levels for miles-per-watt attempts.

An article in the QRP Quarterly (Ref 2) described how to build RF power attenuators and gave some examples of component values to be used. However, choosing component values for other attenuation and power levels was not discussed in detail. Figure 6 is the circuit diagram for a power attenuator. RF input is provided to coaxial jack J1. It is attenuated by the resistive "pi" pad formed by resistors R1, R2 and R3, and the attenuated output is fed to coax jack J2. For the proper amount of attenuation to take place, the input and output impedances are assumed to be 50 ohms. Deviation from this impedance level will change the amount of attenuation provided.

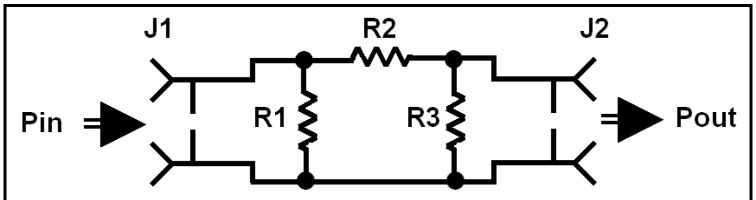


Figure 6 – Pi Pad resistive attenuator

Note that the difference in input power P1 and output P2 is dissipated in the resistive pad, resulting in heat generation. The resistors not only must have the correct resistive value, but they need to be sized appropriately to safely dissipate the power difference P1-P2. In practice, individual resistors are generally not available in power ratings above three watts, so each leg of the pad may consist of a series-parallel group of resistors in order to get the needed resistance value with a high enough dissipation rating.

Appendix B provides formulas for calculating the resistance values to get the desired attenuation. In addition, formulas are provided to determine for a given resistance value and input power how much each leg of the pad sees. By using these formulas, you can design for a wide range of attenuation and power levels. Operating much above the 10 watt power level, however, may require unwieldy series-parallel resistor combinations.

The calculation process can be automated by using a spreadsheet, as was done with impedance network calculations. File pwrattn.xls included with this column provides a means of doing so.

As with the other spreadsheet, blocks with yellow backgrounds are for data input, while the others are automatically filled in. Sample data is entered in the blocks so that you can see the results. Simply over-write the data in the yellow blocks with your own data. The active part of the spreadsheet is surrounded by bold outline boxes. Intermediate data is shown the right of the active area. You can ignore this area but don't delete it or the calculations won't work!

The first section of the power attenuator spreadsheet accepts inputs of the desired input power level and power attenuation in dB. Outputs are the attenuator pad resistors shown in Figure 6 and the power dissipated in each of those resistors.

Practically speaking, the calculated values will not be standard values. The second part of the spreadsheet allows you to plug in resistor values that you have, and then shows the resulting power dissipated in each resistor, the resulting attenuation, the SWR and the input impedance. This lets you try standard resistor values or series parallel combinations (you have to calculate those combinations yourself) to evaluate how close your design comes to the ideal.

For convenience, there are also calculation blocks to see the relationship between dB of attenuation and the resulting input and output voltage and current ratios.

This column has probably been a lot to swallow. I must admit that I had to do some serious head-scratching to make all of the algebra work and to relearn how to express the formulas in Excel spreadsheet form. I definitely expect that there will be questions! Please ask away and add the spreadsheets to *your* bag of tricks.

You can address questions to me at:

Joe Everhart, N2CX
214 New Jersey Rd
Brooklawn, NJ

… or by e-mail at n2cx@amqrp.org

References:

1. Maxim Semiconductor Applications note http://www.eetasia.com/ARTICLES/2004NOV/A/2004NOV24_ICD_ICT_AN.PDF
2. Joe's Quickie No.#19 "Power Attenuator Quickie", in the WA8MCQ Technical Topics column QRP Quarterly October 1996

Appendix A:
Conversion formulas between series parallel and polar impedance representations.

Parallel to series

$Rs = Rp * (Xp^2) / (Rp^2 + Xp^2)$

$Xs = Xp * (Rp^2) / (Rp^2 + Xp^2)$

Series to parallel

$Rp = Rs + Xs^2 / Rs$

$Xp = Xs + Rs^2 / Xs$

Series to polar

$Z = \mathrm{sqrt}(RS^2 + XS^2)$

$\Theta = \arctan (XS/RS)$

Polar to series

$Rs = Z * \cos(\Theta)$

$Xs = Z * \sin(\Theta)$

Appendix B:
Power attenuator formulas

K is atten ratio expressed as a ratio of Vin/Vout

K=al(dB/20) if the attenuation is expressed in dB

The power ratio is al(dB/10)

Vr1=sqrt(P*50)

Pr1=Pin*50/R1

Ro=50*R3/(50+R3)

Vr2=Vr1*R2/(R2+Ro)

Pr2=Vr2^2/R2

Vr3= Vr1*Ro/(R2+Ro)

Pr3= Vr3^2/R3

ρ = sqrt(((50-Rx)^2)/(50+Rx)^2)

SWR = (1+ ρ)/(1- ρ)

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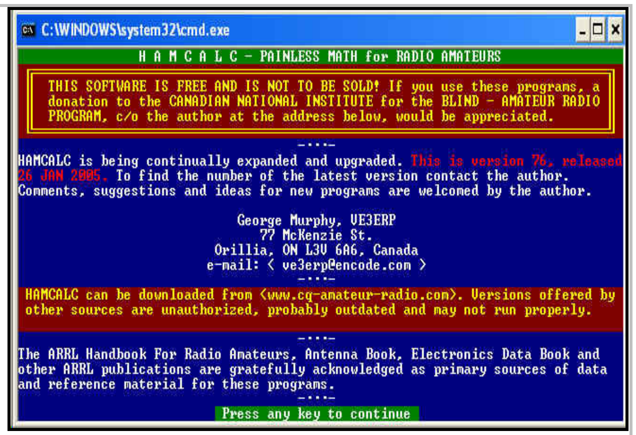
George Murphy, VE3ERP
narration by Nancy Feeny, NJ8B

HamCalc

Designing a Power Supply

HamCalc is free software for WINDOWS or MS-DOS containing over 300 "Painless Math" computer programs for radio amateurs and professionals, used worldwide as a design, reference and learning tool since its introduction in 1993.



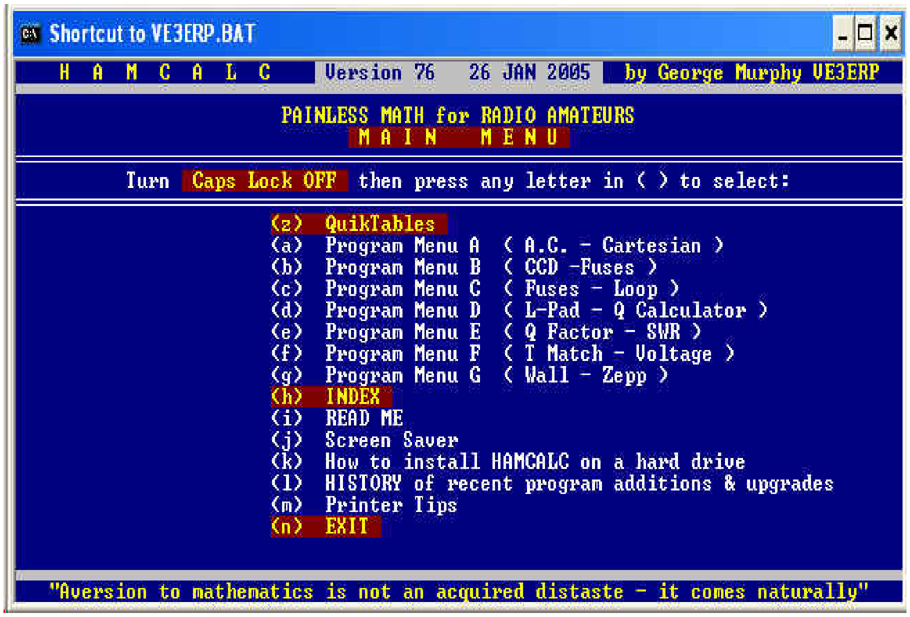
Regular readers of Homebrewer Magazine know that this column is a regular occurrence, whereby in each issue I utilize a different function in HamCalc to demonstrate the usefulness in this gem of a software tool from Murph, VE3ERP. He's given us permission to include the very latest version of his HamCalc program onto our distribution CD for Homebrewer, thus enabling our more than 2,000 subscribers throughout the world to have this powerful utility at their fingertips.

See the Software section of the CD for the HamCalc programs, and reference the HamCalc Installation page at the end of this article for moving it onto your computer.

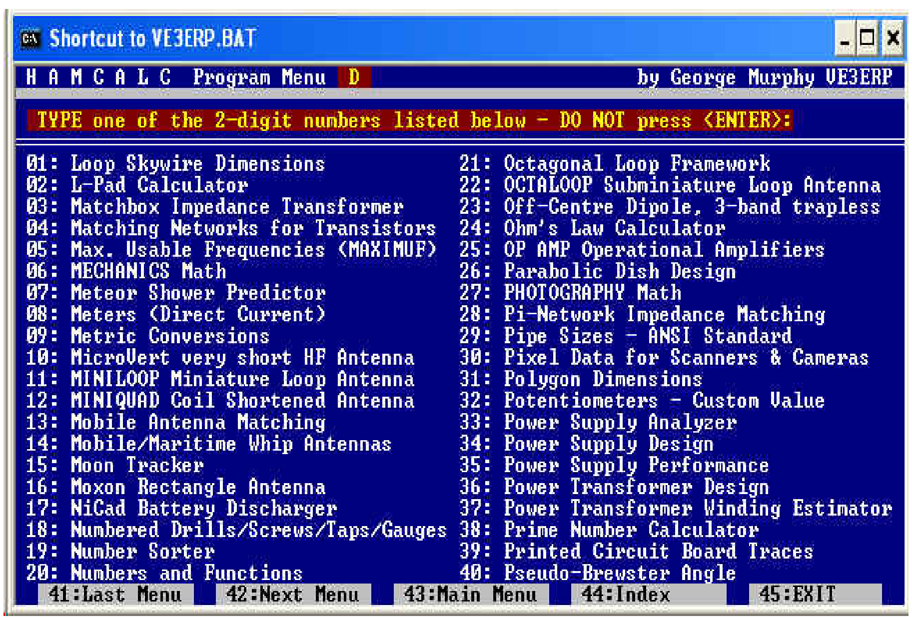
This Time … Designing a Power Supply with HamCalc

In this installment, we are going to use HamCalc to design a simple power supply of the type that many amateurs will find very useful as a project for a bench power supply. The AC from the transformer secondary is rectified by a bridge rectifier, D1 to D4. The principal advantage of a bridge rectifier is you do not need a center tap on the secondary of the transformer. A further but significant advantage is that the ripple frequency at the output is twice the line frequency (i.e. 60 Hz) and makes filtering somewhat easier.

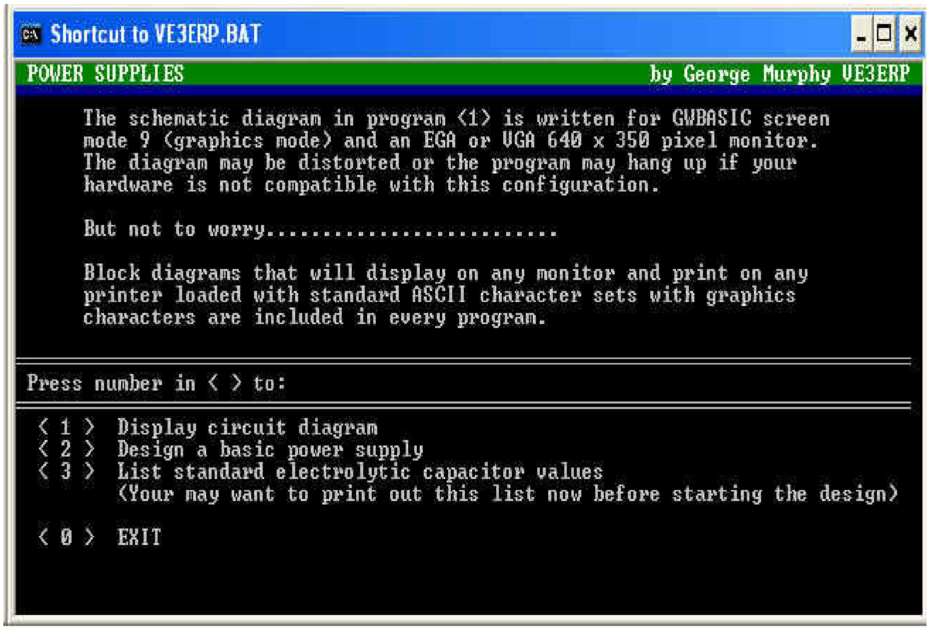
Going into HamCalc, we first find ourselves on the Main Menu page:



Selecting Program Menu <d> (L-Pad – Q Calculator) brings up the following screen:



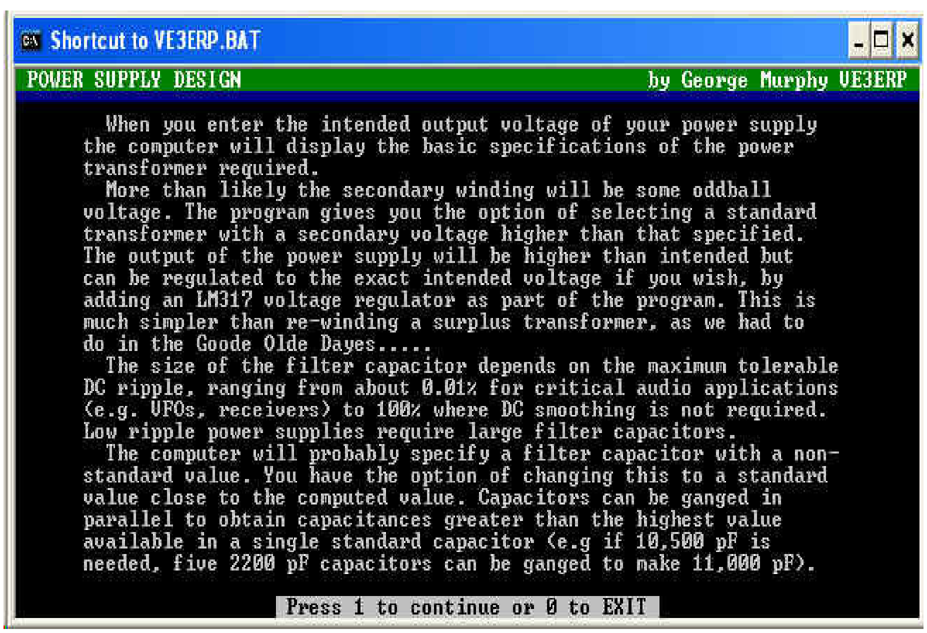
Selecting <34> (Power Supply Design) brings up the following:



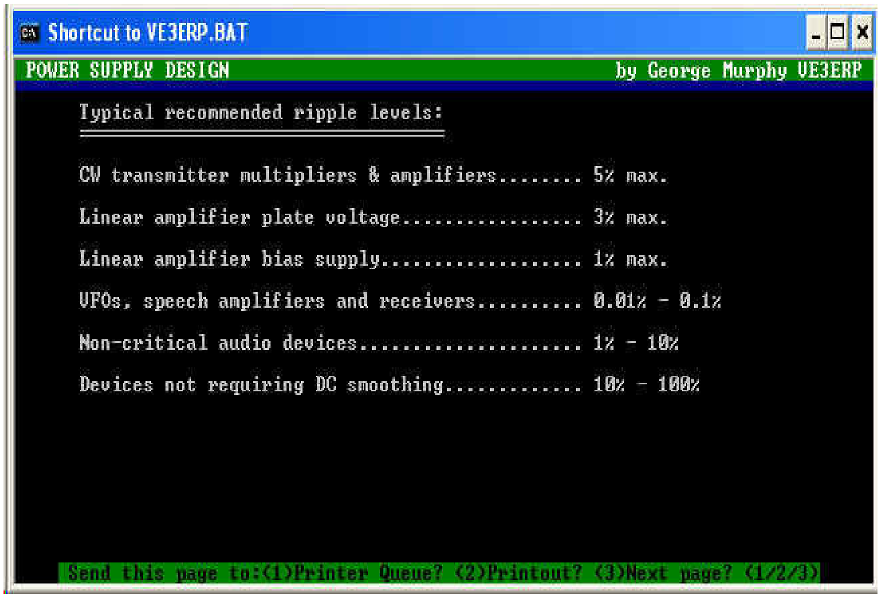
At the prompt

<1> Display circuit diagram
<2> Design a basic power supply
<3> List standard electrolytic capacitor values

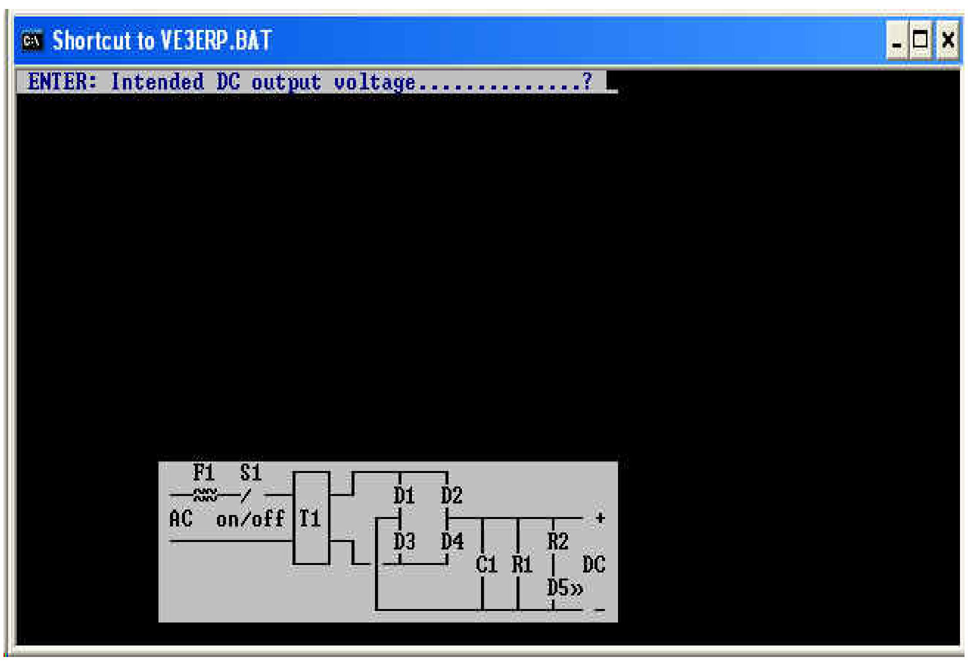
Select <2> (Design a basic power supply). This brings up the following screen:



Press <1> to continue, followed by <3> (Next page). This brings up the following screen:

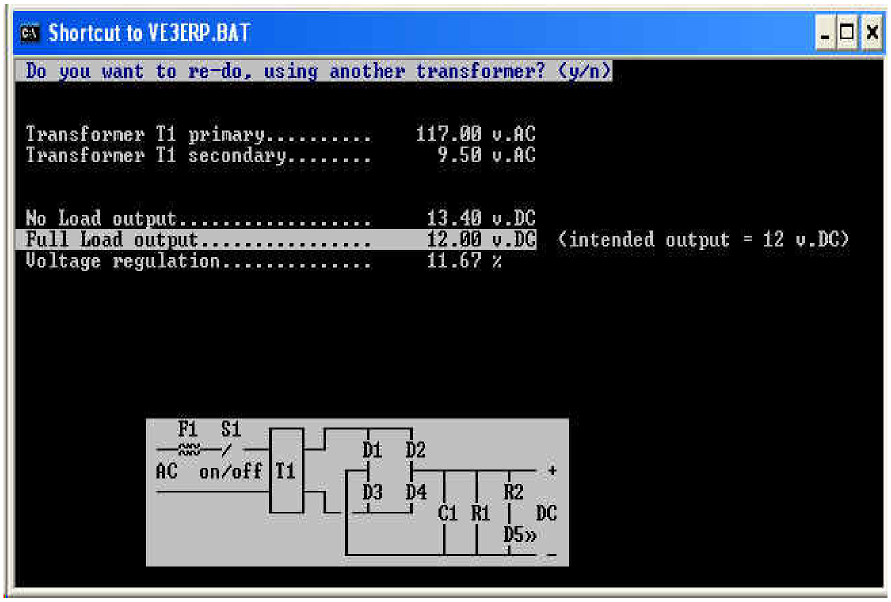


At the prompt “Send this page to: <1> Printer Queue? <2> Printout? <3> Next page? <1/2/3>, select 3 (Next page). This brings up the following screen:

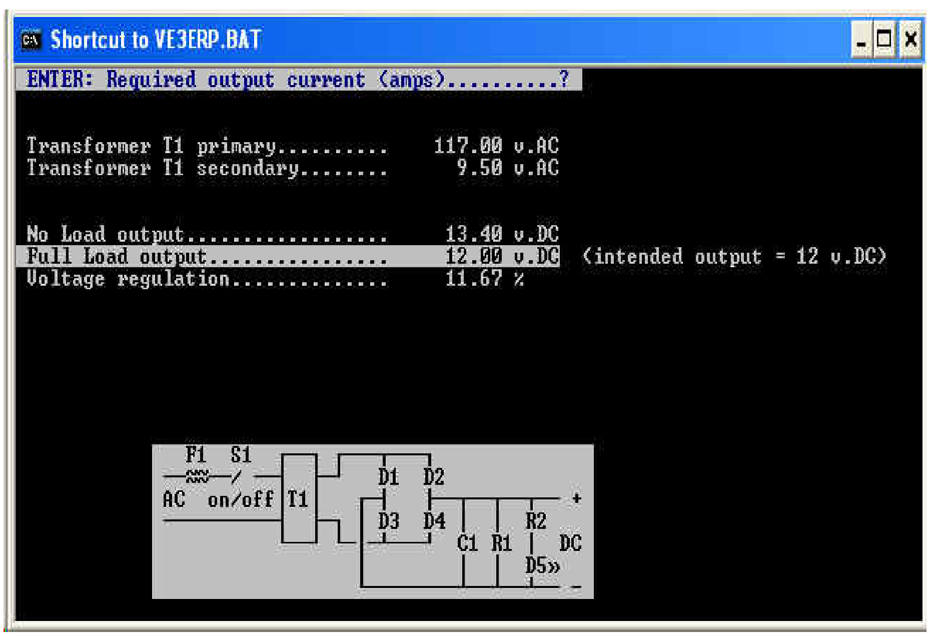


On this, you are prompted to enter the intended DC output voltage. Enter the desired secondary voltage, which in this example is 12 V. Here, the voltage drops across D2 and D4

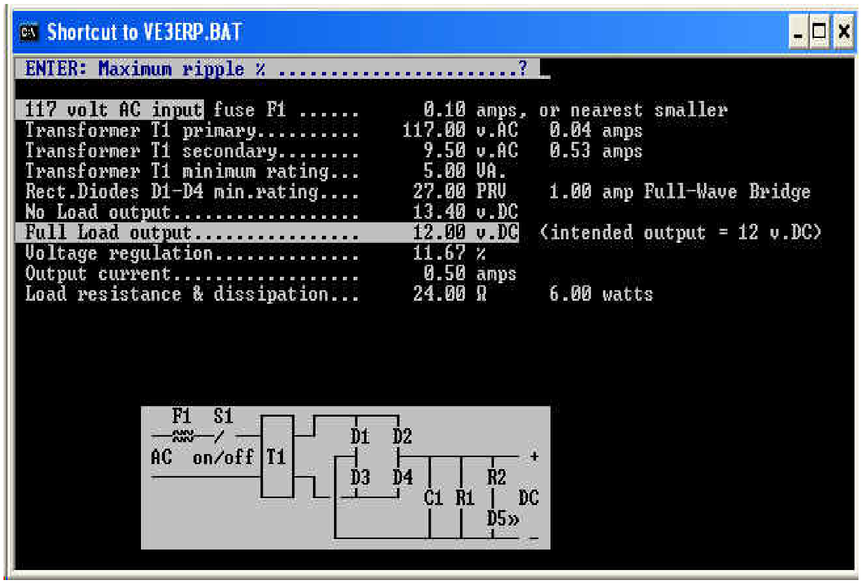
(2 * 0.7V = 1.4 V) are automatically taken into consideration. This brings up the following screen:



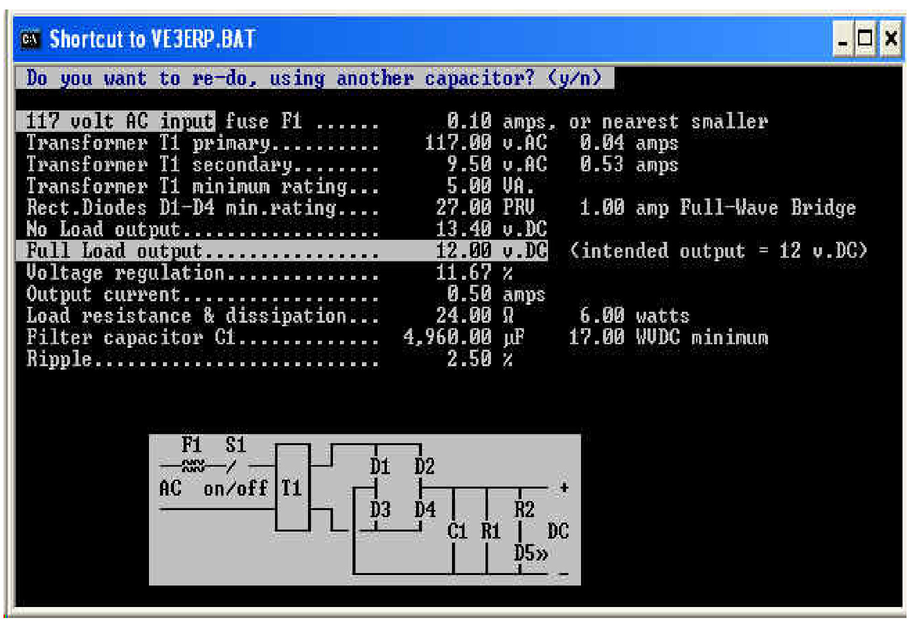
At the prompt "Do you want to re-do, using another transformer? (y/n), enter n. This brings up the following screen.



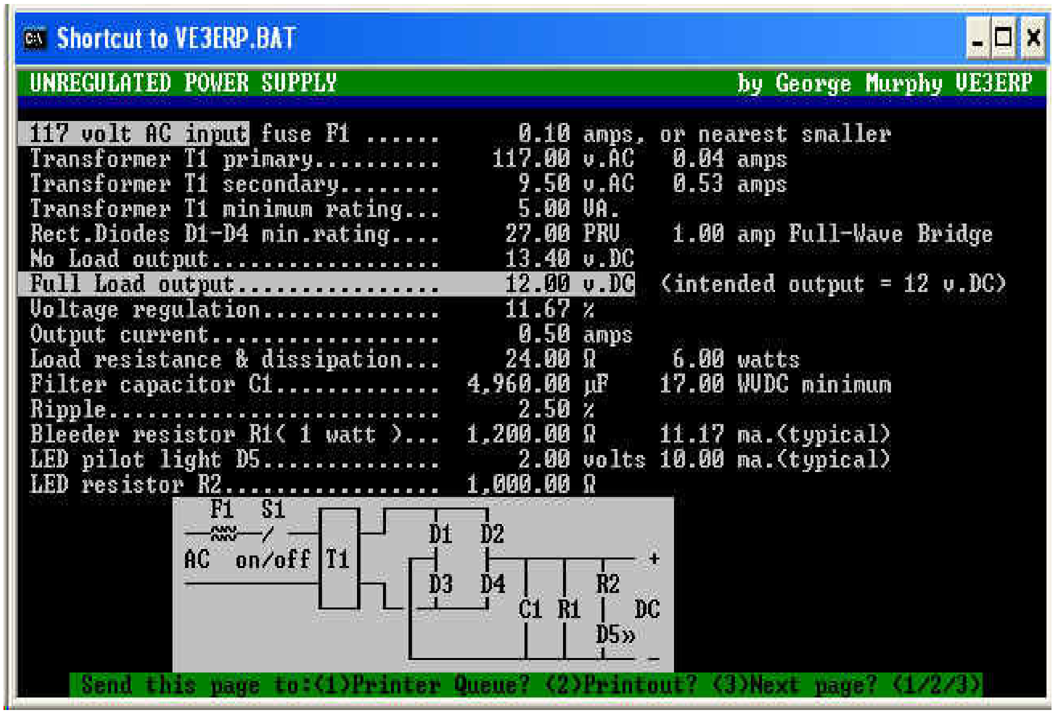
At the prompt "ENTER: Required output current (amps) …..?", enter the desired output current (I_L), which in this example is 500 mA (0.5 A). This brings up the following screen:



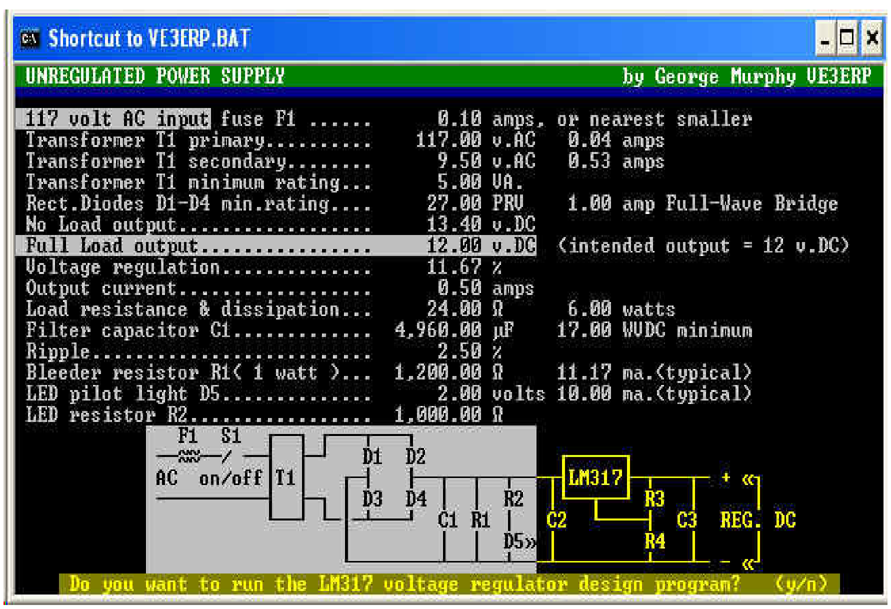
At the prompt “ENTER: Maximum ripple % …..?”, enter the desired ripple, in percent, which for this example, is 2.5 %. This brings up the following screen:



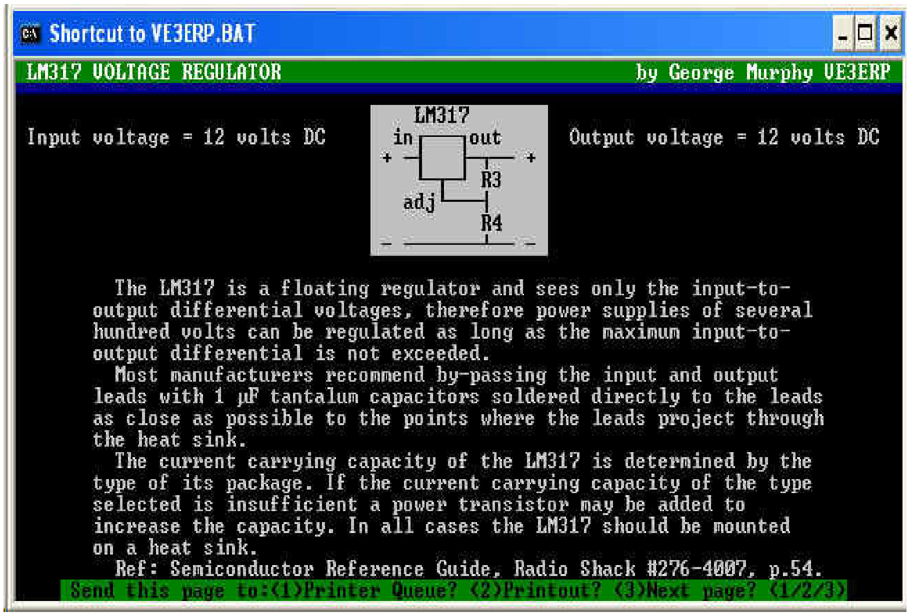
At the prompt “Do you want to re-do, using another capacitor? (y/n), enter n. This brings up the following screen:



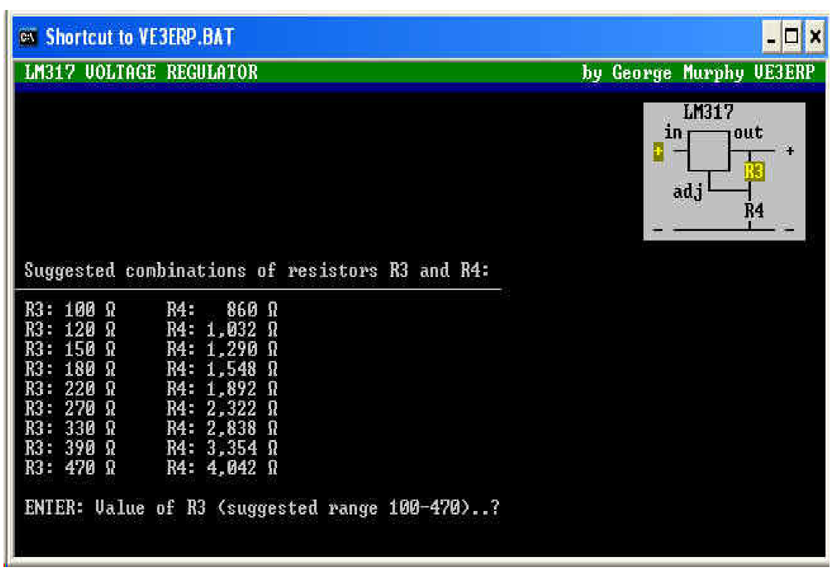
At the prompt “Send this page to: <1> Printer Queue? <2> Printout? <3> Next page? <1/2/3>, select 3 (Next page). This brings up the following screen:



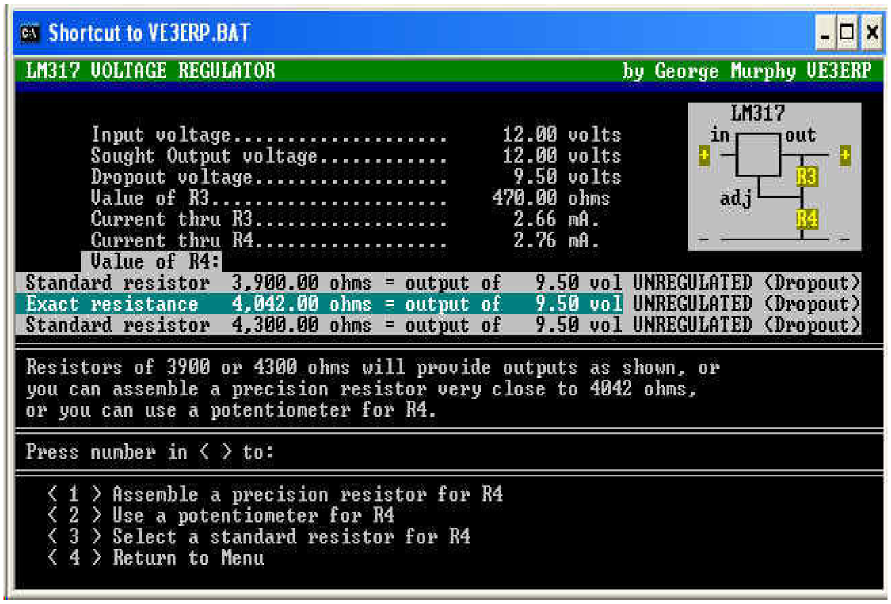
Since we desire to regulate the power supply, at the prompt “Do you want to run the LM317 voltage regulator design program? <y/n>, enter y. This brings up the following screen:



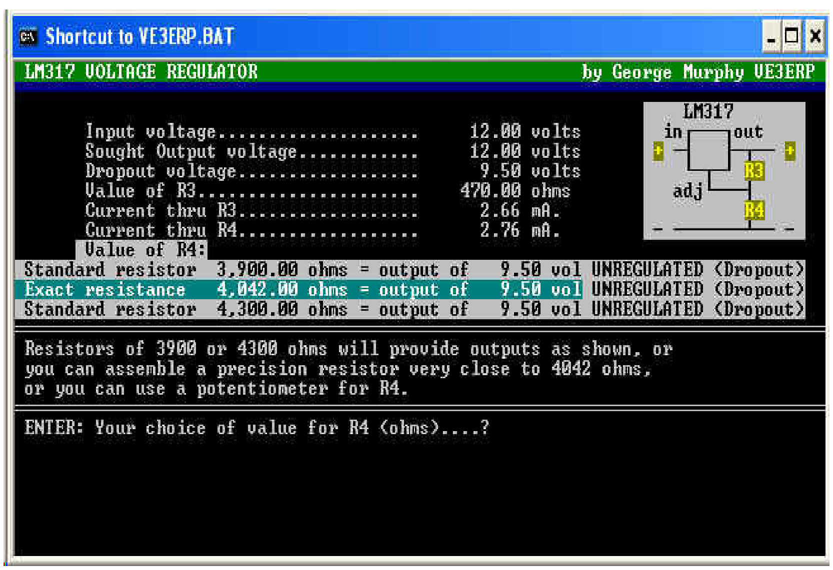
At the prompt "Send this page to: <1> Printer Queue? <2> Printout? <3> Next page? <1/2/3>, select 3 (Next page). This brings up the following screen:



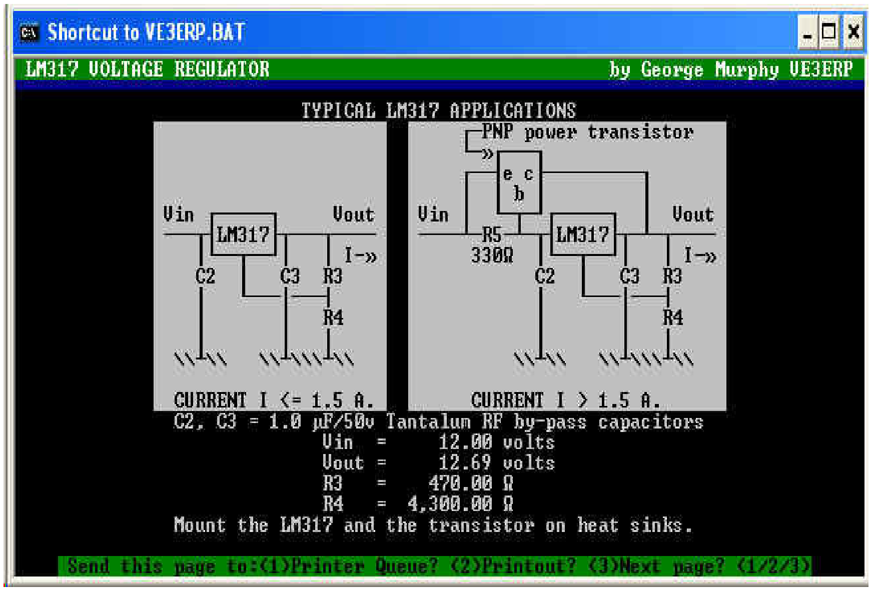
On this screen, several suggested combinations for resistors R3 and R4 are listed. For this example, choosing a value for R3 of 470 ohms brings up the following screen:



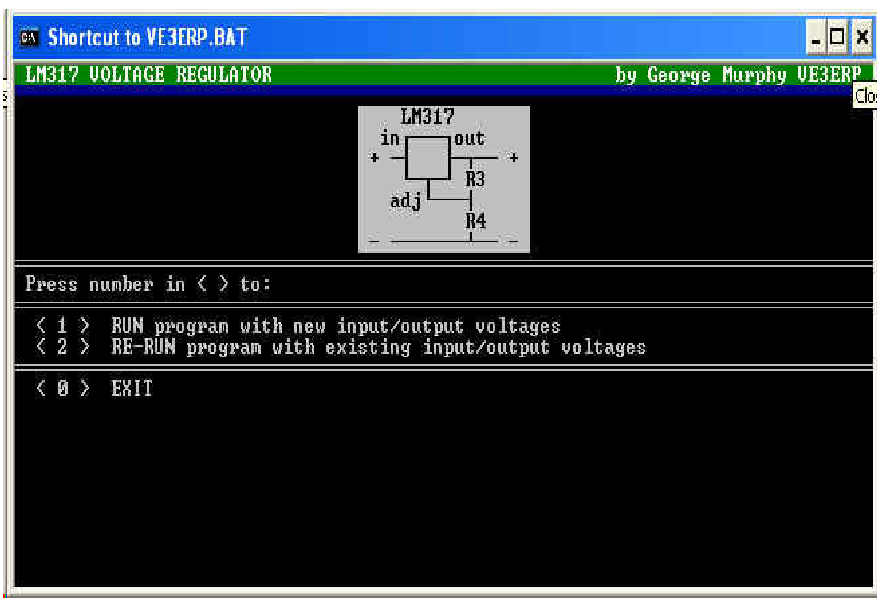
Although we could choose to use a potentiometer to get the exact calculated resistance, we decide to select a standard resistor for R4. After entering <3> (Select a standard resistor for R4), we get the following screen:



At the prompt "ENTER: Your choice of value for R4 <ohms> ….?", we enter a value of 4300 ohms. This brings up the following screen:

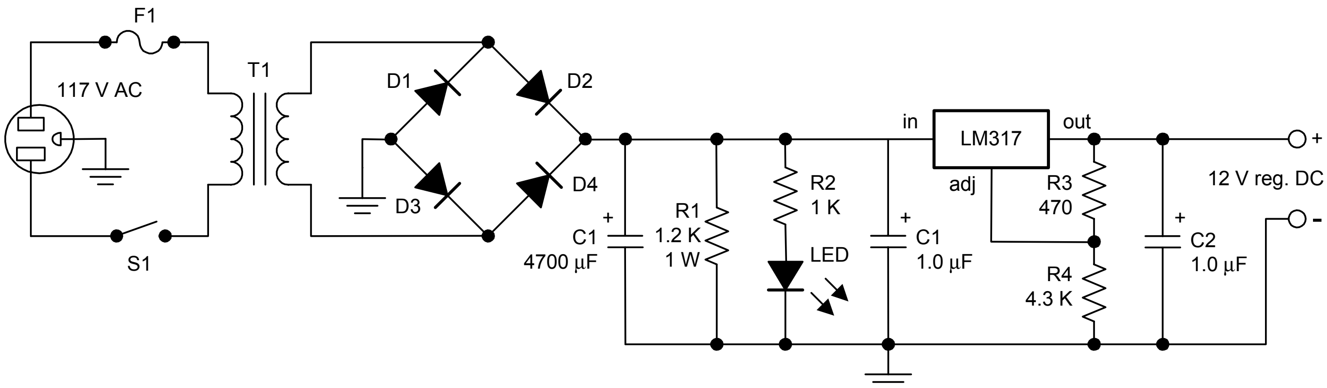


At the prompt "Send this page to: <1> Printer Queue? <2> Printout? <3> Next page? <1/2/3>, select 3 (Next page). This brings up the following screen:



At the prompt "Press number in < > to:
<1> Run program with new input/output voltages
<2> RE-RUN program with existing input/output voltages
<0> EXIT"
we select <0> to exit. That's it, we now have a power supply to build.

The schematic of the power supply is shown as follows:



Power Supply Parts List *

Quantity	Type	Value	Reference Designators	Supplier Part Number
1	Transformer	10 V - 1 A	T1	DK: HM513-ND
4	Diode	1N4004	D1, D2, D3, D4	DK: 1N4004GICT-ND
1	Cap	4700 µF 25 WV	C1	DK: P10289-ND
1	Resistor	1.2 K, 1 W	R1	DK: OA122K-ND
1	Resistor	1 K, ¼ W	R2	DK: 1.0KQBK-ND
1	LED	T-1 3/4	LED1	DK: 160-1713-ND
1	Fuse	0.1 A	F1	DK: F103-ND
1	Fuse Holder	PC Board Mount	Under F1	DK: F1498-ND
1	Switch	S.P.S.T.	S1	RS: 275-634
1	Resistor	470 Ω, ¼ W	R3	DK: 470QBK-ND
1	Resistor	4.3 K, ¼ W	R4	DK: 4.3KQBK-ND
2	Cap	1.0 µF 50 V tantalum	C2, C3	DK: 478-1836-ND
1	Voltage Regulator	LM317	LM317	DK: 497-1575-5-ND
1	Heat Sink	Heat Sink	Under LM317	DK: 294-1108-ND

- Not shown on parts list: power cord, circuit board, mounting hardware, enclosure.

DK = Digi-Key
RS = Radio Shack

The above example uses just one of many programs found in HamCalc. Using this program, you can design a power supply for any desired output voltage. Most of these programs ask you to input data. If you are asked to enter some data that you don't know, or that you want the computer to tell you, just press the <ENTER> key to by-pass the question.

A hard drive is required for the installation of HamCalc. Once installed it can be run in WINDOWS or MS-DOS. HamCalc is written in GWBASIC but does not require MS-DOS to run. GWBASIC.exe is a stand-alone file that runs in WINDOWS and MS-DOS operating systems.

Using one or several of HamCalc's over 300 computer programs, one could easily design or analyze a simple circuit that many QRPers have.

Good luck!

73, Nancy Feeny NJ8B nj8b@amqrp.org

INSTRUCTIONS FOR INSTALLING AND RUNNING HAMCALC

A hard drive is required for the installation of HamCalc. Once installed it can be run in WINDOWS or MS-DOS. HamCalc is written in GWBASIC but does not require MS-DOS to run. GWBASIC.exe is a stand-alone file that runs in WINDOWS and MS-DOS operating systems.

IF YOU ARE USING A WINDOWS OPERATING SYSTEM
DO NOT OPERATE IT IN MS-DOS MODE

If you want to use a printer with HamCalc the printer must be connected to a parallel port of your computer. HAMCALC DOES NOT SUPPORT USB PRINTER CONNECTIONS (see the "Printer Tips" option in the HamCalc Main Menu).

Before installing HamCalc turn off any firewall, anti-virus, and other protective programs.

If you acquired HamCalc as a .ZIP file DO NOT UNZIP IT IN DRIVE C - unzip it in a temporary location of your choice, such as My Documents.

If you acquired HamCalc on a CD (such as here on the Homebrewer CD-ROM), place the CD in your CD drive. In Windows Explorer or My Computer, click on the CD drive icon to display the contents of the CD.

In either case the file contains one folder; "Hamcalc" and two files; "Gwbasic.exe" and Ve3erp.bat". COPY THE FOLDER AND BOTH FILES TO YOUR MAIN DRIVE C DIRECTORY.

HAMCALC MUST BE INSTALLED IN DRIVE C FOR IT TO OPERATE PROPERLY

TO RUN HAMCALC IN WINDOWS;
1.Double click on My Computer or Windows Explorer.
2.Double click on the(C)icon.
3.Double click on Ve3erp.bat
-OR-
1.Click on START, then click on RUN
2.On your keyboard type c:ve3erp
3.Click on OK
-OR-
You can create a DeskTop shortcut to run HamCalc. The shortcut command line is "C:\ve3erp.bat"

TO RUN HAMCALC IN MS-DOS:
At the C:\> prompt type ve3erp and press <ENTER>

OPERATING NOTES:

1.HamCalc does not support mouse operation. Menu selections are by keyboard entry (usually a single keystroke).

2.With some versions of Windows (notably Windows XP), if the HamCalc window cannot be enlarged by the "maximize" button in the upper right hand corner, just press and hold the Alt key and press the Enter key.

3.Call up individual programs from either the Program Menus or the INDEX option on the Main Menu. When you exit HamCalc you are automatically returned to WINDOWS Desktop.

4.To avoid possible confusion, run the READ ME and PRINTER TIPS options on the Main Menu to acquaint yourself with HamCalc's operating features before trying your hand at the individual programs.

5.HamCalc is upgraded frequently. The latest version can be downloaded free from www.cq-amateur-radio.com . HamCalc obtained from any other source is unauthorized, probably outdated and may be corrupted.

6.Do not run HamCalc directly from the CD, it may not work properly.

-73- Murph VE3ERP

QRP Club, published on CD-ROM. Each issue typically contains over 200 pages of QRP-related homebrewing construction and technical articles intended for builders, experimenters, ham radio operators and low power enthusiasts all around the world. HOMEBREWER features include construction projects for beginners all the way up to the advanced digital and RF experimenters. Annual subscriptions are $15 (for US & Canada) and $20 (for foreign addresses). For information, contact editor/publisher George Heron, N2APB at n2apb@amqrp.org or visit HOMEBREWER Magazine home page at www.amqrp.org/homebrewer.

Chuck Adams, K7QO

The K7QO Code Course

Over 12 hours of specially-prepared, varying-speed Morse instruction provided by noted Morse Code specialist K7QO.

FILE	File Contents
073	wx hr is
074	ur rst is
075	ant hr is
076	Question and Double Dash
077	Complete QSO

We are very thankful to Chuck Adams, K7QO for allowing us to include his comprehensive Morse Code Training Course in this issue of Homebrewer Magazine. Chuck is actively involved in training ham clubs in the proper learning and use of Morse code and is quite an accomplished in this communications mode.

The K7QO Code Course consists of 149 MP3 files located on this Homebrewer Mag CD-ROM. Just start by clicking on the Manual link below and then follow the guidance given by K7QO. You'll be able to listen to the audio files by selecting the appropriate MP3 file on this CD using your operating system's file browser, such as Windows Explorer. Just navigate to the CD drive and then into the MorseCourse folder and double-click the desired file. If an "MP3 player" does not automatically start when you select the file, you can use Windows Media Player (or equivalent) to listen to it.

Chuck also provides some additional, and very interesting documents concerning the learning of Morse code. You should start with the first article below, but you can also separately read the other articles.

Course Manual .... *by Chuck Adams, K7QO*
Code Course Answers ... *by Chuck Adams, K7QO*
Using an Iambic Paddle ... *by Chuck Adams, K7QO*
Go with the Flow .... *by Nancy Kott, WZ8C*
Instant Recognition .... *by Nancy Kott, WZ8C*
FISTS C.W. Club Membership Application

Chuck Adams may be reached at k7qo@commspeed.net and his informative website (also containing these course files) is at http://www.k7qo.net/

K7QO's Code Course

by Chuck Adams, K7QO

My name is Chuck Adams and my call is K7QO. I will be your mentor for this course. I have been doing Morse code since 1957 and it is my favorite mode of communication in ham radio. That does not make me an expert on the topic, but I do want to give you what I know and you can modify it to fit your needs. But I have seen too many people learn the Morse code the wrong way and then quit when they couldn't get faster at it. Let's not let that happen to you.

The Morse code may not come easy and in order to get proficient at it you must devote an appreciable amount of time to it. My job is to guide you through the swamp of bad habits and keep you from falling into the quicksand.

I did not start out with a mentor. My dad, W5NNB, felt that he could not teach me the code, since I was his son and probably wouldn't listen to him. So he took me to a ham meeting in Kermit (12 miles away from Wink, TX) and I met some kids my age. This was on a Thursday night. They told me to go home and memorize the code and come back on Saturday and they would start helping me.

And that is what I did. I went back home and started with an Instructograph machine that used paper tapes with holes in them to generate the code. I used a single tube audio oscillator with it to generate the tones. Since I didn't have any one to help me for two days, I started out memorizing the letters using the Instructograph and the manual. On Saturday I went to Terry's, K5WNH, and he and a friend of his sat me down and gave me a test. They asked me how much of the alphabet and numbers had I memorized and I told them all of them. They said "Sure" and began the test. I was doing 12WPM without errors.

What made this possible was the fact that I memorized the letters and numbers at a higher speed than most people probably started teaching in any course. And I did not use any charts, cute little tunes, and other crutches that will later slow you down. If you learned the code any other way than rote memorization of the sounds, you may need to start over. Any one that teaches or shows the Morse code with dots and dashes or other visual aids is killing off high speeds and ruining a bunch of good minds. I'll explain later. Don't use any materials or computer programs that show you dits and dahs, etc. for feedback. Only the letters and characters themselves.

There are a number of people running around that claim you should not use tapes and CDs to learn the code. They claim that it is possible for you to memorize the materials. So what? Didn't we all memorize "See Spot"? And if you memorize all the material on this disc I will buy you a Krispy Kreme donut the next time I see you. There are over 12 hours of Morse on this CD and not a human voice to be heard.

A few years later after I obtained my Novice license I got a set of vinyl records made by Conan W.B. Barger, W3CVE, that made up about 2 hours of code practice. With that set of records (and I have them copied to CD now, but the audio quality is bad) I practiced and got to over 55WPM with them. But that required the variable speed phonograph player to obtain the higher speeds with the same physical tracks on vinyl. I never met Conan and in looking up his call on `www.qrz.com` I see that it expired in May of 2004. He would be 97 this year so here's hoping he is still doing well.

Conan mentions on his record that CW operators are not born but are trained. This is probably true of a majority of the things the human race does. You just have to set aside the time to practice and get good at this if you really want to do it. You can't do it in one day, so set aside some time each day and you will do well.

Course Outline

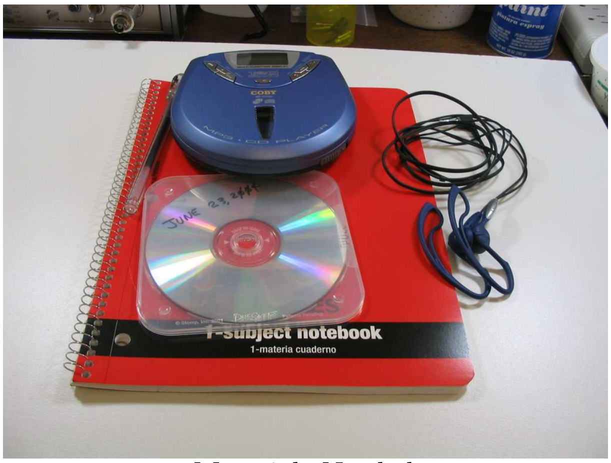
In this course I will teach you how to do three things. It is my hope and my wish that you learn all three techniques for copying code and not skip one or more of them. You should learn each as each has advantages and you should be able to do any of them. But only you will know how much time you want to devote to learning this mode of communication. I can not do it for you.

- Copy Morse code using pen and paper.
- Copy Morse code using a typewriter or keyboard.
- Copy Morse code in your head without hard copy.

Materials You Will Need

This is a list of the materials that I recommend that you start with for this course.

- A Spiral Notebook.
- A rolling writer type pen.
- A portable Walkman type MP3 player.
- The K7QO Code Course CD.
- A good set of headphones for the player.
- Time.



Materials Needed.

Spiral Notebook

I recommend a spiral notebook for several reasons. I buy them from Staples where I can get 6 of the single subject notebooks for under five dollars including tax. I like a notebook that lies flat on the desk when open and I can write on front or back of pages without any problems. And I want you to be proud of the work that you do for this course and keep it all together in one place. Later I am going to give you an exercise that requires you to take everything for this course out into the real world.

I started out with a novice class license in 1957 as KN5FJZ and I wrote down everything that I copied and to this date I still do the same thing. I use the spiral notebooks to record everything during a QSO and then later transfer the date, time, and other information to a computerized logbook. When I was a senior in high school I filled up nine ARRL logbooks with one QSO per line in a period of one year operating only on 40 meter CW using a Heathkit Apache transmitter and a NC-300 receiver. I even had a QSK setup made up of two 1N34 diodes and a 5W 120V bulb in a small metal box. I wrote down everything I heard to paper.

Also in the same time period from the mid– to late–50's a great deal of CW activity occurred in the commercial broadcast bands. Remember. This was before the age of computers, satellites, CNN, and cell phones. Both commercial cargo ships and passenger ships at sea could only get the news via CW stations that broadcast the news daily on certain frequencies. UPI, API, and the wire services at the time ran several stations that did this. I remember some of them and list them here for historical purposes.

- WSC from NY at 25WPM
- NPG from CA at 12–26WPM
- WNU from LA at 16–25WPM
- KPH from CA at 18–22WPM
- WAX from FL at 16–25WPM
- NPM from HI at 12–26WPM
- WOE from FL at 16–25WPM
- KPH from CA at 18–22WPM
- WCO from NY at 22WPM
- WFK from NY at 30WPM

Most of the stations were on daily and at specific times and frequencies while others were on only a day or two per week. The radio operator on each of the ships would copy the daily news using a mechanical typewriter and then post the news on a bulletin board for the crew and passengers to read and keep informed as to what was happening in the rest of the world. People forget that we didn't always have photocopy machines and desktop computers... I used to listen to the above for copying plain text almost daily.

On modern ships there is a complete news department that gets the news from satellite and TV feeds, prints a small on board newspaper and distributes it daily to each cabin under the door. Complete with graphics and all the other frills. Not to mention on board TV and computer links.

While these stations were in operation I used to copy them daily when I wasn't tied up with other school activities. This helped me to get my speed to over 20 WPM in a hurry. I also learned a bunch of the characters that many CW ops don't know, don't use and don't care about. Things like left and right parenthesis, colon and semicolon just to mention a few. I'll have these on some files and would like for you to learn them and impress your family and friends. Of course, after this you may lose some of your friends.

Because of my learning to write down what I heard I still do that and I want you to learn it also. It comes in handy in more ways than you think. I used to win code copying contests at the Midland TX ham meets yearly at 35 and 40 WPM because you could not bring in a typewriter. Soupy Groves from Odessa and I used to battle it out each year for the first place certificate and another high speed op from Austin named Mark and I forget his last name. This was all over 40 years ago.

Writing Instrument

I want you to use a rolling writer or other type gel pen. You want something that has the least amount of friction across the paper. I buy packages of a dozen Uniball GEL STICK pens or Bic GEL ROLLER pens for around three bucks. They write smoothly and are very inexpensive for a quarter each from Staples Office Supply.

The reason for using a rolling writer pen over a ball point or pencil has to do with the physics of friction and resulting writing speed. Also you must not print. You MUST use cursive writing and I won't take no for an answer here. And here is a chance for you to work on your penmanship at the same time. I frequently see articles or letters in the newspaper about how the educational system in America no longer teaches this and I of course see it when I am in stores and other places and watch people write. Look online using your favorite search engine for penmanship, speedwriting, and cursive writing.

Later I will mention that at high speeds you need to reduce the length of descenders and ascenders of letters like g, q, l, and k. And also you might want to practice not crossing your t's and dotting your i's and come back later to do that. It will save time at very high speeds if you ever want to be able to do 30 WPM or so. FYI.

MP3 Player

I recommend that you buy a small Walkman type MP3 player if you can. I bought one at Target and Wal-Mart and have found them on sale from time to time for under 35 dollars. Fry's Electronics regularly has a GPX MP3 player for under 20 dollars. The Code Course will work well with any of them.

Because I wanted to get over 10 hours of audio on a single disc I had to go to this format. Now if you already own a regular audio CD player you can find a computer program to convert the MP3 files back to the format that you need. The only problem is that it will take more than ten CDs to get the 100 plus files in that format.

Make sure that you have fresh batteries or do as I do and use NiMH rechargables. I know that they have saved me a ton of money and they are coming down in price at a rapid rate because of the digital camera craze.

I would like for you to have the portability of being able to take this code course with you and have access during the day if you get 5 or 10 minutes to practice. Every minute helps. And later I will ask you to go to a busy place like a mall and practice an exercise or two to work on your concentration and block distractions.

I do not want you to use a computer for this course to play the CD. The computer is a distraction.

Headphones

OK, first of all. Your ears are very important and you only get issued one set per lifetime. So never never ever do you listen to Morse at loud volumes. Headphones come with documentation and you need to read it. Also make sure you have the volume at a minimum when you turn on the MP3 player. Make sure you or someone hasn't accidently moved the volume control to a higher volume.

I dislike using speakers for copying Morse code. The sound from the speaker echos off of walls and solid objects and it will interfere with your hearing at high speeds. And the quality is an issue.

I like the new Sony `h.ear` light ear pieces that sell for 10 dollars at Wal–Mart. The model number is MDR-J10. I find them to be comfortable for long periods of time, but mileage may vary. And be very very careful as they are efficient and you will not need much volume. These are the earphones that you see in the photo.

I listen at the lowest volume possible. Here are the reasons for me. I want to be able to hear when I'm a hundred years old. Also at higher volumes you will generate a "thump" at the beginning of each element of a character. And the ear drum is like a bass drum. The harder you thump it the longer it will resonate, thus interfering with the next element of the code character and slowing you down.

And I'm sure there is a physiological effect that loud volumes will tire you much faster than low volumes. I have always protected my hearing from an early age in high school when I had a rocket that I built blow up when I bent over to pick it up after it did not launch for 15 minutes. I was very lucky. But my left ear did ring for two days after that event. I even left a KISS concert 5 minutes into it when I was working on my PhD at TAMU because the volume was so loud. I was almost at the back of the coliseum for the concert. My ears rang for an hour after just that short exposure period of high sound levels.

So protect your ears, please.

This CD can be used to experiment with different headphones and earphones. There is no thump on each of the elements of each character. So if you hear a thump or annoying pop then you need to check your volume and experiment by using another set of headphones or earphones.

Time and Place

There's not much I can tell you about this topic. It just seems to be going faster every year for all of us. You should start on this course today. If you don't, you will keep thinking of excuses to wait until tomorrow.

Find a quiet place away from the TV, family, and all the other distractions. Hopefully a desk or kitchen table where you can be comfortable and write easily. You just need about 15 minutes to get started.

Try to set aside the same time period each day and do this almost every day. Don't do this when you are tired as the human mind doesn't work as well and you need every brain cell in top condition.

I taught and developed courses in both the university system and for a large computer company. One of the things that I learned about human attention span is that the average attention span for an adult is 20 minutes. After that the mind starts to wander and daydream. So learning the Morse code is going to teach you something about yourself and how well you concentrate. I find that CW operation and especially contest operation helps me to concentrate for longer periods of time. I play poker tournaments where I may have to sit and concentrate for several hours at a time before a break comes along. Look for me on ESPN starting in July in one of the shows. My experience with Morse seems to have helped.

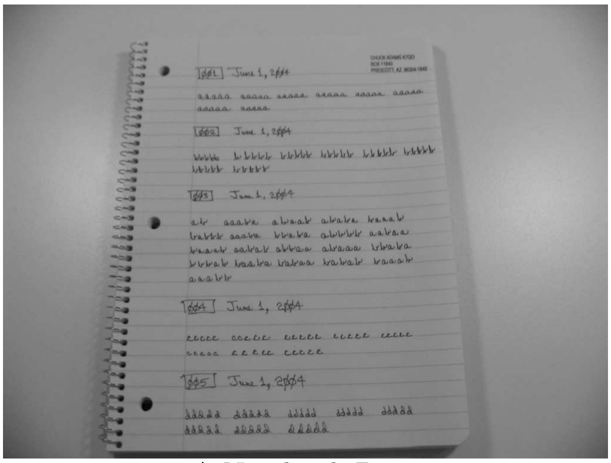
Your short term memory will be helped also because this required concentration helps exercise whatever part that is used for attention to the outside world. If you find that you drift and lose concentration then take a break, but do try to not use that as an excuse not to keep working.

Getting Started

Now we are ready to start the first lesson. I'm going through a lengthy discussion for this to get you started correctly. After that you keep on going until you get to the end.

Get setup with the player, earphones, pen, CD, and paper. OK. Open the notebook to the first or second clean page. You may want to put your name, call if any, etc. on the first page or inside cover in case the notebook gets misplaced so that it can be returned to you. Also make a backup copy of the CD if you have a CD burner on a computer. Make copies and give them to kids, relatives, friends, and even your enemies (drive them insane).

Now I have gone through this entire course myself and used a notebook as shown. What I do for each lesson or test is put the file number enclosed in a block on a line along with the current date. This way you can keep track and make sure that you aren't skipping too many days. You don't have to go to a new page each day or each lesson, but if you retake a test on the same page, then find a blank page to cover up the previous run so that you aren't tempted to compare while the test is in progress. Here is what my first page of my notebook looks like.



A Notebook Page.

The disc is setup at first to teach you two letters in two files and then there is a test that covers all the letters that you have learned up to that point. For example, 001 is for the letter `a` and 002 is for the letter `b`. File 003 is a test over `a` and `b`. Do not write the letters in caps. Always use lower case letters when copying CW as there is no need for capital letters and lower case is faster to write. Then files 004 and 005 are for `c` and `d` respectively with file 006 a test over the letters `a, b, c` and `d`. On the test files you will first hear the letters in the alphabet covered at that point then the letters in random order to test your retention.

The time required for each file or lesson is given in a table near the end of this manual. Start out trying the first 6 files in one session (about 20 minutes or so). Grade yourself on each test using the answer files on the disc. They are too long to include in print here, but if you feel like killing trees then feel free to print them off and glue them into the notebook or whatever.

Morse code is a representation via sound of each character, numeral, punctuation and even some special combinations for procedure signs (prosigns). Do not try to dissect them into individual components and most importantly do not count or visualize the individual elements of the character. This will only slow you down and you will develop habits that are very difficult to break.

On the Internet and in books you will see some people represent the sounds with dots and dashes. These individuals are not doing any one any favors by doing this. I'd bet you a dollar to a hole in a donut that these individuals can't do Morse at more than 35 WPM, otherwise they'd know better than to ruin the future training of other individuals. So don't you do it and I don't want to see you ever with flash cards. Use the CD.

How would you put down the sound of a jet engine, siren, steam locomotive (hope you have heard an actual locomotive in your life other than the big screen), fog horn, or other common sounds? No way. So why do the same thing with Morse?

So, for each character listen to the sound and then immediately write it down. Do this all the time. Don't think about it and if you do not recognize the character then skip it and get ready for the next one. For starters just leave an extra space on the page or put a small dot there for grading purposes. You are training your neural networks in your mind to respond to the code sounds.

You will sometimes know what character is coming next. Do not ever write down a character before it is completed. I could have gotten nasty and made some files and inserted errors on purpose to break you of this habit, but I trust you to do right. The reason for tests with random letters is to make sure that you don't do this and to make sure that you instantly respond to and recognize characters rapidly.

Lesson One

Now open your notebook to your starting page and put 001 in a small block and the current date next to it. Get positioned to write and start the CD player on file 001. This is for the letter `a` (remember write, not print, in lower case). Every time you hear the sound combination for the letter `a` then immediately write it down and get ready for the next one. They may seem to come pretty fast but you'll get used to it. Concentrate on the sound you hear each time. Mentally, do not repeat it or convert it to what you think it is in sound. Don't try to verbalize the sound. Just hear it and then write down the letter. Make sure you try to remember it. There is an exaggerated quiet area between every 5 characters, so you may want to write the characters in groups of 5 letters with a space in between the groups. Write small and neatly and see how many you can get per line and still be able to read them.

After you finish file 001 then get ready for file 002 and do the same thing except this time it is for the letter `b` and write it down each time you hear it.

Hopefully your player doesn't get the two files too close in time, but it is OK to stop the player between files and setup for the next on on the page. Feel free to restart if necessary.

OK, after files 001 and 002 you should now have two letters memorized. But your mind probably needs some work so that is the purpose of file 003. Setup for file 003 and you will first hear `a` followed by `b`. Go ahead and write them down when you hear them. Then will come a sequence of the letters in random order. Copy the entire sequence and then stop the player.

Here is what you should have (don't peek at this until after you finish the test). The spacing is not critical and blanks do not count until we get to plain text.

```
ab
aaaba  abaab  ababa  baaab
babbb  aaaba  bbaba  abbbb
aabaa  baaab  aabab  abbaa
abaaa  bbaba  bbbab  baaba
babaa  babab  baaab  aaabb
```

Now mark your copy with a red pen for each letter that you missed. This test should be an easy one, but don't feel badly if you miss a few. Grade yourself. There are a total of 100 letters not counting the first two. Thus if you missed 5 your grade is 95 per cent. Feel free to do this as many times as you like. You be the guide. Strive for perfection, but don't get too obsessive about this and wear yourself out. If you can tell the difference between a country and western song, classical music and rap, then you can learn the Morse code to any speed you want.

Lesson Two

What you want to do now is move on to files 004, 005 and 006. Do them the same way as you did for the previous files. Now this is the last time I'm going to do this for you, so don't get spoiled easily. Here is what you should get for 006, the test for `a, b, c, and d`.

```
abcd
bdbdb bdcac ccddd aabac
aabbd cdcba caddb cbacb
ccbca cbcad adada caacc
dadac badac bccbc cbcad
badad acbab cdada cbabc
```

How did you do? Good. There is no passing or failing grade here. You want to get to 100 per cent, but that will take time. Especially after you get to the entire alphabet and numbers. Be patient and don't try to bite off too much at one time. If you work on 6 to 9 files per day and do this daily you should have all the alphabet and the numbers in two weeks. Don't try to do them all in one day. That is the way they do things in language schools where they do saturation. You don't need that here.

Review individual letter files regularly. After tests — check which letter or letters are giving you the most trouble and go back to the corresponding file and review it until you copy almost perfectly. Practice makes perfect.

We have now reached the point where there is not much more to tell you. You need to practice daily and do all that is on this CD. Keep a page in the back of your notebook for your test scores and dates. Take the tests multiple times. Each time will improve your ability to copy the Morse code. Do not feel badly if there are some files that seem to give you more trouble than others. Some are more challenging. Keep coming back to them until you get them mastered. You do not have to make 90 per cent or better every time. But it is nice when you reach that skill level and you will.

At some point I'd like for you to start over on the tests starting with 003. But on the second pass through them try to wait one or two characters before you start writing and practice on having one or two characters buffered in your mind. This takes some practice. It is not unlike taking notes in school where you had to copy behind what the instructor was saying or doing.

Advanced Exercises

Make at least one pass through the CD using your notebook and pen. Keep track of your progress. Now it is possible that the speed required for handwriting may be too much for you. Hopefully this will not happen but it could. Just do what you can.

Now that you have made it through the course, let's start all over again. This time start with file 001 and start copying using a keyboard. I just spent 90 dollars for an electric daisy wheel typewriter just to do it myself. I can use a computer keyboard, but what challenge is that?

You want to train yourself to copy direct from sound to the key without any conscious thought. You may have heard the tales of expert Morse operators being able to copy to a mill (old name for the mechanical typewriter) and carry on a conversation at the same time. It comes only with years of practice.

If you are a typist, then there should be no limit to the speed at which you can copy.

Do the entire course several times on the keyboard until you can get excellent results. This may take several months to do, but don't stop in the middle for any reason. Work. Work. Work.

The contents of all the files are given in the `answers` subdirectory on the CD. Use these files to double check your work only after you have written down the code at least once. Try not to use these files as a handicap. You can copy the code and have an idea when an error has occurred. Build up your confidence with practice.

The SweepStakes file (121) contains contest exchanges for the November ARRL SweepStakes CW contest. Each line consists of a series of V's followed by a sequence number, a single letter, a call sign, a two digit number and the abbreviation for an ARRL section. This is good practice as the V's set your mind up for a speed and a tone then the characters start. You don't have to write down the V's as this represents where your call would go during the actual contest.

Wrap Up

Several things that you can do after you have thoroughly mastered the alphabet and all the numerals. You will note that throughout this course I have not mentioned one thing about code speed. That is secondary to learning the code. Practice and the speed will get there as the mind responds more rapidly to the Morse code sounds.

First thing that you might consider doing to supplement this code course is to download files from

`www.arrl.org/w1aw/morse.html`

These are the on the air sessions run by W1AW on a weekly basis. You can also check the ARRL web site for daily W1AW CW practice sessions. These you will know the speed of the transmissions and get an idea of just where your code speed is.

Also note the monthly code proficiency runs from W1AW and after you get your code speed at a comfortable level you can attempt to copy these runs and get a very nice certificate from the ARRL. I collect these regularly at 40WPM, when they have the high speed run. Just a part of the hobby of copying high speed Morse code.

And lastly the most challenging thing of all. Go to the web site:

`www.sk3bg.se/contest/`

and look down the left hand side for Contest Software and click on it. Then look for the RUFZ by DL4MM link and click on it. This will locate a software package RUFZ3.2 that runs only under DOS, so you will need a WIN95/98 system that will run DOS only with an F8 bootup. Read all the info on this page about the program.

I challenge you to try this program. I have the highest score in North America and you can find it under Senior Male scores. But don't be intimidated by it. Just start out practicing and try it every day for 10 minutes. Then submit your highest score via the web as outlined on the web page. We need more new scores from North America. Let's see what you can do.

And I leave you with the words of Alexander Pope. "Not failure but low aim is crime". Give it your best shot and enjoy CW as a simple and efficient means of communication. It is as close as you can get for mind to mind communication when both parties are good at Morse code.

dit dit de K7QO

FILE	File Contents
001	a
002	b
003	a--b Test
004	c
005	d
006	a--d Test
007	e
008	f
009	a--f Test
010	g
011	h
012	a--h Test
013	i
014	j
015	a--j Test
016	k
017	l
018	a--l Test
019	m
020	n
021	a--n Test
022	o
023	p
024	a--p Test
025	q
026	r
027	a--r Test
028	s
029	t
030	a--t Test
031	u
032	v
033	a--v Test
034	w
035	x
036	a--x Test

FILE	File Contents
037	y
038	z
039	a--z Test
040	Two Letter Words
041	Two Letter Words
042	Three Letter Words
043	Three Letter Words
044	Three Letter Words
045	Four Letter Words
046	1
047	1 Call Signs
048	2
049	2 Call Signs
050	3
051	3 Call Signs
052	4
053	4 Call Signs
054	5
055	5 Call Signs
056	6
057	6 Call Signs
058	7
059	7 Call Signs
060	8
061	8 Call Signs
062	9
063	9 Call Signs
064	0
065	0 Call Signs
066	cq de
067	QSO Beginning
068	Comma
069	Period
070	qth hr is
071	name hr is
072	rig hr is

FILE	File Contents
073	`wx hr is`
074	`ur rst is`
075	`ant hr is`
076	Question and Double Dash
077	Complete QSO
078	Complete QSO
079	Complete QSO
080	Complete QSO
081	Complete QSO
082	Complete QSO
083	Random Letters
084	Random Letters
085	Random Numbers
086	Random Numbers
087	Slant Sign /
088	Random Characters
089	Random Characters
090	Punctuation
091	`kilometer`
092	`fort`
093	`fathom`
094	`logbook`
095	`mauna kea`
096	`watt`
097	`zenith`
098	`tugboat`
099	`teflon`
100	`quart`
101	`kakapo`
102	`mint`
103	`photon`
104	`summer`
105	`talc`
106	`putty`
107	`joule`
108	`hardness`

FILE	File Contents
109	`vanilla`
110	`tile`
111	`scissors`
112	`rake`
113	`alberta`
114	`cardboard`
115	`waterplant`
116	`hexagon`
117	`krypton`
118	`liveoak`
119	`integer`
120	`keck`
121	`SweepStakes Contest`
122	`abacus`
123	`almond`
124	`sonar`
125	`umbrella`
126	`bleach`
127	`eclipse`
128	`dew`
129	`liquid`
130	`sprat`
131	`sirius`

References

1. The American Radio Relay League, Inc., "The ARRL Handbook". Connecticut, The ARRL. 1995 and later.

2. The American Radio Relay League, Inc., web page, `http://www.arrl.org/`

001

a a a a a a a a a a a a a a a
a a a a a a a a a a a a a a a
a a a a a a a a a a a a a a a

002

b b b b b b b b b b b b b b b
b b b b b b b b b b b b b b b
b b b b b b b b b b b b b b b

003

a b
a a a b a a b a a b a b a b a b a a a b b a b b b
a a a b a b b a b a a b b b b a a b a a b a a a b
a a b a b a b b a a a b a a a b b a b a b b b a b
b a a b a b a b a a b a b a b b a a a b a a a b b

004

c c c c c c c c c c c c c c c
c c c c c c c c c c c c c c c
c c c c c c c c c c c c c c c

005

d d d d d d d d d d d d d d d
d d d d d d d d d d d d d d d
d d d d d d d d d d d d d d d

006

a b c d
b d b d b b d c a c c c d d d a a b a c a a b b d
c d c b a c a d d b c b a c b c c b c a c b c a d
a d a d a c a a c c d a d a c b a d a c b c c b c
c b c a d b a d a d a c b a b c d a d a c b a b c

007

e e e e e e e e e e e e e e e
e e e e e e e e e e e e e e e
e e e e e e e e e e e e e e e

008

```
f f f f f   f f f f f   f f f f f
f f f f f   f f f f f   f f f f f
f f f f f   f f f f f   f f f f f
```

009

```
a b c d e f
b d a f b  e d b c e  b c a f f  c e a e f  b b e b e
c e f e e  c d f f b  b a e f d  e e e c a  a e f a f
a a e a e  f a e d f  b a c e e  a f e f d  f d e a b
c a a e f  d f a c e  a e f a e  d f b a c  e e a f e
```

010

```
g g g g g   g g g g g   g g g g g
g g g g g   g g g g g   g g g g g
g g g g g   g g g g g   g g g g g
```

011

```
h h h h h   h h h h h   h h h h h
h h h h h   h h h h h   h h h h h
h h h h h   h h h h h   h h h h h
```

012

```
a b c d e f g h
c d f h a  b c g e g  g c c a a  e e g d h  e b c a g
c h h a b  g d f h e  a f a g e  c a g f e  a f d d g
c g c d d  a b f a f  f f a d d  h b a g b  c a g f e
a f d d g  c g c d b  a b f a f  c f a d d  h b a g b
```

013

```
i i i i i   i i i i i   i i i i i
i i i i i   i i i i i   i i i i i
i i i i i   i i i i i   i i i i i
```

014

```
j j j j j   j j j j j   j j j j j
j j j j j   j j j j j   j j j j j
j j j j j   j j j j j   j j j j j
```

015

```
a b c d e f g h i j
c j c i f  d a g e c  g i i f e  c i d c a  i b a j a
c j d g a  a a d g j  b a h e h  d i a j e  d h j c g
c a a b d  e f a d g  f b b a b  h i e d c  j c i f d
a g e c g  i i f e c  i d c a i  b a j a c  j d g a a
```

016

```
k  k  k  k  k    k  k  k  k  k    k  k  k  k  k
k  k  k  k  k    k  k  k  k  k    k  k  k  k  k
k  k  k  k  k    k  k  k  k  k    k  k  k  k  k
```

017

```
l  l  l  l  l    l  l  l  l  l    l  l  l  l  l
l  l  l  l  l    l  l  l  l  l    l  l  l  l  l
l  l  l  l  l    l  l  l  l  l    l  l  l  l  l
```

018

```
a b c d e f g h i j k l
d j j e c  f j a k d  g i f l j  b i h i c  a e i e k
h e b e h  i d c i c  i e a k h  g a h a a  k d k j j
k e l e h  a d d h d  c d h d l  b h i a f  j e a f j
a k d g i  f l j b i  h d c a e  g e k h e  b e h i d
```

019

```
m  m  m  m  m    m  m  m  m  m    m  m  m  m  m
m  m  m  m  m    m  m  m  m  m    m  m  m  m  m
m  m  m  m  m    m  m  m  m  m    m  m  m  m  m
```

020

```
n  n  n  n  n    n  n  n  n  n    n  n  n  n  n
n  n  n  n  n    n  n  n  n  n    n  n  n  n  n
n  n  n  n  n    n  n  n  n  n    n  n  n  n  n
```

021

```
a b c d e f g h i j k l m n
d n j l j  g h h b a  i m l g d  e l l d d  d b n l k
a j b l f  b e a b h  g d n i c  m n d d m  n l d i g
m e d k g  n a f l g  k g a n h  a m f g e  d k g n a
f l g k g  a n h m c  m n d d m  n l d i g  m a m f g
```

022

```
o o o o o   o o o o o   o o o o o
o o o o o   o o o o o   o o o o o
o o o o o   o o o o o   o o o o o
```

023

```
p p p p p   p p p p p   p p p p p
p p p p p   p p p p p   p p p p p
p p p p p   p p p p p   p p p p p
```

024

```
a b c d e f g h i j k l m n o p
e c k e c  h e a f m  k c c p l  g p a n f  h n c d k
h a b d d  j f m h m  d a o f m  e o n g l  c g j f b
o j o e f  i d c d l  n i a k i  n h e a g  d p j f d
e k l b e  h m n l p  c h n b p  p h a o l  m k a h j
```

025

```
q q q q q   q q q q q   q q q q q
q q q q q   q q q q q   q q q q q
q q q q q   q q q q q   q q q q q
```

026

```
r r r r r   r r r r r   r r r r r
r r r r r   r r r r r   r r r r r
r r r r r   r r r r r   r r r r r
```

027

```
a b c d e f g h i j k l m n o p q r
f m n n r  k c g p c  i m b b p  c i g d h  l k e m e
q k m d k  f m l c a  m a h i a  d h h j a  r q c l o
d l n o a  h o e c c  d n m r g  f i h p f  d k c f l
i m b p i  m a f g q  f j l g r  h l b b q  g h n q o
```

028

```
s  s  s  s  s    s  s  s  s  s    s  s  s  s  s
s  s  s  s  s    s  s  s  s  s    s  s  s  s  s
s  s  s  s  s    s  s  s  s  s    s  s  s  s  s
```

029

```
t  t  t  t  t    t  t  t  t  t    t  t  t  t  t
t  t  t  t  t    t  t  t  t  t    t  t  t  t  t
t  t  t  t  t    t  t  t  t  t    t  t  t  t  t
```

030

```
a b c d e f g h i j k l m n o p q r s t
f l e e m  n s q f d  i m n i d  b g m m k  p q r c a
h t j r c  r s j d f  g i n s t  g n a n m  j i b d t
q t n b f  a l k k o  p s c e e  o d n k j  n j f k l
b t l o k  k h d l q  d j r i l  h a m d l  i j c n q
```

031

```
u  u  u  u  u    u  u  u  u  u    u  u  u  u  u
u  u  u  u  u    u  u  u  u  u    u  u  u  u  u
u  u  u  u  u    u  u  u  u  u    u  u  u  u  u
```

032

```
v  v  v  v  v    v  v  v  v  v    v  v  v  v  v
v  v  v  v  v    v  v  v  v  v    v  v  v  v  v
v  v  v  v  v    v  v  v  v  v    v  v  v  v  v
```

033

```
a b c d e f g h i j k l m n o p q r s t u v
g r e a t  g q d p t  s s k e t  t k i b m  v s f b p
g k e p b  k e g m k  s c m e l  h l b s m  d k r c t
g c a u q  q f e d f  q o e a a  n a t r m  u p n n r
k c a b c  b o s a q  e v i n t  m r u s k  f t o g u
```

034

```
w  w  w  w  w    w  w  w  w  w    w  w  w  w  w
w  w  w  w  w    w  w  w  w  w    w  w  w  w  w
w  w  w  w  w    w  w  w  w  w    w  w  w  w  w
```

035

```
x  x  x  x  x    x  x  x  x  x    x  x  x  x  x
x  x  x  x  x    x  x  x  x  x    x  x  x  x  x
x  x  x  x  x    x  x  x  x  x    x  x  x  x  x
```

036

```
a b c d e f g h i j k l m n o p q r s t u v w x
g j b q r  l o m f g  q k k h x  o a q j p  c n h m g
s a t q k  d n e f p  i b b i t  g a p w w  x x h k n
n d u k j  p u g c r  c v u h v  a b b p l  v g e o e
q c j u f  g w g p p  h a e u v  x a w a q  t o i q d
```

037

```
y  y  y  y  y    y  y  y  y  y    y  y  y  y  y
y  y  y  y  y    y  y  y  y  y    y  y  y  y  y
y  y  y  y  y    y  y  y  y  y    y  y  y  y  y
```

038

```
z  z  z  z  z    z  z  z  z  z    z  z  z  z  z
z  z  z  z  z    z  z  z  z  z    z  z  z  z  z
z  z  z  z  z    z  z  z  z  z    z  z  z  z  z
```

039

```
a b c d e f g h i j k l m n o p q r s t u v w x y z
z e b r a  z e r o s  v y l a r  y l v b t  j u d x j
e f z v m  n l x y a  f h t k a  x r h d a  v n c k r
y a y c w  o y w h o  e y v m q  k e j y f  n u m j g
y z b w c  j l z c n  s o e y v  m q k j y  f n l x y
```

040

```
WA WA  Ms Ms  my my  AL AL  FL FL  DE DE  an an  go go  is is  DC DC
IL IL  to to  PM PM  be be  MD MD  is is  MD MD  in in  St St  ad ad
in in  my my  NM NM  Mr Mr  of of  it it  as as  at at  TV TV  SD SD
OK OK  NJ NJ  NJ NJ  me me  do do  ND ND  if if  WI WI  me me  ha ha
SC SC  or or  MI MI  NY NY  us us  or or  Dr Dr  NM NM  MD MD  MD MD
is is  do do  it it  TX TX  Mr Mr  my my  ND ND  of of  AK AK  Dr Dr
ND ND  re re  OK OK  NY NY  in in  NM NM  MT MT  FM FM  TV TV  St St
AK AK  WI WI  WA WA  FL FL  to to  ad ad  my my  by by  to to  ad ad
SC SC  NH NH  ad ad  pa pa  go go  AL AL  AC AC  PM PM  on on  on on
my my  if if  DC DC  ND ND  DC DC  UK UK  OK OK  pa pa  at at  am am
PM PM  re re  MD MD  is is  NH NH  we we  no no  Mr Mr  NY NY  go go
by by  AC AC  ha ha  it it  GM GM  TV TV  if if  GM GM  TV TV  FM FM
```

041

```
is is  at at  do do  us us  DE DE  NC NC  on on  MT MT  do do  on on
up up  AL AL  DC DC  TV TV  OK OK  Ms Ms  no no  hi hi  me me  MI MI
TX TX  up up  FM FM  to to  am am  DE DE  OK OK  FM FM  PM PM  WI WI
if if  no no  ha ha  my my  MT MT  at at  MT MT  FL FL  MD MD  UK UK
SD SD  OK OK  at at  is is  re re  hi hi  no no  MD MD  up up  NJ NJ
on on  TV TV  of of  SC SC  ad ad  GM GM  OK OK  TV TV  go go  by by
TV TV  Dr Dr  re re  go go  if if  WA WA  AK AK  Dr Dr  go go  of of
GM GM  AL AL  AK AK  or or  ad ad  SC SC  NC NC  ha ha  on on  ha ha
us us  NC NC  no no  MI MI  SC SC  WA WA  DC DC  TV TV  be be  AC AC
of of  on on  PM PM  up up  PM PM  SD SD  MT MT  we we  in in  us us
```

042

```
cub  cub   net  net   she  she   elm  elm   got  got
yea  yea   ran  ran   zig  zig   ohm  ohm   Rex  Rex
did  did   jam  jam   boo  boo   GMT  GMT   leg  leg
Kay  Kay   jar  jar   pea  pea   had  had   rip  rip
her  her   eve  eve   sir  sir   jay  jay   Jim  Jim
jab  jab   ice  ice   Amy  Amy   hip  hip   bet  bet
lit  lit   Gil  Gil   tin  tin   ant  ant   Amy  Amy
Kay  Kay   end  end   tin  tin   mix  mix   ale  ale
map  map   wax  wax   tie  tie   don  don   box  box
gel  gel   tap  tap   ale  ale   you  you   FCC  FCC
one  one   mew  mew   gum  gum   ion  ion   now  now
icy  icy   bop  bop   oar  oar   vet  vet   air  air
odd  odd   USA  USA   Ike  Ike   set  set   fed  fed
owl  owl   hug  hug   ham  ham   alp  alp   men  men
jay  jay   Joe  Joe   are  are   put  put   Lou  Lou
vee  vee   tow  tow   sir  sir   nor  nor   Feb  Feb
```

043

bet	bet	lee	lee	Tim	Tim	hoe	hoe	log	log
car	car	kid	kid	lip	lip	law	law	wet	wet
fur	fur	men	men	ape	ape	out	out	boy	boy
bed	bed	cub	cub	ACS	ACS	try	try	hop	hop
fin	fin	fed	fed	Roy	Roy	run	run	rip	rip
men	men	did	did	Rex	Rex	jar	jar	sir	sir
all	all	flu	flu	red	red	had	had	Sam	Sam
dub	dub	vee	vee	spy	spy	and	and	bit	bit
wet	wet	gum	gum	why	why	lad	lad	age	age
hub	hub	jet	jet	pea	pea	nut	nut	toe	toe
dim	dim	ion	ion	leg	leg	dad	dad	our	our
bag	bag	bid	bid	for	for	oak	oak	Dow	Dow
lad	lad	lot	lot	fan	fan	Gus	Gus	tap	tap
cub	cub	way	way	hen	hen	fat	fat	fan	fan
NYC	NYC	add	add	day	day				

044

bus	bus	pod	pod	mad	mad	ray	ray	fin	fin
ion	ion	guy	guy	red	red	hum	hum	gin	gin
fry	fry	oaf	oaf	Jim	Jim	add	add	yea	yea
Len	Len	Pam	Pam	set	set	Los	Los	off	off
pow	pow	dug	dug	spy	spy	cam	cam	peg	peg
bud	bud	lab	lab	bud	bud	rat	rat	you	you
egg	egg	try	try	why	why	tax	tax	buy	buy
web	web	map	map	pop	pop	Ron	Ron	toe	toe
aim	aim	bug	bug	tin	tin	met	met	leg	leg
ACM	ACM	lad	lad	lad	lad	Ben	Ben	own	own
hey	hey	dim	dim	see	see	sad	sad	mop	mop
hop	hop	Tim	Tim	tad	tad	hat	hat	don	don
bun	bun	hey	hey	bun	bun	vat	vat	ore	ore
bin	bin	sir	sir	sea	sea	sub	sub	old	old
was	was	run	run	kid	kid	mop	mop	eve	eve

045

```
Mary Mary   bowl bowl   clad clad   gulf gulf   weak weak
Pete Pete   ammo ammo   gage gage   Ajax Ajax   each each
Kent Kent   east east   glad glad   step step   atom atom
aide aide   crab crab   acid acid   city city   blue blue
edge edge   dear dear   babe babe   Anna Anna   Asia Asia
coal coal   dash dash   Greg Greg   cola cola   Dave Dave
look look   skip skip   coal coal   wire wire   care care
bear bear   diet diet   look look   dime dime   deck deck
vent vent   text text   crow crow   vote vote   even even
seen seen   cafe cafe   loud loud   axle axle   stop stop
well well   void void   watt watt   Jose Jose   John John
fall fall   bell bell   Acts Acts   Jeff Jeff   boot boot
coat coat   bike bike   send send   cool cool   gage gage
plus plus   deep deep   also also   only only   five five
send send   bend bend   lend lend   mend mend   tend tend
```

046

```
one
1 1 1 1 1  1 1 1 1 1  1 1 1 1 1  1 1 1 1 1
1 1 1 1 1  1 1 1 1 1  1 1 1 1 1  1 1 1 1 1
1 1 1 1 1  1 1 1 1 1  1 1 1 1 1  1 1 1 1 1
1 1 1 1 1  1 1 1 1 1  1 1 1 1 1  1 1 1 1 1
1 1 1 1 1  1 1 1 1 1  1 1 1 1 1  1 1 1 1 1
1 1 1 1 1  1 1 1 1 1  1 1 1 1 1  1 1 1 1 1
```

047

```
k1oji k1lh  k1ts  ak1h  k1eec a1zp
a1fa  ag1n  a1pl  wh1z  wb1l  w1yx
k1dx  az1e  np1g  a1ruz nv1q  w1luo

w1tr  k1dut n1op  k1vq  w1jpk ko1d
w1ue  nl1f  w1yfu n1vcp a1jua k1zfg
k1rzz no1t  kw1m  kk1s  a1fg  kx1m

a1rl  kg1a  n1hw  k1qfa wx1f  a1au
kx1g  k1gns w1yen n1iph w1vjd n1lh
a1kfp kk1n  a1qe  nr1w  nd1f  kw1e
```

048

```
two
2 2 2 2 2  2 2 2 2 2  2 2 2 2 2  2 2 2 2 2
2 2 2 2 2  2 2 2 2 2  2 2 2 2 2  2 2 2 2 2
2 2 2 2 2  2 2 2 2 2  2 2 2 2 2  2 2 2 2 2
2 2 2 2 2  2 2 2 2 2  2 2 2 2 2  2 2 2 2 2
2 2 2 2 2  2 2 2 2 2  2 2 2 2 2  2 2 2 2 2
2 2 2 2 2  2 2 2 2 2  2 2 2 2 2  2 2 2 2 2
```

049

```
a2dqc n2rre n2acr n2xl  k2obn a2hye
w2yfy wx2g  wz2i  w2eh  k2evc n2ca
k2cl  k2kr  wy2s  n2av  wv2i  ng2c
112 122 122 211 121 221 122 222 212 212 211 112 222 112 121 222 122
112 122 112 211 121 211 112 112 221 221 112 221 121 221 111 112 121
```

050

```
three
3 3 3 3 3  3 3 3 3 3  3 3 3 3 3  3 3 3 3 3
3 3 3 3 3  3 3 3 3 3  3 3 3 3 3  3 3 3 3 3
3 3 3 3 3  3 3 3 3 3  3 3 3 3 3  3 3 3 3 3
3 3 3 3 3  3 3 3 3 3  3 3 3 3 3  3 3 3 3 3
3 3 3 3 3  3 3 3 3 3  3 3 3 3 3  3 3 3 3 3
3 3 3 3 3  3 3 3 3 3  3 3 3 3 3  3 3 3 3 3
```

051

```
nk3r  wj3q  wu3l  k3mz  a3bfx a3sh
at3y  n3cki kc3b  a3qw  w3lxp w3lva
k3kf  k3bgf n3czi a3rfa k3eo  n3vi
221 323 112 113 131 311 121 211 122 122 231 333 213 221 232 232 223
112 121 312 132 222 131 321 111 332 322 133 123 213 111 323 332 313
```

052

```
four
4 4 4 4 4  4 4 4 4 4  4 4 4 4 4  4 4 4 4 4
4 4 4 4 4  4 4 4 4 4  4 4 4 4 4  4 4 4 4 4
4 4 4 4 4  4 4 4 4 4  4 4 4 4 4  4 4 4 4 4
4 4 4 4 4  4 4 4 4 4  4 4 4 4 4  4 4 4 4 4
4 4 4 4 4  4 4 4 4 4  4 4 4 4 4  4 4 4 4 4
4 4 4 4 4  4 4 4 4 4  4 4 4 4 4  4 4 4 4 4
```

053

```
n4rrx n4wb  k4ir  a4rl  ki4e
k4xv  w4ngg a4if  aq4w  w4ysh
nc4f  k4qat ay4h  n4bxb a4zg
244 433 411 232 434 314 341 231 242 141 441 212 442 431 212 433 113
144 112 134 343 124 132 123 122 323 244 224 321 234 233 113 213 444
```

054

```
five
5 5 5 5 5  5 5 5 5 5  5 5 5 5 5  5 5 5 5 5
5 5 5 5 5  5 5 5 5 5  5 5 5 5 5  5 5 5 5 5
5 5 5 5 5  5 5 5 5 5  5 5 5 5 5  5 5 5 5 5
5 5 5 5 5  5 5 5 5 5  5 5 5 5 5  5 5 5 5 5
5 5 5 5 5  5 5 5 5 5  5 5 5 5 5  5 5 5 5 5
5 5 5 5 5  5 5 5 5 5  5 5 5 5 5  5 5 5 5 5
```

055

```
au5n  w5vtc w5jqp wc5q  ax5y
n5pg  ww5x  w5hz  aa5c  wq5d
311 555 135 121 141 152 145 525 252 133 122 152 422 131 144 134 535
524 315 233 535 215 445 551 151 121 322 325 313 313 411 444 253 523
```

056

```
six
6 6 6 6 6  6 6 6 6 6  6 6 6 6 6  6 6 6 6 6
6 6 6 6 6  6 6 6 6 6  6 6 6 6 6  6 6 6 6 6
6 6 6 6 6  6 6 6 6 6  6 6 6 6 6  6 6 6 6 6
6 6 6 6 6  6 6 6 6 6  6 6 6 6 6  6 6 6 6 6
6 6 6 6 6  6 6 6 6 6  6 6 6 6 6  6 6 6 6 6
6 6 6 6 6  6 6 6 6 6  6 6 6 6 6  6 6 6 6 6
```

057

```
ng6g  na6t  nc6e  a6mgu k6mtq
a6syr a6kbl w6xr  a6hnl nf6q
n6vpx a6of  k6to  n6mzz n6zww
361 662 131 453 334 643 415 411 636 412 443 333 313 562 143 534 451
523 465 226 554 356 313 456 444 561 111 146 335 246 411 112 612 612
546 165 644 263 134 134 626 622 642 446 634 516 365 434 244 126 366
```

058

```
seven
7 7 7 7 7  7 7 7 7 7  7 7 7 7 7  7 7 7 7 7
7 7 7 7 7  7 7 7 7 7  7 7 7 7 7  7 7 7 7 7
7 7 7 7 7  7 7 7 7 7  7 7 7 7 7  7 7 7 7 7
7 7 7 7 7  7 7 7 7 7  7 7 7 7 7  7 7 7 7 7
7 7 7 7 7  7 7 7 7 7  7 7 7 7 7  7 7 7 7 7
7 7 7 7 7  7 7 7 7 7  7 7 7 7 7  7 7 7 7 7
```

059

```
kq7l  a7dn  k7rl  k7bnm nl7o
wv7q  ko7m  w7kl  k7iim a7aon
k7dk  a7rv  k7uu  n7wvv w7yuc

376 514 642 756 342 123 471 524 173 336 135 723 563 215 435 341 231
633 311 774 126 641 672 376 442 176 712 172 524 615 657 116 451 431
414 434 674 671 474 464 165 277 222 432 335 275 347 531 562 566 654
```

060

```
eight
8 8 8 8 8  8 8 8 8 8  8 8 8 8 8  8 8 8 8 8
8 8 8 8 8  8 8 8 8 8  8 8 8 8 8  8 8 8 8 8
8 8 8 8 8  8 8 8 8 8  8 8 8 8 8  8 8 8 8 8
8 8 8 8 8  8 8 8 8 8  8 8 8 8 8  8 8 8 8 8
8 8 8 8 8  8 8 8 8 8  8 8 8 8 8  8 8 8 8 8
8 8 8 8 8  8 8 8 8 8  8 8 8 8 8  8 8 8 8 8
```

061

```
k8pul az8d  no8l  kv8s  w8bnh
a8khg a8rmq wv8k  k8uab n8xuw
at8i  k8js  nn8j  kk8j  wy8n
428 737 878 644 565 486 767 274 183 313 267 674 344 586 388 538 173
363 885 171 361 721 276 141 578 481 146 172 476 164 334 776 348 485
661 487 872 861 625 351 127 847 532 475 351 336 738 741 147 164 363
```

062

```
nine
9 9 9 9 9  9 9 9 9 9  9 9 9 9 9  9 9 9 9 9
9 9 9 9 9  9 9 9 9 9  9 9 9 9 9  9 9 9 9 9
9 9 9 9 9  9 9 9 9 9  9 9 9 9 9  9 9 9 9 9
9 9 9 9 9  9 9 9 9 9  9 9 9 9 9  9 9 9 9 9
9 9 9 9 9  9 9 9 9 9  9 9 9 9 9  9 9 9 9 9
9 9 9 9 9  9 9 9 9 9  9 9 9 9 9  9 9 9 9 9
```

063

```
kt9z  am9z  ny9t  a9mvc n9zmj
ad9h  kk9t  k9pqi wb9u  a9zr
n9xyk w9ek  kp9x  w9vw  k9jn
483 277 961 774 637 542 457 997 272 447 992 131 822 945 249 653 364
572 766 816 632 297 396 262 429 122 928 925 153 772 478 826 515 516
826 213 269 484 738 959 474 725 221 825 962 868 821 896 591 538 967
```

064

```
zero
0 0 0 0 0  0 0 0 0 0  0 0 0 0 0  0 0 0 0 0
0 0 0 0 0  0 0 0 0 0  0 0 0 0 0  0 0 0 0 0
0 0 0 0 0  0 0 0 0 0  0 0 0 0 0  0 0 0 0 0
0 0 0 0 0  0 0 0 0 0  0 0 0 0 0  0 0 0 0 0
0 0 0 0 0  0 0 0 0 0  0 0 0 0 0  0 0 0 0 0
0 0 0 0 0  0 0 0 0 0  0 0 0 0 0  0 0 0 0 0
```

065

```
kv0o  au0x  kl0r  w0ug  wc0e
a0nz  kj0i  n0eh  k0ho  n0rf
567 637 141 924 800 697 137 822 461 682 937 578 409 392 199 686 556
781 628 633 092 785 417 483 361 844 909 869 719 579 534 065 871 517
162 038 557 028 732 749 730 583 819 365 663 300 003 041 954 982 560
```

066

```
slant sign
/ / / / /  / / / / /  / / / / /  / / / / /  / / / / /  / / / / /

portable call signs using slant sign

k5jk/8  k8ilm/1  k1no/2  w6efj/7  na5n/6   kl7ak/0  w2rca/4
w9mb/3  k4jkb/0  kh4rc/2  n3cc/3  aa4ra/7  kc3pq/5

cq cq cq de wh8s wh8s wh8s k
cq cq cq de w9bcr w9bcr w9bcr k
cq cq cq de n5sj n5sj n5sj k
cq cq cq de ky2y/3 ky2y/3 ky2y/3 k
cq cq cq de n8hip n8hip n8hip k
cq cq cq de kr5c/6 kr5c/6 kr5c/6 k
cq cq cq de k4gc k4gc k4gc k
cq cq cq de k7xx/0 k7xx/0 k7xx/0 k
cq cq cq de kg7q kg7q kg7q k
cq cq cq de nc0r/9 nc0r/9 nc0r/9 k
cq cq cq de ae6s ae6s ae6s k
cq cq cq de a3dm/4 a3dm/4 a3dm/4 k
cq cq cq de n9cb n9cb n9cb k
cq cq cq de w6fbp w6fbp w6fbp k
cq cq cq de k3fmh/1 k3fmh/1 k3fmh/1 k
cq cq cq de a5ozn/5 a5ozn/5 a5ozn/5 k
cq cq cq de n1dmi/8 n1dmi/8 n1dmi/8 k
```

067

```
cq cq cq de k3vg k3vg k3vg k
k3vg k3vg de av6d av6d k

cq cq cq de wq8e wq8e wq8e k
wq8e wq8e de n5zre n5zre k

cq cq cq de w2grw w2grw w2grw k
w2grw w2grw de nc4p  nc4p  k

cq cq cq de kw5s kw5s kw5s k
kw5s kw5s de a6up  a6up  k

cq cq cq de w6mcz w6mcz w6mcz k
w6mcz w6mcz de k4rpg k4rpg k
```

```
cq cq cq de a9da a9da a9da k
a9da a9da de a6en a6en k

cq cq cq de w7lc w7lc w7lc k
w7lc w7lc de at1g at1g k

cq cq cq de kg8c kg8c kg8c k
kg8c kg8c de w3xzv w3xzv k
```

068

```
comma

, , , , ,   , , , , ,   , , , , ,
, , , , ,   , , , , ,   , , , , ,
, , , , ,   , , , , ,   , , , , ,
, , , , ,   , , , , ,   , , , , ,
, , , , ,   , , , , ,   , , , , ,
```

069

```
period

. . . . .   . . . . .   . . . . .
. . . . .   . . . . .   . . . . .
. . . . .   . . . . .   . . . . .
. . . . .   . . . . .   . . . . .
. . . . .   . . . . .   . . . . .
```

070

```
qth hr is wink, tx.
qth hr is dallas, tx.
qth hr is houston, tx.
qth hr is detroit, mi.
qth hr is seattle, wa.
qth hr is boston, ma.
qth hr is miami, fl.
qth hr is miami, oh.
qth hr is denver, co.
qth hr is las vegas, nv.
qth hr is
paris, france.
qth hr is
phoenix, az.
```

071

```
name hr is carol carol.
name hr is steve steve.
name hr is bob bob.
name hr is chuck chuck.
name hr is doug doug.
name hr is harry harry.
name hr is eve eve.
name hr is harv harv.
name hr is ben ben.
name hr is ken ken.
name hr is ralph ralph.
name hr is jeff jeff.
```

072

```
rig hr is tentec tentec.
rig hr is yaesu yaesu.
rig hr is kenwood kenwood.
rig hr is knwd knwd.
rig hr is elecraft elecraft.
rig hr is heathkit heathkit.
rig hr is norcal norcal.
rig hr is homebrew homebrew.
rig hr is hb hb.
rig hr is collins collins.
```

073

```
wx hr is clear clear.
wx hr is cloudy cloudy.
wx hr is cldy cldy.
wx hr is rainy rainy.
wx hr is snowing snowing.
wx hr is windy windy.
wx hr is cold cold.
wx hr is dry dry.
wx hr is hot hot.
wx hr is wet es cold.
wx hr is hot es dry.
```

074

```
ur rst is 599 599.
ur rst is 579 579.
ur rst is 569 569.
ur rst is 559 559.
ur rst is 339 339.
ur rst is 589 589.
ur rst is 579 579 wid qsb.
ur rst is 559 559 wid qrm.
ur rst is 559 559 wid qrn fm local storm.
```

075

```
ant hr is dipole dipole.
ant hr is 3 el yagi 3 el yagi.
ant hr is inv vee inv vee.
ant hr is vertical vertical.
ant hr is vee beam vee beam.
ant hr is g5rv dipole g5rv beam.
ant hr is long wire long wire.
ant hr is rhombic rhombic.
ant hr is loop loop.
ant hr is 40m dipole up 10 mtrs  40m dipole up 10 mtrs.
```

076

```
question mark

? ? ? ? ?   ? ? ? ? ?   ? ? ? ? ?
? ? ? ? ?   ? ? ? ? ?   ? ? ? ? ?
? ? ? ? ?   ? ? ? ? ?   ? ? ? ? ?
? ? ? ? ?   ? ? ? ? ?   ? ? ? ? ?

who?  who?  what?  what?  where?  where?
when?  when?  why?  why?  how?  how?

double dash or equal sign

= = = = =   = = = = =   = = = = =
= = = = =   = = = = =   = = = = =
= = = = =   = = = = =   = = = = =
= = = = =   = = = = =   = = = = =

name hr is chuck chuck = town of prescott prescott =
state is az az = wx is cold and windy =
```

077

cq cq cq de k7qo k7qo k7qo k

cq cq cq de k7qo k7qo k7qo k

k7qo k7qo de kl7ja kl7ja k

kl7ja kl7ja de k7qo r tu fer call om =
ur rst is 589 589 hr in prescott, az prescott, az =
name hr is chuck chuck = so hw cpy? kl7ja de k7qo k

k7qo de kl7ja r tu chuck fer report fm az =
ur rst is 559 559 hr in juno, ak juno, ak =
name is leo leo = so bk to u chuck = k7qo de kl7ja k

kl7ja de k7qo fb leo and tnx fer sig rpt fm ak =
wx hr is cool and windy = temp is 52 f 52 f =
rig is tentec corsair 1 running 5w to a vee beam up 10 mtrs =
hw is signal holding leo? kl7ja de k7qo k

k7qo de kl7ja fb agn chuck = wx hr is cold and snowing =
temp is 10 f 10 f = have 1 meter of snow and more falling =
rig is elecraft k2 running 5w to a 3 element yagi at 15 mtrs =
band sounds like it is closing so will say 73 fer now = 73
gl es gn fm ak = c u agn chuck <sk> k7qo de kl7ja ee

kl7ja de k7qo fb leo and tnx fer qso = ur my first kl7 on
this band so qsl sure via buro =73 gl es gn fm az = cul <sk> kl7ja de k7qo ee

078

cq cq cq de k2lu k2lu k2lu k

k2lu k2lu de k7un k7un k

k7un de k2lu tu fer call = ur rst 559 559 in albany ny =
name is mary = so hw? k7un de k2lu k

de k7un r ok mary es ga = ur rst 599 599 = qth reno nv = name is bill =
bk to u mary = k2lu de k7un k

de k2lu solid cpy bill es tnx fer report =
rig is tentec corsair running abt 50 wts = ant is dipole up at 55 ft =
wx is clear = temp abt 60 deg f = bk to u bill = k7un de k2lu k

de k7un ok mary fb on all = rig is norcal 40a =
runs abt 2 wts to a long wire at 45 ft = wx is cldy es 50 deg = bk to u mary =
k2lu de k7un k

r r fb agn bill = dinner about ready = so must run so will sign wid u nw =
73 es gl bill = cu agn <sk> k7un de k2lu ee

de k7un ok mary = tnx fer qso = c u agn = gl es 73
<sk> k2lu de k7un ee

079

cq de w4rx w4rx k

w4rx de k0dx k0dx k

k0dx de w4rx tu fer call = ur rst 579 =
qth is atlanta ga = name is ed = so hw cpy? =
k0dx de w4rx k

de k0dx r ok ed es gm = ur rst 599 599 =
qth st louis mo = name is doug =
bk to u ed = w4rx de k0dx k

de w4rx solid cpy doug = tnx fer report =
rig is yaesu ft1000mp = running abt 100 wts = ant is
yagi up at 55 ft = wx is clear es abt 75 f =
bk to u doug = k0dx de w4rx k

de k0dx ok ed fb on all = rig is kenwood ts840s =
runs abt 75 wts to a vertical = wx is cldy es 60 deg =
bk to u ed = w4rx de k0dx k

r r fb agn doug = time to get to wrk =
so fer nw 73 doug = bcnu <sk> k0dx de w4rx ee

de k0dx ok ed = tnx ed = cul 73 gl <sk> w4rx de k0dx ee

080

cq de kh6jl kh6jl k

kh6jl de kl7aa kl7aa k

kl7aa de kh6jl tu fer call = ur rst 569 =
qth is honolulu hi = name is ted = so hw cpy? kl7aa de kh6jl k

de kl7aa r ok ted es ge r = ur rst 589 589 =
qth fairbanks ak = name is henry =
bk to u ted = kh6jl de kl7aa k

de kh6jl = solid cpy henry es tnx =
rig is homebrew = running abt 3 wts = ant is
3 el beam up at 55 ft = wx is clear es abt 75 f =
bk to u henry = kl7aa de kh6jl k

de kl7aa ok ted fb on all = rig is kenwood ts940s =
runs abt 75 wts to a 4 el yagi at 100 ft = wx is
cldy es 30 deg = bk to u ted = kh6jl de kl7aa k

r r = fb agn henry = well time to get some sleep =
so fer nw 73 henry = bcnu <sk> kl7aa de kh6jl ee

de kl7aa ok ted = tnx = cul = 73 gl
<sk> kh6jl de kl7aa ee

081

cq de k1es k1es k

k1es de k3az k3az k

k3az de k1es tu fer call   ur rst 549
in bangor me name is jim so hw? k3az de k1es k

de k3az r ok jim es gm   ur rst 579 579
qth baltimore md es name is larry
bk to u jim k1es de k3az k

de k1es solid cpy larry es tnx
rig is collins running abt 90 wts   ant is
dipole up at 25 ft   wx is clr es 40 f
bk to u larry k3az de k1es k

de k3az ok jim fb on all   using drake tr7
runs abt 85 wts to a vert gnd mntd wx is
clr es 34 deg bk to u jim
k1es de k3az k

r r fb agn larry wl time to wrk sked wid friend so fer nw 73 larry bcnu <sk> k3az de k1es ee

de k3az ok jim tnx cul 73 gl
<sk> k1es de k3az ee

082

cq cq de aa5uu aa5uu k

aa5uu de xe1cc xe1cc k

xe1cc de aa5uu tu fer call   ur rst 559
in albuquerque nm name is lisa so hw nw? xe1cc de aa5uu k

de xe1cc r ok lisa es gm   ur rst 579 579
qth cancun mexico es name is jose
bk to u lisa aa5uu de xe1cc k

de aa5uu solid cpy jose es tnx
rig is heathkit hw16 running abt 75 wts   ant is
dipole up at 40 ft   wx is clr es 45 f
bk to u jose xe1cc de aa5uu k

de xe1cc ok lisa fb on all   using collins s line
runs abt 85 wts to a dipole wx is
clr es 84 deg bk to u lisa
aa5uu de xe1cc k

r r fb agn jose wl time to wrk i am a pilot for airline
age is 38 so fer nw 73 es 88 jose bcnu <sk> xe1cc de aa5uu ee

de xe1cc ok lisa gracias cul 73 gl
<sk> aa5uu de xe1cc ee

083

e f j a n   x m p r v   j b x i m   v o k v u   v b h s u   f p h p l
v p q a v   f y x m f   e v z u m   c c d w n   e v v i r   o h y j w
x i p o r   q a v o k   e z k t m   o m a k u   r t o l y   o x y f m
b s e o a   s q k b y   e d m j m   k v a q b   a s k z a   m d d r x
q f c y a   m o m f w   e n m n k   c j x j m   y y p v l   i b c v a

084

```
a l v x c   u p g z w   f p t b n   e j z o a   p w o x b   p p r e a
h b h z a   e a r g z   w t n s f   u z p s l   w n s r l   k c y e o
d p m w u   v i e u z   v v b f q   q p e t i   d g k v x   n a z g a
n w x z u   k j x f q   t w u s y   u l d l f   y u v m b   c j c l a
x f d e x   s n h d e   j e n s s   g q u a l   q z r g e   j t n a f
```

085

```
2 8 8 0 9  3 8 7 3 1  5 1 4 1 2  6 3 7 9 2  4 4 0 6 5  2 3 9 2 3  5 5 6 1 3
6 5 1 1 9  2 8 7 4 7  8 6 6 2 2  7 2 8 9 0  1 4 9 5 4  3 9 1 9 7  2 4 9 1 0
3 0 9 6 9  3 6 3 5 4  5 4 2 4 4  2 0 6 2 0  6 6 6 3 4  8 9 3 2 4  1 1 8 6 5
4 8 6 4 0  4 1 6 5 1  2 6 6 5 7  0 1 3 4 3  0 8 4 3 8  3 3 6 4 9  1 3 8 3 0
0 5 3 4 3  8 3 7 2 8  7 5 9 0 4  3 3 2 3 2  8 6 2 5 5  6 5 8 0 4  7 9 3 7 3
```

086

```
3 . 14159 26535 89793 23846 26433 83279 50288 41971 69399
37510 58209 74944 59230 78164 06286 20899 86280 34825
34211 70679 82148 08651 32823 06647 09384 46095 50582
23172 53594 08128 48111 74502 84102 70193 85211 05559
64462 29489 54930 38196 44288 10975 66593 34461 28475
64823 37867 83165 27120 19091 45648 56692 34603 48610
45432 66482 13393 60726 02491 41273 72458 70066 06315
58817 48815 20920 96282 92540 91715 36436 78925 90360
01133 05305 48820 46652 13841 46951 94151 16094 33057
27036 57595 91953 09218 61173 81932 61179 31051 18548
07446 23799 62749 56735 18857 52724 89122 79381 83011
94912 98336 73362 44065 66430 86021 39494 63952 24737
19070 21798 60943 70277 05392 17176 29317 67523 84674
81846 76694 05132 00056 81271 45263 56082 77857 71342
75778 96091 73637 17872 14684 40901 22495 34301 46549
58537 10507 92279 68925 89235 42019 95611 21290 21960
86403 44181 59813 62977 47713 09960 51870 72113 49999
99837 29780 49951 05973 17328 16096 31859 50244 59455
34690 83026 42522 30825 33446 85035 26193 11881 71010
00313 78387 52886 58753 32083 81420 61717 76691 47303
59825 34904 28755 46873 11595 62863 88235 37875 93751
95778 18577 80532 17122 68066 13001 92787 66111 95909
```

087

```
slant sign
/ / / / /  / / / / /  / / / / /  / / / / /  / / / / /  / / / / /
```

portable call signs using slant sign

k5jk/8 k8ilm/1 k1no/2 w6efj/7 na5n/6 kl7ak/0 w2rca/4
w9mb/3 k4jkb/0 kh4rc/2 n3cc/3 aa4ra/7 kc3pq/5

088

lt371 i6bhb 3y7yl .zoei rrd/6 t13ks umzk8 2jf8d 9yqnb e2z1l dorp3
dnuzy h8su8 tpvev jgrk3 cj.na nso06 jjej0 qihdz ds,c7 l.7hl q,wki
lab99 zvdnt 1r8bp 4w57x 0.91m vh.6u l,knr m1ht2 nh,w3 zwuas i2fn,
mv1,y 9boev v3315 /jrxd memi3 uowba flqx5 zyq/6 r,8j. /c,ik j4d..
t3yz. utau/ x7ldp 7,igm eznh2 7osl1 dw.a/ b8rs/ nr7te dgvz8 uik16

089

```
l.ntw hg1q8 zhaba l4wc7 7.ryg 0smpn 3/2/. 26mfb izo/5 rlds5 91d1z
hv6xr y.etg an/,x mj.sc dp5xs mcepo qnvuf 56uz/ 02i.m fyn4h nrvkz
./vsa kej/b 5tvh, ,b.hp gsakf 4e0gb b/aba stl6d tf5t1 v7ip3 ay2mg
fvpxb qn19f q2c4b 52fco 5wn,n cd504 9l1zl slb.u ayfj0 qffo/ /vtmc
rk6hw ogw7b mv2l9 ak5vn sohd3 1ubqf e2wjd 8xi3v 4ce.y 3qa73 e59bk
```

090

```
dash or hyphen
- - - - -  - - - - -
- - - - -  - - - - -

colon
: : : : :  : : : : :
: : : : :  : : : : :

semicolon
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091

Kilometer, pronounced KIHL uh mee tuhr or kuh LAHM uh tuhr,
is a unit of distance in the metric system. The word is
also spelled kilometre. Its symbol is km.
One kilometer equals 1,000 meters, a distance of about
five-eighths of a mile.

092

Fort originally was a fortified building or place that
provided defense against attack. On the American frontier,
many forts also served as trading posts. Many cities that
grew up around forts bear their names, including Fort Wayne, IN.
The term fort now applies to permanent United States Army posts.

093

Fathom, pronounced FATH uhm, is a unit of length
used to measure ropes or cables and the depths of water.
One fathom is equal to 1.8 meters.
Navigators mark a rope in fathoms and drop it into the
water to measure the depth.
Sailors of average height often measured fathoms roughly
by extending both arms and measuring the rope from
fingertip to fingertip.

094

Logbook is the official or legal written record of
the events that take place during a ships voyage. The log
may be written up once a day by the captain of the ship, or
it may be written by the officer in charge of each watch.
It includes a record of the ships course and speed, the weather,
and any ships or lands sighted. It also includes mention of any
sickness, death, or crime on board ship, and of any other unusual event.

095

Mauna Kea, pronounced MOW nuh KAY uh, is a volcano on the
island of Hawaii. Its peak rises 4,205 meters above sea
level and 10,203 meters above the base of the mountain on
the floor of the Pacific Ocean. Its rise from base to peak
is the greatest in the world. This distance is 1,356 meters
longer than the rise from sea level to the peak of Mount Everest.
The name Mauna Kea means white mountain.

096

Watt is a unit of power in the metric system.
Power is the rate of producing or using energy.
The symbol for the watt is a capital W.
The watt is commonly used to measure electric power, even in countries that have not adopted the metric system. An electric device uses 1 watt when 1 volt of electric potential drives 1 ampere of current through it.
The number on a light bulb shows its power requirement in watts.
For example, a light bulb operating at 100 volts and using 2 amperes consumes 200 watts. Often, power is measured in kilowatts. One kilowatt equals 1,000 watts. The watt also is used to measure mechanical power. A machine requires a power of 1 watt if it uses 1 joule of energy in 1 second. The watt was named for the Scottish engineer and inventor James Watt.

097

Zenith, pronounced ZEE nihth, in astronomy, is any point directly above a person on the earth. Zeniths lie on the celestial sphere, which can be pictured as an imaginary sphere that encloses the universe.
A point directly below a person on the earth is called a nadir.
Astronomers speak of two kinds of zeniths, astronomical zeniths and geocentric zeniths. An astronomical zenith is determined by gravity.
It is any point where an extended plumb line would intersect the celestial sphere. A geocentric zenith is determined by geometry. It is any point where a line drawn from the earths center through a person on its surface would intersect the celestial sphere. The angular distance of a star or other celestial body from a zenith is called the zenith distance.
This information can be used to describe the position of such an object.

098

Tugboat, also called tug, is a small, powerful boat that maneuvers large vessels. Tugs that are used in harbors can tow large ocean liners or freighters and aid all types of vessels in entering or leaving their anchoring places.
They can tow from the front or side, or push from the back.
Tugs measure from 65 to more than 250 feet (20 to 76 meters) long.
They are driven by engines with 2,000 to 22,000 horsepower (1,500 to 16,400 kilowatts). The largest tugboats are the oceangoing tugs, which rescue or assist ships at sea. Tugs used on inland lakes and rivers tow or push long lines of barges loaded with heavy cargoes. Modern tugs can push 40 or more barges at once.

099

Teflon is a trade name for polytetrafluoroethylene,
a type of synthetic material that
is used in cookware, insulation, and many other products.
Teflon is manufactured by the DuPont Company, and the name
Teflon is a registered trademark of DuPont. Roy J. Plunkett,
an American chemist, invented this material in 1938.

Teflon is a polymer, a substance consisting of long, chainlike
molecules. Each molecule is made up of a chain of tens of
thousands of carbon atoms, with each carbon atom also connected
to two fluorine atoms. Teflon is inert - that is, it does not
react with most other chemicals. It also resists moisture and
remains stable in extreme heat and cold. Teflon feels slippery
to the touch, and adhesive materials will not stick to it.

100

Quart is a unit of volume and capacity for both dry
and liquid substances in the inch-pound system of measurement.
This system is used in the United States. The liquid quart
equals 1/4 of a gallon and contains 57.750 cubic inches.
It equals 0.946 liter in the metric system. The dry quart
equals 1/32 of a bushel and contains 67.200 cubic inches. It
equals 1.101 liters. Quarts are divided into two pints. The
imperial quart was once used in Britain and such countries as
Canada and New Zealand. But it has been replaced with metric
units of measurement. The imperial quart contains 69.355 cubic
inches, or 1.137 liters.

101

Kakapo is a rare New Zealand parrot. It now survives only in beech
forests in Fiordland and Stewart Island, off the coast of the South
Island of New Zealand. Some kakapos have also been released on
Little Barrier Island, near Auckland, in an effort to save the birds
from extinction.

The bird is about 60 centimeters long. Its plumage is green with black
and brown bars. It cannot fly like most other birds but must leap from
a high point and glide. It normally travels along the ground, clearing
tracks through the bush, low scrub, and grass.

Kakapos eat berries, fern roots, and lizards. The birds nest in large
natural crevices or in burrows. Female kakapos usually lay from two to
four white eggs.

102

Mint is a place where coins are made.
In the United States and most other countries, only the government
may mint coins. American mints are supervised by the United States
Mint, a division of the Department of the Treasury. Mints now
operate in Denver, Philadelphia, San Francisco, and West Point, N.Y.
They make only coins. The Bureau of Engraving and Printing in Washington,
D.C., makes paper money. U.S. mints make half dollars, quarters, dimes,
nickels, and cents for general circulation. They also make commemorative
coins for special occasions and gold and silver bullion coins for investors.
Historians believe the world's first mint was founded during the 600s B.C.
in Lydia, now a part of Turkey. Ancient Mediterranean civilizations,
including Greece and Rome, used coins in commerce. The use of coins
gradually spread throughout Europe and Asia. The first mint in the
United States was established in Boston in 1652. It produced coins
under the authority of the General Court of the Massachusetts Bay Colony.
The Articles of Confederation of 1781 gave both the U.S. Congress and
the individual states authority to mint money and regulate its value.
The first federal mint opened in Philadelphia in 1792 and is still in
operation.

103

Photon, pronounced FOH tahn, is the elementary particle that makes up
light and all other forms of electromagnetic radiation.
Like all particles, photons have properties of waves, including
frequency and wavelength. But photons have no mass and no electric charge.
The speed at which photons travel in a vacuum is the speed of light.
The exchange of photons between electrically charged particles transmits
the electromagnetic force, one of the four fundamental forces.
In 1900, the German physicist Max Planck showed that the energy of a
photon (then called a radiation quantum) is proportional to the frequency
of its light. The German-born physicist Albert Einstein carried
Planck's discovery further. In 1905, Einstein used the idea of photons
to explain the ability of light to knock electrons out of atoms - a
phenomenon known as the photoelectric effect.
His predictions about photons, which were later confirmed by experiment,
contributed much to the development of the quantum theory.

104

Summer is the warmest season of the year. The Northern Hemisphere, the northern half of the earth, has summer weather during late June, July, August, and early September. Summerlike days sometimes occur in mid-autumn. In the Southern Hemisphere, summer lasts from late December until early March. For dates of the first day of summer and details about the position of the earth and sun, see season.

In summer, warm southern winds carry moisture north from the Gulf of Mexico to central and eastern North America. They can bring warm, humid weather to much of the region east of the Rocky Mountains and as far north as Canada. Thunderstorms often develop in and along the northern boundary of this warm, moist air. The highest summer temperatures usually occur in the middle of the continent.

105

Talc is a soft mineral found in flat smooth layers of rock, and in compact masses. It is so soft that it can be scratched with the fingernail, and it feels soapy or greasy. Talc is translucent, which means that it will allow light to go through, yet is not transparent. Talc is white, greenish, or dark gray. Steatite, soapstone, is a compact talc. Talc has many commercial uses. It is sold in slabs or in powdered form. Slabs are used to line furnaces and heating stoves, and for electric insulation, because talc is a poor conductor of heat and electricity. It is ground up to make talcum powder. Powdered talc is also used in crayons, paint, paper, and soap. The leading talc-producing nations include China, Finland, India, and the United States. Montana, New York, Texas, and Vermont are important talc-producing states.

106

Putty is a filler material that is soft when applied but slowly hardens. It is used to fill knotholes, cracks, and other defects in wood surfaces before the surfaces are painted. Putty is also placed around the edges of panes of glass to seal them in a window sash or door.

The most common putty is a mixture of powdered natural chalk, called whiting, and linseed oil to which a small proportion of coloring agents may be added. Putty hardens because some of the oil combines with oxygen from the air and the rest of the oil soaks into the wood.

Some projects require special, more elastic putty. This type of putty is made from vegetable oil, nondrying oils, driers that make the putty harden, synthetic fibers, a powdered limestone filler, and a coloring agent.

107

Joule, pronounced jool or pronounced jowl, a unit in the metric system of measurement, is used to measure work or energy. Its symbol is a capital J. One joule is the amount of work done when a force of 1 newton acts on an object that moves 1 meter in the direction of the force.

The joule is used to measure all forms of energy, including heat, electrical energy, and mechanical energy. One joule equals about 0.239 calorie. A calorie is the amount of energy needed to raise the temperature of 1 gram of water by 1 Celsius degree. One joule of energy per second is required to pass an electric current of 1 ampere through 1 ohm resistance. One joule per second equals one watt, a unit of electric and mechanical power.

In the inch-pound system of measurement customarily used in the United States, work or energy is measured in foot-pounds. One joule equals about 0.738 foot-pound. The joule was named for the British physicist James P. Joule.

108

Hardness is the ability of a material to scratch a mark on other substances or to resist being scratched by them. Scientists measure the hardness of a material by comparing it with a table of 10 well-known minerals. The minerals are arranged in order from 1 to 10. Each mineral in the table scratches the ones with lower numbers, and can be scratched by all those with higher numbers.
The standard "scale of hardness" follows: (1) talc, (2) gypsum, (3) calcite, (4) fluorite, (5) apatite, (6) feldspar, (7) quartz, (8) topaz, (9) corundum, (10) diamond.

To test another substance, you match it against the minerals of the hardness scale. You can get an approximate idea of the hardness of a mineral by using your fingernail, a copper coin, a piece of window glass, or a knife blade. The hardness of these materials is as follows: fingernail, 2 to 2 1/2; copper coin, 2 1/2 to 3; window glass, 5 to 5 1/2; and knife blade, 5 1/2.

When materials must be accurately tested, as in the manufacture of tools and gears, machinists use an instrument called a sclerometer. This device registers the force required to dent or scratch the material with a diamond or borazon, the hardest substances known.

109

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Vanilla is the name of a group of climbing orchids.
The vanilla extract that is used to flavor chocolate, ice
cream, pastry, and candy comes from these plants.
The vanilla vine has been cultivated in Mexico for hundreds of years.
This type of vanilla has been introduced into other tropical areas.
Comoros, Indonesia, Madagascar, and Reunion produce much of the worlds supply.
Another species grows on the island of Tahiti in the South Pacific.
The vanilla vine has little rootlets by which the plant attaches itself
to trees.  The cultivated plant lives about 10 years.  It produces its
first crop after three years.
The plant produces a fruit in the shape of a cylindrical pod, bean, that
measures from 13 to 25 centimeters long.
The fruit has an oily black pulp that contains many tiny black seeds.
The pods are gathered when they are a yellow-green in color.
Then the curing, or drying, process takes place.
This process shrinks the bean and turns it a rich, chocolate-brown color.
The process also gives the bean the flavor and aroma of vanilla as we know it.
Vanilla extract is prepared by a complicated and expensive process.
The beans are chopped into small pieces and then percolated with alcohol and water.
Food scientists have developed artificial vanilla flavors because of the high
cost of vanilla.
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110

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The several kinds of clay tile are made in much the same way.
Thin sheets of clay are pressed or molded to shape, and fired in
kilns in the same process as is used for making brick.
The tile may be left in its rough state.
It may also be given a smooth surface, called glazing, by dipping
or spraying the tile with a material that joins with the clay.
Other ways include throwing salt into the kiln or treating the clay
with a chemical wash.
Tile pipe is used for sewage-disposal systems and for draining fields
of excess water.
A continuous tile line is formed by fitting together short sections,
each of which has one end enlarged to form a bell into which the small
end of the next section fits.
Drain tiles are laid with uncemented butt ends through which the drainage
 water may seep.  Sewer pipes are laid with tight cement joints.
Finer grades of clay are used in making tiles for roofs, for walls, and for floors.
Roofing tiles are made in various shapes and colors.
Hollow clay tile blocks are used in load-bearing walls and partitions.
Home builders use decorative tiles for interior floors and walls.
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They obtain artistic effects by using tiles of different colors.
Mosaics are small, unglazed tiles that are combined to form a design in colors.
Glazed tiles are popular for the walls of kitchens and bathrooms.
Encaustic tiling is the trade name for decorative tiles used in such a way that there is a background of one color and a pattern of another, contrasting color.
Floor tiles are made of rubber, linoleum, terrazzo, cork, asphalt, plastic, and terra cotta and other ceramics.
Acoustic ceiling tiles are made of cork granules, wood fiber, and mineral fiber.

111

Scissors. A pair of scissors is really two knife blades joined together to form a double lever. Each blade operates as a lever of the first class. A pin or bolt holds the blades together and acts as their common fulcrum or support. The user squeezes the open scissors handles together to apply pressure against both sides of the material, which then is cut.

To most people, scissors and shears refer to the same instrument. But, in the hardware trade, shears refers to scissors with blades more than 15 centimeters long. The handles of scissors usually have rings of equal size. Most shears have a larger ring on one handle for the four fingers of the cutting hand. The thumb of the cutting hand fits through the other ring. Scissors and shears range in size from tiny manicuring scissors to giant, power-operated shears that cut scrap metal for steel-mill furnaces. Pinking shears, or pinking scissors, have sawtooth edges. They are used to give cloth a scalloped edge, which keeps the material from raveling.

Scissors developed shortly after people learned how to make knives. Sharp, sturdy scissors were developed in the late 1200's.

112

Rake is a machine used to gather mowed hay and place it in long piles called windrows. The windrows are then gathered by a hay loader or baler. The first rakes were wooden hand rakes. People still use hand rakes to rake leaves from lawns. Modern rakes are usually pulled by, or mounted on, a tractor. Rakes can also be used to gather straw, green forage, and seed crops.

The dump rake consists of curved steel teeth mounted on an axle between two wheels. The teeth slide over the ground and rake hay as the machine moves forward. The operator dumps the hay in a windrow by pulling a lever that causes the teeth to lift from the ground.

The side-delivery rake leaves the hay in a continuous windrow at the side of the vehicle carrying the rake. In one type of side-delivery rake, the teeth are attached to cylinders that roll along at an angle to the direction traveled. The teeth just clear the ground as the cylinder rotates. As the machine moves ahead, the teeth brush the hay to the side, leaving it in a windrow. A dual rake consists of two side-delivery rakes, which deposit two windrows together at one time.

The finger-wheel rake consists of several wheels with spikes on the rim. The wheels are set at an angle to the direction traveled, and move the hay sideways to form a windrow. The drag-type rake has no moving parts. It has curved fingers that move the hay to one side, much as a snowplow moves snow.

113

Canada's westernmost Prairie Province gained large revenues from its oil resources in 1976. It set aside some of these funds for future generations by establishing the Alberta Heritage Savings Trust Fund, a $1.5-billion public endowment. The act authorizing the fund provided that 30 per cent of oil royalties would be paid into it annually.

The Progressive Conservatives dominated the 75-seat Legislative Assembly, holding 69 seats. There were also 4 Social Credit members, 1 New Democratic Party representative, and 1 Independent. The Assembly passed 58 bills during its 51-day session, including a measure creating a home-mortgage corporation and a plan to reorganize provincial courts. A $2.9-billion budget presented on March 19 called for a 7.7 per cent increase in expenditures, modest when compared to the 25 per cent growth each year over the previous five years. There were no tax increases, retaining Alberta's distinction of having the lowest provincial taxes in Canada.

A new policy for exploiting Alberta's billions of tons of coal - half Canada's reserves - was announced in June. A complicated formula will net the province much larger revenues from future coal royalties. The $2-billion Syncrude Canada, Limited, plant on the Athabaska tar sands passed the halfway point in construction.

114

Cardboard is a popular name for any stiff paper or paperboard that is more than 0.1524 millimeter thick. It usually does not mean paper used for special purposes, such as wallboard or corrugated boxboard. Papermakers

use various names for different kinds of
cardboard. The name may be based on the raw
material used, such as strawboard or newsboard.
It may indicate useful characteristics, such as
bending board. Or it may designate the final use,
such as poster board or shoe board. A familiar
type of cardboard, called bristol board, is used
for such products as index cards and postal cards.
Manufacturers make cardboard by pasting several
layers of paper together or by pressing layers
of wet pulp together. They often coat cardboard
for decoration or to improve the surface of the
cardboard for printing.

115

Water plant, also called aquatic plant or hydrophyte, is a
name used for any plant that is specially adapted to live in
water. Many botanists also consider the term water plant to
include those plants that grow in water-saturated soils.

Water plants may be rooted in the mud and have their leaves and
blossoms above or at the surface of the water. Some kinds grow
completely underwater. Submerged water plants often have air bladders
or large air pores in their stems and leaves that help the plants stand
upright or stay afloat. Some of the best-known water plants are water
lilies, sedges, and cattails. These plants often grow in lakes and ponds.
Some biologists consider certain types of algae to be water plants. However,
most scientists do not include algae in the plant kingdom. They classify
algae in the kingdoms Protista and Prokaryotae.

116

Hexagon, pronounced HEHK suh gahn, is a plane figure that has
six sides. It is a type of polygon. The sides of a hexagon meet
at points called vertices, forming six interior angles. The sum of
a hexagon's interior angles is always 720 degrees. A hexagon is said
to be regular if all its sides and angles are equal. Each angle of a
regular hexagon measures 120 degrees. The area of a regular hexagon
equals one-half the product of its perimeter and its apothem, which is
the distance from the center of a regular polygon to the midpoint of
one of its sides.

117

Krypton, pronounced KRIHP tahn, is a chemical element that
makes up only about one-millionth of the earths atmosphere.
The British chemists Sir William Ramsay and Morris W. Travers
discovered it in 1898.
It was named krypton for the Greek word which means the hidden one.
Most fluorescent lamps are filled with a mixture of krypton and argon.
Krypton is also used in certain electronic tubes, and in luminous sign
tubes where a greenish-yellow color is desired.

Krypton is a colorless, odorless, tasteless gas.
It does not react readily with other substances and is classed as a noble gas.
Its symbol is Kr.
The element has the atomic number 36, and an atomic weight of 83.80.

118

Live oak is a beautiful evergreen oak that grows chiefly along the
southeastern coast of the United States. It is also found in dry
parts of Texas. The tree grows about 50 feet (15 meters) high.
Its horizontal limbs form a wide-spreading, dense head. The dark,
glossy, oblong leaves may be 2 to 5 inches (5 to 13 centimeters) long.
The live oak is a favorite tree for lawns and streets because it resists
damage from storms, insects, and diseases. It is the state tree of Georgia.

Scientific Classification. The live oak is a member of the beech family,
Fagaceae. It is classified as Quercus virginiana.

119

Integer, pronounced IHN tuh juhr, is a number. The most
familiar integers are the counting numbers, such as 1, 7,
28, and 105. The complete set of integers also includes zero
and such numbers as -1, -7, -28, and -105. For every positive
integer, there is a corresponding negative integer that, when added
to the positive integer, gives a sum of zero. For example, 5 + (-5) = 0.
Integers can be added, subtracted, multiplied, and divided.

Most mathematics involves the use of integers, and some mathematical
calculations would be impossible without them. Integers also help
describe certain everyday situations. For example, temperatures can
be above or below zero.

120

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Keck Observatory is an astronomical observatory
on Mauna Kea, a mountain on the island of Hawaii.
The observatory consists of two identical
telescopes, Keck I and Keck II, which are the
largest optical telescopes in the world.
Keck I was completed in 1992 and Keck II in 1996.
The California Association for
Research in Astronomy, which is a partnership of
the University of California
and the California Institute of Technology,
operates the observatory.
The facilitys full name is the W. M. Keck
Observatory.
Keck I and II collect and focus visible light
waves and infrared waves from objects in space.
One use of the telescopes is to analyze
radiation coming to Earth from the farthest
known galaxies.  Astronomers can use the
information gathered to determine a galaxys
distance, size, age, and other characteristics.
Keck I and II are reflecting telescopes - that is,
they use a large mirror to collect and focus
light.  The light-gathering mirror is a segmented
mirror that consists of 36 smaller mirrors
mounted together.  The segments form a reflecting
surface 10 meters in diameter.
An electronic sensing system holds the segments
in place.  If a segment gets out of position,
sensors on its edges activate pistons in the support
structure that move the segment.
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121

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VVV 12 A K5KJ 66 NTX
VVV 1062 B K5GN 72 STX
VVV 378 A KX1E 56 ME
VVV 346 B WA8CDU 66 MI
VVV 11 A W0OF 48 IA
VVV 951 M N4TO 60 WCF
VVV 289 A NI6W 79 NV
VVV 155 A WO7Y 60 ID
VVV 608 B WC4E 84 NFL
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VVV 250 B N9RV 67 IN
VVV 275 B K7JJ 54 SDG
VVV 727 B WB8BMV 68 NC
VVV 155 A AA3LX 94 WPA
VVV 54 A KB9AMG 88 WI
VVV 121 A KB5IXI 89 MS
VVV 678 A KI4SN 77 NC
VVV 186 A W8DHG 48 OH
VVV 192 B AB5QY 92 NTX
VVV 22 A VE3WG 65 ON
VVV 32 U N1AU 55 EMA
VVV 105 Q AB5OU 54 NM
VVV 228 A K3WU 71 EPA
VVV 196 A VE7IN 61 BC
VVV 780 B W1BIH 30 CT

122

The left parenthesis is (. (((((
The right parenthesis is).)))))

Abacus is an ancient device used in China and other
countries to perform arithmetic problems. It can be used to add, subtract,
multiply, and divide, and to calculate square roots and cube roots. The
abacus consists of a frame containing columns of beads. The beads, which
represent numbers, are strung on wires or narrow wooden rods attached to
the frame.

The abacus was used by the ancient Greeks and Romans. The Chinese abacus is
called suanpan, which means counting, or reckoning, board. A typical Chinese
abacus has columns of beads separated by a crossbar. Each column has two beads
above the crossbar and five below it. Each upper bead represents five units,
and each lower bead equals one unit.

The first column on the right is the ones column. The second column is the
tens column. The third column is the hundreds, and so on. The ones column
represents numbers from one to nine. Each bead below the crossbar has a value
of one (or 1), and each bead above the crossbar has a value of 5 ones (or 5).
The tens column represents numbers from 10 to 90.

Each lower bead in the tens column represents 1 ten (or 10), and each upper
bead represents 5 tens (or 50). A number is represented on the abacus by
moving the appropriate beads to the crossbar.

123

Almond, pronounced AH muhnd or pronounced AHL muhnd, is a delicious nut.
The nuts are the seeds of the beautiful almond tree.
Each nut grows in a thin, smooth shell that looks somewhat like a peach stone.
A dry, leathery hull covers the shell.
The hull splits open when the nut is ripe.

Some almond trees produce sweet nuts; others have bitter ones.
Sweet almonds are a popular delicacy when toasted, salted, and eaten whole,
or added to candies and rich pastries.
Bitter almonds are not edible.
Trees that produce them are grown only for oil, although oil is also extracted
from the sweet nuts.
Oil of bitter almonds contains the poisonous hydrocyanic (prussic) acid.
After the acid is removed, the oil is used in flavoring extracts.

The almond tree is native to southwestern Asia.
But today it is widely grown in the countries that border the Mediterranean Sea.
The trees also thrive in California, where commercial groves produce large annual
crops of almond nuts.

Almond trees are well-proportioned and may grow 12 meters high.
They have long, pointed leaves that curl, and showy pink blossoms that may be
3.8 centimeters across.
The blossoms open early in spring, long before the leaves appear.
For this reason, almonds are grown commercially only in regions that do not
have early spring frosts.

124

Sonar, pronounced SOH nahr, is a device that uses sound energy to
locate objects - measure their distance, direction, and speed. Even
produce pictures of them. The word sonar comes from sound navigation and ranging.

People associate the word sonar with devices that detect submarines and other
underwater objects. Sonar works well underwater, where sound travels quickly
and efficiently over long distances and where radar does not work.
However, certain sonar devices operate in the air.
For example, some burglar alarms use airborne waves of ultrasound, sound whose
pitch is too high for people to hear, to detect movement.

Dolphins and some bats use a natural sonar technique called echolocation.
This technique helps them locate food, avoid obstacles, and communicate.

How sonar works. There are two types of sonar. Active and passive.
Active sonar uses a transmitter, a device that converts electrical energy to sound energy, to send out sound waves.
Transmitters used underwater can produce a sharp pinging sound.
The sound waves travel through the water until they strike an object.
The object reflects them in various directions.
Some of the reflected waves return to the sonar, where they strike a receiver.
The receiver converts the sound back into electrical signals.
In modern sonars, a computer analyzes these signals to perform the sonars job, such as locating the object or determining the object's distance from the sonar.

A sonar determines distances by measuring the time taken for a sound wave to travel from the transmitter, reflect from the object, and travel to the receiver.
This method of finding distance is called echo ranging.

125

Umbrella is a device that protects people from rain and sun. It consists of a circular piece of fabric stretched on a frame attached to a central handle. The frame can be folded when it is not needed.

Umbrellas were originally used as sunshades. In many cultures, they were a symbol of rank. In ancient Egypt and Babylonia, for example, only royalty and nobility were permitted to have umbrellas.

Umbrellas were first widely used against rain during the 1700's, when heavy umbrellas made of wood and oilcloth became common in Europe. During the 1800's, light, decorative sunshades called parasols became fashionable among women throughout Europe and the United States. Many of these umbrellas had whalebone or metal frames and fine silk coverings edged with lace and fringe. They were popular until about the 1920's.

Today, umbrellas are used primarily as protection against rain or snow. Most umbrellas are made with metal or plastic frames and covered with plain or patterned fabric or clear plastic. They come in a wide variety of colors.
Many umbrellas fold up to fit in purses and briefcases.

126

Bleach is any substance that lightens, brightens, or removes the color from a material. Manufacturers bleach textiles, paper, and other materials to whiten them or to prepare them to be dyed.
Homemakers use laundry bleach to brighten clothes. People also use some bleaches as disinfectants. There are two main kinds of bleaches,

chemical and optical. Chemical bleaches act on the colored molecules
that give a material its color.
The bleaches make these molecules colorless or nearly colorless.
The most widely used chemical bleaches include chlorine bleaches and
oxygen bleaches. Many household and industrial bleaches are chlorine
bleaches, which remove the color from most textiles, wood pulp, pottery,
and other materials.

Oxygen bleaches are milder than chlorine ones. People use hydrogen
peroxide and other oxygen bleaches to lighten hair and to brighten colored
fabrics and other materials that might be harmed by chlorine bleaches.
Other chemical bleaches include certain sulfur compounds.
These compounds are used to bleach some wools, silks, and various types of
manufactured fibers. Optical bleaches mask yellow discoloration in a material.
These bleaches, commonly called fabric brighteners, absorb ultraviolet light
and change it to blue light. The combination of the blue light and the
yellow discoloration produces white light that makes the material seem brighter.

127

Eclipse is the darkening of a heavenly body. It occurs when the
shadow of one object in space falls on another object or when
one object moves in front of another to block its light. A
solar eclipse takes place when the sun appears to become dark as
the moon passes between the sun and the earth. A lunar eclipse occurs
when the moon darkens as it passes through the earth's shadow.

Heavenly bodies other than the earth and the moon also can eclipse
each other. The planet Jupiter sometimes blocks sunlight from its moons.
Likewise, Jupiter's moons sometimes cast shadows on the planet. Sometimes
the moon or some other heavenly body blocks light from a planet or a distant
star. Astronomers use the term occultation for this blocking action.
Astronomers also refer to a certain kind of variable star as an eclipsing binary.
An eclipsing binary consists of two stars that revolve around each other so
that each periodically blocks the light from the other.

When eclipses occur. The earth and the moon always cast shadows into space,
and the moon orbits the earth about once every month. But an eclipse - either
solar or lunar - does not occur every month. The moon's orbit is tilted
about 5 degrees to the earth's orbit around the sun. For this reason,
the moon's shadow generally misses the earth, and so a solar eclipse does not occur.
Likewise, the moon most often escapes being eclipsed by passing above or below
the shadow of the earth. Thus, a solar or a lunar eclipse can occur only when
the earth, sun, and moon are in nearly a straight line.

128

Dew is the name given to the glistening beads of water that often appear on blades of grass, leaves, and car tops early on clear mornings. Dew forms when air near the ground cools to the point where it cannot hold all its water vapor. The excess water vapor then condenses (changes to liquid) on objects near the ground.

During the day, objects absorb heat from the sun. At night, they lose this heat through a process known as thermal radiation. As objects near the ground cool, the temperature of the air immediately surrounding them is also reduced. Colder air cannot hold as much water vapor as warmer air can. If the air continues to cool, it will eventually reach the dew point. The dew point is the temperature at which the air contains as much water vapor as it possibly can hold. If the air cools further, some of the vapor condenses on the nearest available surface.

Dew forms best on calm, clear nights. When the wind is blowing, air cannot stay in contact with cool objects as long and it needs more time to cool to the dew point. When it is cloudy, objects cool more slowly because the clouds radiate heat back to earth. Dew also forms better when the humidity is high.

Dew evaporates as the sun rises. The sunshine heats the ground, which in turn warms the air. This warmer air is able to hold more water vapor, and dew evaporates into this air.

129

Liquid is one of the three basic states in which matter exists. The other two states are gaseous and solid. A liquid is similar to a gas because its molecules are not fixed to each other in any particular way. Liquids and gases are both called fluids because they can flow to fit the shape of any container in which they are put. A liquid is unlike a gas and similar to a solid because it has a definite volume, and its molecules are only slightly compressible. A liquid always seeks its own level. If a liquid is put in a container with several arms, it will rise to the same level in all the arms.

A thin layer on the surface of a liquid has a tension caused by molecular action, and acts like a skin. This is called surface tension. Because of surface tension, a greased needle will rest on the surface of water without sinking.

The molecules of a liquid often have a greater attraction for other substances than they have for each other. For this reason, they will rise in narrow tubes above their own level. This action is called capillarity. Plants draw water by capillary action.

If liquids are heated beyond a certain point, they vaporize (change into gas). Water changes into steam when it boils. If liquids are cooled below a certain point, they change into solids. Water freezes into ice. Different liquids have different freezing and boiling points. Substances that are normally gases can be cooled and compressed into a liquid state. Some normally solid substances can be heated until they turn into liquids. For more information, see the articles on GAS, SOLID, and WATER.

130

Sprat is one of the smaller sea fish in the herring family. Sprat grow to 20 centimeters long. They live in European coastal waters from the Baltic and North seas to the Mediterranean and Black seas. They have a flattened body with a saw-toothed edge along the belly. Sprat are important food fish. They are eaten fresh or smoked. Some are canned in oil as brisling sardines. Others are processed for oil and fish meal.

131

Sirius, pronounced SIHR ee uhs, also called the Dog Star, is the brightest star that can be seen from the earth at night. Sirius has a diameter more than twice as large as that of the sun, and it gives off nearly 30 times as much light. It is a star of the first magnitude.

Sirius forms part of Canis Major, a constellation in the sky of the Southern Hemisphere. Sirius is one of the stars nearest the earth. It is about nine light-years away. A light-year, the distance that light travels in a year, equals about 9.46 trillion kilometers.

Astronomers classify Sirius as a binary star because it has a companion star, Sirius B. Sirius B is a white dwarf, an extremely dense star that can be as small as the earth. It consists of matter that is 4 million times as dense as water. If matter from Sirius B were brought to the earth's surface, it would weigh approximately 120,000 tons per cubic foot (4,000,000 metric tons per cubic meter). Because of its tremendous density, Sirius B exerts a strong gravitational pull on Sirius. This powerful gravitational force causes Sirius to move in a wavy line as it travels through space. Sirius and Sirius B make a complete orbit around each other about every 50 years.

132

What is a solstice?

In simple terms, the solstice is the date at which the sun appears directly overhead at noon the furthest north, the tropic of Cancer, and the furthest south, the tropic of Capricorn, during the year. The summer and winter solstices mark the beginnings of those astronomical seasons. Between these two latitudes are found the Tropics. Summer officially starts with the solstice on about the 21st of June, when the sun is furthest north. Yet the warmest part of the year over most of the United States does not occur until mid-July. Similarly the warmest part of the day is usually several hours after noon, when the sun is highest in the sky. The lag is due to the time required for ground and water to heat up. The longest day of the year occurs at the summer solstice in the Northern Hemisphere. On this day, north of the Arctic circle in Alaska there is continuous 24-hour sunshine. Along the U.S.-Canadian border the sun appears for 16.25 hours, and in southern Texas and Florida, 13.75 hours of sunshine are all that is available. The winter solstice is about 22 December. It is the shortest day of the year in the Northern Hemisphere. It is also the first day of the Southern Hemisphere summer, and on this day the atmosphere above the South Pole receives more light from the sun than any other place in the world, yet the temperature averages only about minus 10 degrees F.

133

Who invented the barometer?

The barometer, which measures the pressure exerted by the mass of the atmosphere, was first devised in 1644 by Evangelista Torricelli, a student of Calileo, who had noted that a column of water in a tube could not be made to stand to a height greater than 34 feet. Torricelli experimented with fluids of different densities, including sea water, honey, and finally mercury, a liquid metal 14 times heavier than water. The mercury tube, when plugged at one end, filled with mercury, and placed upright with the open end in a container of more mercury, would only stand to a height of about 30 inches, or about 1/14th that of the water column. The mercury column was being held up by the pressure exerted on the reservoir of mercury by the atmosphere. Thus, the barometer was perfected. This instrument allows the continuous measurement of atmospheric pressure, which rises and falls with the passage of traveling weather disturbances in which the weight of the air column overhead is alternately heavier or lighter. Torricelli put it more elegantly, We live submerged at the bottom of an ocean of elementary air, which is known by incontestable experiments to have weight.

What is the highest barometer reading ever measured?

Siberia has justly earned its reputation for cold. But cold air is also dense, and therefore the atmosphere weighs more and the barometer soars to the upper end of the scale. On New Years Eve of 1968, in Agata, Siberia, the hammer really fell. During a deep cold wave, the barometer set an all time record for the Eastern Hemisphere, peaking at 32.01 inches.

134

What is terminal velocity?

Terminal velocity is the maximum speed that a person or object can achieve while falling toward the Earth. The term is used in skydiving as the top speed a person achieves during a fall. Without air resistance, a person would theoretically fall faster and faster, accelerating at a rate of 9.8 meters per second squared until he strikes the Earth. But in reality, there is a rather large air resistant force when jumping from an airplane. Terminal velocity occurs when the air resistant force upward on the diver equals the downward force of gravity acting on the diver.
When the two forces are equal, the person stops accelerating and falls to the Earth at a constant velocity.

135

Why do ocean waves break as they approach the beach?

Ocean waves rarely break before they come in contact with a cliff or mountainside shoreline. Ocean waves only seem to break as they approach a gradual decrease in depths, such as beaches. A shoreline with a gradual decrease in depth will produce a more spectacular break than a wave that encounters a steep decrease in depth.

The reason waves break has to do with the velocity of the wave and the depth of the water. An ocean wave with a large velocity has a long wavelength and large amplitude. As the wave moves toward the beach, it wants to continue traveling at a constant velocity. Unfortunately for the wave, as the ocean depth begins to decrease, the bottom of the wave gradually encounters more and more friction, causing the lower section of the wave to travel slower than the upper section of the wave. As the lower section decreases its velocity, the inertia of the crest carries it over the trough. When there is not enough water underneath it to support the crest, the wave breaks.

136

What is radar?

Radar, a frequency band on the electromagnetic spectrum, is an acronym for radio detection and ranging. Radar involves emitting electromagnetic waves and calculating the time, frequency, and directional changes of the reflected waves to locate the position and speed of an object. Radar is used in many different arenas, but was first used for military purposes to locate ships and planes when visibility was poor.

Who developed radar?

In 1935, Robert Watson-Watt, a Scottish physicist, created the first radar defense system for the British military. Although the British government originally asked for a device that would fry Nazi pilots in their cockpits, Watson-Watt explained that this was not possible, but a reliable early warning signaling system might be feasible with the technology of the early 1930s. Watson-Watt used the information and breakthroughs from such physicists as Hertz and Marconi, the inventors of the first radio transmitter and antenna, to develop a British radar network that could detect enemy planes 100 miles off the coast of England.

Ironically, Watson-Watt became a deserving victim of his own technology nineteen years later. According to Canadian police, Watson-Watt had been speeding on a stretch of Canadian road, and was detected by a police radar gun. Watson-Watt willingly paid the fine and drove away.

137

Why do people hear ringing after leaving a loud rock concert?

After leaving loud rock concerts, many concert-goers often complain of ringing in their ears. The ringing sound is a result of the destruction of the cilia by the high volume sounds. Resonating objects often end up damaged or destroyed. Cilia resonate when a sound reaches the hair's natural frequency. If the sound is extremely loud and goes on for some period of time, it can cause destructive resonance to the cilia and kill it. the ringing sensation is actually the cilia dying. Usually the ringing is gone the day after the concert, but permanent damage has already been done, because those hair cells will never grow back. Although the effects of such hearing loss may take many years and repeated exposure to loud sounds to become apparent, they can nonetheless become very devastating.

What are the best ways to protect ones ears at loud rock concerts?

The first protection against damage to the cilia cells is to increase the distance from your ears to the speakers. The inverse square law dictates that the intensity of a sound is inversely proportional to the distance squared. In plain English, the farther away one is from the speakers, the lower the intensity of the sound. By simply doubling the distance, the intensity becomes one fourth of what it was originally.

138

Who was the first physicist to make a serious effort to measure the speed of light?

Light travels at a very high speed and therefore can be extremely difficult to measure. Prior to 1600, most people

believed that light traveled instantaneously. However, Galileo felt that there had to be some finite speed of light and attempted to measure it by gauging the amount of time it took for a distant light to reach his eyes. To perform this experiment, Galileo had an assistant with a lamp stand a great distance away from him. Galileo instructed the assistant to uncover his lamp immediately when the helper saw Galileo uncover his own lamp. By measuring the time it would take the light to travel from Galileo and back again from the assistant, Galileo felt that he could measure the speed of light.
His experiment failed because there was no possible way for him to measure such a short period of time. Galileo walked away from the experiment without a number for the speed of light, but with a deep appreciation for how fast light actually does travel.

139

A FUNDAMENTAL FACT about English is that what is acceptable in speech is not always acceptable in writing. When we speak, our listeners understand that we are composing our sentences on the spur of the moment, and they are fairly tolerant of deviations from Standard English.
There is, however, little acceptable variation in the grammar of written English. When writing violates grammatical rules, the violations distract the reader's attention from the content of the writing. Unfair as it may seem, readers often judge the value of what we have to say by the grammar we use in expressing it. Grammar is, then, one of the basic tools of writers, and writers, like all other craftsmen, should know how to use their tools.
Fortunately, most of the grammatical rules of written English are identical to the grammatical rules of spoken English. As native speakers of English, we know these rules intuitively and do not need to memorize them the way we memorize the grammatical rules of a foreign language.
Normally, problems arise only in those instances where acceptable written English differs from acceptable spoken English.

In a discussion of almost any subject, it is necessary to use a certain amount of technical terminology. When we talk about automobiles, we use the technical term muffler as a kind of shorthand for a device to deaden the noise of escaping gases from an internal-combustion engine. The sports announcer who says They are going to try for a field goal is using the technical term field goal to avoid having to say They are going to try to earn three points by place kicking or drop kicking the ball over the crossbar between their opponents goal posts. Similarly, in a discussion of a sentence, it is, of course, possible to say The word used to define the action does not have the right form to match the form of the word used to indicate what is being talked about. But it is much more efficient to say The verb does not agree with the subject", the words verb, agree, and subject are all technical terms with specific meanings that make discussion of grammar both easier and clearer. Thus, although it may seem tiresome to have to learn or relearn a certain amount of grammatical terminology, in the long run it will save you much time and frustration.

140

Sentence Patterns

The basic unit of the written language is the sentence. A sentence is a group of words that includes a subject and a predicate and that is not dependent upon any other group of words. In short, a sentence can stand alone as a single utterance. The subject of a sentence is what or who is talked about, and the predicate is what is said about or asked about the subject. In many but not all sentences, the subject is the first word in the sentence.

Elsa bought some green paint yesterday.

Last week Peter was sick.

Because of budget cuts, the library will close.

Did you feed the dog?

The predicate of a sentence must contain a verb phrase. A verb phrase is a word or words that express an action done by the subject or a state of existence of the subject. Although the word phrase is commonly thought of as referring to two or more words, the term verb phrase can be used for single words as well. As the fourth sentence below illustrates, the parts of a verb phrase are sometimes separated by other elements of the sentence.

Elsa bought some green paint.

Last week Peter was sick.

Because of budget cuts, the library will close.

Did you feed the dog?

All complete sentences contain a subject and a verb phrase.

141

Verbs

Verbs are traditionally defined as words that express an action, an occurrence, or a state of existence. This definition by meaning is not always satisfactory, because other parts of speech, such as nouns, also express action or existence. But verbs can also be identified by their inflections and by their functions.

Characteristics

Verbs are characterized by inflections for tense, person, voice, and mood, and by their function in a sentence as the main element of the predicate.

Inflections Verbs have five forms, an infinitive and four inflected forms. The infinitive is either the base form of the verb, carry, or the base form preceded by to, to carry. The four inflected forms are 1. third-person singular present tense, 2. past tense, 3. present participle, also called progressive participle, and 4. past participle.

142

Adjectives

Adjectives are traditionally defined as words that modify nouns or pronouns by defining, describing, limiting, or qualifying those nouns or pronouns. Many adjectives also can be identified by their inflections or by their positions in sentences.

Characteristics

Some adjectives have inflections showing comparative and superlative degrees. Adjectives are also identified by the positions they take as modifiers of nouns or noun substitutes.

Inflections

Many adjectives can be inflected to show comparison. The three degrees of comparison are positive, comparative, and superlative.
The positive degree of an adjective has no ending, the comparative ending is -er, and the superlative ending is -est.

POSITIVE COMPARATIVE SUPERLATIVE

fine finer finest

poor poorer poorest

A few adjectives have irregular inflections.

POSITIVE COMPARATIVE SUPERLATIVE

good better best

bad worse worst

a little less least

many/much more most

far farther/further farthest/furthest

old older/elder oldest/eldest

143

Periods

Use a Period . At the end of most sentences, After abbreviations and initials, In dramatic, poetic, and Biblical citations.

The period is the most important mark of punctuation in English because it separates one sentence from another, and sentences are the basic units of writing. In addition to its structural use as ending punctuation for sentences, the period has a number of conventional uses.

As Ending Punctuation

Every sentence or deliberate sentence fragment should end with a mark of punctuation. The most common mark for ending sentences is the period, or stop or full stop, as it is sometimes called.

After Complete Sentences

Periods are used at the end of declarative sentences, indirect questions, and polite commands or requests, even though these commands may have the word order of a question.

DECLARATIVE SENTENCES

All cows eat grass.

During the battle, General Wolfe was mortally wounded.

POLITE REQUESTS

I asked how I could remove airplane glue from my clothes.

People have often wondered whether there is life on other planets.

Please turn down your radio.

Would you kindly refund my money as guaranteed.

Periods are also used after deliberate or conventionally acceptable sentence fragments.

Yes.
Good night.

Better late than never.
So much for rose petals.

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Question Marks

Use a Question Mark ? After direct questions. After doubtful figures.

Like a period, the question mark is used as a mark of ending punctuation.
Unlike a period, it is used only after direct questions.

What is the difference between a duck and a goose?

Do you have a good book on bricklaying?

Even if the word order of a sentence is that of a statement, use a question mark if a direct question is being asked. In other words, if the voice would rise at the end when the sentence is spoken, a question mark should be used.

The newspaper was late again this morning?

You said you called the office and complained?

If a sentence contains a question within a question, use only one question mark.

Who was it that asked, Of what use is a baby?

When a sentence contains a series of words, all of which are being questioned, a single question mark may be placed at the end of the entire sentence.

What does he propose to do about rising taxes, crime in the cities, unemployment, the international situation, and inflation?

145

Commas

The comma is by far the most important mark of internal punctuation. It serves as a separator-separating clauses and phrases from each other, separating items in a series, and separating nonessential elements from the rest of the sentence. The comma also has a number of other uses, both as a separator of words and numbers and simply as a mark that conventionally appears in certain places.

Independent clauses contain a subject and a finite verb and are not preceded by a subordinating word such as that, until, or whenever. Finite verbs are those that can serve as complete verb phrases. When two or more independent clauses appear within one sentence, they must be separated by some mark of punctuation. If a coordinating conjunction connects these clauses, a comma is the appropriate mark of punctuation.

With Coordinating Conjunctions

Use a comma before a
coordinating conjunction connecting two independent clauses. The coordinating conjunctions are and, but, or, and nor.

The land has been worked for centuries, and no effort has been made to maintain the fertility of the soil.

Ballads appeared as early as the thirteenth century, but they did not become popular until much later.

The architecture may have an English flavor, or it may display French influence.

No photography courses are offered at the local high school, nor are any planned for the future.

Note The comma is often omitted if the two clauses are short. However, it is never wrong to use a comma, even between short clauses.

The soil is poor and water is scarce.

Her sins were scarlet but her books were read.

I don't like rutabagas nor will I eat parsnips.

146

Spelling

Some people seem to be natural-born spellers, but most of us have difficulty spelling at least some words or groups of words. Spelling is not necessarily related to intelligence or writing ability, yet it is one of the first things that readers notice. If there are a number of misspelled words, the writer will probably be classified as ignorant or careless. Furthermore, misspellings can confuse readers, diverting their attention from the subject matter. Even if you are a terrible speller, your difficulties are not as insolvable as you may think. You already spell better than you realize.
After all, you spell most words correctly. You never spell a word entirely wrong. you miss only a letter or two. A little attention to spelling can lead to a great deal of improvement.

Keep a dictionary handy while you are writing, and refer to it whenever you have doubts about the correct spelling of a word. When you find a misspelling in your writing or when one is pointed out to you, check the correct spelling. Spell the entire word aloud and write it down. Try to fix the correct spelling in your mind, making a mental image of the written word. Write the word on a 3 by 5 inch card and review your collection when you have a few minutes to spare. Develop your own crutches for remembering the spelling of words that you misspell over and over again. It does not matter how silly the crutch is as long as it helps you. For example, many people have difficulty remembering whether a word ends in sede, cede, or ceed. If you memorize the rather foolish sentence, The proceeds succeeded in exceeding estimates, you will have learned the only three words that end in ceed. Then, if you remember that supersede is the only word that ends in sede, you know that any other word with the same sound must end in cede, intercede, precede, recede, concede, accede, antecede, secede, and all their derivatives, such as procedure, antecedent, and conceded.

147

Paragraphs

Everyone understands, at least implicitly, what a sentence is because we all speak in sentences. Regardless of how long and rambling or how short and incomplete the sentences may be, changes in the speaker's voice tell us when one sentence has ended and another has begun. Paragraph changes are not as obvious; we may realize that a speaker has changed the subject, but we normally do not hear the point at which he or she made the switch. Nor does it disturb us that we do not hear paragraphs because paragraphs are not essential to most kinds of speech.

Paragraphs are, however, conventional and essential in writing. Because we are accustomed to seeing paragraph divisions, we are uneasy when they do not appear or even when they appear only infrequently. All of us are familiar with the sense of despair that comes from turning a page and discovering that the next page does not contain a single new paragraph. Paragraphs are both a physical and a mental convenience for readers. Physically, they provide a break and allow readers to keep their places on the page more easily. They also signal that one unit of thought has been completed and another is about to begin. Paragraphs are a convenience for writers too because they help them organize their ideas into manageable blocks.

A common definition of a paragraph is a group of related sentences developing one idea. It often includes a topic sentence that summarizes that idea, followed by additional sentences that expand, qualify, analyze, or explain the idea. Ideas, however, are not like automobiles. they are not clearly distinct units with standardized parts that can be easily counted and classified. Ideas may be as simple as I am eating a Reeses Peanut Butter Cup or as complex as the role of technology in the universe. One idea may blend into another with no sharp division between the two. Yet if we are to deal with ideas at all, we must have ways of segmenting them. we cannot comprehend or express complex ideas all in one breath or all in one sentence. In writing, we use the paragraph to handle one segment at a time. Because ideas are so diverse in their content and complexity and because the possible ways of segmenting them vary greatly, we cannot state hard and fast rules for what constitutes a good paragraph. Rather, we can only talk about typical paragraphs.

148

Outlines

All of us use outlines of one kind or another, even if we don't always think of them as outlines. The notes in our pocket calendars are an outline-however incomplete-of our day's activities. The list we take to the supermarket or stationery store is an outline of our intended purchases. When we write a letter to a friend, we have at least a mental outline of what we intend to say before we start writing. All of these are informal outlines, used to help us organize our thoughts and activities.

For many kinds of writing, an informal outline, either mental or written in the form of sketchy notes, is adequate. However, for long papers or for papers with complex arguments or ideas, a more formal outline is usually necessary because we cannot keep a mental picture of all the important points and their relationships. A written outline helps provide coherence to the final paper and reveals imbalances, logical gaps, and inadequate development of our thesis before we start writing. A well-developed outline also helps us estimate the length of the final paper and provides us with a guide as we write. Finally, an outline actually stimulates thought and ideas; seeing ideas written down makes us think of other ideas and of interrelationships among ideas.

In addition to their usefulness in writing papers, outlines are helpful in taking notes from material that has already been written. An outline reveals the structure of the author's argument more clearly and more quickly than several rereadings can. An outline of an unsatisfactory paper of your own can show what went wrong with it. An informal outline made before you answer an essay question on an examination helps you cover all important points in a logical order. Some classroom lectures lend themselves to note-taking in at least rough outline form. If not, putting the notes into outline form after the class is over provides a more organized, coherent picture of what the instructor considers important.

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ALICES ADVENTURES IN WONDERLAND by Lewis Carroll

CHAPTER I

Down the Rabbit Hole

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. once or twice she had peeped into the book her sister was reading, but it had no pictures or conversations in it, and what is the use of a book, thought Alice without pictures or conversation?

So she was considering in her own mind, as well as she could, for the hot day made her feel very sleepy and stupid, whether the pleasure of making a daisy chain would be worth the trouble of getting up and picking the daisies, when suddenly a White Rabbit with pink eyes ran close by her.

There was nothing so VERY remarkable in that nor did Alice think it so VERY much out of the way to hear the Rabbit say to itself, Oh dear. Oh dear. I shall be late. when she thought it over afterwards, it occurred to her that she ought to have wondered at this, but at the time it all seemed quite natural.

but when the Rabbit actually TOOK A WATCH OUT OF ITS WAISTCOAT POCKET, and looked at it, and then hurried on, Alice started to her feet, for it flashed across her mind that she had never before seen a rabbit with either a waistcoat pocket, or a watch to take out of it, and burning with curiosity, she ran across the field after it, and fortunately was just in time to see it pop down a large rabbit hole under the hedge.

In another moment down went Alice after it, never once considering how in the world she was to get out again.

The rabbit hole went straight on like a tunnel for some way, and then dipped suddenly down, so suddenly that Alice had not a moment to think about stopping herself before she found herself falling down a very deep well.

Either the well was very deep, or she fell very slowly, for she had plenty of time as she went down to look about her and to wonder what was going to happen next. First, she tried to look

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down and make out what she was coming to, but it was too dark to
see anything  then she looked at the sides of the well, and
noticed that they were filled with cupboards and book shelves
here and there she saw maps and pictures hung upon pegs.  She
took down a jar from one of the shelves as she passed  it was
labelled ORANGE MARMALADE, but to her great disappointment it
was empty   she did not like to drop the jar for fear of killing
somebody, so managed to put it into one of the cupboards as she
fell past it.
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Using an Iambic Paddle

by Chuck Adams, K7QO

Revised December 26, 2004

This article is for iambic paddles only. Single lever paddles like those made by Vibroplex and others take more mechanical motion to send the Morse characters. I'll prove this later.

For sending Morse at speeds greater than 20 to 30 wpm you will need something other than a straight key or you will get very tired and frustrated. You may have experience sending Morse or not. If you don't, then let me personally recommend that you start with an iambic paddle and a keyer. Most modern commercial rigs and kits that I know of have a built-in electronic keyer. You should learn to make good use of it if you haven't already.

First let me take the 'bug' (mechanical paddle) people aside. You know that it takes a certain force to hit the paddle and get the lever that sends the dits to move and stay moving long enough to get dits sent. You will have to kill off the tendency that you have to "hit" the paddle with a lot of force. Be gentle, please. The following steps will guide you. Please bear with me and don't skip anything.

From personal observations over the years at swapmeets, ham conventions, field day events and other contests, I have noted that I cringe when I see someone else use an iambic paddle. They "slap" the paddle around like it was a bug. Just a light touch is all it takes if you have it adjusted correctly. If the paddle moves around the table while you are sending then you are using too much force. If you are sending with one hand and holding the paddle in one place with the other, you are doing it wrong. It shouldn't be moving if you are using a gentle force on the paddles. The typical paddle has a mass around 2 kg or so. Take it easy. It isn't going anywhere on its own.

So let's begin. You will need the following items.

- an iambic paddle
- a keyer
- connecting cables
- phone book, dictionary, book or a newspaper.

Let's first have a look at your paddle. Hopefully you can find one used and get it at a good price, if you don't have one already. I have gotten Brown Brothers and Bencher paddles for less than $30 at swapmeets on the last day when everyone is in a dealing mood and doesn't want to pack up all that stuff left over to take back home. You know the story, they were told not to come back home with anything..... The paddles didn't look pretty but I spent some elbow grease, paint remover, primer, and paint to get them looking like new again.

Take a good look at the paddle and see how it fits all together. The iambic paddle has two separate movements and sets of contacts which I will call the left side and the right side. Note the adjustments for spacing on the contacts. Play with the adjustments and see if they are clean and operate in a smooth manner. If you are mechanically inclined and working with a used paddle that needs some work then take it apart and clean it up and put it back together. Take notes before you take it apart. Keep a small box to hold all the parts 'cuz Ace Hardware and others may not have a replacement part if you lose it or damage it in anyway. Also there are many manufacturers that are no longer in business to obtain spare parts from. Use common sense on chemicals, etc. Also, do this in one sitting if possible so you don't forget and reassemble the device incorrectly. Keep kids away from the parts unless you are showing them what a wizard you are or showing them how to do some mechanical work.

Also do not use a file, fingernail file, sandpaper, or other abrasive material on the contacts. I use a sheet of typing paper that I slide between the contacts to clean them aperiodically. The sulpher dioxide and other pollutants in the air tarnish the contacts and cause problems while in use. The contacts are either silver or gold plated and you do not want to remove the material. Hopefully the contacts have not been abused by previous owners if you working with a used paddle.

Now that we have a working paddle let's go and hook it up to the keyer. I will assume that you are right-handed. Just reverse things for left-handed operation. You need a small cable that has two wires and a shield. It should be long enough to reach from where you will have the paddle on the operating desk to where you would like the keyer or rig to be. I have used the audio output cable found in CD drives for computers. It is small and flexible. If you are lucky to have the manual for the keyer then find out the connections needed to the paddle. The following connections are what I used for the AEA keyers and my rigs. Hook the left paddle contact to the tip connection of the stereo plug, the right paddle contact to the ring connection of the stereo plug, and the shield to the ground of the paddle and to the ground connection of the stereo plug. You need shielded cable so that later when you connect this setup to a transmitter you will not have problems with RF getting into the keyer and cause it to malfunction.

Power up the keyer and see if touching the left paddle sends dits and the right paddle sends dahs. If you have a keyer built into the rig, then set the power output to the lowest level and use a dummy load. Historically the reason for the dits on the left paddle and the dahs on the right paddle is due to the semi-automatic mechanic paddle, a.k.a. bug, first being built in the configuration that gave dits with the left paddle, etc. A number of people do it the opposite way and that is fine. Just be prepared to be unable to walk up to any operating position and use their setup unless they have a keyer that will electronically switch to the opposite paddles for dits and dahs (reverse mode).

OK, now first adjustments. Make sure that all the adjustment components are aligned correctly and ready to be adjusted. With the keyer powered on I take the adjustment on the dit contact closure and move it to narrow the spacing until contact is made and the keyer starts sending a continuous string of dits. Then I back off the adjustment until the dits stop. This is just a small part of a turn on the typical adjustment. Don't make the spacing too wide as I will explain in a minute. I find that a sheet of 20 pound typing paper just barely fits and there is a slight amount of friction. That's how narrow it is when I make the adjustment. Now some people are going to come along and suggest or demand that you use a wider spacing. I don't think so. If the paddle will hold the adjustment and stop sending when you release pressure on the paddle then it is fine.

Next do the same thing on the opposite side for the dah paddle, and you are just about done. There may be a tension adjustment for either a spring or springs or magnets. Adjust this for the minimum tension you can get and still have the contacts stay open after you release pressure on either or both paddles.

So with the light touch and the narrow spacing, let's get down to some real exercises. Sit down at the desk you will be using and place your entire arm from the elbow to the wrist on the table in a comfortable position. Some of you may want your arm parallel to the edge of the desk and some at an small angle. I don't think straight into the desk is a good idea. You want to be able to do this for hours on end later in your CW career. Now point your pointing finger straight along the same direction as the rest of the arm. This is the direction I want your paddle to line up with the paddles towards your hand. Extend your thumb straight out and place the paddle with the left paddle just touching it. The thumb should be relaxed and you may want it bent just a little. It's up to you. The index finger should just touch the opposite paddle on the right side of the pair. I use the tip of the finger while the finger is curved. I find my wrist is turned to the left a little so that it is not vertical to the desk surface and the wrist and arm are resting on the table.

With the thumb and index finger touching both paddles and no dits or dahs being sent and with you in a comfortable position I want you to hold this position for a few minutes. Don't take your fingers off the paddles and don't push on them either. Not a word and not a sound for a few minutes. Think about what you are doing and if there is something that doesn't feel right then adjust your posture, arm position, etc. until you feel comfortable. I don't need 5 minutes from you, but you get the picture. If you can't do this for 5 minutes then how are you going to do it for longer periods of time while talking to someone on the air?

Get ready to send. I assume that you know all the characters and numbers and if not, pick the ones you do know. If you have the manual on the keyer, look and make sure that it is in Mode B. Set the keyer speed to 15 wpm or so and no slower. Apply pressure to the left paddle with your thumb. You should hear a string of dits the entire time you have it depressed. Do this with the right paddle and you hear a string of dahs. Here is the neat part. Hold down both paddles at the same time. This requires a 'squeezing' motion on the part of both fingers, thus the term 'squeeze keying' in some literature and advertising. The sound pattern will alternate continuously between dits and dahs. With both paddles closed lightly, let the pressure off of one of the paddles, but DON'T remove the finger from the paddle. Always touching is the motto. Now bring pressure back on with the finger you let off and get the alternating pattern going again. Now let off with the other paddle, again keeping the finger or thumb touching and get a continuous pattern of dits or dahs. Bring the finger or thumb back. Do this until you get the feel of it. The important thing that I want you to learn is that you can do this with the thumb and index finger still in contact with the paddles.

Remember when you learned to write? What did your parent(s) or teacher(s) or whoever have you do? They gave you some paper, most likely a Big Chief writing tablet, a pencil and a picture of the alphabet. A sample of the alphabet was usually on the inside cover of the Big Chief pad. You started with the letter A and I don't remember whether it was lower case first or capital. Probably caps first 'cuz you could do those with straight lines. Then you did one or more complete lines of all A's, then B's, etc. Well welcome back kid, we're gonna do the same thing all over.

First do a letter A. This is done with a di-dah sound combination. I'm going to adopt the following notation for the finger pushes. A lower case 'r' means the right paddle and only long enough for one element, the dah. An upper case 'R' means the right paddle for at least two or more elements. Of course you can figure out what a 'l' and 'L' are.

So an A looks like the combo of `lr` with almost no time between the first and the second depression. Try it. You have to gently tap the left paddle and immediately tap the right paddle with a gentle pressure. Never let your finger or thumb come off the paddle if possible. Also make sure you are not sending ET as we aren't trying to phone home just yet. It is important to not leave a gap larger than the time of a single dit between the dit and the dah. The neat thing about a keyer is that it will always put at least the smallest allowed spacing and you have to react fast enough on the next element so that it doesn't leave some more space. Some keyers will automatically space for a word if you go just a fraction of a dit too long.

OK, just like pre-school, kindergarten or the first grade. Time to do a line of A's. Get a watch or clock with a second hand and send an A every two seconds. Not any faster. Do this for 15 seconds to 20 seconds. And repeat until you can do this without a SINGLE error. Remember how you used to complain and say to your parents? "Oh mom, oh dad, this is so easy and so boring. Can't I do something more interesting?" No. Do your homework and no dessert until you finish........

Now here is the time to tell you something. Did you notice that if you didn't let up on the left paddle very quickly you'd get the letter R? This has to do with an internal memory of the keyer. Here is the way the Mode B works. If the left paddle is still depressed at the half-way point of the dah or later, the keyer will do an automatic 'lock' into memory this fact and after the dah is finished the keyer will go ahead and send an additional dit EVEN if you have released pressure on the left paddle!! This is gonna make the letter R and some other stuff easier to send as we will see later.

OK, now the letter B. The finger combination will be 'rL' where we will hold the left paddle down in order to get the string of dits. I don't any other way to say this. Don't you dare count. Counting is bad. Counting kills. Just remember the sound of the letter B and do just what it takes to sound the letter. If you start counting dits you are dead meat. You'll never get to high speeds. So break the habit now and work on it until you do. Go back to the beginning code CDs or tapes if you must.

Repeat the same exercise we did for the letter A. Send a letter B every two seconds for 15 seconds until you get a perfect sequence. Then go to 30 seconds until you get it perfect.

Now the letter C. The letter C is the first neat one that you get to demo the power of IAMBIC KEYING. Watch someone who was a bug user and maybe even you have the tendency to do this. They will do this combination 'rlrl' for the letter C. You try it. This is a waste of time and energy. You just took four strokes to get one letter. Now try this combo to get C - 'RL'. Hold the right paddle down and then immediately depress the left. Hold the right until after the second dah is half finished or complete and release and immediately release the left paddle at the mid-point or later during the second dah. Work on this until you can send C perfectly.

OK, we did a C with only TWO strokes instead of four. This is the beauty of Iambic Keying with a little help from Mode B. There is a Mode A for iambic keying that can do the same thing but requires a longer timing and I don't care for it at all. In fact, with Mode B we can send all the letters and numbers with TWO strokes except for the letters X and P.

Now practice on the letter C until you can send one every two seconds for 30 or more seconds without a single error. Practice makes perfect. I find that people who are accomplished musicians make the best students. Know why? They learned very early in life that patience and sticking to something will allow you to do most anything. I don't think it is so much music but the love of doing something well that makes them better at a lot of things.

OK, here is the combo for each of the letters using the K7QO notation for Mode B Iambic Keying. Hopefully I don't have any typos here. Take each letter and learn the combo for doing it. Send the letter for thirty seconds with correct spacing without error and go on to the next one. Afterwards, forget the chart. Just concentrate on the sounds and the feel of sending each character.

```
A - lr
B - rL
C - RL
D - rL
E - l
F - Lr  note: hold L down and tap r
              during the second dit
G - Rl
H - L   don't count
I - L   don't count
J - lR  don't count, not ever.......
K - Rl
L - Lr
M - R
N - rl
O - R   don't count  :-)
P - lRl  OK, this took three strokes
Q - Rl
R - Lr
S - L
T - r
U - Lr
V - Lr
X - rLr  The other letter that requires
         three strokes to send.
Y - Rl
Z - RL   There is no overlap on closures.
```

Now note that this notation isn't perfect. It relies on you knowing the letters and working out the physical timing.

For the numbers

```
1 - lR   Don't count
2 - LR   Don't count
3 - LR   Don't count
4 - LR   Don't count
5 - L    Don't count
6 - rL   Don't count
7 - RL   Don't count
8 - RL   Don't count
9 - RL   Don't count
0 - R    Don't count
```

Those puppies take a long time to send at 15 to 20 words per minute. Makes 'em easy if you memorize them by sound and not count the elements. This is the biggest killer of CW operators, the worst habit to obtain and the most difficult to undo. So get to work if you have the bad habit of counting for any letter or number. Think sound sound sound....

I'll leave it as an exercise for the student to figure out the punctuation symbols , . ? and the / (slant symbol). HINT: 3, 2, 3 and 3 strokes.

Here is something that I found to be interesting and I had never seen done anywhere. Here are the number of strokes it takes to send each letter using a straight key.

```
One Stroke    ---  E and T
Two Strokes   ---  A, I, N, and M
Three Strokes ---  K, O, S, U, W, R,
                   D, and G
Four Strokes  ---  B, C, F, H, J, L,
                   P, Q, V, X, Y, and Z
Five Strokes  ---- 1, 2, 3, 4, 5, 6, 7,
                   8, 9, and 0 (zero)
```

So if I asked you to send the entire alphabet and all the numerals, you would have to work the key a total of 2 + 8 + 24 + 48 + 50 which is 132 key closures. No wonder you get tired after sending a long session with a straight key.

Now let's graduate to the old 'bug'. Historically the bug was invented before we had a lot of digital designers around who weren't making the big bucks in computers.

```
One Stroke    ---  E, I, S, H, 5, T
Two Strokes   ---  A, B, D, M, N, 6,
                   U, V, 4, 6
Three Strokes ---  F, G, K, L, O, R,
                   W, X, Z, 3, 7
Four Strokes  ---  C, J, P, Q, Y, 2, 8
Five Strokes  ---  9, 0 (zero)
```

Again, totaling up the number of strokes we get 6 + 20 + 33 + 28 + 10 giving us the winning number of 87 motions. This is quite a savings over 132 strokes required for the straight key. Timing-wise it gave the operator considerable more accurate timing on the dits. There is still a limit of human capabilities to send by hand each long element rapidly.

Then came along the first electronic keyer. Now let's again go through our counting exercise but this time using only a single lever paddle used with an electronic keyer. Some of the better CW ops that I know still only use a single lever paddle. I can see that it closely approximates a bug in operation and it would be a much simpler transition to the new technology with a rapid learning curve. Here is the count that I get.

```
One Stroke    --- E, H, I, M, O, S,
                  T, 0 (zero), and 5
Two Strokes   --- A, B, D, G, J, N,
                  U, V, W, Z, 1, 2,
                  3, 4, 6, 7, 8 and 9
Three Strokes --- F, K, L, P, Q, R, X,
                  and Y
Four Storkes  --- C
```

Wow!! That saved a lot. Totaling up the damages we get 9 + 36 + 24 + 4 for a total of 73 which again is a reduction from the previous two methods that involved 132 and 87 strokes for their respective totals.

And then came the dual iambic paddles and more sophisticated keyers.

```
One Stroke    --- E, H, I, M, O, S,
                  T, 0 (zero), and 5
Two Strokes   --- A, B, C, D, F, G,
                  J, K, L, N, Q, R, U,
                  V, W, Y, Z, 1, 2, 3,
                  4, 6, 7, 8 and 9
Three Strokes --- P and X
```

Now we have 9 + 50 + 6 for a total of 65 strokes with again a savings in strokes.

So look at the totals again 132, 87, 69, and 65 for each of the methods of sending Morse. With the Iambic Keying you can save over 50 per cent of the work of using a straight key. Something to think about and wow your friends and neighbors with.

OK, now it's time to start practicing. Here I'm leaving you on your very own to do the work. Now I asked you to get a phone directory, dictionary or newpaper or book. The reason? I want you to randomly open it to a page and start sending line by line. If you make a mistake, you have to start over with that line. Do this for about 15 minutes at a time and take a break. Do this for at least 30 minutes a day for a week. I know it's hard work but when you get to the point that you can do this in your sleep then you will forever be able to get on the air and sent flawless CW day in and day out without breaking into a sweat. Get a copy of QST and send all the calls you see for more practice.

OK, graduation time. If you have followed the above instructions and practiced dutifully, you are ready to get on the air daily. Of course, read the ARRL Operators Manual and review all on air procedures that you need. And hopefully I will work you on one of the FISTS calling frequencies and I will be impressed with your skills, then we can work on your speed.

dit dit

Go With the Flow

By Nancy Kott WZ8C

Morse code. These two words conjure up more emotions than any other phrase in Amateur Radio. For some reason, Hams who enjoy Morse code are fiercely protective of it. When the no- code rumblings began, people started taking sides. It even brought mild-mannered hermits out of their shacks and motivated them to write letters to the FCC and the ARRL. The threat that the bandspace dedicated to code might be taken away brought them together in a way that has never been seen before.

Why would they care? No one is going to make code illegal; no one is going to make them stop using code. So what does it matter? What is it about code?

You may assume they feel that they had to suffer through the code test, so everyone should. Or they feel it is a filter to keep out the riff-raff. Sure, there may be some of that - on the surface - but to bring out feelings this explosive, it has to go deeper.

I started thinking about my own experience. When I moved to Metamora in 1985, my mother would telephone every day, worried about me living in the boondocks. My father, more worried about the rising phone bill than the possibility of me being eaten up by a grizzly bear, suggested that we get our tickets so we could use 2 meters instead of the telephone. My mother said, "I will if you will." And I said, "OK." I had taken electronics in college and worked as an electronic technician at Chevy Engineering seven years, so I didn't have a problem with the theory. But, Morse code? Forget it.

"WHY do I have to learn that stupid code," I whined. "All I want to do it get on two meters. It's not fair." I can't tell you how deeply I resented being forced to do something because of an antiquated requirement. If there had been a no- code Tech license at that time, I would have snatched it up in an instant and not thought twice.

My mother got her Novice license in about six months. It took me over two years to get to 5 wpm. I lost count of how many times I quit and started up again. I fought it every step of the way. When I finally got the 5 wpm in June of 1988 I was relieved. Now I could forget about it.

My mother and I chatted happily on 2 meters for most of that summer, until one day we were talking about what I was going to do that night. We were using the repeater instead of simplex and I had a tendency to forget that people read the mail, especially on repeaters. So, I told her I had stopped at the video rental for some tearjerkers, picked up a pizza, bought a new nightgown and planned on spending the evening taking a bubble bath and relaxing. After my transmission, a male voice came on and said "uh, what is the color of that nightgown, Nancy?" and another piped in, "what time does the movie start?" The local guys were razzing me, all in good fun of course, but I was so embarrassed!

My father said, "You know, if you used CW you could talk on 40 or 80 meters and no one would hear you." That wasn't entirely true, so the idea was appealing. At least there would be a purpose for that darned code. Grudgingly, I started practicing again. My mother upgraded to Extra in a couple months. It took me a year to get to 13 wpm and get my General.

During that year, I spent enough time with code that I got comfortable with it and once I got my 13, something clicked and I got my 20 in about a month with barely any effort at all. Suddenly it became fun!

After I got on the air at that speed, I couldn't get enough of it. I'd come home and rag chew. It would make my day to work a new state or a special event station. Getting the mail each day was like Christmas - QSL cards..certificates! What happened when I reached about 13 wpm that suddenly made it enjoyable?

While doing research on code courses and how people learn, I came across an explanation: Instant Recognition. When you get to a point that you can instantly recognize a code symbol without having to translate it in your mind or do any sort of conscious thinking about it at all, you have Instant Recognition. Once that happens, it becomes effortless and more like a satisfying game. You aren't working, you already "own" those letters. They're part of your subconscious vocabulary.

This is where people get into trouble using the so-called short-cut programs. Believe me, there are no short cuts. You have to do the work. Programs with memorization tricks make learning more fun and will get you to 5 wpm - maybe 10 - but they will not give you Instant Recognition, which is what you need to get past that "wall" you hear about. You hit that wall when the code is coming at you faster than you can translate.

There are no short cuts. There is no magic pill. This is unfortunate because learning code is boring. Rote memorization is about the most mind numbing thing in the world. But once you get it, it is yours forever, just like riding a bicycle. And it is worth it.

Why is it worth it? That brings me back to what I said in the beginning. There is something about code that creates a feeling that is deep seated and very strong.

I was reading a book called The Flow by Professor Mihaly Csikszentmihalyi and it dawned on me that this is what makes people so passionate about Morse code!

Dr. Csikszentmihalyi is a behavioral scientist. He works at the University of Chicago now, teaching and doing research on human behavior. He grew up in a very poor, war-ravaged part of Europe. He was a curious, observant child and noticed that while most of the adults around him were bitter and unhappy, there were a few who were content and seemed almost happy. When he got older and went to college, he decided to study human behavior so he could see what it was that made these happy people, happy.

He discovered that when a person is deeply wrapped up in an activity that meets certain requirements they go into a state of mind he calls "Flow". Professional athletes and musicians typically go into Flow during their practice sessions.

Hams go into the state of Flow when they get on the air. But it doesn't happen to all Hams, it tends to happen to CW ops, contesters, or serious DX'ers.

There are seven criteria for the State of Flow. Let's look at them briefly as they relate to Amateur Radio.

1 - The experience must have a definite goal. 2 - We must know the steps to reach our goal 3 - We must have feedback on how we are doing at each step. 4 - We must be able to focus on the event. 5 - We must feel in control of the situation.

Ham radio in general satisfies these five requirements. The goal is a QSO. We have to turn the rig on to have a QSO, we get feedback and focus while communicating on the air, we are in control because we can always pull the plug. So far, these Flow requirements could apply to either SSB or CW. But with the next two requirements, important differences occur.

6. Our attention must be completely absorbed in the operation. When we operate CW, especially at or near out fastest copying speed, the operation demands our full attention. If our mind wanders, we miss a letter or a word. Dr. Csikszentmihalyi calls this mental state "optimal experience." When at this optimal experience, the mind is at its best and happiest. This state also alters one's sense of time, time flies by faster. When the optimal experience is over the person feels content, satisfied, and has increased self-esteem.

Using SSB involves little concentration; you can count the spare change from your pocket or look out the window to check the weather while waiting for your turn to talk. Optimal experience is rarely, if ever, achieved.

7. We must have the possibility of increasing our skill level. When working CW, after a rest, your mind is ready to enjoy another optimal experience. Each experience adds to the proficiency of the operator who develops a desire to increase his speed because he has found that an increase in speed is an increase in fun and self-esteem. There is a huge range for improvement; some operators have reached over sixty words per minute.

When using SSB, there is little chance of developing new skills. This eventually leads to boredom and cessation of operation. This does not bode well for Ham radio as a whole.

Although the no-code license has increased the number of licenses issued, these new licensees are not going to stay with the hobby in the long run because they are not getting the satisfaction of Flow. They might get up to 10 wpm or so, but still don't feel good about it. They get discouraged and quit or they flounder around wishing they could join in the fun, but aren't sure what to do about it. They aren't experiencing Flow because if they try to learn code at all, they are generally learning code with the aide of crutches and therefore not achieving Instant Recognition.

If you are going to invest the time to learn code, you should do it efficiently. This will allow you to see progress and cut the time you need to practice. Aristotle was the first one to discover and document that when you experience two things within a second of each other, the brain can easily associate them together. The further apart the two actions occur, the longer it takes the brain to associate them and the longer it takes to memorize them. What this means to us, is that when we hear the symbol for a letter we must immediately, within a half second, say or write, or both, that letter. Dit dah A . Not dit dah umm.A. The very instant you hear the last dit or dah, SAY the letter. Do this over and over and over. Take on two or three letters, one at a time, and learn them until you OWN them. Then add another letter, but still keep reviewing the ones you already know. The trick is to OVERLEARN them so they become second nature.

Think back to a time when you heard someone from a non- speaking country speak English. They will be chatting along, comfortable with the vocabulary, until they get to a word they haven't used very often. They'll stop and say 'oh.how do you say.?". They have to stop and mentally translate it because they haven't overlearned that phrase.

Only spend five minutes or so at a time, and spread out your practice sessions throughout the day. Don't forget to INSTANTLY associate the letter with the symbol. This is critical. The most important thing is to get that instant association going in your brain with the symbol and the letter. You may think you are already doing this, but you will probably be surprised. If you already are at 7 or 10 wpm and think that not having Instant Recognition isn't your problem, play a code tape and test yourself. If you hesitate for even a fraction of a second, you don't have Instant Recognition. Having to translate even one or two characters will impede you.

Play those letters over and over and using the Instant Recognition half-second technique. If you work on them one at a time, you WILL own those letters and have the whole alphabet in your subconscious and you will find your proficiency increasing and you will get into The Flow of CW.

You will then understand why CW operators defend the code so passionately and hopefully you will join us in preserving the music of Morse on the air for future generations.

If you'd like to learn more about Flow,

there are many web sites available. One is
`http://www.brainchannels.com/thinker/mihaly.html`

Instant Recognition

by Nancy Kott, WZ8C

Some Hams are content to rag chew at slow speeds and don't have a desire to go faster. This is fine! As long as you are getting on the air and having fun with Morse code, that is what is important. However, many frustrated Hams want to go faster. "How can I increase my code speed?" is the most commonly asked question. After learning the alphabet, Hams seemingly reach a "plateau", a period where they can't make further progress. Usually they can copy 5 or 6 WPM fairly well, but they go to pieces above 7 or 8 WPM. The answer is simple: they have not adequately learned the alphabet.

They may deny this is true since they obviously must know the characters to copy 6 or 7 WPM.

However, to copy CW at higher speeds requires more than merely recognizing characters: the recognizing must be instantaneous. By instantaneous recognition I mean the ability to recognize a CW character within a half-second after hearing its completion.

Bill Pierpont, N6HFF, author of "The Art and Skill of Telegraphy," puts it this way: "Associate the code signal with the printed letter so intimately that when you hear or think of one, the other immediately pops into mind. Instant recognition is what we strive for. We must develop that patient, receptive state of mind that allows us to recognize each character instantly and accurately as soon as it has been completed."

How do you find out if you have instant recognition? One way is to play a code practice program. As each letter plays, can you immediately say or write the letter? Or do you think "ummm...A" or "...dit dah...ummm...A"? If there is a split second delay in your recognition of the letter, then you haven't learned that letter to the point of instant recognition. A split second may not seem like much; it's not going to make much difference when you're going 5 or 10 WPM but when you get to higher speeds it's going to mess you up. The time it takes you to think "...ummm" before recognizing the letter will be long enough to make you miss the next letter after it. It will snowball to the point where you lose whole words. You may get enough of it to make sense of the copy, but you will not feel comfortable chatting on the air. It might discourage you enough to make you want to give up because you feel you are practicing and practicing and aren't making progress.

I'm sure you've heard the stories of legendary CW operators who can carry on a high speed chat on the air while drinking a cup of coffee and fielding questions from people in the room. These operators are comfortable with the code because it's so familiar they don't have to think about what they're copying.

Irene, WO8E, feels she is at a plateau. Even though she has passed the 20 WPM test and has her Extra class license she doesn't feel comfortable carrying on a conversation at 20 WPM. We wondered if she had instant recognition, maybe she didn't and this was holding her back. She listened to the code characters one by one and sure enough there are a handful of characters that she has to think about before identifying them! Once you find you don't have instant recognition, how do you acquire it? There are two ways: the hard way and the easy way. The hard way is to proceed as you are doing, eventually instant recognition will come to you. With some people it may take years.

The simple way is to go back to the alphabet and learn it as it should have been done in the first place. Your first reaction is probably to think it would be a waste of time because you may feel you've already memorized the alphabet. But, you've proved that you don't really know the letters because you don't have instant recognition of them yet. Once properly learned, the alphabet will produce faster speeds quickly and easily. The key is to overlearn the alphabet so it becomes so ingrained in your brain that it's second nature. In psychology there is a "Law of Contiguity", which says that if two events occur no more than one-half second apart, the mind associates the two events. This means when a Morse code character is heard and it is followed within one-half second by a spoken letter of the alphabet, the mind will associate the Morse sound with the translation. The association works automatically, as a workman thinks "lunch" when he hears the noon whistle blow. But we quickly forget things learned by this association method, so we need to "overlearn" them to make the code a part of our permanent memory. Overlearning occurs when we continue to practice something we feel we have already learned. However, boredom soon sets in when we go over and over material we think we've already mastered. This is why practice sessions should be short, two or three minutes at a time. Short, frequent practice sessions produce more results than fewer longer sessions. Concentrate, stay focused on your goal!

Determine what characters you don't recognize immediately after they are played and concentrate on these. You should be able to say the name of the character as the last dit or dah is heard. If you don't, add it to your list. You can relearn the alphabet by using basic code tapes, listening to slow code on the air or even whistling it to yourself. It would be ideal if you could make your own tape concentrating on your problem letters, but don't omit the letters you already know. Remember, our goal is to overlearn the code: all the reinforcement you can get is good for you.

The key to success with this method is to say the letter within a half second of hearing it; hearing it and quickly saying it over and over and over. The INSTANT you recognize the letter being played, say it out loud as fast as you can. Use spare moments during the day to whistle the code under your breath and quietly say the letter to yourself immediately afterwards. Do it while driving, sitting at your desk at work (no one will even suspect!), during commercials while watching TV, anytime you think of it. Spending just a few minutes many times a day will work wonders. By tapping out the letter with your finger as you say the letter aloud or whistle it, you involve more of your brain's memory centers. This increases your learning efficiency by reinforcing instant recognition with what is called "motor memory". Doing a practice session right before you go to sleep has also been proven to help your brain commit material to memory.

When you find that you have instant recognition with the letters, your code speed will increase effortlessly. Then you will get to the point where you can work on having instant recognition with common words As always, I welcome your comments. Contact me at Nancy Kott, WZ8C, PO Box 47, Hadley MI 48440 or via Email at nancy@tir.com

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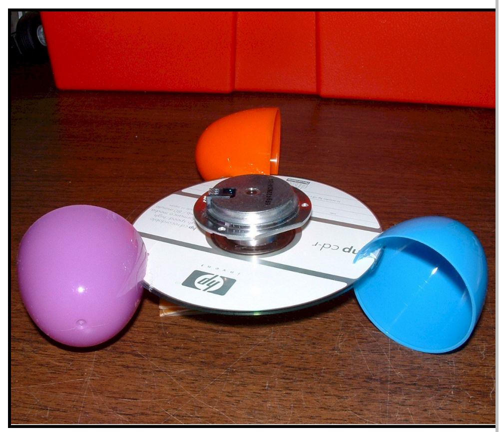
The PIC-based APRS Weather Station Project

The PIC-WX is a special project done by a very talented QRPer - Dave Ek, NK0E. Dave has a unique blend of interests that results here in a PIC-controlled APRS weather station that will be of great interest to homebrewers, QRPers out in the field, and many other hams at their home stations. He graciously agreed to let us play along with him when he started on this adventure several years ago and we've been documenting his progress over seven issues of QHB and Homebrewer Magazine. This issue brings all projects installments together at once to enable newcomers to the magazine to see the Big Picture and give a shot at reproducing Dave's project. In the end, you'll end up with a very cool project that can be used as an automated and Internet-connected, APRS-capable personal weather station for the radio shack.



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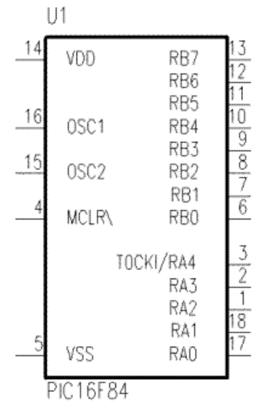
HOMEBREWER

David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 1: Getting Started

Using a PIC microcontroller to build a homebrew weather station.



PIC Source Code **PIC Hex Code** **Readme Part 1**

I'm Dave Ek, NK0E. George has graciously granted me some of his regular Digital QRP Homebrewing column space so I can share my latest project with you as it develops. I've been a ham now for about six years, and I've been playing with the PIC16F84 microcontroller for three of those years. My first design was a system of digital setting circles for an astronomical telescope using rotary encoders and a serial link to a PC (see http://home.earthlink.net/~digicircles). More recently, I designed the Serial CW Sender, a circuit that allows you to key your CW rig via contesting software running on your Palm PDA. The Serial CW Sender was featured in the July 2001 issue of QRP Quarterly, and you can read more about it and the accompanying software at http://home.earthlink.net/~golog/.

Lately I've been messing around with packet radio and APRS (Automatic Position Reporting System). APRS is quite different from your typical packet BBS. Instead of connecting to a single BBS system, you use APRS software (like WinAPRS or UIView) to periodically beacon your station position on the standard APRS frequency (144.39 MHz), and to plot on a map the positions of other APRS stations heard. Some APRS stations act as digipeaters so that your beacon (and others) is heard over much wider areas. It's typical for my APRS software to show locations of stations all over the state and also in neighboring states. In addition, some stations act as internet gates, rebroadcasting position beacons onto the internet where they're heard and displayed at http://www.findu.com/. It's pretty neat to see my station beacon, sent from my station as RF, show up seconds later on the internet!

"So what?" you say? Good question. It turns out that APRS packets aren't limited to position information. I can send messages, send short emails (I can do this through satellites or even the International Space Station), and even broadcast weather conditions using APRS. Weather, of course, is especially near and dear to the hearts of many hams, since many of us are active as weather spotters during storm season. It occurred to me that being able to automatically beacon weather conditions at my QTH would be especially cool. But alas, I had no weather station, and I couldn't see myself spending several hundred bucks to buy one.

But hey, I'm a clever guy. I can design and build a weather station, once again using a PIC microcontroller as its brains. This is the kind of project that I live for—I know that I can make it work, but I'm not exactly sure what it's going to look like when it's done. You know what I mean—it's full of opportunities to learn. After all, it's the journey, not the destination, right?

So, over the next few issues, George has invited me to use his column to share my progress as I tread this path. I'll do my best to include enough information so you can follow along if you, too, want to end up with a cool homebrew weather station. You'll see that there are many QRP applications both for PICs and also for the circuitry we'll be using to interface our weather sensors. I'll even let you tag along when I venture down those blind alleys and dead ends—after all, we learn as much from our mistakes as our successes. And rest assured that, as I write this, I really don't know how this project is going to look at the end. I only know that it'll provide some great entertainment over the next several months.

So, let's get started!

Requirements

It's generally good to know what you want your end product to do when you start a project like this. Quite simply, I want to be able to measure the weather conditions at my QTH, record them on my PC, and then broadcast them periodically using my APRS software and station. In particular, I want to be able to measure temperature, relative humidity, barometric pressure, wind speed and direction, and rainfall. I also want to be able to easily control the time interval between measurements and allow different intervals to be used for different quantities (say temperature every minute and relative humidity every 10 minutes). I don't want to require that all sensors be present, either, because I'll probably implement them one at a time. I also want to be able to use my PC to do any calibration and conversion so that the weather station itself only has to return raw data (this allows me to fine-tune my sensor calibrations without having to modify the weather station firmware). This will require me to write some PC software, but that's not a problem for me.

I've already decided to use the PIC16F84 microcontroller for this project. I'm using it because it's cheap, easy to program, and I know that it'll do everything I need to do. The PIC will have the job of gathering sensor data and transmitting it to the PC whenever the PC asks for it. The PIC and the PC will communicate via a serial port on the PC. (Okay, some of you smart guys know that the PIC16F84 doesn't have serial communications capabilities built in, but I have an answer for that. I'll tell you about it next time.)

Getting Started

In order to use PICs in electronics projects, you need to be able to do three things:

1) Write the program that goes into the PIC

2) Compile the program
3) Put the program into the PIC

The first two are handled by software you run on your PC. I use a program called MPLab from Microchip (the maker of the PIC chips). MPLab is free, and you can download it from Microchip's web site (www.microchip.com). It includes a source code editor and a compiler. It can be used to write code for any of Microchip's PIC microcontrollers. MPLab can also directly control many of the commercial PIC programmer devices on the market (the hardware used to transfer the code into the chip itself). If you use MPLab to write your PIC code, you'll be using assembly language. It looks cryptic and daunting, but it's not nearly as hard as many people make it out to be. Nevertheless, if you prefer to program in C or BASIC, you can also buy (for money, not for free) other development tools. I'll be using the free MPLab tool for this project. Although I'm not going to try to teach you everything you need to know about writing code in assembly, I'll try to point out the highlights and make sure my code is commented well so you can figure it out. If you're interested in learning how to program PICs in assembly language, get a book by David Benson (not K1SWL) titled *Easy PIC'n*. It's a good introduction. Also, read the article by John Hansen W2FS in the October 1998 QST Magazine titled "Using PIC Microcontrollers in Amateur Radio Projects." That article got me started with PICs.

Besides being able to write and compile the code for the PIC, you also need to be able to load the code into an actual PIC chip. That's where the PIC programmer comes in. This is a hardware device, usually controlled by software running on your PC, that transfers the compiled PIC code into the chip's ROM memory where it will stay forever, or until you overwrite it with another program. You can buy commercially-made PIC programmers, but they start at about $100. If you're cheap like me (and I'll bet you are), you'd rather build one for a few bucks that works just as well. The QST article by W2FS describes a programmer called the Ludipipo that can be built easily (in fact, you can get a PC board from FAR Circuits), and there are lots of freeware programs that will control the Ludipipo. The one I'm using now is called IC-Prog. It's free and can be downloaded from http://www.ic-prog.net/.

The Ludipipo programmer plugs into a serial port on your PC, so you need to make sure you have a free serial port. Alternatively, you can build a programmer that uses the parallel port (try searching the web for the No-Parts PIC Programmer), but you'll need different software (not Picprog) to run it. Parallel-port programmers must generally be used in DOS mode, because Windows doesn't make it easy to control the parallel port pins individually.

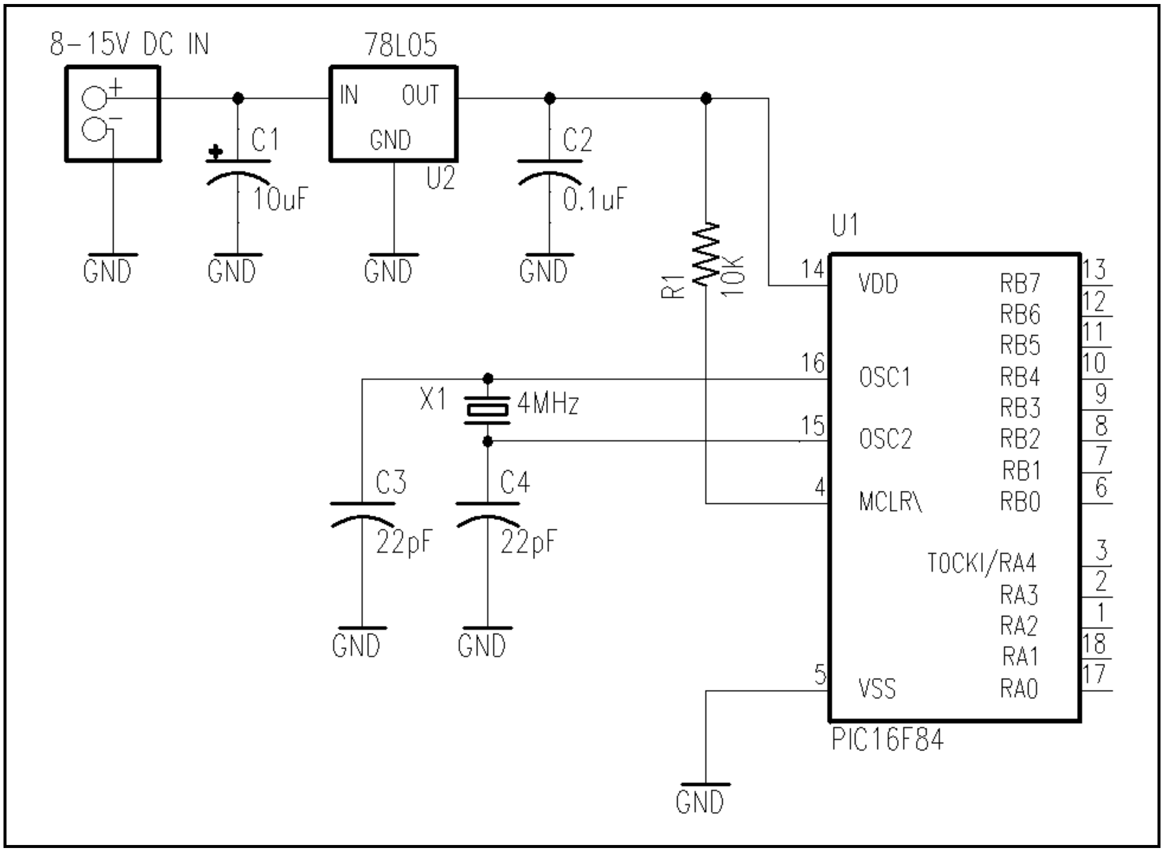
The great thing about this PIC chip is that it can be easily reprogrammed without any lengthy erasure process. With some types of EPROMs, it was necessary to expose the chip to UV light for a lengthy time to erase it prior to reprogramming. The PIC16F84 is an EEPROM (electrically-erasable programmable read-only memory) and can be reprogrammed simply by running it through the programming process again.

I should stress here that there are many web pages devoted to various designs for homebrew PIC programmers, and there are quite a few programs that can be used to control them. I suggest the Ludipipo and Picprog simply because I'm familiar with them and I know that they work. If you're brand new to PICs, using these should help to guarantee success. If you're adventurous or experienced, use whatever tickles your fancy.

What PICs Do

Before we get too far down the road with programming PICs, we should probably discuss what they are and how they work. A PIC microcontroller is a single-chip package that combines a microprocessor, ROM program memory, and RAM variable memory, along with several input and output logic gates. This makes them a one-chip computer, with an operating system supplied by you, the programmer. The PIC16F84 has 13 digital input/output lines. As inputs, they can either be high (+5V) or low (ground). As outputs, they can either be driven high or low. You can decide which lines are inputs and outputs, and can even switch a line from being an input to being an output during program execution.

The PIC16F84 requires a few external components in order to operate. The figure below shows the minimum circuit needed for a PIC. First, a regulated voltage supply is needed. The PIC16F84 can use a supply voltage from 3 to 6V DC. I usually use a 78L05 voltage regulator to provide +5V DC to the chip. A clock signal is also needed. There are a few different ways to do this, but I'm using a 4 MHz crystal for high speed and precise timing (we'll need both later for this project). A 4 MHz crystal (along with two 22 pF capacitors running from either lead to ground) will give an instruction speed of one million instructions per second in the PIC. The only other component needed is a 10K resistor to hold the reset line (pin 4) high. Taking this line low will cause the PIC to reset (start executing its program from the beginning, like it would when first powered up).



Bare Minimum PIC16F84 Circuit.

That's going to wrap up this first installment of the PIC Weather Station project. Your homework assignment is to build a programmer for the PIC16F84 (like the Ludipipo), and then download some programming software (like IC-Prog) and the MPLab software from Microchip. After that, lay out the circuit shown above (use a solderless breadboard—it works great for PIC circuits) and then cruise over to the Digital QRP Homebrewing web site (http://www.njqrp.org/digitalhomebrewing/) and grab the sample PIC program to try out. Next time, we'll cover adding serial communications capabilities to the circuit so it can easily communicate with a PC. After that, we'll be ready to start adding sensors to our weather station.

See you next time—73 de Dave NK0E

nk0e@earthlink.net

Continue reading in Part 2

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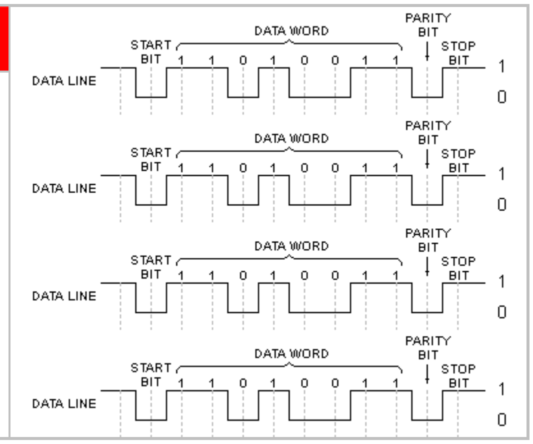
David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 2: Communications

In this installment, we show how to communicate with a PC via serial communications.



PIC Source Code   PIC Hex Code

Hi gang! Last time we got started with the basics of PIC circuits and PIC programming. Hopefully, you now have a PIC and a programmer, and you know how to use them. In this installment we'll begin to add useful functionality to our circuit by teaching it how to communicate with a PC via serial communications.

There are some PIC chips that have serial communication capability built-in, but the PIC16F84 isn't one of them. When I first began messing with PIC circuits, all I knew was the 'F84 and my home-built programmer, so without knowing any better I set out to code the serial capabilities manually. It turned out great, though, and I've since reused the very same code for other projects. Since the 'F84 is cheap and easy to program, I've stuck with it despite the availability of superior PICs. That being said, let's get started!

Since you might not be familiar with the nuts and bolts of serial communications, let's begin with an overview. You've probably had to set parameters like baud rate, stop bits, parity, and the like when using communications software on your computer. When your PC communicates with another device using its serial port, it sends a bunch of bytes (characters) one at a time. Furthermore, each byte is sent one bit at a time (eight bits to a byte). When a bit is sent, the voltage on the serial wire is set to one value for a "1" and another value for a "0". The specific values depend upon the type of logic in use (TTL, CMOS, RS-232, etc.). We'll be concerned with two types of logic: TTL, where 1's are +5V and 0's are 0V, and RS-232, where 1's are –12V and 0's are +12V. Note that these are *typical* voltages, but the specifications actually allow for a range of voltages for these values; we'll stick with these values for the sake of simplicity. Our PIC chip talks using TTL voltages, but the PC uses the RS-232 voltage levels. We'll need some way to convert between the two—more on that later.

We'll be talking exclusively about *asynchronous* serial communications here. There is also a flavor of serial communications called *synchronous*, where the two communicating devices share a clock line to synchronize their chatter. In asynchronous communications, the devices are responsible for handling timing themselves. Let's look at a diagram of a typical stream of bits and see what sense we can make of it.

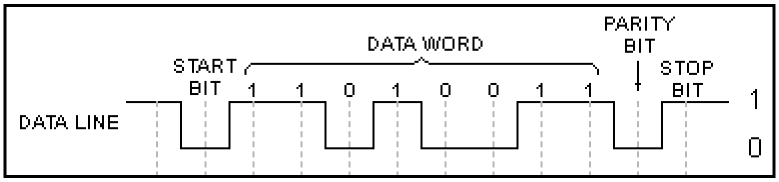


Figure 1: serial communications bit stream.

Here, voltage is the vertical axis of the graph, and time is the horizontal axis. Before any data is sent, the sending device holds the data line high (the "1" voltage). When it's time to transmit a byte, the sending device sends a *start bit* by taking the data line low (the "0" voltage). The start bit is the signal to the receiving device that data is coming.

The duration of each bit is determined by the baud rate set for the communications. A typical value is 9600 baud, which means that 9600 bits are sent per second, or each bit lasts for 1/9600 sec (0.000104167 sec). After the start bit is sent, each of the eight bits making up the byte is sent, with the most significant bit (the leftmost bit) sent first. The voltage of the data line changes to high or low depending on whether each bit is a "1" or a "0". Note that if two or more successive "1" bits are sent, the data line stays high for the duration of the bits—there is no "delimiter" to signal the end of one bit and the start of another. Thus, it's up to the receiving device to "time" the bits to determine when one bit ends and another begins. Usually, there are eight data bits sent for each byte, but it's possible to use only seven data bits if all the bytes to be sent are alphanumeric data because the most significant bit is always zero for alphanumeric characters (meaning their ASCII values are less than 128).

Once the byte is sent, a *parity bit* can optionally be sent. If *even* parity is chosen for the protocol, if the number of "1" bits in the byte is even, the parity bit is set to "1", or it's set to "0" if the number "1" bits is odd. If *odd* parity is chosen, the setting of the parity bit is reversed. It's also possible (and actually more typical) to select *no* parity for the protocol, in which case no parity bit is sent.

Once the parity bit is sent (if parity is selected), the *stop bit* is sent. The stop bit is simply a "1", ensuring that the data line is held in the "1" state for a time before the next start bit is sent. Although only one stop bit is typically sent, it's possible to specify that one and a half or two stop bits are sent. In this case, the line is held in the "1" state for the duration of one and a half or two bits.

Obviously, both the sending and receiving devices must agree on the baud rate, the number of data bits, the number of stop bits, and the parity setting, or else there will not be successful serial communications between the two devices. Almost universally, eight data bits, one stop bit, and no parity are chosen. That's what we'll be using for this project. We'll also be using a baud rate of 9600. I chose this rather arbitrarily. Normally, faster baud rates are favored, but the amount of data exchanged between PIC and PC for this project will be small, and speed won't be an issue.

There is one other communication parameter that we haven't yet discussed: *flow control*. In some systems, the receiving device needs to signal the sending device to stop sending for a moment, perhaps to allow the receiving device to empty its receive buffer and process and store the data. Commonly, systems use either *xon/xoff* or *hardware* flow control. Frankly, I don't know much about flow control so I'm not going to discuss it in any detail here. The PIC Wx project doesn't use flow control.

We've already discussed the difference between the voltage levels for TTL vs RS-232 logic. Our PIC chip uses TTL logic levels, but it must communicate with a PC that uses RS-232. Thus, we need to be able to convert between the two. Luckily, Maxim (www.maxim-ic.com) makes a nice chip called the MAX232 that does this for us. It requires a +5V supply and four 1-uF electrolytic capacitors, and provides two channels of TTL-to-RS-232 conversion, and two channels of RS-232-to-TTL conversion. We only need one channel of each for this project. Simply put, the MAX232 chip is connected between the PIC and the PC, as you can see from the schematic below. You can get the MAX232 from a variety of sources, including Jameco (www.jameco.com). Get the MAX232CPE version.

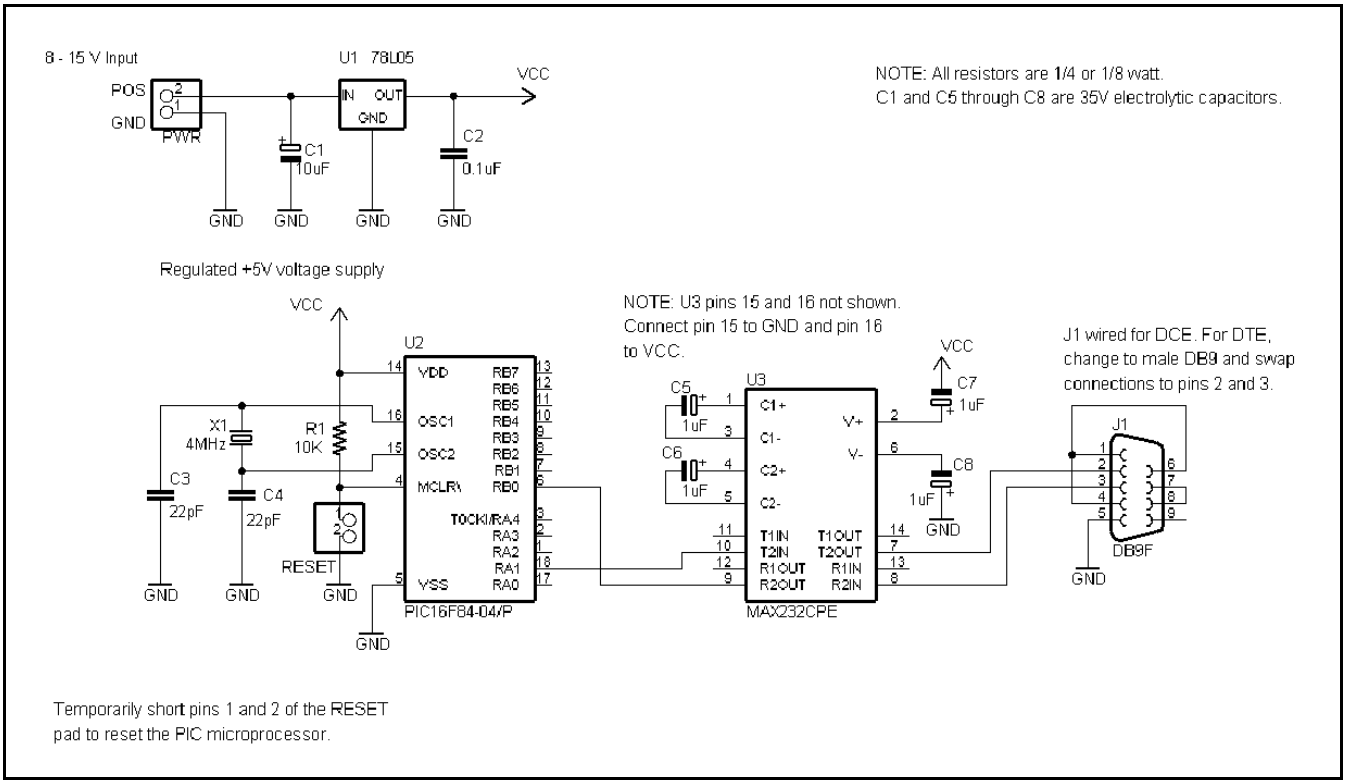


Figure 2: Schematic diagram for part 2 of the PIC Wx project.

The DB9F connector shown in the schematic is a female DB9 connector—you've undoubtedly seen one of these before, most likely on the cable end of a computer mouse. There are really only three pins that we care about on this connector. Pins 2 and 3 are the transmit and receive lines for the data, and pin 5 is the ground line. Some of the other pins are connected to each other: pins 1, 4, and 6, and also pins 7 and 8. This was done in case the PC expects flow control to be used. It's a way of faking out the PC into thinking that it's getting the correct response when doing flow control things. I'm not going to discuss this any further here, but the ARRL Handbook has some additional information if you're interested.

While we're on the subject, we need to discuss one other aspect of serial communications. Did you ever wonder why PCs have male connectors, and mice have female connectors? The obvious reason for this, of course, is so that you can plug your mouse into the PC! There's a little more to it, though. The circuit as shown above is wired as *data communications equipment* (DCE) so that it can be plugged directly into the PC, which is wired as *data terminal equipment* (DTE). Generally, DCE has a female DB9 connector, and DTE has a male DB9 connector. In addition, DCE sends data on DB9 pin 2 and receives data on DB9 pin 3, while DTE receives on pin 2 and pin sends on pin 3. Of course this makes sense since you want DCE to receive whatever DTE sends, and vice versa. If you want to connect DCE to DCE, or DTE to DTE, you need to use a null modem cable, which switches lines 2 and 3. That won't be necessary here.

The code for the PIC is much more complex this time than it was for the first installment. I'm not going to cover it all in great detail because of time and space constraints. Here are some highlights. First, most of the code is for handling the serial communications. The PIC always expects to get a command from the PC before sending anything, so it uses an *external interrupt* to know when the PC has sent a start bit. Pin RB0 on the PIC functions in this capacity when the external interrupt is enabled using the OPTION register. Then, when RB0 changes state, the PIC stops what it's doing and jumps to address 0x04 and begins executing code there. I've written code at that location to begin listening for bits and saving them. It does this by sampling the RB0 state at the same interval as the bit duration, checking in the middle of each bit. Once all eight bits have been received, the received character is placed in a file register for use by the program, and a flag is set in the SerialReg file register to indicate that a character was received.

Another type of interrupt, a *timer interrupt*, is used to wait for each bit to arrive. Instead of simply doing nothing between bits, the internal timer is set to generate an interrupt when it's time to check for the next bit. That way, the PIC can be doing other things while waiting for the next bit to arrive.

When sending characters back to the PC, a similar procedure is used. The timer interrupt is set to remind the PIC when it's time to send the next bit. At those times, the PIC simply looks at the next bit and sets the RA1 line high or low as appropriate. When the character has been sent, a flag is set in the SerialReg file register to indicate completion.

This all sounds complicated, but to actually *use* these routines is easy. There are two subroutines, named GetAChar and SendAChar, which you can call. GetAChar continuously checks the SerialReg file register until the "character received" flag indicates that a byte was received. Then it returns, and the received character will be found in the RXBuff file register. GetAChar also does one other thing: it calls subroutine Idle, which can be used to do other things while waiting for the character to arrive.

Subroutine SendAChar works similarly. First, you place the character to be sent in the TXChar file register. Then you call subroutine SendAChar. It calls the appropriate serial routine to get the character sent, and waits for the flag to be set indicating completion. While it waits, it also calls subroutine Idle to allow for other processing to occur. Once the character has been sent, SendAChar returns.

Subroutine MainLoop handles the receiving and processing of commands. It calls GetAChar, and then checks the received command against the list of allowed commands and calls the appropriate subroutine. If it doesn't recognize the command it simply ignores it. Here, there are two commands that will be processed. Sending a 't' from the PC will cause the PIC to return a five-digit number in ASCII form, that will change each time the command is received. A 'v' command from the PC will cause the PIC to return a version string.

Your assignment now is to build the circuit shown in the schematic, program the PIC with the code for this installment (from the Digital QRP Homebrewing web site http://www.njqrp.org/digitalhomebrewing/), connect the whole works to your PC, and test it out using Hyperterminal or some other communications software. Remember to configure the software to talk directly to the serial port instead of a modem, and set it up for 9600 baud, 8 bits, 1 stop bit, no parity, and no flow control. Type a 'v' and see if you get a response, and then try typing 't' several times.

Next time we'll be adding our first weather sensor to the system—a temperature sensor. Should be lots of fun!

See you next time—73 de Dave NK0E

nk0e@earthlink.net

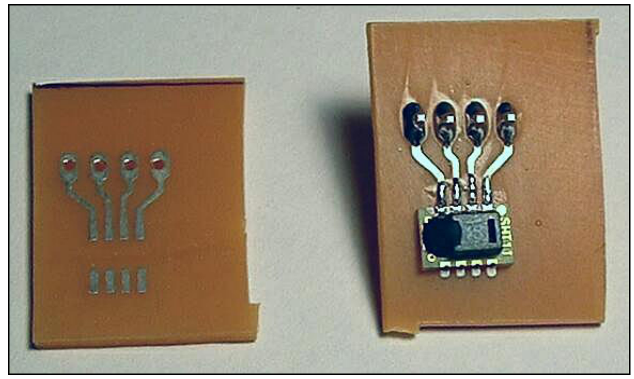
Continue reading in Part 3

David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 3: Temperature and Humidity

Adding a sensor for temperature and relative humidity to this ongoing fun and educational project.



PIC Source Code   PIC Hex Code

Hi gang! Finally, after laying the groundwork in the first two episodes of the PIC WX saga, it's time to get down to the business of actually measuring weather data! We're going to start by adding a sensor for temperature and relative humidity. The sensor I've chosen is the SHT11 from Sensirion (www.sensirion.com). The SHT11 is a digital device that, when queried, returns an unsigned 16-bit number that must be converted into the actual value for temperature or humidity by using simple formulas given in the SHT11 data sheet. It requires no calibration and is reasonably accurate (for temperature, better than ±3.6 °F between –40 and 100 °F, and ±3.5% for relative humidity). Purchasing information is found on Sensirion's web site—it's around $20, but you can also request a free sample (mine arrived within a week of my request).

The SHT11 sensor is pretty small—only 0.3" by 0.2", basically in a surface-mount package. The pin spacing on the package is 0.05". Because of this, I fabricated a small PC board on which to mount it so that it would be easier to handle. Figure 1 shows the PC board before and after the SHT11 was mounted. I included pads for 0.1" header pins to make it easier to connect the board to the rest of the circuit. I made several extra PC boards for the SHT11, so contact me if you're following along and need one.

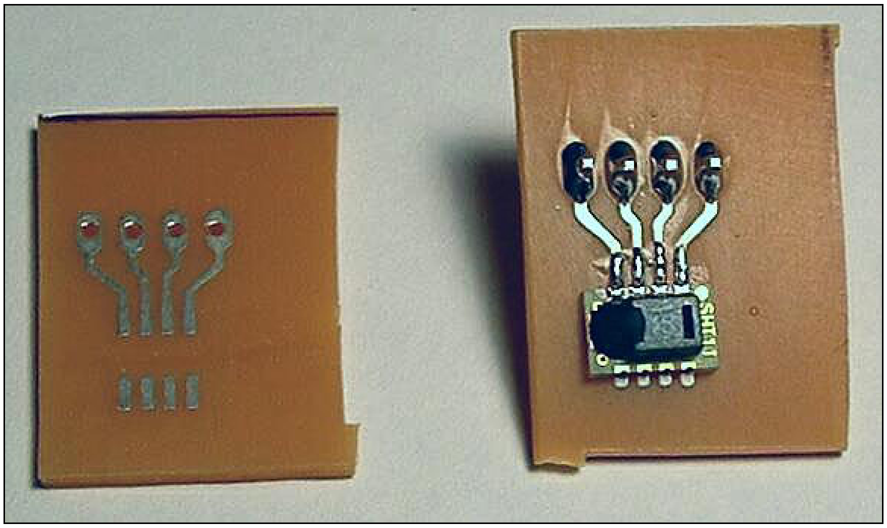


Figure 1. The carrier board for the SHT11 sensor.

The data sheet for the SHT11 cautions that care must be taken when soldering the sensor. Contact time must be limited to 5 seconds with an iron at 350 °C. In addition, the sensor should be stored for at least 24 hours at a relative humidity of 75% or higher after soldering to allow it to recover (since it's always dry here in Colorado, I stored mine in a small container with a wet sponge).

Although the SHT11 has eight pins, only pins 1 through 4 are actually used:

Pin	Name	Connection
1	GND	Ground
2	DATA	Serial data bi-directional
3	SCK	Serial clock input
4	VDD	Supply 2.4 – 5.5V
5-8	nc	Do not connect

You probably figured out for yourself that pins 2 and 3 must be connected to the PIC chip so that the PIC chip can communicate with the SHT11. The PIC and SHT11 communicate using *synchronous* serial communications—synchronous because they share a clock line (SCK) to indicate when each bit can be written/read. The PIC chip controls the SCK line, while the PIC and the SHT11 take turns controlling the DATA line.

The PIC uses the SCK line to signal when each bit can be written or read. Although it's called a clock line, it doesn't need to have a fixed frequency. When the clock line goes high, a bit can be read from the DATA line. When the clock line goes low, a bit can be written to the DATA line. In other words, the device currently sending the data should set the value of the DATA line whenever the clock line goes low, and the device reading the data should get the value of the DATA line whenever the clock line goes high. The PIC chip controls this line at all times. There is no danger of the PIC chip changing the clock line at too high of a frequency for the SHT11—the maximum clock frequency for the SHT11 is 10 MHz, while the

PIC can change it at a maximum frequency of only 1 MHz (determined by its own clock rate of 4 MHz).

The SHT11 datasheet covers the operation of the sensor in great detail. In a nutshell, here is the sequence of events for obtaining a reading from the sensor:

1) The PIC chip sends a “transmission start” sequence. While SCK is high, the DATA line is taken low. While the DATA line is low, the SCK line is taken low and then high again, and then the DATA line is taken high. This signals the SHT11 that a command will be sent to it.

2) The PIC chip sends an 8-bit command. “00000011” is sent if temperature is desired, or “00000101” is sent for humidity.

3) The SHT11 acknowledges receipt of the command by pulling the DATA line low for one clock cycle, and then releasing the DATA line (which goes high).

4) After it has completed its measurement (which can take up to 210 ms), the SHT11 again pulls the DATA line low to indicate that it’s ready to send data back to the PIC. The data is returned as three bytes (high byte, low byte, checksum). After receiving each byte, the PIC must acknowledge by pulling the DATA line low for one clock cycle.

Figure 2 shows the schematic diagram for the entire circuit. It differs from the schematic for the previous installment only by the addition of the SHT11 sensor. Note that the DATA line for the sensor has a pull-up resistor connected to it. The SHT11 datasheet indicates that the pull-up resistor is necessary.

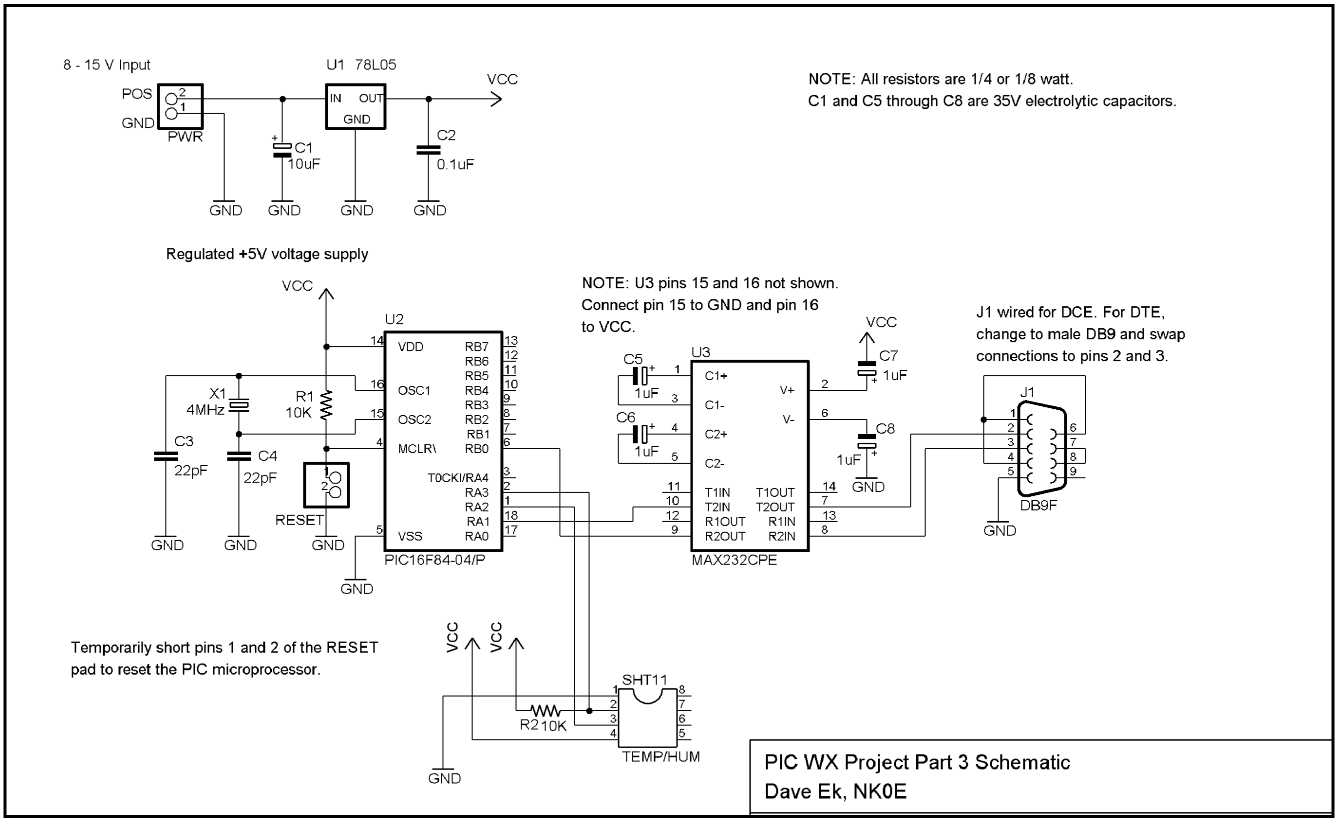


Figure 2: PICWX schematic for part 3.

The operation of the circuit is quite simple. The PIC accepts the ‘t’ command to initiate a temperature measurement and the ‘h’ command to initiate a humidity measurement. In either case, the PIC returns a five digit number (as an ASCII string) followed by a carriage return and line feed. Once you’ve built the circuit (don’t forget to reprogram the PIC), connect it to the serial port on your computer and start up Hyperterminal (or your favorite communications program). Configure your communications program for 9600 baud, 8 bits, 1 stop bit, no parity, and no flow control. Then, type a ‘v’. The PIC should transmit a version string back to the PC (“WxPIC v0.3b (c) 2002 by NK0E”). If so, try typing ‘t’. The PIC should get a temperature measurement from the SHT11 and transmit a five-digit number back to the PC. Also try typing ‘h’. Again, the PIC should get a humidity measurement from the SHT11 and return a five-digit number.

To convert the five-digit numbers to temperature and humidity, use the following formulas (also given in the SHT11 datasheet):

$$T = 0.018N - 40$$
$$H = 0.0405N - 2.8\times10^{-6}N^2 - 4$$

In those formulas, temperature *T* is given in degrees F, and humidity *H* is the percent relative humidity. *N* is the number returned by the PIC chip.

If you examine the PIC code, you'll see that the 't' and 'h' commands reuse the same code that communicates with the SHT11. I wrote several subroutines, to send the command to the SHT11, get a byte from the SHT11, and acknowledge bytes received from the SHT11. I also reused the code from last time that converts a two-byte binary integer to an ASCII string and sends the ASCII string back to the PC.

Finally, I wrote a simple Windows program (using Microsoft Visual C++) that periodically queries the PICWX for temperature and humidity and displays it on the screen. A screen shot is shown in Figure 3. When you first run it, click the Settings button to tell it the serial port to which the PIC WX circuit is connected, and also to set the measurement intervals. When you start the PIC WX program, it places a small thermometer icon in your system tray. If you hover your mouse pointer over that icon, a small box will pop up that shows the current measurements. If you minimize the PIC WX program, it disappears completely except for the icon in the system tray. Double-click the icon to make the PIC WX program reappear. You can download the PIC WX Windows program from the Digital QRP Homebrewing page at www.njqrp.org.

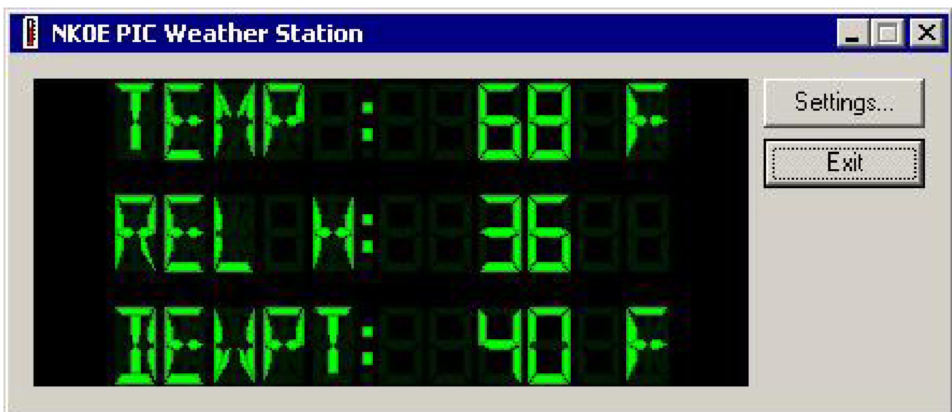


Figure 3: The PIC WX Windows program for reading the PIC weather station.

That wraps up this installment of the PIC WX project. Next time we'll add a sensor for wind speed. That'll probably be a bit more complicated than the SHT11 sensor!

See you next time—73 de Dave NK0E

nk0e@earthlink.net

Continue reading in Part 4

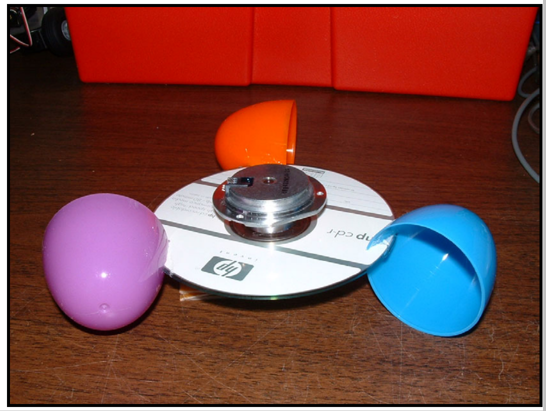
AmQRP.ORG HOMEBREWER

David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 4: Wind Speed

In this installment, we start working on a homebrew anemometer.



PIC Source Code   **PIC Hex Code**   **PC Program**

Hi again, folks! In this installment we're going to start working on a homebrew anemometer. I plucked this design off the internet and adapted it for our use here. The anemometer we're going to build is called the Easter Egg Anemometer, for reasons that will soon be obvious. The original design can be seen at http://www.otherpower.com/anemometer.html. This design uses a brushless DC permanent magnet motor to which plastic easter egg halves are attached to make it spin in the wind. Figure 1 shows how it looks from the top, and Figure 2 shows how it looks underneath (where you can see the motor). From the pictures, it should be obvious how this design got its name!

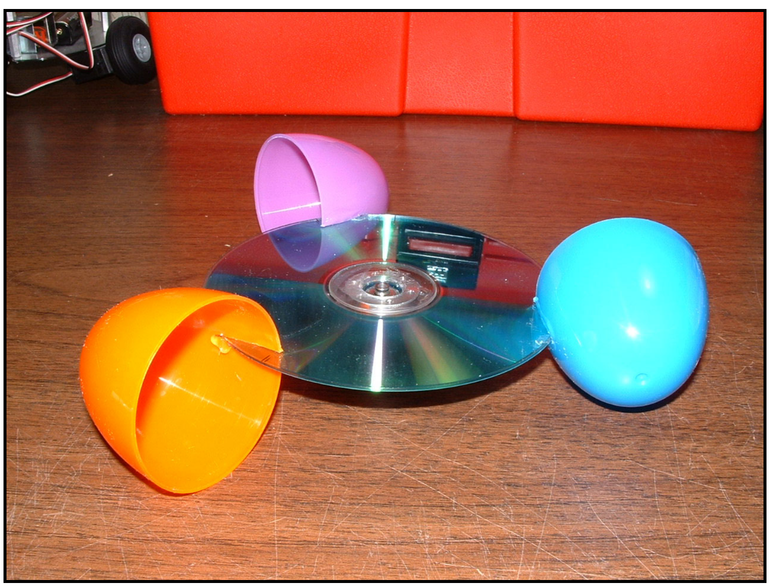


Figure 1

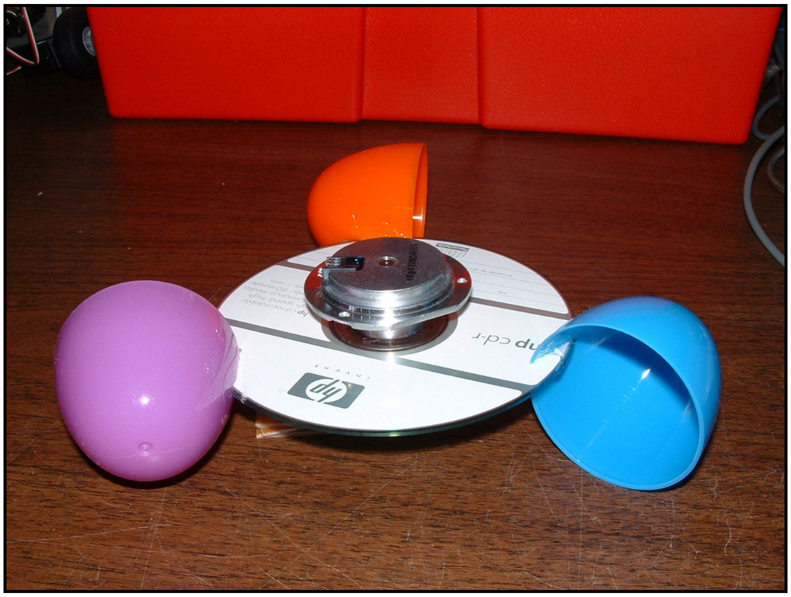


Figure 2

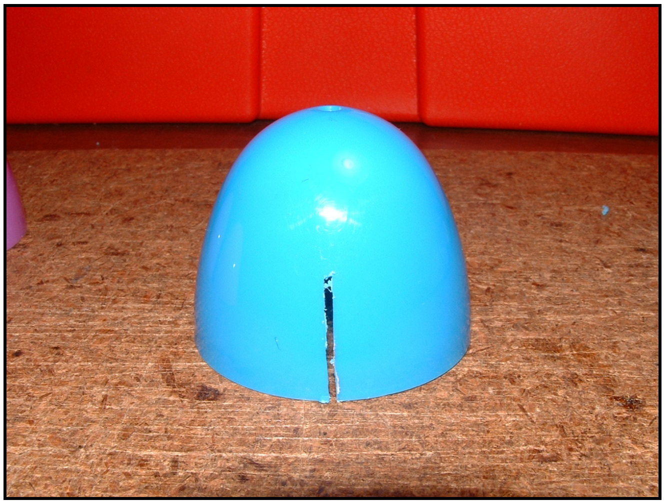
The principle behind this anemometer is that the motor acts as a voltage generator as it spins. The output varies in frequency and amplitude with the speed of the motor. The faster the motor turns, the higher the frequency of the output sine wave. If we amplify this output we can use the PIC to count the frequency of the output and determine from a calibration table the speed of the wind that's making it turn.

I'll mention up front that a shortcoming of this design is that it doesn't work for slight winds. It appears that it takes about 10 MPH or so to get it to measure. Lighter winds either fail to make it turn at all, or it turns too slowly for the output sine wave to be detected. If you're skilled at creating mechanical things, you might be able to come up with a better design. As long as it outputs a series of pulses or a sine wave, it should be usable in place of the easter egg anemometer.

Building the Anemometer

Luckily, the people who designed this anemometer also sell the motors so others can build it. Go to http://www.otherpower.com/cgi-bin/v2/order1.cgi on the web (or click the "ORDER NOW!" link at the bottom of the anemometer page listed previously), and search the list for "Brushless Permanent Magnet DC Motor for Anemometer." As I write this, they sell for $2.50 apiece plus shipping.

I constructed my anemometer by gluing a CD to the top of the motor (carefully ensuring that it's centered) such that the CD spins on the motor's axle. Then I took three easter egg halves, cut slits in their sides (see Figure 3) using a Dremel tool, and glued them in place on the CD by slipping the slits over the edge of the CD. You'll want to make sure that the eggs are distributed evenly around the CD so that the system stays balanced. I recommend using the larger size of plastic easter eggs. Those that are the size of real eggs don't work as well as the larger ones.



Of course, feel free to use a design of your own choosing when attaching the easter eggs to the motor if you'd like. The only important thing here is that the anemometer must spin at a speed approximately proportional to the wind speed. One thing done in the original article was to glue a fourth easter egg half over the top of the motor to seal it from the elements. I haven't done that here yet but I probably will.

The motor has three pins for electrical connection. The center pin is ground, and the outside pins would be used to provide the driving signals when used as a motor. In our application, we'll use the ground pin and only one of the outside pins (either one is fine). According to the original design, this motor will produce a 6-Hz sine wave when it is rotated at 1 RPM.

Anemometer Signal Amplification

The amplitude of the signal coming out of the motor when it spins isn't large enough for our PIC to be able to detect the signal, so I added a simple common-emitter amplifier circuit to bump up the voltage. I used the information in the "Hands-On Radio" article by H. Ward Silver, N0AX, from the February 2003 *QST Magazine* (pp.65-66), which worked quite well for my purposes. For the record, here are the design parameters I used:

- Voltage gain A_V=10
- Transistor β=200 for the 2N2222A
- Quiescent collector current I_{cq}=4 mA
- Quiescent collector-emitter voltage V_{ceq}=2.5 V
- Supply current V_{cc}=5 V
- Base-emitter voltage V_{be}=0.7 V

If you work out the math given in the article, you arrive at resistors values of R_1=20.3 kΩ, R_2=4.6 kΩ, R_C=570 Ω, and R_E=57 Ω. I chose the standard resistor values of 22 kΩ, 4.7 kΩ, 680 Ω, and 27 Ω to use in my amplifier. N0AX's article does a good job of explaining this amplifier and I won't repeat the explanation here.

PIC Code for Counting Pulses

The code added to our PIC for counting pulses is actually pretty simple and short. The GetWindSpeed subroutine is where the pulses are actually counted. This routine sets up a loop (actually two nested loops) that checks once per millisecond to see if the wind input (RB1) has changed value (gone from high to low or vice-versa). If it has, a 16-bit counter made up of the lo and hi registers is incremented, and the new value of the wind input is saved for the next check. The actual checking and saving is done in subroutine CountWind. GetWindSpeed counts pulses for a total of about 3 seconds, and the total count is saved in lo and hi as a sixteen bit word.

GetWindSpeed is called from one of two other subroutines: TellWindSpeed and TellWindSpeedCW. TellWindSpeed is called from the main program loop when the PIC receives an ASCII "w" via its serial line. TellWindSpeed calls GetWindSpeed, and then calls SendAsciiNum to convert the 16-bit word in lo and hi to ASCII and return it to the PC as a five-digit string. After that, TellWindSpeed calls SendCRLF to send a carriage return and line feed (to go to the next line if you're using something like Hyperterminal for debugging).

So, what the PC gets for wind speed is just a raw number indicating the number of transitions that occurred on the wind input line during the 3-second counting period. Since there are two transitions per complete sine wave, and the motor generates a 6 Hz signal at 1 RPM, you can divide the raw number by twelve to get the RPM of the motor if you'd like. Later we'll use the raw number directly to develop a calibration between the anemometer output and true wind speed.

Calibration without a PC

The original anemometer article explained how they calibrated it by mounting it on a vehicle and driving at set speeds while observing the anemometer output. This seems to me to be a simple and straightforward method, but in our case it would require a notebook PC to be used in the car. Knowing that not everyone has a notebook PC at their disposal, I decided to add some code to the PIC that would output the anemometer output on an LED using CW whenever a pushbutton is pressed. Since I already had some code from my Serial CW Sender project for doing so, it was only a matter of a few minutes before I had added the code and gotten it working. The LED is connected through a 1 kΩ resistor to RA0 (pin 17) of the PIC, such that when RA0 goes low, the LED lights. The pushbutton is connected to RB2 (pin 8), and RB2 is tied to +5 V using a 10 kΩ resistor, such that pressing the pushbutton grounds RB2, and releasing it causes RB2 to go high.

In the PIC code, TellWindSpeedCW is called whenever RB2 is low (meaning the pushbutton was pressed). TellWindSpeedCW calls GetWindSpeed, but instead of returning the anemometer output via the serial port, it calls SendCWAsciiNum to output the value in CW on the LED. SendCWAsciiNum behaves just like SendAsciiNum except that it calls

SendCWChar for each digit to send. SendCWChar is a subroutine that takes the ASCII value in the CharToSend register and converts it into a stream of dits and dahs. It uses the ASCII value to look up the “CW value” in a lookup table named (appropriately) Table. Table is just a jump table, where the length of the jump is determined by the value in the W register, which is preloaded by SendCWChar. SendCWChar loads it with zero for the “0” character, one for the “1” character, etc. When Table is called, this value is added to the current program counter to make execution shift to one of the “retlw” statements. “retlw” is just a “return” statement where the value following the “retlw” instruction is placed in the W register prior to the return.

The value returned to SendCWChar by Table stores the dit/dah values in the lowest five bits, with a one meaning a dah and a zero meaning a dit. SendCWChar just marches through the bits, sending dits and dahs by calling SendCWDit and SendCWDah, respectively. I restricted the allowed values for CW characters to just the digits zero through nine. If you’re interested in a more general capability, Go examine my Serial CW Sender PIC code (which also includes code to handle a paddle). You can see it at http://home.earthlink.net/~golog.

With the addition of the LED and the pushbutton, then, you can calibrate the anemometer without needing to use a PC. If you choose not to use this method, the LED and pushbutton can be omitted, but make sure to tie RB2 to +5 V with a 10 kΩ resistor.

Calibration

As I mentioned previously, probably the easiest way to calibrate the anemometer is to mount it on your car or truck and record the raw anemometer output at various highway speeds. It’s important to do this on a calm day, or the wind will skew your values. What you should end up with is a table that shows the raw anemometer output for each speed at which it was measured. Once you have that, it’s easy to determine a simple formula to use in calculating MPH from any value of anemometer output.

I haven’t gotten this far with my own setup yet, but the original article indicates that the response of the anemometer should be linear with wind speed, such that a simple straight line can be drawn through the calibration points. This means that I should be able to convert the raw anemometer output to a wind speed in MPH using a formula like

$$v = mf + b$$

where *v* is the wind speed in MPH, *f* is the raw anemometer output, and *m* and *b* are constants. Some of you will recognize that formula as being that of a straight line, with a slope of *m* and a y-intercept of *b*. In our case, b should be close to zero, and *m* can be found fairly easily by choosing two data points from your table of calibration data and using the following formula:

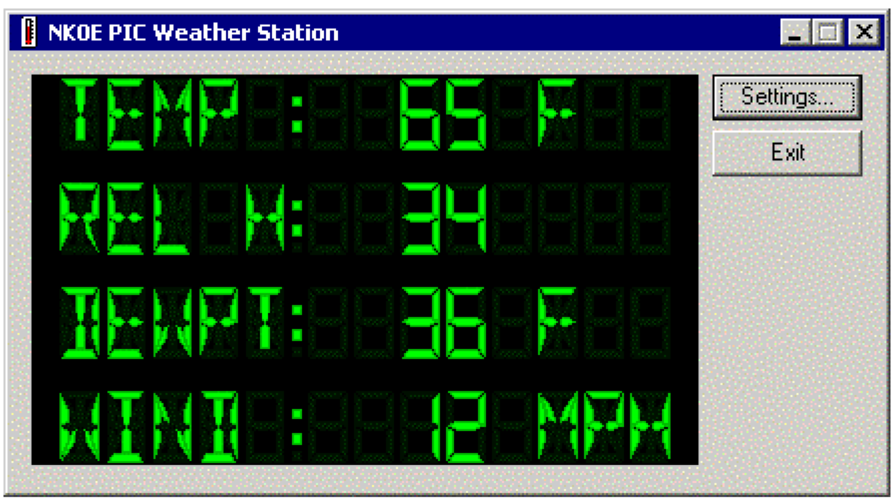
$$m = \frac{v_2 - v_1}{f_2 - f_1}$$

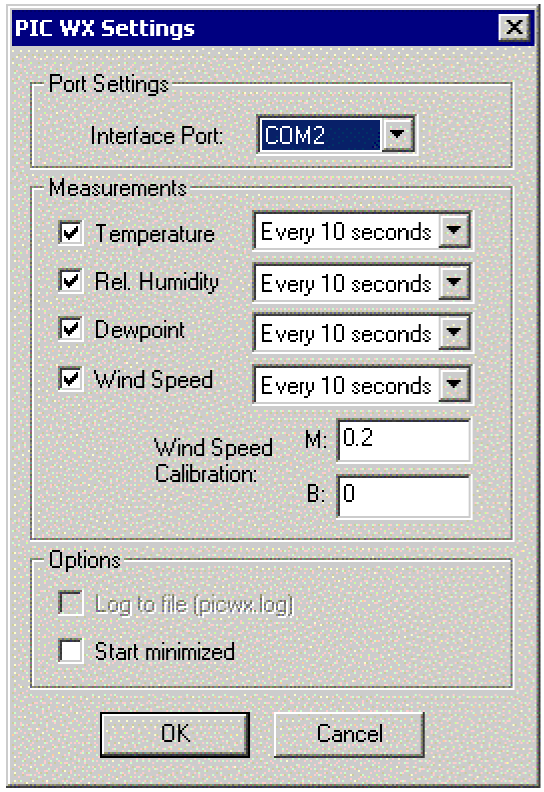
where v_2 and f_2 are the speed in MPH and raw anemometer output from one data point, and v_1 and f_1 are the speed in MPH and raw anemometer output from your other data point. It would be best to choose two data points that are at opposite ends of your calibration range.

Another method of obtaining *m* from your calibration data involves the use of a linear least squares fit to your data points. Many scientific calculators can do this for you. If you'd like this to be done but don't know how, email your data to me and I'll do it for you. In the mean time, a value of 0.2 or so for *m* will give you ballpark results.

Windows Software

I've modified my Windows software so that it includes an output for wind speed, and so that you can enter wind speed calibration information (the values of *m* and *b* previously discussed) for obtaining accurate speeds. Figure 4 shows the new display that includes wind speed. Figure 5 shows the Settings dialog box where you enter values of *m* and *b*. Even if you haven't taken any calibration data yet, you can test your anemometer with a fan just to see that the indicated wind speed increases when the anemometer spins faster. Enter a value of 0.2 for *m* and *0* for b and that should give you reasonable numbers for output. Then try changing the value of *m* to see how it affects the reported wind speed.





Next Time

That's all for this installment. Next time I'll follow up with my own calibration experience, and then we'll get started on another sensor for the stations (although I'm not sure which one yet). Here's a homework assignment: I've been thinking for awhile now about how to design an easy-to-build rain gauge for our system. Obviously, it needs some sort of digital output. Commercial systems use a tipping bucket, where a bucket empties itself when it gets full, and the tipping action triggers a switch. I haven't yet figured out how to homebrew the mechanical parts of such a device yet. Any ideas?

See you next time—73 de Dave NK0E

nk0e@earthlink.net

Continue reading in Part 5

HOMEBREWER

David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 5: Wind Speed Calibration

In this installment, we show how to calibrate the anemometer.

PC Program   Calibration Spreadsheet

Hi again, everybody! We began this article series almost two years ago in the pages of QRP Quarterly, but have now decided to continue the project here in HOMEBREWER Magazine. You can catch up on the first four installments of my PicWx project on the AmQRP website, and the editor tells me that the entire article set will be included as a bonus on the CD-ROM that all subscribers will get with HOMEBREWER issue #5. What a deal! So review the online version of my project and we'll dive in right now to the current progress.

In this installment, we'll finish our anemometer by going through the calibration process. But first, since this is the beginning of the second year for publication of this series on the PIC Wx project, I want to take a moment to review what I'm trying to accomplish with this project and how it relates to ham radio. After all, this *is* a ham radio journal, right?

It's no secret that many hams are interested in the weather. I almost always get a weather report from the other operator during a QSO, and many of us are trained weather spotters for the National Weather Service. Many hams already possess weather stations at home, and some of those hams broadcast weather observations at their QTH via the Automated Position Reporting System (APRS) on 144.390 MHz using 1200-baud packet radio. APRS can be used for many things, including reporting your position and heading, exchanging messages, and even sending email, and anyone who has connected their packet radio system to their PC running APRS software (like WinAPRS or UI-View) can see this information depicted graphically on a map.

I began experimenting with APRS early in 2002 and found it intriguing. It's also popular—at any time I can count 50 or 60 active stations heard by my station either directly or through digipeaters. Some of these stations are fixed in location, while others are in vehicles whose movements are then trackable. Even the National Weather Service sends out APRS messages with weather alerts (at least in some areas). With very little imagination, you can think of any number of interesting applications for APRS.

In my case, the notion of broadcasting weather data from my QTH via APRS was intriguing, but alas, I had no weather station. Sure, they're easy to find and buy, but they can be a bit pricey. Besides, I have the know-how to build a weather station of my own and hook it into the APRS system to get my weather observations broadcast--and that's the basis for this series of articles.

If you've been following along up to this point, you know that our station currently consists of a temperature and humidity sensor and an anemometer, along with some PC software to display the readings. One of the things that I haven't done yet is connect the weather station to my APRS software so that the weather observations are broadcast over APRS. I use UI-View (http://www.packetradio.org.uk/) as my APRS software, and it includes a rudimentary ability to pick up and broadcast weather data from a file that some other software creates. For example, my PicWx PC software would write a file every few minutes that contains the various weather data, and UI-View would look for the file every few minutes and broadcast its contents. UI-View looks for a file that contains data in the following format:

Aug 17 2002 19:47
272/000g006t069P000b0150h61

The second line of this data contains the actual weather data, according to the following format:

CSE/SPDgXXXtXXXrXXXpXXXPXXXhXXbXXXXX

Where:

CSE/SPD is wind direction and sustained 1 minute speed
t is in degrees F
r is Rain per last 60 minutes
p is precipitation per last 24 hours (sliding 24 hour window)
P is precip per last 24 hours since midnight
b is Baro in tenths of a mb
h is humidity in percent. 00=100
g is Gust (peak winds in last 5 minutes)

I'm still researching this format, but you can see where we're headed. At some point, my PicWx software will need to create this file for UI-View so that the weather data can be broadcast. I'll try to work this into one of the next installments, so we can actually get our data out to other APRS users.

Calibrating the Anemometer

As I mentioned last time, the easiest way to do the calibration is to mount the anemometer on a vehicle and then take anemometer readings at various speeds. I mounted my anemometer onto the end of a 1.5" ID PVC pipe about four feet long. I had to build up the diameter of the motor a bit with some electrical tape before it would fit snugly into the end of the pipe. To secure it, I used some additional electrical tape wrapped around the side of the motor and the pipe. Figure 1 shows my mounting arrangement, including the addition of an Easter egg "hat" to cover the bearings. Once I'm ready to mount the anemometer permanently, I'll probably use some epoxy to attach it to the pipe.

Experimental Procedure

My plan for calibrating this puppy was for me to stick the pipe up vertically outside the passenger window of my wife's minivan and take readings while my 17-year-old son Andrew drove. Andrew would hold the van at a fixed speed while I took several readings using the CW output on the LED that I included for just this purpose. Then, when I was done, I'd average the readings at each speed and use some math software to calculate a best fit straight line through the data. Easy, right?

Yeah, right. I discovered that "easy" is a relative term when it came to calibrating my anemometer with a vehicle. I live in the middle of Colorado Springs, a city of around 400,000 people, and probably the same number of bumps and potholes in the roads. Not to mention hills and curves—there must be a city ordinance against building straight streets in this town! And it seems like every one of those 400,000 people is on the road at the same time—traffic is lousy! I decided I'd stick close to home and calibrate for speeds from 10 MPH to 40 MPH, and maybe try calibration at 50 to 60 MPH later. So, Andrew and I backed out of the driveway and headed up the street at 10 MPH. I tried not to make eye contact with any of my neighbors as we tooled up the street with me holding my Easter egg contraption out the window, looking like the geek that I am.

The first thing I discovered was that the bumps and seams in the road made it a challenge to read the LED output, so I had to redo some trials. The hills and curves were making it a challenge for Andrew to hold a fixed speed, too, and there was significant variation in the readings, especially for higher speeds. There was also some wind to further skew the readings. In short, I managed four or five data points for 10, 20, and 30 MPH. Frustration mounted, and I decided to call it quits in favor of another try at a later date, if I could find a flat, smooth, straight road with light traffic. In the mean time, I had enough data to do a trial calibration.

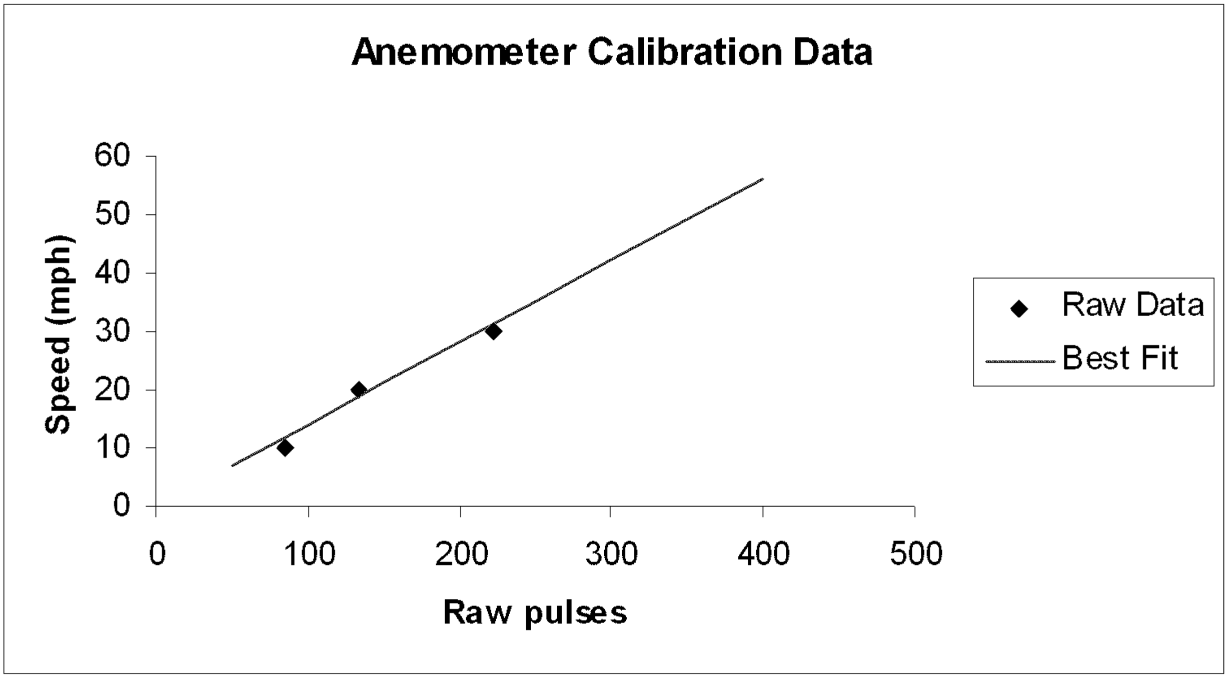
Analysis & Results

The following table gives the data that I took and the average values:

Speed (MPH)	**Data points (raw anemometer output)**	**Average output**
10	80, 107, 77, 77	85.25
20	125, 120, 133, 162	135
30	242, 260, 254, 186, 177	223.8

You can see that there is significant variation in the readings, especially at 30 MPH, but data is data, and I had no reason to throw out those data points.

Three data points aren't exactly a ton of data, but it's enough to draw a line through. I used Microsoft Excel to plot the data and compute a best fit straight line using a linear regression. Excel makes this easy to do by providing the SLOPE and INTERCEPT functions. Figure 2 shows a plot of my data and the resulting straight-line fit. Surprisingly, the fit is rather good. The slope is 0.14, and the y-intercept is negative 0.8 (close to zero, as I would expect it to be). Although it looks like a good fit, I'll feel better about the data once I go out and attempt another calibration, this time with points at 40 and 50 MPH.



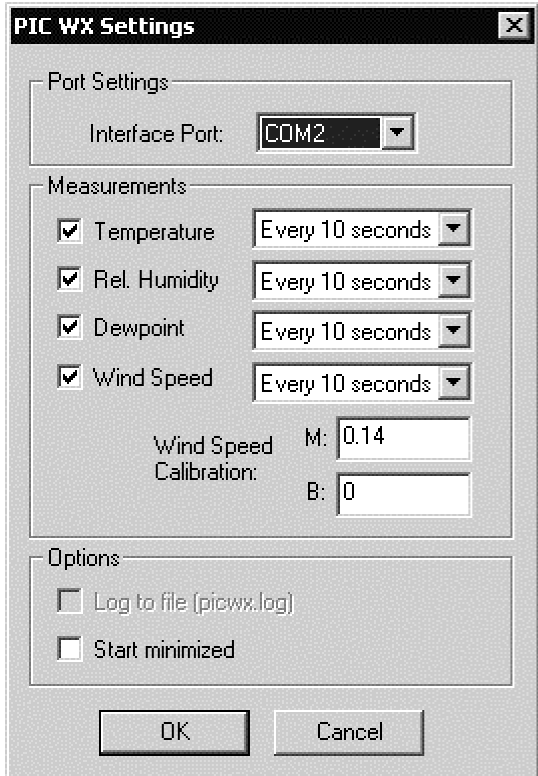
My Excel spreadsheet turned out to be a very convenient way to analyze the data. You can download a copy of the spreadsheet (calibrate.xls) from the NJQRP Digital QRP Homebrewing web pages (http://www.njqrp.org/digitalhomebrewing/).

For those of you who don't have Microsoft Excel, there are a few other options. One is to simply graph your data by hand and draw a line through the data and compute the slope graphically. Many calculators are also capable of doing linear fits. Finally, I wrote a command-line program to do the same thing. It's called linfit.exe and can also be downloaded from the NJQRP site. To run it, simply type "linfit" at the command prompt, and follow the instructions. Here's a sample session (text that I typed as the user is in boldface):

```
C:\Documents and Settings\Dave\My Documents\wx project\part5>linfit

How many points (max of 20)? 3

point 1: enter x, y: 85.25, 10
point 2: enter x, y: 135, 20
point 3: enter x, y: 223.8, 30

slope: 0.140628
y-intercept: -0.815357
error:   7.69%

(Error is the average percent difference between the actual y values
and the y values from the fit.)
```

Once you've determined the slope of your data, enter it into the PicWx software by clicking the Settings button on the main screen. The slope is entered in the edit box labeled "M". Figure 3 shows the settings entered for my anemometer. I left the y-intercept ("B") set to zero.

You can leave it at zero, or you can enter the value that you obtained (which should be close to zero—if not, your data may be suspect).



I'll be going back out to try another calibration soon. I can think of several reasons why mine was not as successful as it could have been, including poor speed control and windy conditions.

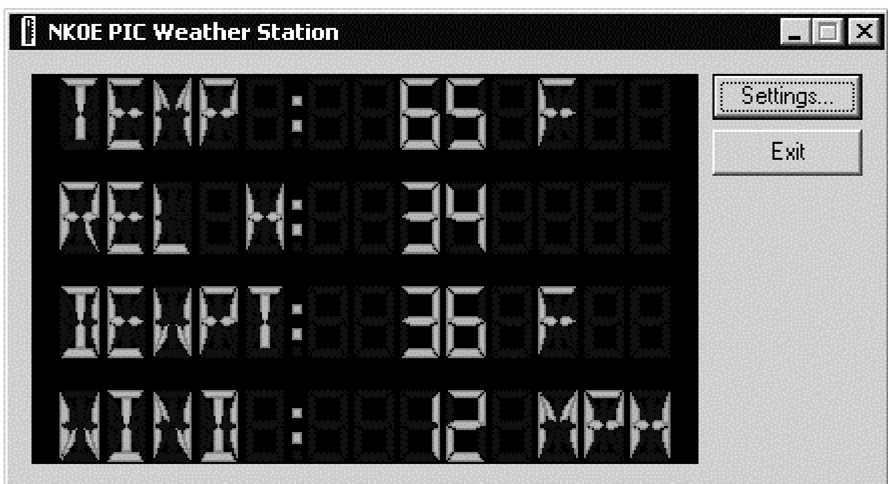
PIC Programmer Notes

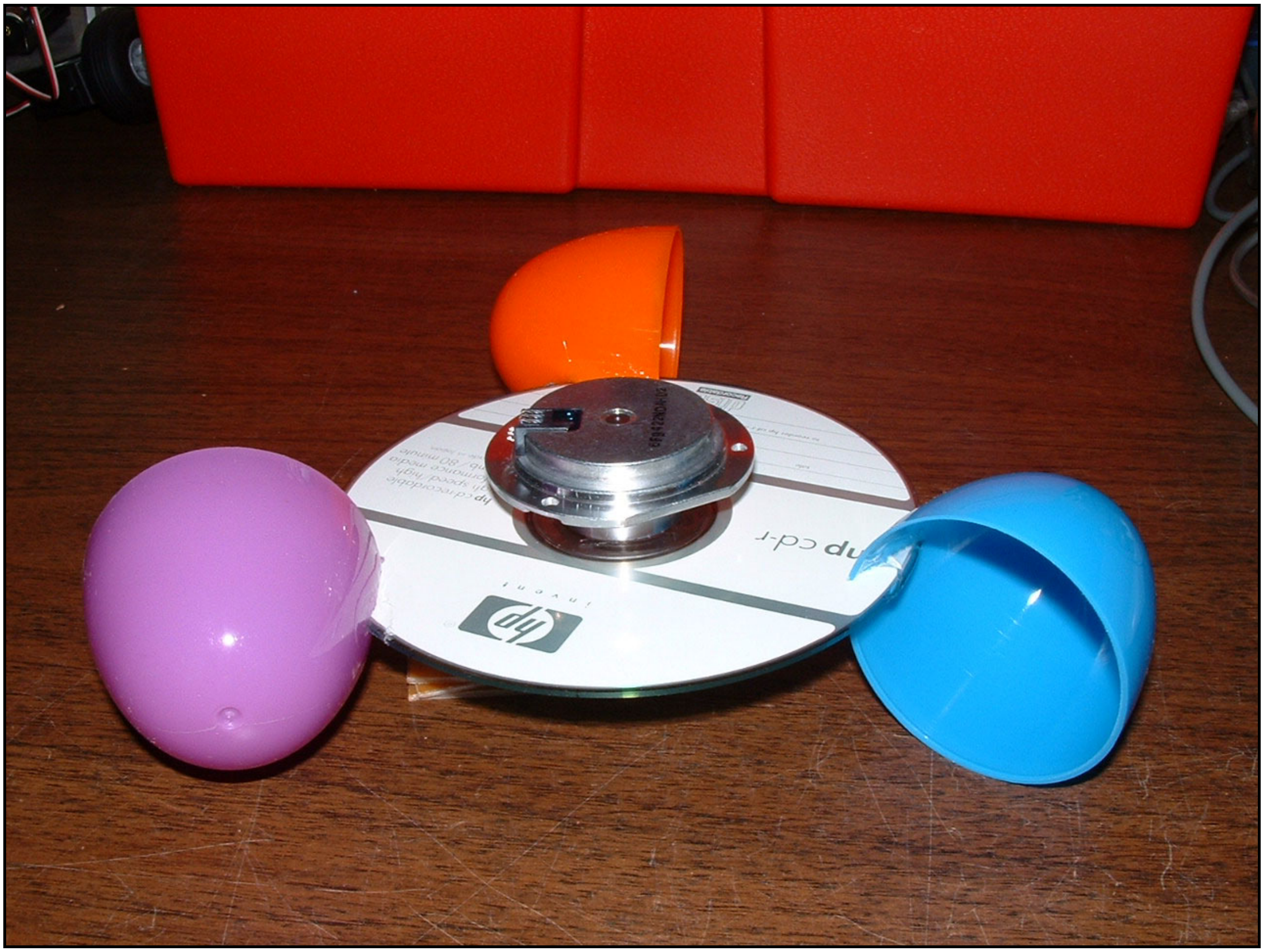
You may have noticed that there are many other microcontrollers in the PIC family from Microchip. They vary in capability (and price), with the more sophisticated ones having built-in serial communications, A/D converters, and other goodies. It turns out that many simple programmers for the PIC16F84 can be adapted to program these other chips fairly easily. The PIC16F84 uses pins V_{DD}, V_{SS}, MCLR/V_{PP}, RB6, and RB7 (pins 14, 5, 4, 12, and 13, respectively) for programming. Recently, I became interested in the PIC16F73, which has more data lines, an integral UART, and A/D conversion, and when I looked at its data sheet, I saw that this chip used the same five lines (but on pins 20, 19, 1, 27, and 28) for programming. It occurred to me that all I needed to do to program this chip using my Ludipipo programmer was to create an adapter to get the right programming signals to the right pins of the 16F73. I breadboarded a test and, lo and behold, it worked! So, don't let the fact that your programmer was designed with the PIC16F84 in mind stop you from trying out other PIC chips.

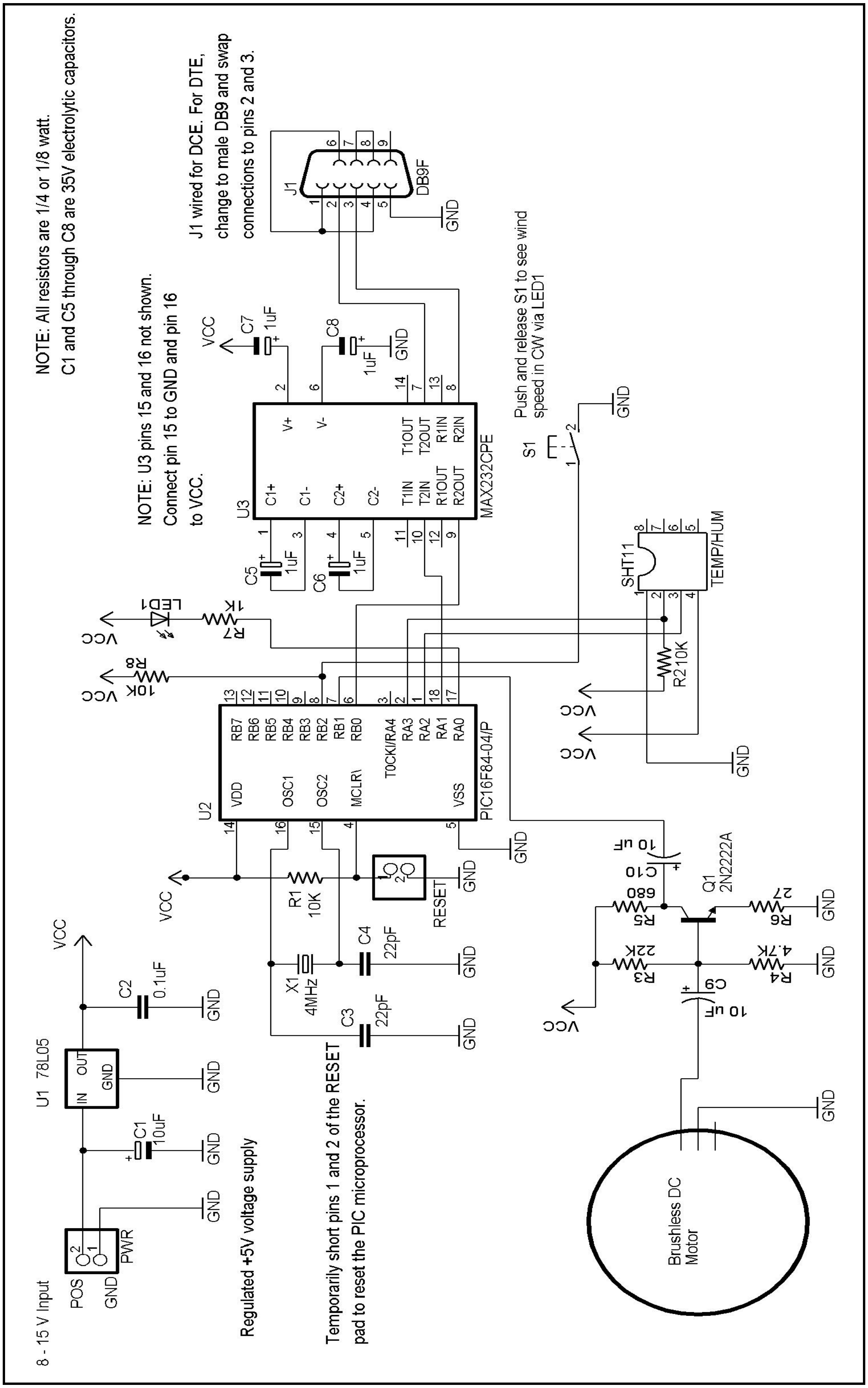
That being said, I recently opted to purchase a "commercial" programmer for the sake of convenience. There are several available, including the PICStart Plus from Microchip and the EPIC Plus from MicroEngineering Labs, but I purchased the Warp-13a programmer from Newfound Electronics. It's the only programmer I could find (besides the pricey PICStart Plus) that worked directly with the MPLab development software. The Warp-13a runs from a serial port, includes a ZIF socket, and will handle almost all the PIC parts up through the 40-pin models. I paid less than a hundred bucks for the programmer. If you're interested, you can see details at http://www.newfoundelectronics.com/. I purchased mine from the Mark III Robot Store (http://www.junun.org/MarkIII/Store.jsp).

Wrap-Up

Next time we'll start work on a barometric sensor, probably using the Motorola MPX4115 pressure sensor. I've seen various plans on the Internet for barometers and even model rocket altimeters that are based on the MPX4115, so we should have plenty of experience from which to draw. The MPX4115 outputs an analog voltage proportional to the barometric pressure, so we'll need some sort of A/D conversion to turn this into a digital output. See you next time!




hp cd-r


NOTE: All resistors are 1/4 or 1/8 watt.
C1 and C5 through C8 are 35V electrolytic capacitors.
J1 wired for DCE. For DTE, change to male DB9 and swap connections to pins 2 and 3.
NOTE: U3 pins 15 and 16 not shown. Connect pin 15 to GND and pin 16 to VCC.
Push and release S1 to see wind speed in CW via LED1
8 - 15 V Input
POS
GND
PWR
U1 78L05
IN
OUT
GND
C1
10uF
C2
0.1uF
VCC
Regulated +5V voltage supply
Temporarily short pins 1 and 2 of the RESET pad to reset the PIC microprocessor.
U2
PIC16F84-04/P
VDD
OSC1
OSC2
MCLR\
VSS
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0
T0CKI/RA4
RA3
RA2
RA1
RA0
R1
10K
RESET
X1
4MHz
C3
22pF
C4
22pF
U3
MAX232CPE
C1+
C1-
C2+
C2-
V+
V-
T1IN
T2IN
R1OUT
R2OUT
T1OUT
T2OUT
R1IN
R2IN
C5
1uF
C6
1uF
C7
1uF
C8
1uF
J1
DB9F
LED1
R7
1K
R8
10K
S1
SHT11
TEMP/HUM
R2 10K
C10
10 uF
Q1
2N2222A
R5
680
R6
27
R3
22K
R4
4.7K
C9
10 uF
Brushless DC Motor
GND

Until next time, 73 de NK0E.

David Ek, NK0E

nk0e@earthlink.net

Continue reading in Part 6

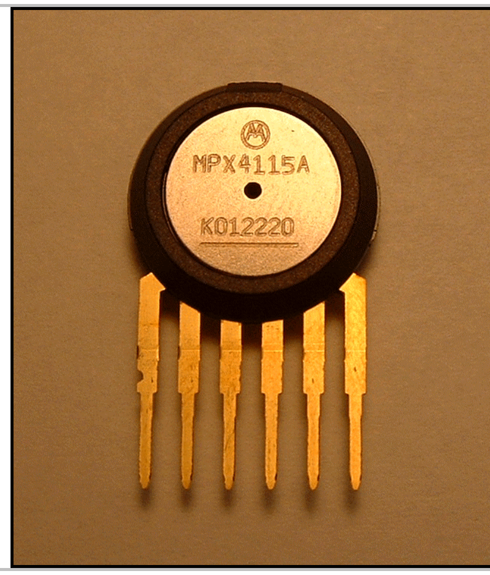
HOMEBREWER

David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 6: Atmospheric Pressure Measurement for PIC-Wx

Adding an atmospheric pressure sensor to this ongoing fun and educational project.



PIC Source Code PIC Hex Code PC Program Calibration Spreadsheet

Hi, everybody! Installments in my PIC weather station project have been few and far between lately, but things are going to be picking up again with this fun installment where we add an atmospheric pressure sensor to the station. By the way, thanks to those of you who've taken the time to drop me an email and tell me that you're following along and having fun. It really makes it easier to buckle down and crank new installments out when I know someone's looking forward to them. Don't hesitate to drop me a note with a question or a comment on the project. Now, let's get started by briefly reviewing the concept of atmospheric pressure.

Barometer Basics

Barometers are devices that measure atmospheric pressure. Atmospheric pressure exists because, quite simply, air has weight. The weight of the air pressing down on you from above is about 14.7 lbs/in^2 if you're at sea level, and it decreases as you increase your elevation above sea level. Atmospheric pressure is commonly expressed as some number of inches of mercury (in. Hg) that is displaced by the weight of the air. The average atmospheric pressure at sea level is usually given as 29.92 in. Hg. This is really an indirect way of specifying atmospheric pressure, though, since you have to calculate the weight of that column of mercury in order to determine the actual pressure needed to displace it. Other common units of pressure are kilopascals (kPa) and millibars (mb). Millibars are also known as hectopascals (hPa). To convert from one unit to another, you only need to know that one in. Hg equals 3.3857 kPa and that 10 mb equals 1 kPa. You can do the math.

One other thing worth noting is that, regardless of your elevation above sea level, the atmospheric pressure reported for your location is the pressure that we estimate we'd measure at sea level for that location. This is done so that all higher elevations don't show up as low pressure areas on the weather maps. The estimate can be done a number of ways, but it is usually based on the U.S. Standard Atmospherei[i], an average profile of the atmosphere developed by the government that gives average absolute atmospheric pressure for a number of altitudes (among other things). In our case, we'll calibrate our barometers against data that's already been corrected to sea level, so this problem will take care of itself.

The Electronic Barometer Circuit

David Bray has published a fairly simple design on the webii[ii] for a barometer based on the MPX4115A, and I've adapted it slightly for our use in this project. Figure 1 shows a block diagram of how we'll measure the atmospheric pressure. At the heart of the circuit is our pressure sensor, the Motorola MPX4115A. It outputs a voltage that is linearly proportional to the absolute atmospheric pressure. The MPX4115A is capable of measuring atmospheric pressure from 15 to 115 kPa and outputs a voltage from 0.2 to 4.8 V. However, the range of pressures that we'll encounter in measuring atmospheric pressure is only about 10 kPa wide, and the corresponding voltages output by the MPX4115A will occupy a range of less than a half volt. In order to widen that range, we'll employ an amplifier to increase the resolution we can obtain when we convert the analog voltage to a digital value in the A/D converter. The digital value will then be transmitted to the PIC, which transmits it to the PC for conversion to the actual pressure value (kPa or in. Hg). The PC then formats it and puts it out to the APRS network as part of a weather packet. That's it in a nutshell. Now let's get down to the details.

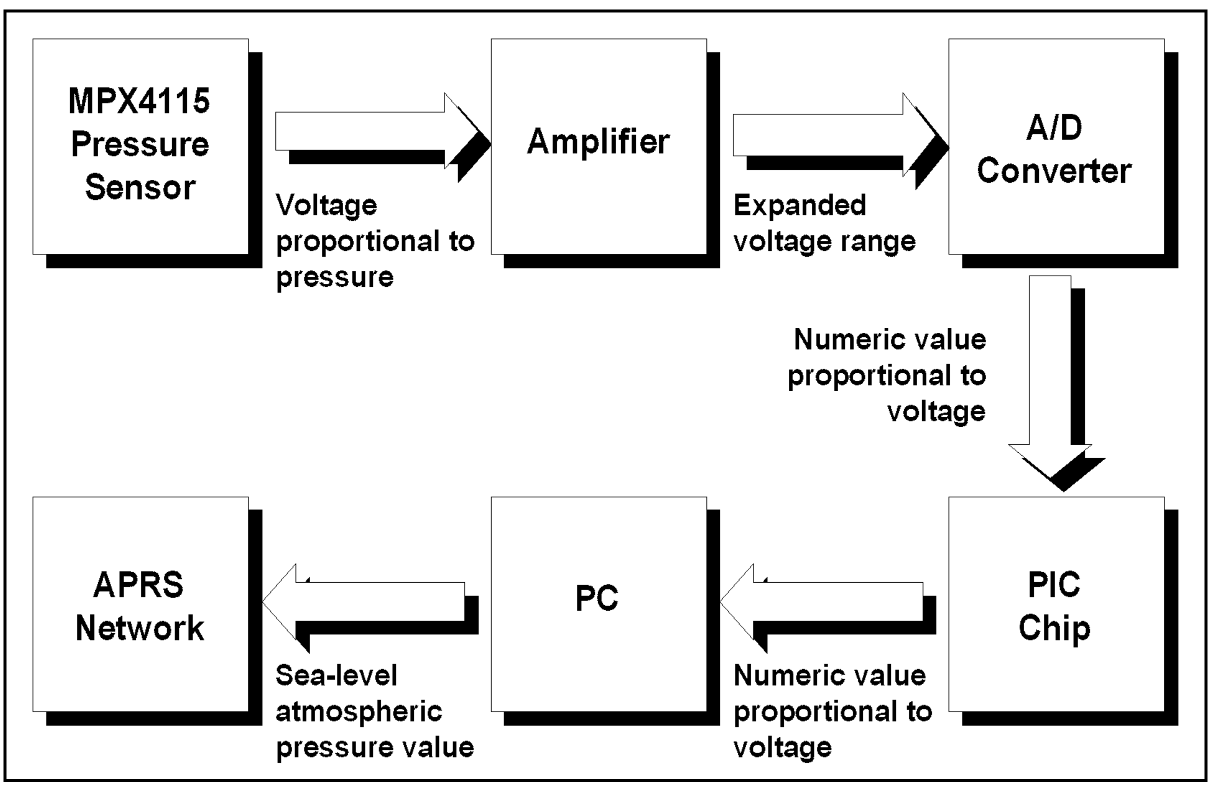


Figure 1. Barometer block diagram

The MPX4115A Pressure Sensor

The MPX4115A pressure sensor from Motorola is shown in Figure 2. Only three of its six leads are used (and other packages exist for this sensor with eight leads, in surface mount form). 5 V is provided to pin 3, pin 2 is grounded, and pin 1 (the one with the little notch in the side) outputs a voltage that is linearly proportional to the absolute atmospheric pressure. The pressure and voltage are related by

$$\frac{V_{out}}{V_S} = 0.009 \cdot P - 0.095$$

Equation 1

where V_{out} is the output of the sensor in volts, V_S is the 5 V supply voltage, and P is the absolute pressure in kPa. You can see that this is the equation of a straight line, and it is a simple matter to convert from voltage to pressure and vice versa.

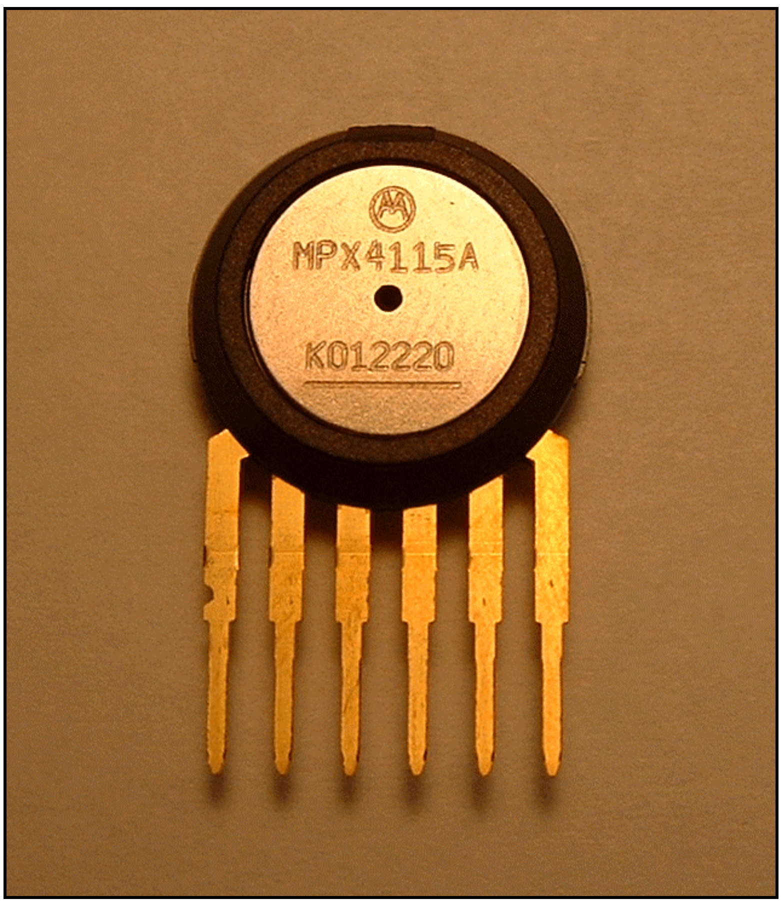


Figure 2. The Motorola MPX4115A absolute pressure sensor.

When I first received my MPX4115A, I just hooked it straight to a 5 V supply and measured its output with a voltmeter, then used the formula above to calculate the pressure. Pretty simple! But the pressure I measured was nowhere near the pressure that the National Weather Service was reporting at the airport nearby. The reason, of course, is that I'm in Colorado Springs , Colorado at an elevation of 6550 feet. My barometer is reading absolute pressure, but the NWS is reporting pressure corrected to sea level. How do we correct our barometer for sea level? David Bray used the following equation to relate absolute pressure at some elevation to that at sea level:

$$P = P_{SL}\, e^{\ln(1-6.87324^{-6} E)\cdot 5.256}$$

Equation 2

where P is the absolute pressure at elevation E, P_{SL} is the sea level pressure, and E is the elevation in feet. P and P_{SL} can be given in whatever pressure units you'd like, as long as you use the same units for both. If we use equation 2 for my location at 6550 ft above sea level, a sea-level pressure of 31 in. Hg corresponds to an absolute pressure equal to 24.33 in. Hg at my location. Likewise, a sea-level pressure of 28 in. Hg corresponds to an absolute pressure of 21.98 in. Hg at my location. Since this represents a reasonable maximum range for our barometer, we can use equation 1 to determine the range of voltages that will be output by the MPX4115A for this pressure range (but don't forget to convert the pressures to kPa first). Again, for my location the range of voltages output by the MPX4115A will be from 2.87 V to 3.23 V. That's not a very big range, so we'll use an amplifier circuit to amplify the output of the MPX4115A to enlarge its range and give us better resolution.

Amplifier Circuit

The amplifier circuit uses both halves of the LM358N dual op amp. Each amplifier uses negative feedback to control the gain. Pots R14 and R16 are multi-turn trimmers. They will be adjusted so that when the voltage range of interest output by the MPX4115A is input to the amplifier, the amplifier output range will be from 1.25 V to 3.25 V (the linear region for the amplifier when powered by 5 V). This way we'll get higher resolution from the A/D converter. I'm not going to explain the amplifier circuit in detail here since it's fairly simple, but drop me a note if it puzzles you and I'll help you understand it.

When I built up this circuit, I added pot R19 so that I could calibrate the amplifier. I needed a way to control the input voltage to the amplifier that's normally provided by the MPX4115A, and I couldn't think of a way to readily change the air pressure, so temporarily replacing the sensor with a pot gave me an easy way to calibrate the amplifier. My goal was to have the output of the amplifier range from 1.25 V to 3.25 V over the expected input voltage range (2.87 V to 3.23 V for me at my location). So, I disconnected the MPX4115A and used R19 to set the input voltage for the amplifier. I connected one DMM to the wiper of R19 to monitor the input voltage, and I connected another DMM to the output (pin 1) of the op amp to monitor the output voltage. Then I adjusted R19 to the upper voltage in my range of interest (3.23 V), and I adjusted R16 until the output voltage was 3.25 V. Then I adjusted R19 to the lower voltage in my range (2.87 V) and adjusted R14 until the output of the amplifier was 1.25

V. I repeated this process of alternately adjusting R14 and R16 at each end of the range several times, until the trimmers no longer needed adjustment.

Once the adjustment of the amplifier was complete, I needed a way to compute the sea-level pressure from the output voltage. First, I measured the amplifier output voltage at several input voltages over the range of interest. Then, using equation 1, I calculated the absolute pressure corresponding to that input voltage (and thus the output voltage). Then I used equation 2 to compute the corresponding sea-level pressure. The results of this exercise are shown in Table 1.

Table 1. Amplifier Calibration Data.

Amplifier Input (V)	Amplifier Output (V)	Absolute Pressure (kPa)	Sea Level Pressure (kPa)	Sea Level Pressure (in.Hg)
2.85	1.14	73.89	94.13	27.80
2.9	1.44	75.00	95.54	28.22
2.95	1.71	76.11	96.96	28.64
3	2	77.22	98.37	29.06
3.05	2.25	78.33	99.79	29.47
3.1	2.53	79.44	101.20	29.89
3.15	2.81	80.56	102.62	30.31
3.2	3.08	81.67	104.03	30.73
3.25	3.37	82.78	105.45	31.15

Once I had the data, I used Microsoft Excel to plot the sea-level pressure versus the amplifier output and compute a linear fit to the data. The resulting plot is shown in Figure 3. As you can see, the data is practically perfectly linear, and all I need to do to get the pressure from the output voltage is to use the equation for the linear fit shown on the plot. But before I can do that in my PIC chip, I need to convert the voltage to a number. Enter the analog-to-digital converter.

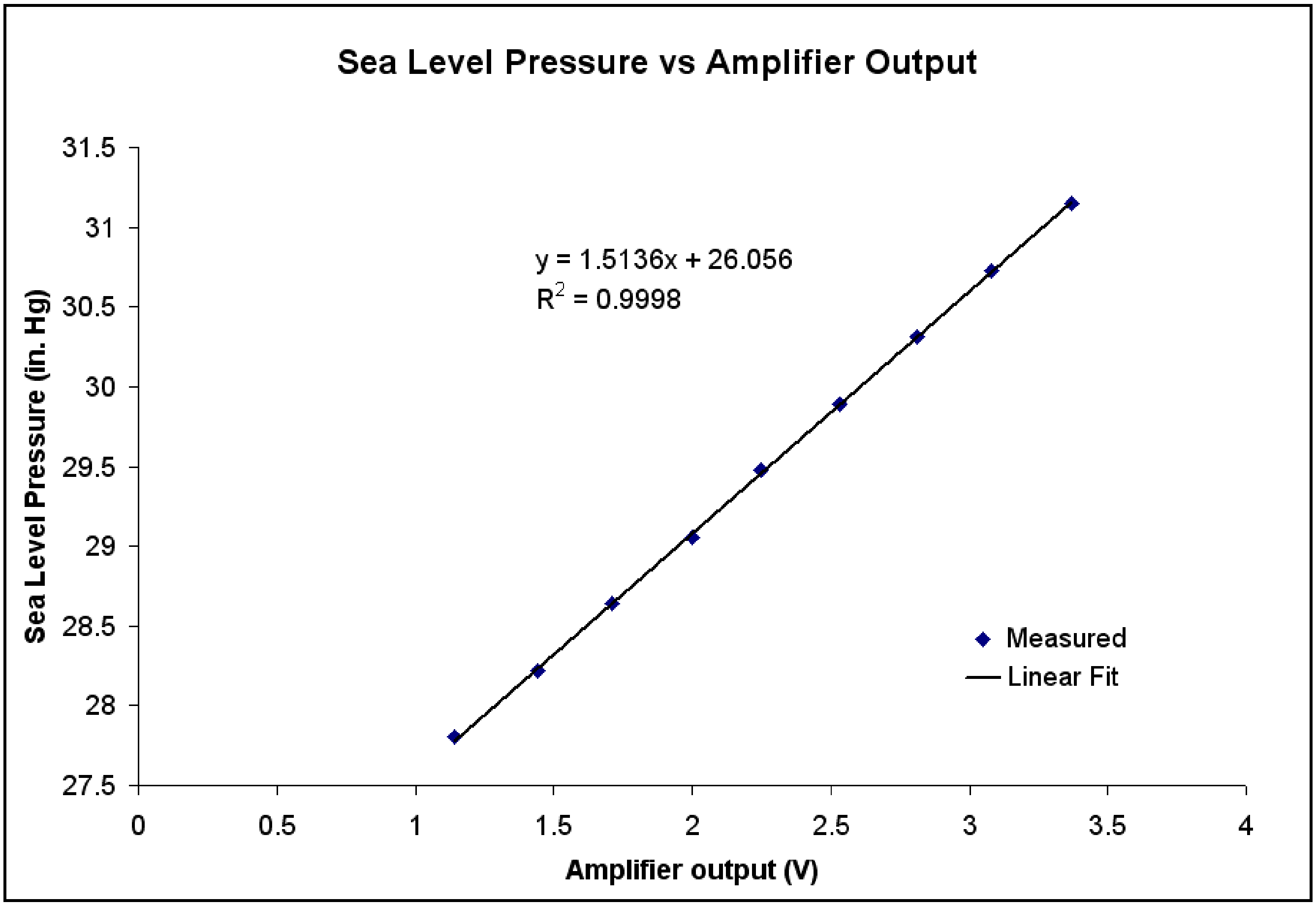


Figure 3. Calibration of Sea-Level Pressure to Amplifier Output Voltage.

A/D Converter

Unlike David Bray's design, I selected a 12-bit serial A/D converter for my barometer, the Microchip MCP3201. The MCP3201 takes three inputs. V_{REF} (pin 1) is a reference voltage that sets the upper limit for voltage measurements. V_{IN+} (pin 2) is the positive analog input and is where the actual voltage to be measured. V_{IN-} (pin 3) is the negative analog input and must be within 100 mV of ground. It can be used to cancel small-signal common mode noise that is present on both the V_{IN+} and V_{IN-} inputs. Here we simply ground V_{IN-}. Given those inputs, the output of the MCP3201 will be a 12-bit integer given by

$$N = 4096 \cdot \frac{V_{IN+} - V_{IN-}}{V_{REF}}$$

Equation 3

For this design I've set V_{REF} to be 5 V. Note that the range of the output is from zero to 4095.

The other pins of interest on the MCP3201 are CS/SHDN (pin 5), D_{OUT} (pin 6), and CLK (pin 7). These pins are used to get the MCP3201 to send the digital output one bit at a time to the PIC. CS/SHDN is used to signal the MCP3201 to make a measurement and send it to the PIC. The CLK (clock) line is repeatedly toggled between high and low to synchronize the data output between the MCP3201 and the PIC. The D_{OUT} line is used to actually send each bit. Here's how it works. CS/SHDN is held high until it's time to take a voltage reading, at which point it must be taken to ground. The MCP3201 will then begin to sample the voltage inputs as soon as the CLK line is taken from low to high, and the sample will end in the falling edge of the second clock. The D_{OUT} line is set to high or low on the falling edge of each subsequent clock cycle to signal the value of the bit being sent. After all twelve bits are sent (the most significant bit sent first), the CS/SHDN line must be taken high again before another measurement can be made.

It should be fairly obvious at this point that once we have the number from the MCP3201 it's a piece of cake to compute the pressure. Simply use equation 3 to determine the voltage from the number received from the MCP3201, and then use the formula given on the graph in Figure 3 to find the sea-level pressure.

Along with the usual PIC code and PC software, you'll find a spreadsheet available for downloading as part of this installment that automates the process of creating your calibration formula and generating the calibration numbers that you'll need to stick into the PC code. Numbers colored in red in that spreadsheet are the values you'll need to enter. You'll enter the elevation above sea level for your station and the minimum and maximum sea level pressure values over which you'll want to measure (28 and 31 in. Hg are suggested). The spreadsheet will then tell you the minimum and maximum output voltages of the MPX4115 pressure sensor for which you should calibrate your amplifier. Once calibrated, you can enter the input and output amplifier voltages like what are in Table 1, and the spreadsheet will calculate the M and B values (slope and y-intercept) that you'll enter into the PC software.

PIC Code

As the schematic indicates, the MCP3201's CS/SHDN line is connected to RB5 on the PIC, the DOUT line is connected to RB6, and the CLK line is connected to RB7. The PIC code that was needed for the barometer was fairly simple. First, I added a handler for the 'p' command so that we had some way of signaling the PIC to get the pressure and tell us what it was. Second, I added subroutine TellPressure to do the actual communication with the MCP3201. TellPressure starts the measurement by taking RB5 low to signal the MCP3201 to start measuring. Then RB7 (the clock) is cycled twice to complete the measurement. After that, subroutine GetPressureByte is called twice to get the data. Before calling GetPressureByte, the FSR register is loaded with the address of the register in which the data should be stored, and the W register is loaded with the number of bits to get. The first call to GetPressureByte gets the most significant four bits (into the hi register), and the second call gets the remaining eight bits (into the lo register). Once the lo and hi registers are loaded, SendAsciiNum is called to send the pressure value to the PC via the serial port.

If you're not familiar with their use, the FSR and INDF registers are special registers that give you the ability to do indirect addressing. If you address the INDF register with an instruction, you are really addressing the register whose address is stored in the FSR register. In the GetPressureByte subroutine, you'll see that the value of RB6 (the data line from the MCP3201) is always written to bit 0 of INDF, and then INDF is rotated to the left to make room for the next bit. By preloading the FSR register with the address of either the lo or hi register, the GetPressureByte subroutine can write to either register, making it more versatile. Another use of the FSR and INDF registers is if you need to perform some action on a range of contiguous registers. Simply by incrementing the FSR register you can use INDF to address each register in the range sequentially.

Data Acquisition

Once I had the circuit sending pressure data over the serial port, I did a quick modification to my PicWx PC software so that it would get the data and use the formulas given above to compute sea-level pressure. I also had it write the raw A/D output and the computed sea-level pressure out to a data file along with the date and time of each measurement. I set the software to read the pressure every five minutes and let it run for a couple days.

While I was accumulating pressure data from the circuit, I went to the web in search of National Weather Service pressure measurements that I could compare to the pressures I was measuring. I discovered that a two-day history is available for practically every reporting location. To find this data for your location, go to http://weather.gov/ and enter your city and state in the space on the left side of the page to get to your local forecast. On the web page for your local forecast, you'll see an area labeled "Current Conditions," where the current weather conditions and the place they're being measured are reported. Just below that is a link to the "2 Day History". Click that link to see hourly observations for the previous 48 hours.

After I had collected a day's worth of data, I was eager to see how well it compared to the official NWS data, so I used Excel once again to make a graph, shown in Figure 4. As you can see, the agreement between my measured data and the NWS data is excellent. I had thought that I'd need to adjust the calibration formula once I compared to real measurements, but I can't see how I could improve the agreement appreciably.

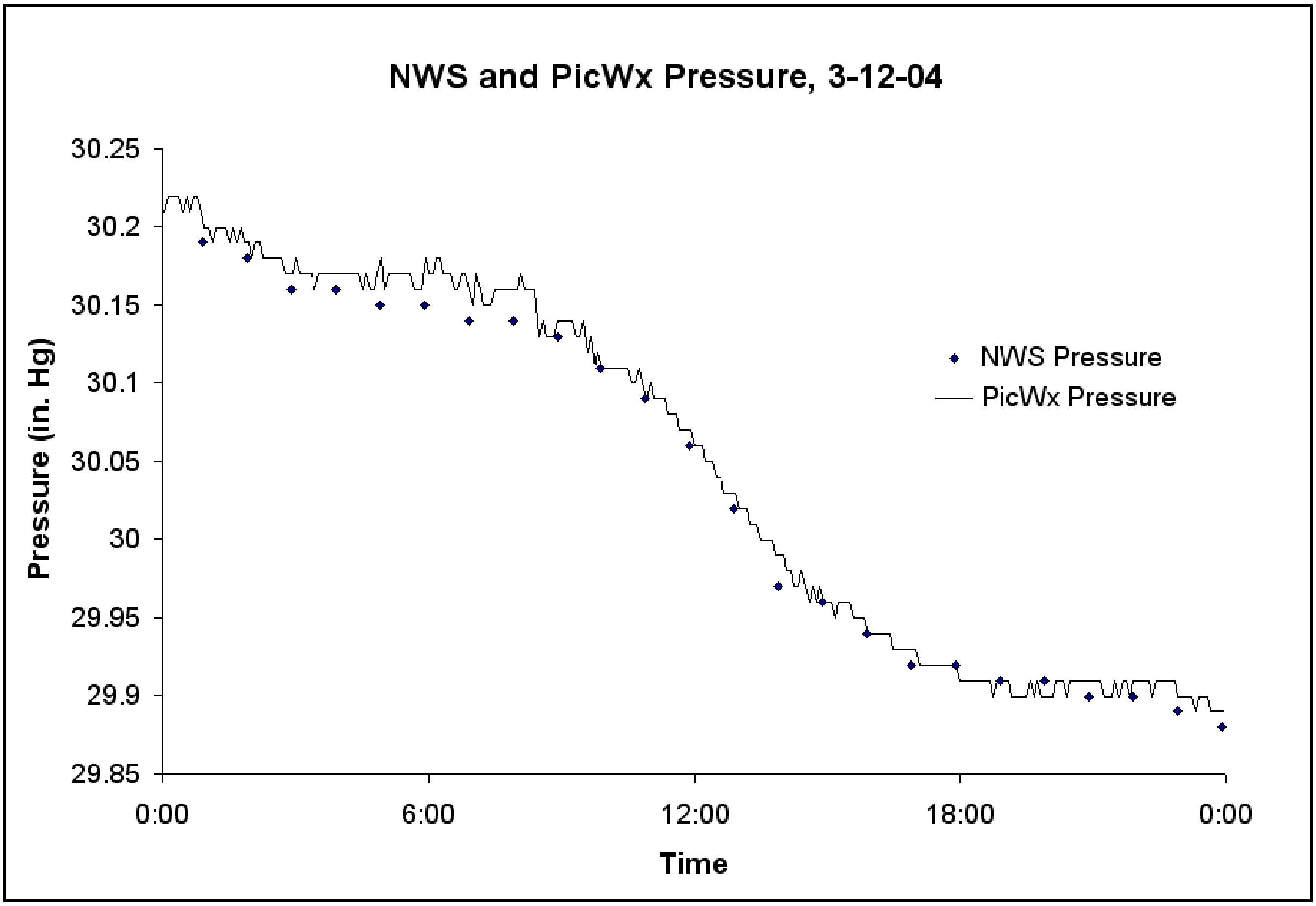


Figure 4. Comparison of PicWx measured pressure with NWS measurements

PC Software

I updated my PicWx PC software to include the measurement of barometric pressure. You can see the latest version in Figure 5. Figure 6 shows the settings dialog box, and this has changed quite a bit since the last version. First, now you can select among various units for displaying your data. I received several requests for metric units, so now you Canadians and Europeans can hopefully see the readings in familiar units (if I missed some, let me know). The settings screen also includes the calibration values for the barometer. Simply take the values created for you in the spreadsheet I told you about earlier in the article, and transfer them to the fields shown in this dialog box. Nothing to it, right? Finally, I enabled the logging feature so that you can capture the data you measure to a file for later examination. Simply check the box, and the data will be logged into a file named picwx_XXXXX.log (where XXXXX is “temp”, “hum”, “pres”, “dewpt”, or “wind”) in the same directory where you installed the PicWx software (probably \Program Files\PicWx). It’s very easy to import the contents of these files into a spreadsheet for graphing.

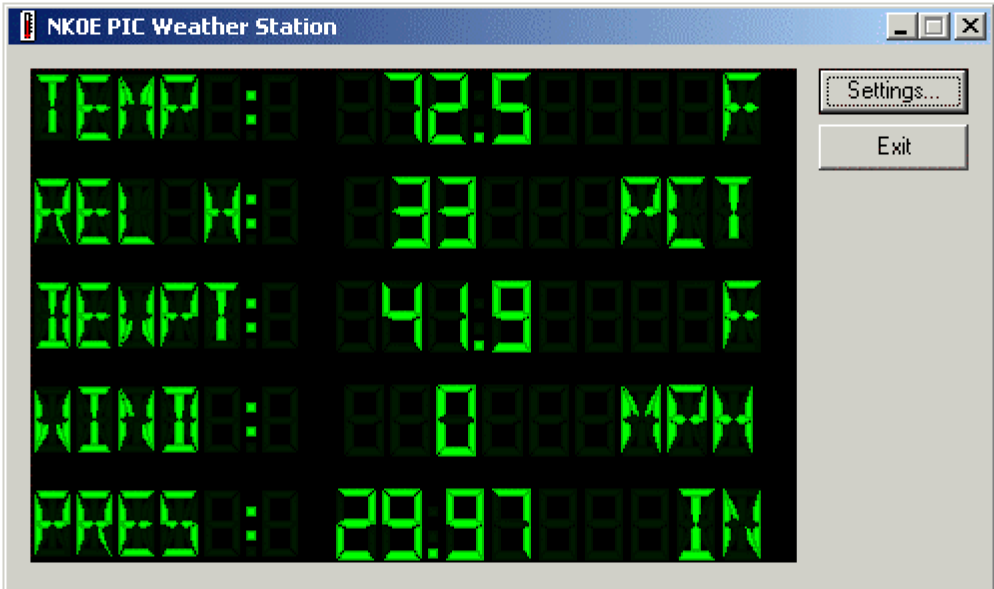


Figure 5. The PicWx PC software main window

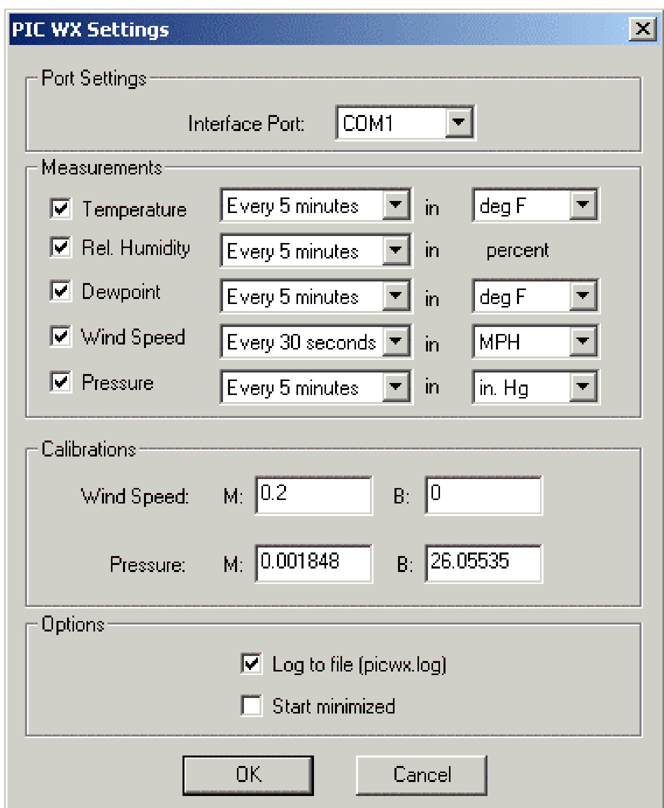


Figure 6. The PicWx PC Software settings dialog box.

Wrap-up

Be sure to grab the Microsoft Excel spreadsheet along with the software for the PC and the PIC from the NJQRP web site, so you can quickly and easily create your own calibration data. By the way, if you're not lucky enough to have access to Microsoft Office, there is a free alternative called Open Office that's very good and can handle files created by Microsoft Office. It's a big download (over 50 MB), but it's a good alternative to shelling out big bucks for Microsoft's package. You can find it at www.openoffice.org.

That's all for this installment. I'm keeping the topic of the next installment a secret (even from myself, until I figure out what it's going to be about). Keep those cards and letters coming!

73, Dave NK0E

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i[i] U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington , D.C. , 1976.

ii[ii] http://davidbray.org/onewire/barometer.html

David Ek, NK0E may be reached by mail at 5605 Oro Grande Drive, Colorado Springs, Colorado 80918, or by email at david.ek@earthlink.net

Continue reading in Part 7

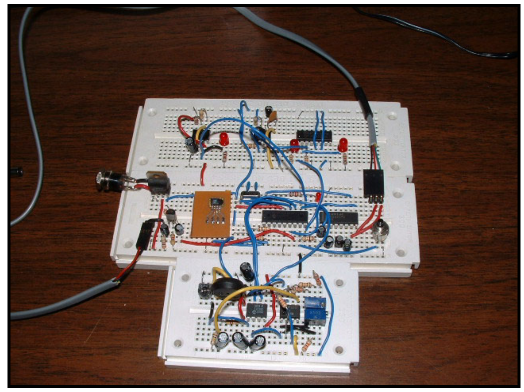
AmQRP.ORG HOMEBREWER

David Ek, NKØE

The PIC-based APRS Weather Station Project

... Part 7: Rain Measurement

Adding a Rain Gauge to this ongoing fun and educational project.



PIC Source Code **PC Program**

Hi Gang! I'm back with another installment in the PIC Weather Station project. This time, we're going to add a rain gauge. Mike Fenske VE7MKF was kind enough to send me a link to his web page where he shows how he's built his weather station based on my series of articles here in the Homebrewer. His page is at

http://www3.telus.net/ve7mkf/wxstation.html

Plus, he has a link to another web page describing yet another homebrew APRS weather station, complete with a homebrewed rain gauge. I'd been wondering myself how to build one, so this page was a great find. It's at

http://www.theworks.com/~wa6ylb/wxstn.htm

If you'd prefer to buy rather than build, check out this page for an inexpensive rain gauge that should also work (thanks to Nick Kemp for this tip):

http://www.fascinatingelectronics.com/index.html

Both of these rain gauges (as well as many other commercial ones) are of the "tipping bucket" variety. Figure 1 should give you an idea of how they work. The funnel collects and concentrates the rain so that it ends up in either the left side or the right side of the bucket. When that side of the bucket gets full, it gets unbalanced and tips, pouring out its contents and putting the other side of the bucket in place for filling. Each time the bucket tips, a magnet attached to the bucket passes by a magnetic switch, causing the switch to momentarily close. Our PIC circuit will sense the switch closure and increment a counter for each bucket tip. The PC software will ask the PIC circuit for the current tip count and convert that to an amount of rainfall by multiplying by a calibration value.

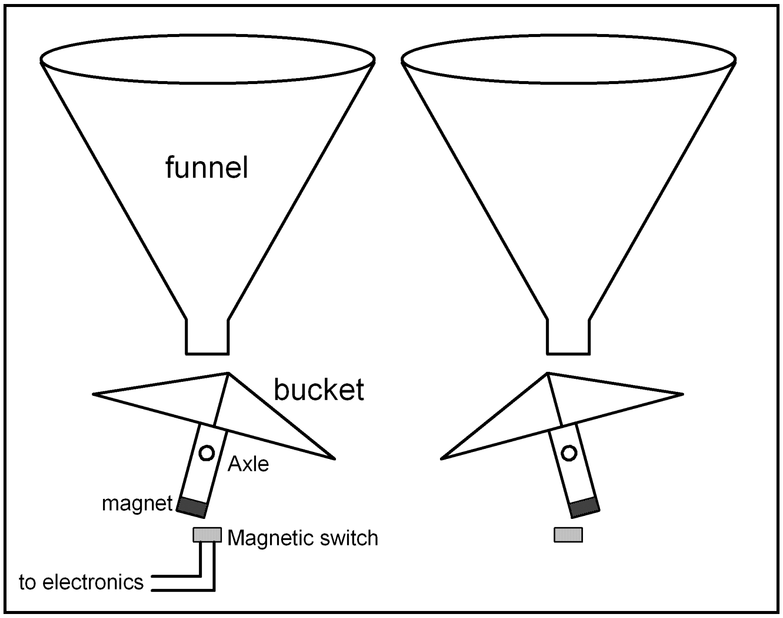


Figure 1: A Tipping Bucket Rain Gauge (showing the bucket tipped both ways).

Pulse Counting

It's a fairly simple matter to connect the magnetic switch from the rain gauge to a +5V supply so that we can drive one of the PIC's pins high whenever the switch closes. Then it's just a matter of watching that pin in the PIC code and incrementing a register each time the switch closes and then opens. Can it really be that simple?

Well, no—it's more complicated than that. The problem is that we have the PIC busy doing all sorts of things and it might miss the momentary switch closure. Our rain sensor is different from the others in that, for the other sensors, the PIC isn't doing anything while it's waiting for a command to read one of the sensors. But our rain sensor requires constant attention lest it misses a bucket tip and reads incorrectly. So, if a bucket tip happens to occur while the PIC is busy reading one of the other sensors, we need some way of remembering that information until the PIC can get to it. My solution to this problem was to use a flip-flop to latch onto the momentary pulse from the magnetic switch and remember it long enough for the PIC to have a chance to detect it.

Flip-Flops

No, we're not talking about the kind you wear on your feet—a flip-flop is an electronic circuit made from digital gates that has the ability to assume either of two stable states, depending on the input it's given. Figure 2 shows the most basic type of flip-flop, the RS flip-flop. It has two inputs, S and R (for Set and Reset), and two outputs, Q and No, we're not talking about the kind you wear on your feet—a flip-flop is an electronic circuit made from digital gates that has the ability to assume either of two stable states, depending on the input it's given. Figure 2 shows the most basic type of flip-flop, the RS flip-flop. It has two inputs, S and R (for Set and Reset), and two outputs, Q and $\overline{Q}$ ($\overline{Q}$ is always the opposite of Q; the bar over the top indicates it’s "NOT Q"). From the logic diagram in Figure 2, you can see that a momentary pulse on the S input causes Q to go high and stay high until a momentary pulse is received on the R input. In an RS flip-flop, R and S should not be allowed to go high at the same time because it results in an uncertain state for Q.

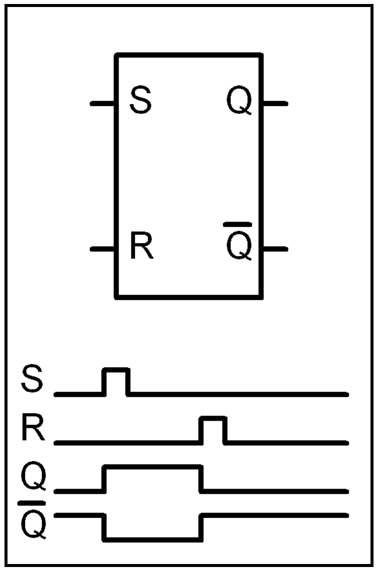


Figure 2: The RS Flip-Flop.

A more commonly-used flip-flop, the JK flip-flop, is shown in Figure 3. The JK flip-flop has three inputs: J and K, which function much like S and R in the RS flip-flop, and a CK, or clock, input. The difference between the operation of the RS and JK flip-flops is that the outputs of the JK flip-flop will only change state on the leading edge of a pulse to the CK line. You can see in the logic diagram that even though the J input goes high, the Q output doesn’t go high until the subsequent pulse on the CK line. The same is true for the K input taking Q low again—it doesn’t happen until the pulse occurs on the CK line.

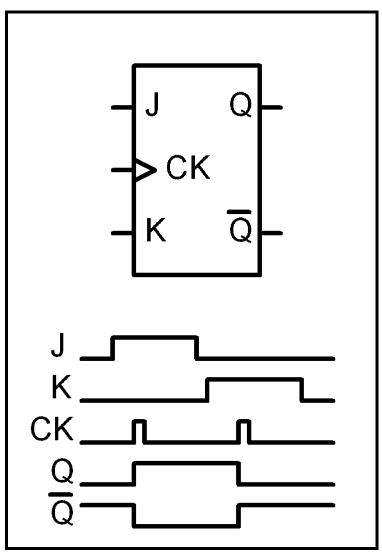


Figure 3: The JK Flip-Flop.

One other difference between the RS and JK flip-flops is that it's okay for both the J and K inputs to be high at the same time. In fact, that's a very useful state because it causes the outputs to toggle each time a pulse is received on the clock line. We're going to use this feature to latch onto pulses received due to momentary closings of the magnetic switch in the rain gauge. Then all our PIC needs to do is sense a state change on the corresponding input and increment its counter—something that it should be able to do at its leisure since we'd expect this to happen no more frequently than every few seconds.

Debouncing the Switch

There's one other little issue that we need to deal with. Switches have a nasty habit of "bouncing" when closed or opened. What is bouncing? The contacts don't close or open perfectly—instead, they bounce against each other a few times, making and breaking the connection until they come to rest. In many cases this is no big deal, but here it results in several pulses on the clock line each time the switch closes instead of just one. Obviously, this can royally mess with the accuracy of the rain gauge.

There are a number of techniques that can be used to debounce a switch. I happened to have a copy of Forest Mims' 555 Timer IC Circuits Engineer's Mini-Notebook laying around, and in it is a nice little circuit for debouncing a switch. If you examine the schematic for this installment (Figure 4), the first thing you'll notice is that I'm using a 556 instead of a 555. A 556 is essentially two 555's, and I'm using the second 555 for a purpose I'll describe later. Here, one half of the 556 IC (pins 1 through 6) is used in one-shot mode: a trigger pulse on pin 6 causes the 555 to generate a fixed-width output pulse on pin 5. R21 and C15 are the parts used to set the width of the output pulse (which is about 1 second here). Reducing the value of C15 to 1 uF will reduce the width of the output pulse to about 0.1 seconds. The key here is to make the output pulse width wider than the input pulse, but not so wide as to obscure the next input pulse. One second seemed like a good choice here. Figure 5 shows a logic diagram relating the input from the rain gauge's magnetic switch, the output from the 556 timer, and the Q output from the JK flip-flop. We now have a nice, reliable pulse train that should be easy to count with the PIC.

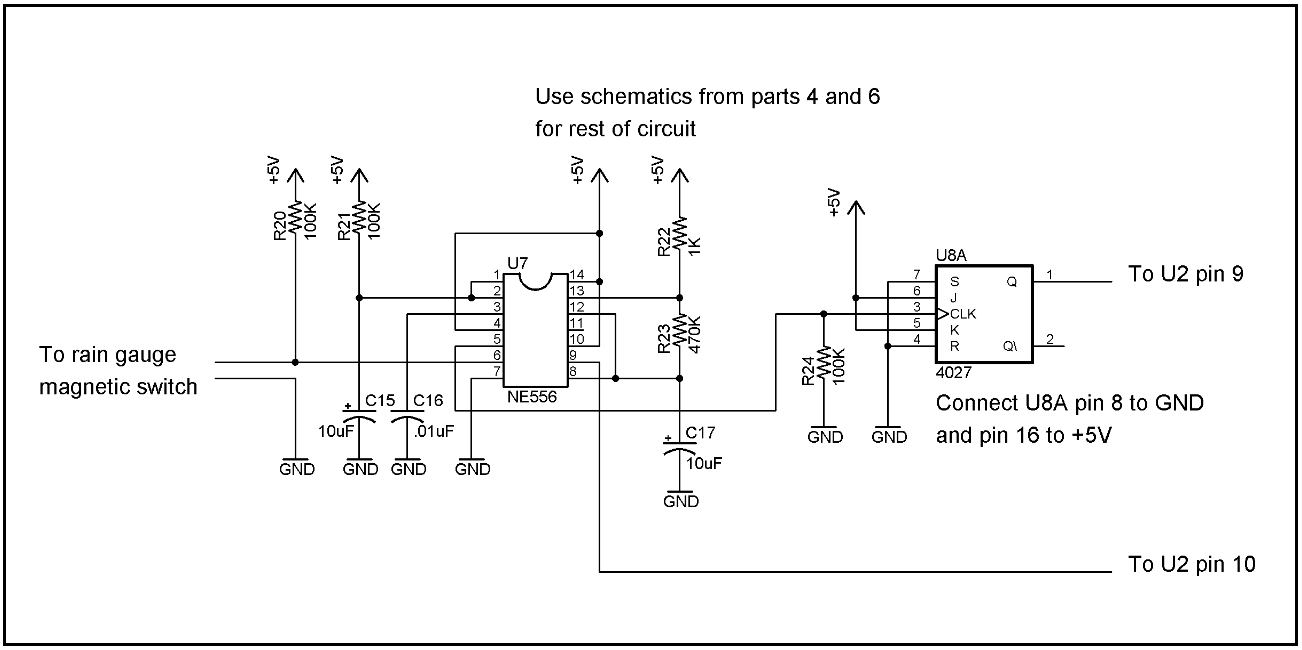


Figure 4: Schematic Diagram for PicWx Part 7.

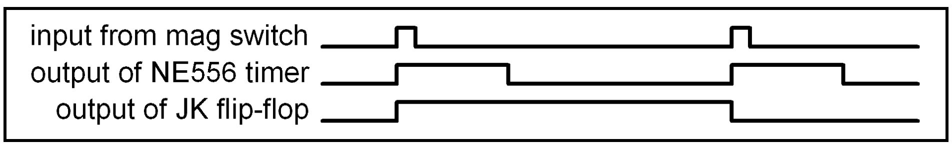


Figure 5: Rain Gauge Pulse-Sensing Logic Diagram.

Idle Processing

Now that we have a nice circuit for signaling the PIC whenever the bucket in the rain gauge tips, we have to teach the PIC to monitor that input and keep a counter of bucket tips. The PIC also needs to be able to report the counter value to the PC and reset the counter to zero on request. Let's begin with monitoring the rain gauge input. The input from the rain gauge is wired to pin 9 (RB3) of the PIC. Each time the input changes state (goes from low to high or high to low), the PIC needs to increment its rainfall counter.

The way we make sure to catch each state change is through a subroutine named Idle in the PIC code. Subroutine Idle is called whenever the PIC is checking for input from the PC, from subroutine GetAChar. So, Idle ends up being called very frequently, much more often than the state of the rain gauge input might change. Subroutine Idle calls another subroutine named RecordRainfall to do the actual checking of the rain gauge input. RecordRainfall remembers the previous value of the rain gauge input in a general-purpose register named RegSave, and compares it with the current value. If they are different, RecordRainfall increments the two-byte counter made up of RainHi and RainLo, saves the new state of the rain gauge input in RegSave and then returns.

To report the rainfall, the PIC responds to the 'r' command from the PC and simply sends back the current value of the two-byte rain counter (RainHi and RainLo) as a five-digit ASCII string, using the SendAsciiNum subroutine (just like for every other command). To reset the rain counter to zero, the PIC responds to the 'e' command and simply zeroes RainHi and RainLo (nothing is returned to the PC).

The Anemometer Revisited

I'm flattered that many of you have taken the time to follow along with this series and construct the PicWx station for yourselves. Some of you have even created your own variations. For example, Brian VE6OH wrote, "For the anemometer, I used a ball bearing PC fan with the CD disk and the 3 egg cups glued onto the fan hub top. I removed the fan blades, magnet and coil. Next I drilled holes in the side wall of the fan hub, then placed and aligned an optical sensor to pick off the pulses as the side wall holes turned past the IR led and IR receiver diodes."

I have to confess that I've never been completely happy with my implementation of the anemometer. One thing that I disliked is how I measured the wind speed in the PIC code. When the 'w' command is received, the PIC basically wastes 3 seconds to count the pulses being generated by the anemometer before it'll return a value to the PC. But seeing how I was using subroutine Idle to check the rain gauge input, I had to wonder how I could do the same thing to monitor the wind speed. The problem is that the wind speed needs to be measured over a fixed interval in time, and the only way I had up to now of measuring that interval was to have the PIC do it (to the exclusion of everything else). If I could somehow signal the PIC externally whenever it was time to stop one wind measurement and start another, then I could use subroutine Idle to do it.

The answer came to me when I pulled out the 555 timer Mini-Notebook and remembered that a 555 could be used to provide a continuous train of pulses (astable mode). If I could feed a steady stream of three-second pulses to the PIC from the 555, that would serve as a signal to the PIC to start a new measurement. If you examine the schematic in Figure 4, the second half (pins 9 through 13) of the 556 is configured to do exactly this. C17, R22, and R23 set the frequency of the pulse train. If t_1 is the width of the pulse, and t_2 is the time between pulses, then t_1 and t_2 are determined by the following formulas:

$$t_1 = 0.693\ (\ R22 + R23\ )\ C17$$

$$t_2 = 0.693\ (\ R23\ )\ C17$$

We want t_1 and t_2 to be the same, and they'll be essentially equal if R22 is small compared to R23. If we use a value of 10 uF for C17, then using 1K for R22 and 470K for R23 gives us a pulse width of about 3.25 seconds.

Triggering Wind Measurements

The output from this half of the 556 is fed into pin 10 (RB4) of the PIC. Subroutine Idle is used once again to monitor this line, and now the anemometer input line at pin 7 (RB1). After subroutine RecordRainfall is called to check the rain gauge, subroutine CountWind is called to check to see if the state of the anemometer input has changed. If you compare CountWind to RecordRainfall, you'll see that they are very similar in that they use the same exact method to count state changes and increment a counter. In the case of CountWind, the CountWindHi and CountWindLo registers are used to count the wind speed.

After subroutine CountWind is called in subroutine Idle, another subroutine called CheckWindInterval is called. CheckWindInterval monitors the RB4 line (from the 556). Whenever that line changes state, CheckWindInterval copies the contents of CountWindHi and CountWindLo into two other registers, WindHi and WindLo, and then zeroes out CountWindHi and CountWindLo to begin a new wind measurement interval.

Now, if the PIC receives the 'w' command, it simply grabs the data from WindHi and WindLo and sends it back to the PC as a five-digit string using subroutine SendAsciiNum. This is done immediately rather than waiting for a measurement to complete like was done before—WindHi and WindLo always hold the results of the most recent measurement.

One final thing—you'll notice that there is a call to WaitMS at the beginning of subroutine Idle. Without this call (which causes a delay of a millisecond), my wind measurements were all screwy—low wind speeds would give higher numbers than high wind speeds! I'm speculating that this was because at low wind speeds, the variation in the voltage of the anemometer input was less, and it was spending a lot of time in the voltage region where the PIC port would transition from high to low. This probably led to lots of extra transitions that weren't what we wanted to count (kind of like switch bounces). Waiting a millisecond between measurements seems to eliminate most of those.

Note that you might need to recalibrate your anemometer after this installment. I tried to make the measurement interval the same as before (three seconds), but there will probably be some variation in the new interval due to parts tolerances and such. Alternatively, you can try to fine-tune the value of R23 to match your original calibration.

Construction

Figure 4 shows the portion of the circuit we added for this installment. Refer to installments 4 and 6 for the remainder of the schematic. U7 is the 556 timer chip and U8 is the flip-flop, a 4027 dual JK flip-flop. U8 actually contains two flip-flops. Only one half of U8 is used here. The 4027 is a CMOS device and is especially susceptible to damage from static electricity, so use care in handling it. Both of these chips are inexpensive and readily available. Here are some catalog numbers:

Part	Digikey	Jameco
556	296-6504-5-ND	24328CL
4027	296-2044-5-ND	12888CL

When I built this circuit, I connected each of pins 1 and 2 of the 4027 to an LED in series with a 1K resistor to ground, so that I could see the outputs go high and low as I simulated the magnetic switch pulses by momentarily grounding pin 6 of the 556. I did the same thing with pin 9 of the 556 so I could watch the pulses signaling the wind speed timing intervals to the PIC. The LEDs aren't needed for normal circuit operation, of course. It's just an easy way to verify correct operation of the circuit.

Calibration and the PC Software

The web page showing the homebrew rain gauge also gives instructions on how to calibrate it. Ultimately, what you need to know is the amount of rainfall that corresponds to one bucket tip. This is the number you'll need to enter into the Settings dialog of the PicWx PC software. When you start the latest version of the software, downloaded from the Digital QRP Homebrewing web page at

http://www.njqrp.org/digitalhomebrewing/

just click the Settings button and enter the calibration value in the space provided. Hit the "Empty" button when you want to reset the rain gauge.

Wrapping It Up

Well, if you've been keeping track, we've use all of the PIC I/O lines except for RA4. The only thing I can think of to add at this point is a wind direction sensor, but I don't know how to do that with only one input line available. So, the next installment will wrap up the PicWx series by talking about some options for deploying the weather station outdoors, and hooking it up (finally) to my APRS software and getting the measurements out onto the APRS system. Hopefully, I'll also be able to announce the availability of PC boards for the project. Mine's all on solderless breadboards right now, and I'm sure not going to put those outside! Figure 6 shows my rat's nest, in case you're curious.

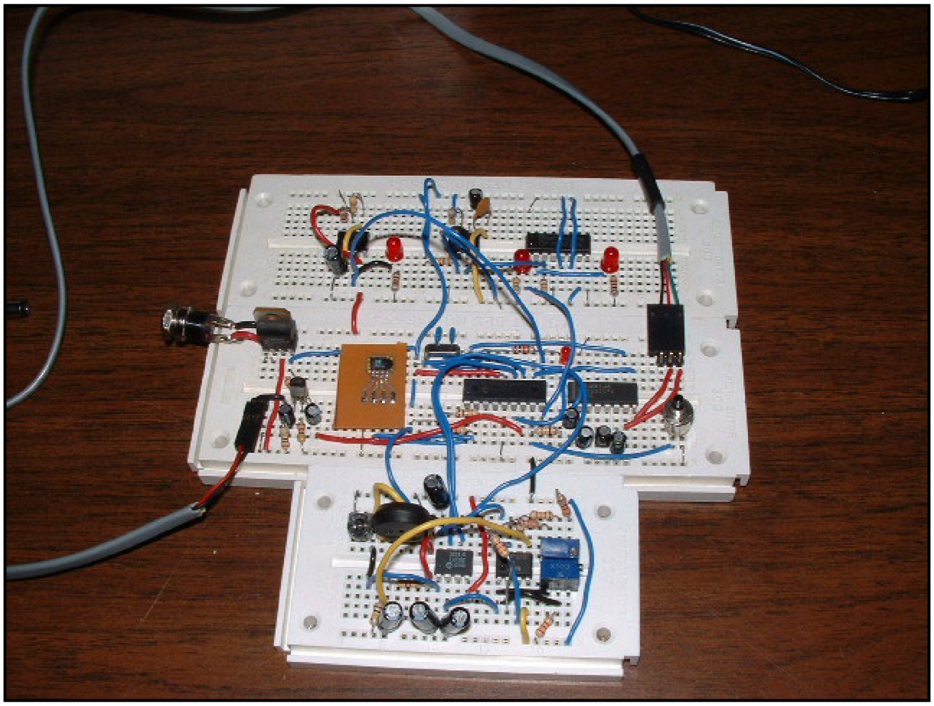


Figure 6: My PicWx project on its solderless breadboards.

Thanks for following along. I know it's been a long trip, but it's been a fun trip, too. Until next time, 73 de NK0E.

David Ek, NK0E

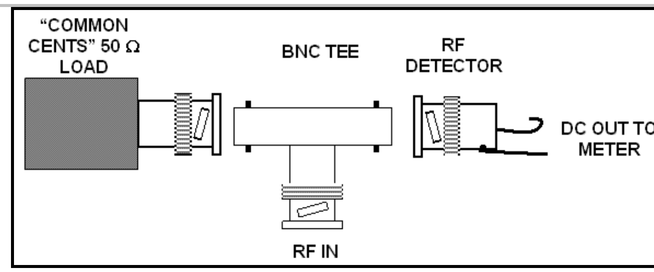
nk0e@earthlink.net

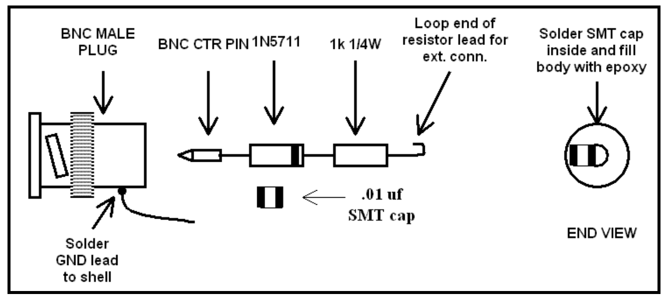
AmQRP.ORG HOMEBREWER

Joe Everhart, N2CX

RF Power Meter Cookbook … Part 5

Previous installments in this series have discussed the theory behind a number of RF power measurement techniques, and have provided pros and cons for each. Now it is time for N2CX to present a real working design!





In writing this article series, it became obvious that trying to present too much material in each installment was a hopeless task. What began as a two-part series has now significantly grown. A single article simply does not have the space needed to provide adequate descriptions of the circuitry, construction methods and calibration. It became apparent that the series demanded expansion to do it well.

This time around we will see a design implementing a simple terminating wattmeter as outlined in Ref 1. Two ways of monitoring the power are presented. The first implementation uses an analog microammeter with a calibrated scale, and the second uses the NJQRP QuickieLab to measure, compute and display the RF power. Calibration methods will be outlined for both types of display that use no more than common components and an inexpensive digital multimeter (DMM).

In future installments of this article series, I will describe a working forward and reverse RF wattmeter using a broadband directional coupler and a similar device using a resistive reflectometer.

Terminating Wattmeter

As mentioned in Part 1, the terminating wattmeter is about the simplest wattmeter one can build. As you can see in **Figure 1** it consists of a 50 ohm dummy load and a detector that measures the RF voltage across the load and an analog or digital power display. The load itself is ideally within 1% of 50 ohms needs to be able to dissipate at least the maximum power that the meter will measure. Both the precision load and the detector can be used with either display method discussed in this article.

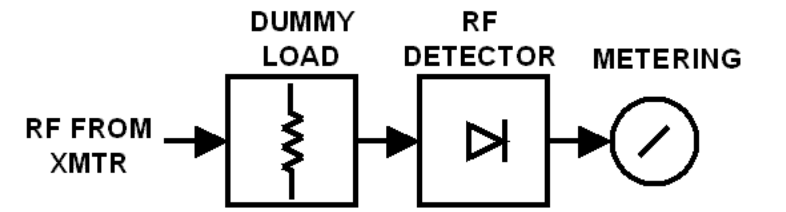


Figure 1 – Terminating Wattmeter Functions

Dave Ottenberg, WA2DJN described a simple load he called the “Common Cents” dummy load which was described in Ref 2 and shown in **Figure 2**. Using 1-watt resistors, it is capable of dissipating 4 watts for extended periods of time, or 5 watts for short periods. It consists of four paralleled 200-ohm resistors connected directly to a BNC male connector. The parallel combination is chosen to equal exactly 50 ohms. For simplicity, you can use an ohmmeter to select from a number of resistors to get a final value that is very close to ideal. If you use good quality carbon or film resistors, you will have a good match across the HF bands.

Figure 2 – Common Cents QRP Dummy Load (WA2DJN)

I chose another method for one of my loads as shown in **Figure 3**. It consists of four 3-watt 200-ohm film resistors connected in parallel and wired to a board-mount BNC female connector. The board was a scrap board with pads for mounting the BNC connector. Other traces were removed from the underside and the resistors were hand-wired. I purchased ten resistors and selected four that measured within ½ ohm of 50 ohms. The other resistors will be used for non-precision dummy loads.

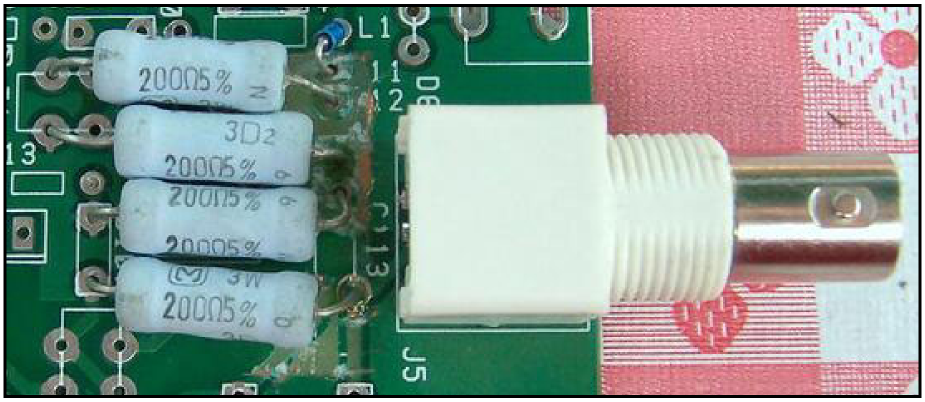


Figure 3 -- N2CX HB Dummy Load

Figure 4 diagrams the RF detector. It is similar to the one described in Part 2. I decided on using a 1N5711 Schottky diode for the detector rather than using 1N34 diodes since there is much less unit-to-unit variation and less error caused by temperature variation.

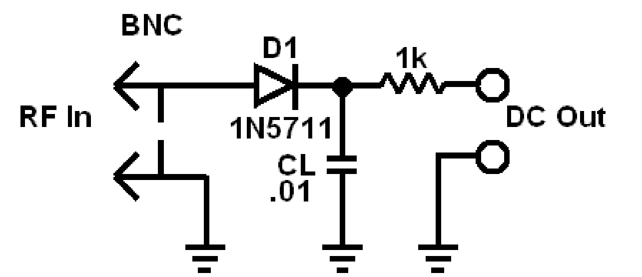


Figure 4- RF Detector Circuit

The detector is mounted in a BNC connector as illustrated in **Figure 5**. A resistor is used in series with the detector diode since it is physically more rugged. The value isn't critical – I used 1K but anything of that value or smaller is fine.

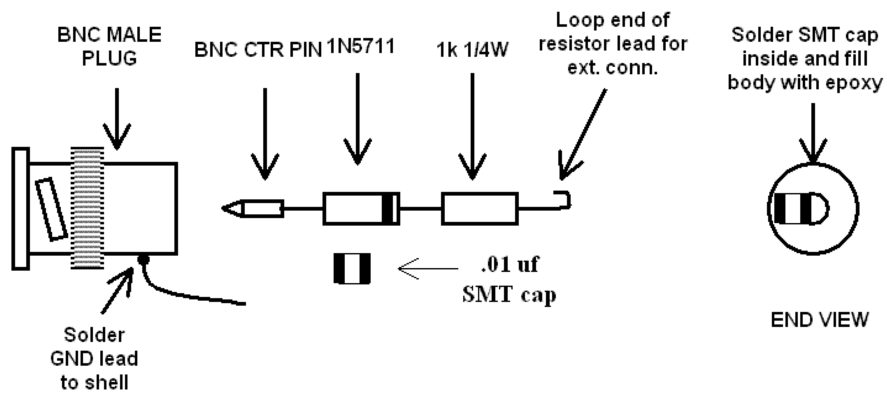


Figure 5 - BNC- Mounted Detector

The wattmeter components are connected as shown in **Figures 6 and 7** for both types of dummy load described above. Now let's talk about how to measure and display the power readings.

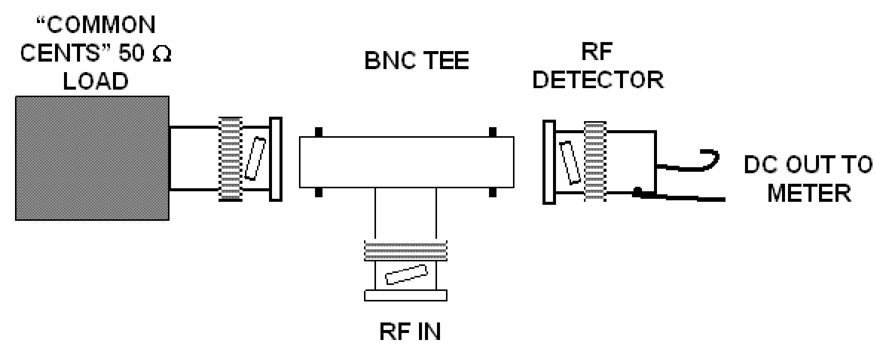


Figure 6 - Terminating Wattmeter Components BNC Male on Load

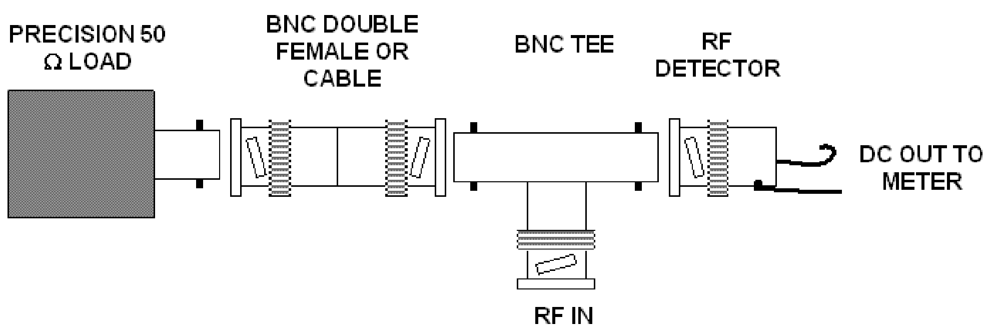


Figure 7 - Terminating Wattmeter Components BNC Female on Load

Analog Metering

Perhaps the simplest way to display the measured power is to use an analog meter. For best sensitivity, a microammeter could be used if available. I regularly scrounge at hamfests to locate them for reasonable cost, and sometimes have purchased old projects for a couple of dollars knowing that I could salvage a perfectly good meter, even if the rest of the circuit didn't work. I recommend a meter with a full-scale deflection of between 50 and 250 ua. Meters with less sensitivity load the detector too much, resulting in poor accuracy; more sensitive meters cost too much. One with a large face gives the best readability.

Figure 8 shows the analog metering schematic diagram. Component values are given for a power meter that has two ranges both with the QRPer in mind. The high range reads from 1 to 10 watts and the low range is 100 mw to 1 watt. Simply scale the resistors appropriately if you use a meter with a deflection other than 100 ua.

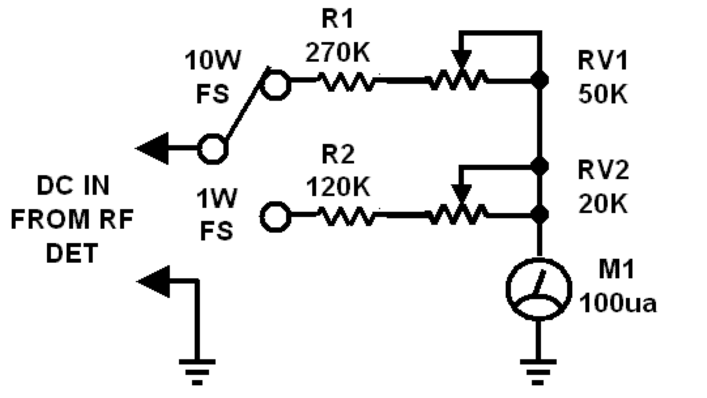


Figure 8- Display With Analog Meter

Analog meters have a linear display. That is, the needle deflection is exactly proportional to the current applied to its coil. For example, a 100 ua meter swings to full scale with a dc current of 100 ua, half way for a 50 ua current, and one-tenth full scale with 10 ua. The RF detector in the wattmeter outputs a voltage (which is made into a current by the display resistors) that does not vary linearly with RF power. The power is proportional to the square of the RF voltage. At 10 watts the RF voltage is 22.36V; at 5 watts it is 15.81V; and at 1 watt it is only 7.07V. This means that the linear meter scale cannot directly display the wattage.

There are two relatively simple solutions to this dilemma. The first is to use a calibration chart such as the sample in **Table 2**. The left-hand column is the meter reading (in this case 0-100) while the other column shows the corresponding power.

Table 2 – Sample Analog Power Meter Calibration Chart

Meter Reading	Power
100	10W
97.8	9.5
94.8	9
92.3	8.5
89.5	8
86.3	7.5
83.1	7
80.3	6.5
77.1	6
73.5	5.5
70	5
66.8	4.5
62.9	4
58.6	3.5
54.3	3
49.7	2.5
44.4	2
38.4	1.5
31.3	1
22	0.5

The second method is to make up an overlay for the meter scale marked directly with power. Either method is easy to do during power meter calibration. Making a new meter face gives a much neater appearance though it does require artistic skills. **Figure 9** shows the general idea. Also a multi-range wattmeter will require two sets of marking due to detector non-linearity.

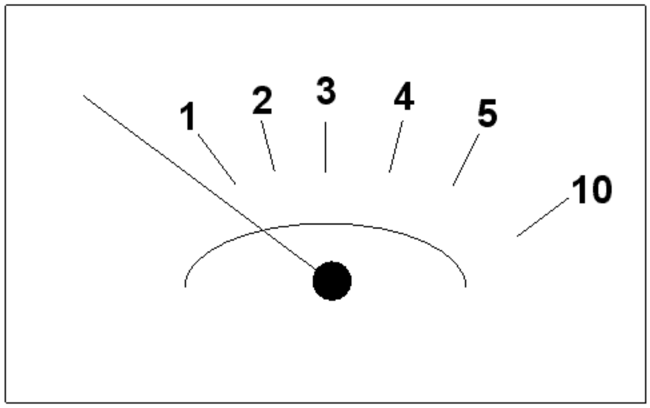


Figure 10 – Artist's Concept of a Hand-Calibrated Meter Face

Analog Meter Calibration

The calibration method here is a variation of the one described in Part 3 of this series. It relies on the wide bandwidth of the basic diode detector, which ranges easily from low audio frequencies up through at least 30 MHz. In fact, with the construction of Figure 5 and the 1N5711 Schottky diode, it will be quite usable at least to the two-meter amateur band.

Getting back to the task at hand, calibration will be done using a 60 Hz source. The only consideration needed for accuracy at this frequency is that a larger filter capacitor needs to be used. The 50-ohm dummy load is not connected for the calibration process.

Figure 10 details the calibration setup. The 60 Hz AC voltage is provided by a 25V transformer fed by the AC line. Alternatively, you can use two 12.5 VAC transformers in series. While not shown for simplicity, I suggest that you also use a power switch and a fuse rated at no higher than 1A in the primary circuit.

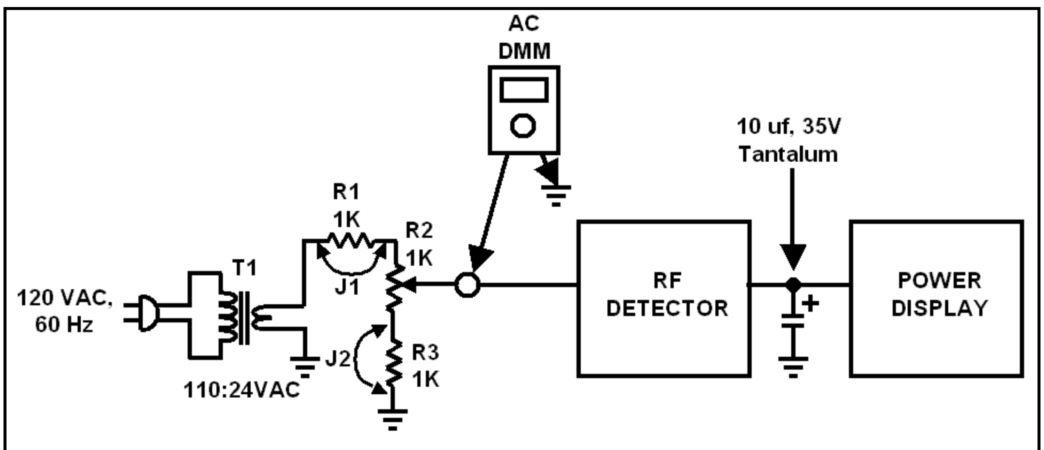


Figure 10 – Calibration Circuit

The 25 VAC is fed to a voltage divider consisting of R1, R2 and R3 to produce a variable voltage to take the place of the RF signal that will be seen in the power meter. R1 and R3 are not needed if you can find a 1K potentiometer rated at 1 watt or more. All of the ones in my junk box happen to have only a ½-watt rating. Since 25 volts across 100 ohms results in 0.625 watts, this is beyond the pot ratings.

Jumpers J1 and J2 are used across the resistors to give full adjustability from 0 to 25 volts. Use jumper J1 across R1 for about 16 to 25 volts, no jumper for about 8 to 16 volts, and jumper J2 for 0 to about 8 volts output. Note that only one jumper should be used at a time or the pot will burn up!

Capacitor C1 should be a good quality tantalum type with low leakage – a common electrolytic capacitor ***will not*** work here due to grossly high leakage. I used one similar to the AVX TAP106K035SCS, available from Digi-Key with their part number 478-1842-ND. Panasonic and Kemet also make suitable capacitors. Just be sure it is rated for 10 uF and has a rating of 35 or 50 VDC.

The calibration process is straightforward. First be sure to adjust potentiometer Rv in the metering circuit to its maximum value. Then jumper R1 with clip lead J1 and adjust R2 in the calibration circuit for the desired maximum power level – we will assume 10W. Now carefully set Rv such that the analog meter reads exactly full scale. Rv will not be touched again! Now go through the remaining voltages in Table 3 and record the meter deflection corresponding to each power level. This completes calibration.

Next, either make up a permanent meter calibration chart, or a custom meter face as described above. If the meter needs two power ranges, switch to the lower power position (assumed to be 0.1 to 1 watt) and repeat the calibration process for the values in Table 4. When the detector is used with the 50-ohm dummy load, it should provide excellent power reading accuracy. Remember that C1 is only part of the calibration setup so it is not connected to the final power meter.

Table 3- RMS Voltages for ½ to 10W

Power Level	RMS Voltage	Jumper
10W	22.36V	J1
9.5	21.79	J1
9	21.21	J1
8.5	20.62	J1
8	20	J1
7.5	19.36	J1
7	18.71	J1
6.5	18.03	J1
6	17.32	J1
5.5	16.58	J1
5	15.81	None
4.5	15	None

4	14.14	None
3.5	13.23	None
3	12.25	None
2.5	11.18	None
2	10	None
1.5	8.66	None
1	7.07	J2
0.5	5	J2

Table 4- RMS Voltages for 05 to 1W

Power Level	RMS Voltage	Jumper
1W	7.07V	J2
0.95	6.89	J2
0.9	6.71	J2
0.85	6.52	J2
0.8	6.32	J2
0.75	6.12	J2
0.7	5.92	J2
0.65	5.70	J2
0.6	5.48	J2
0.55	5.24	J2
0.5	5	J2
0.45	4.74	J2
0.4	4.47	J2
0.35	4.18	J2
0.3	3.87	J2
0.25	3.54	J2
0.2	3.16	J2
0.15	2.74	J2
0.1	2.24	J2
0.05	1.58	J2

Digital Metering

Digital metering for the RF power meter is based on a digital voltmeter that was developed using the NJQRP QuickieLab (Ref 3), an expandable microcontroller based on the Parallax BS2 Basic Stamp chip. It includes the BS2, a 5V regulator, a loudspeaker, a multifunction Input Output Expander (IOX) board, an experimenter plugboard, and a number of input and output connectors. The IOX chip adds an LCD display, a frequency counter and an Analog to Digital Converter (ADC). The experimenter plugboard provides a convenient way to build interface circuitry directly on the QuickieLab.

The QuickieLab is a convenient development platform for simple microprocessor projects by virtue of the included input and output provisions, the circuit plugboard, and the easy-to-use BS2 programming language based on the simple BASIC language. I like to think of the QuickieLab as an easy to use microcontroller breadboard. With it, the average homebrewer can develop numerous digital projects and easily program them. Complete details on the QuickieLab, and links to a wealth of information, can all be found on the web page referenced at the end of this article.

One of the applications written for the QuickieLab was called the Audio-Visual Voltmeter, or "AVV". See Ref 4. The application uses the plugboard to build up a simple interface amplifier that accepts DC inputs and buffers them before feeding the ADC (analog to digital converter) on the IOX. The digital output of the ADC is used to calculate the equivalent input voltage and display the numerical result on the LCD. Pushbuttons on the QuickieLab allow for selection of this visual display, or an audible output in Morse code, or a tone whose pitch rises with increased input voltage.

Except for the input amplifier, all connections for the power meter display are the same as for the AVV. See the web reference for details. Since the AVV was designed for an input voltage of only 2 VDC, the DC output from the power meter RF detector is much higher. The modified RF power meter interface amplifier is shown schematically in **Figure 11**.

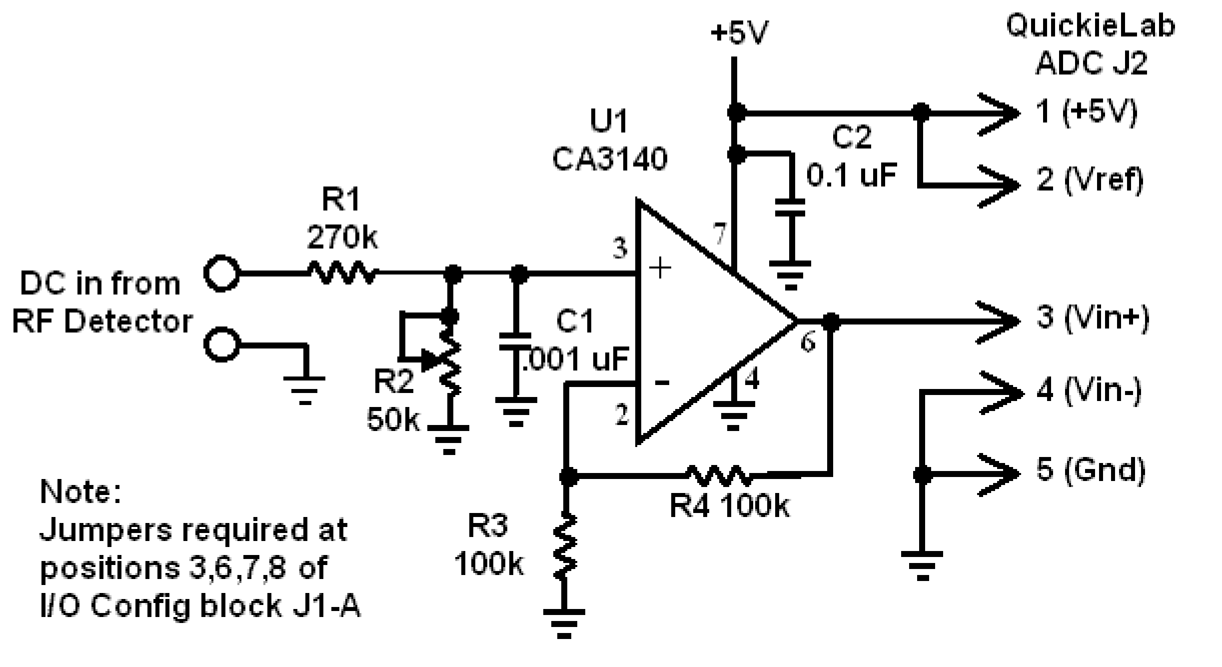


Figure 11 – RF Power Meter Display Input Amplifier

The input buffer amplifier takes the RF detector output, which can be over 30V, and scales it down to no more than the 5V input allowable by the ADC. It also buffers the signal to lessen errors that might occur if a high-impedance voltage input were supplied to the ADC. Finally the 5V DC power source is jumpered to the ADC reference input.

Digital power display operation is the same as the AVV. DC from the RF detector is fed to the buffer amplifier as shown in Figure 6 and the QuickieLab outputs a numeric power indication. On power up, the “display” appears visually on the LCD screen. One press of the QuickieLab pushbutton instructs the setup to provide a Morse code audible output corresponding exactly to the visual display, including the numeric value and the letter “W” to indicate watts. A second press of the pushbutton results in an audible tone whose pitch is proportional to RF power. The latter is handy for a “near-analog” indication while making adjustments on an RF circuit. A third press of the pushbutton returns the unit to the LCD readout.

Digital Meter Calibration

Calibration of the digital metering circuit is even simpler than for the analog meter. Use the same basic circuit as for the analog calibration (Figure 9) except, naturally, connect the digital readout circuit instead of the analog meter. Do not apply AC input to the 24V transformer yet.

Turn on the QuickieLab power and make sure that the output display is set for visual readout. It will probably read close to 00.0W since there is no input.

Now connect only J1, which is the clip lead across R1 in the calibration circuit. Apply AC to the transformer and set potentiometer R2 for a reading of 22.36V to the RF detector. The QuickieLab display should now have a reading. Adjust trimpot R3 on the buffer amplifier for a reading of 10.0 watts. This sets the full scale power indication. Calibration is now complete; however, you can check the readings for other power levels by setting R1 in the calibration circuit for the appropriate values, as shown in Tables 3 and 4. You will note that power displays show only one digit to the right of the decimal point corresponding to a resolution of 1/10 watt. If you do check the readings at various power levels, you will see that they are fairly accurate for powers of several watts, with lesser accuracy at lower levels. This is typical for a simple detector as used in this meter. Be sure to disconnect calibrator capacitor C1 before attaching the dummy load to configure the RF power meter.

Final Thoughts

The power meter circuits that have been described are capable of good operation for the average homebrewer without the need for expensive test equipment or sophisticated techniques. Accuracy is sufficient for day to day use. Calibration is performed at 60 Hz where an inexpensive DMM provides accurate readings. By following the construction and component recommendations given here, you will have an RF power meter with few frequency-related errors over the HF range.

The analog metering method has an accuracy that is dependent on the care taken by the builder to perform the calibration, and also the skill in making a custom meter face if that is done.

Total measurement error can be less than 5% over the range of 100 mW to 10W. It has the distinct advantage of providing and easy to read indications when used for monitoring power level changes during transmitter tuned where watching changing digits on an LCD screen can be confusing.

The digital display has the advantage of providing an unambiguous reading. It requires no squinting to tell exactly what a reading is, as opposed to when using an analog meter. However, the simple detector circuit and the unsophisticated computations provided by the QuickieLab rely on accurate detection by the RF detector. While the analog meter allowed us to calibrate out the error by using a calibration chart, the QuickieLab does not have enough computing power to perform detailed compensation. As described earlier, the error is small for inputs of several watts, but degrades at the low end of the measurement range. A later installment in this series will incorporate detector compensation methods described at the beginning of article series to provide improved accuracy for low power levels.

The software for the QuickieLab is currently not in a state that can be published. I had hoped to be able to provide at least a rudimentary version for inclusion with this article; but unfortunately, the current version does not yet work well enough to unleash upon the world. Development is proceeding and a good working version will be posted on the QuickieLab web page at the NJQRP site (Ref 3), hopefully by the time this article is publicly available.

References:

1. RF Power Meter Cookbook Part 2 Homebrewer #2, Fall 2003

2. The "Common Cents" QRP Dummy Load, by Dave Ottenberg, WA2DJN, NJQRP QRP Homebrewer, Issue #2

3. NJQRP QuickieLab - http://www.njqrp.org/quickielab/index.html

4. Audio Visual Voltmeter - http://www.njqrp.org/quickielab/AN1-AVV.html

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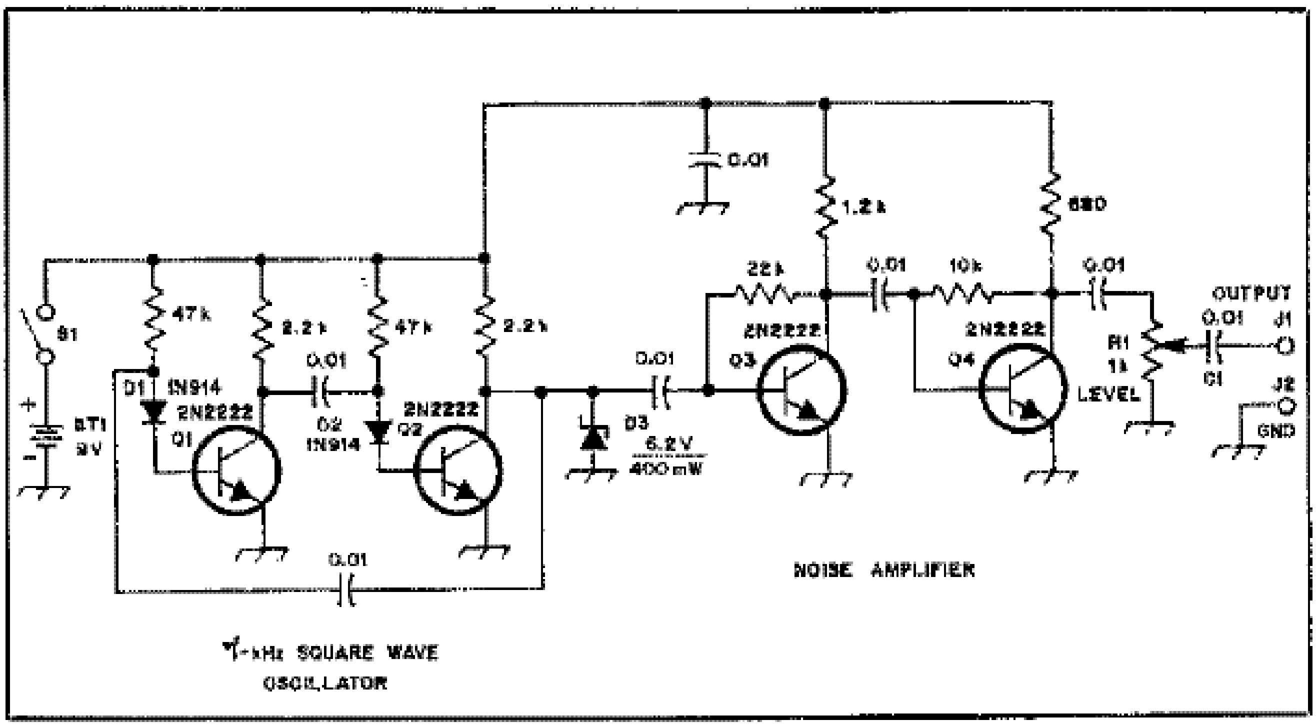
Dave Ottenberg, WA2DJN

Build this simple AF/RF Signal Injector

I recently visited a friend of mine, Jeff Harshman, and he took me down to his combined workshop-hamshack in the basement. He has a lot of test equipment and he showed me one of his favorite devices called a signal injector.

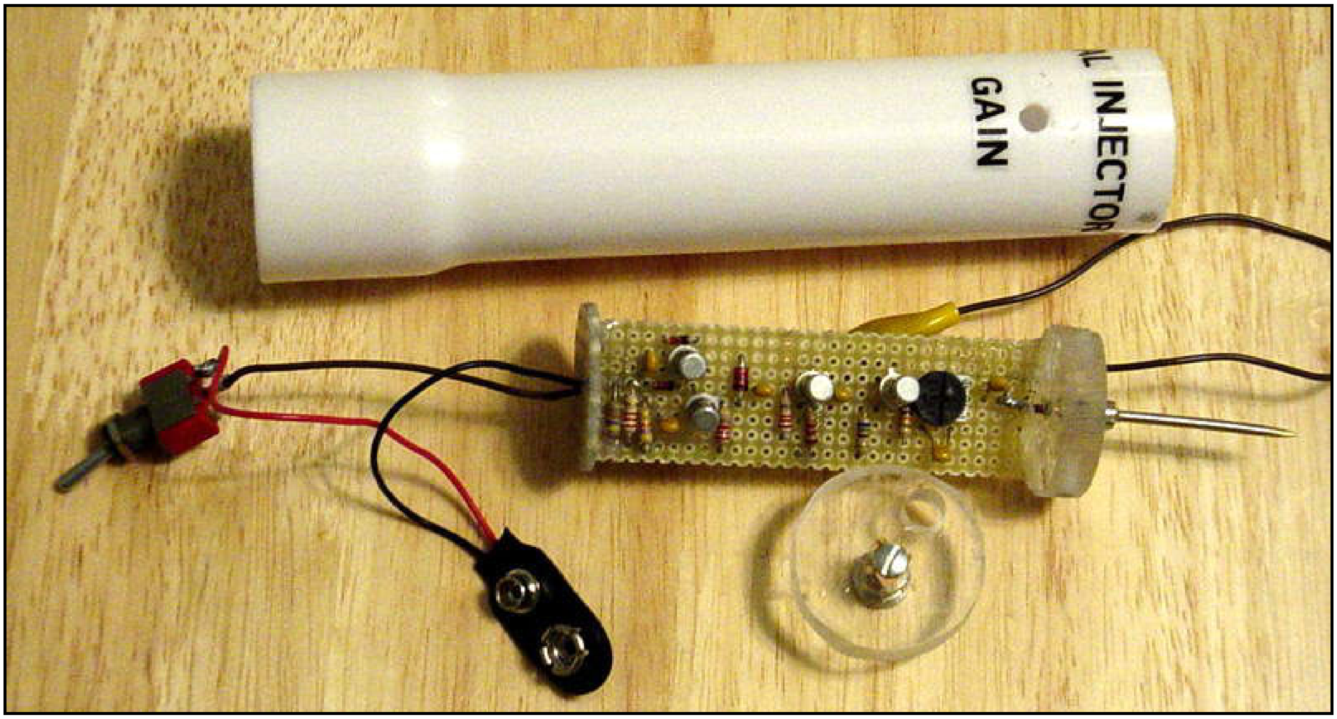


AF / RF Signal Generator

This device generates a 1 kHz tone that you can apply to the input of an audio circuit in order to troubleshoot it and get it working properly. The idea is that if you can see/hear the signal downstream, you know that the circuit-under-test is working. Further, the zener diode D3 acts as a noise generator that is useful for injecting RF into a receiver front end (for example) and you can hear a hissing if you put the probe of the injector on the antenna input. Q3 and Q4 serve as a two-stage amplifier to boost the test signals to usable levels.

I thought this instrument was pretty neat and I asked him for a copy of the circuit. Jeff graciously did that and also gave me a handful of parts that I could use in building up my own version of his signal injector.

I proceeded to build the circuit on perf board, and I purchased a 1-1/4" plastic drain adaptor at Home Depot for use as the enclosure. I then took some ¼" plastic and made some inserts to fit the drain adapter, and I mounted a test tip in one end and a switch in the other end.



I had to find some thin metal to shim the 9V battery in the rear of the drain adapter so it wouldn't rattle around inside the PVC enclosure. This battery now powers the signal injector. I labeled and tested the injector , then used my oscilloscope to trace it out to make sure it was working as intended before mounting everything into the drain adapter. I now can use this device to check amplifiers, receivers and othger circuits to find out if they are working properly.

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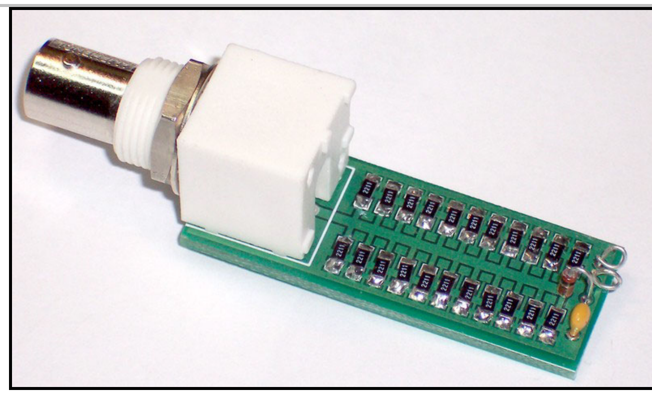
Tony Parks, KB9YIG

The SMT Soldering Practice Dummy Load

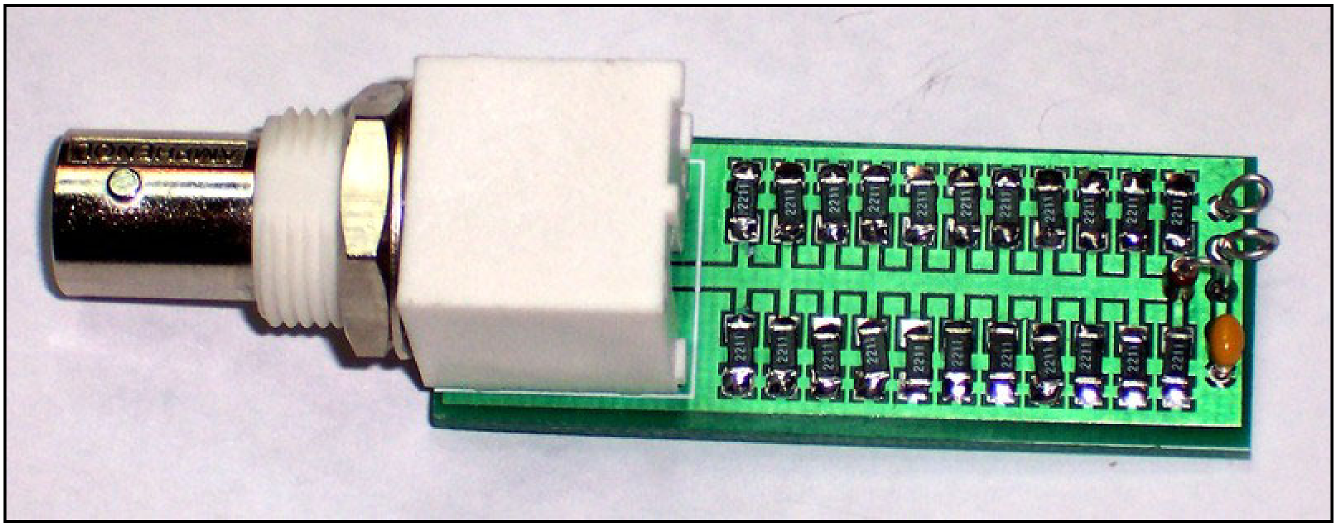
Need some practice attaching SMT resistors to a pc board? Here's how you can get that experience … and end up with a useful QRP dummy load in the process!

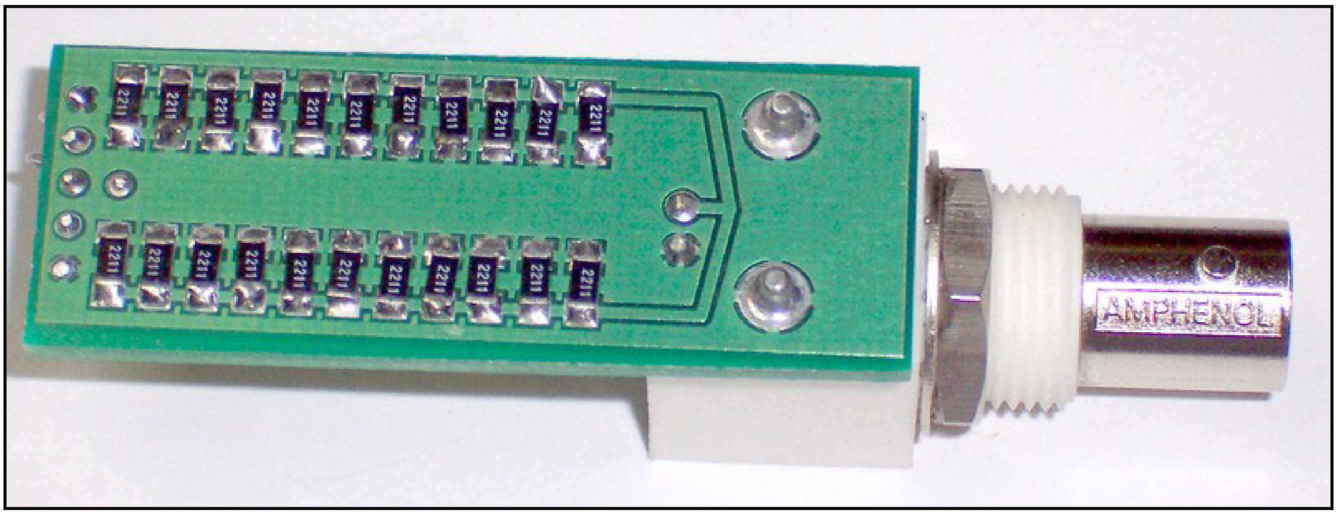


Several weeks ago I purchased a reel of 0.1 uF, 0805 SMT capacitors from a surplus electronics dealer. I was thinking at the time that ten bucks for a huge supply of bypass capacitors was not too bad of a deal. At least I thought I was getting capacitors, well anyway that is what was on the reel's label. Closer examination at home showed that I actually had purchased a reel of 2.2k ohm, 1206-sized SMT resistors. Later I jokingly told a friend that I guess I would use forty-four of them in parallel to make a QRP dummy load. Several days ago as I completed a prototype circuit panel for the SoftRock-40, I found I had extra area on the panel that I could not use because the project was close to the hole-count limit on the panel. As I thought about what could be done with the unused area, I remembered my joke about the SMT resistor dummy load … well, why not give it a try?!

It didn't take long to layout a pattern of four rows of 2.2k, 1206 SMT resistors. Two rows were placed on the top side of the board and two rows went on the bottom side of the board. Within each row, the resistors are connected in parallel as well as each row being connected across the BNC connector on one end of the rectangular board. Ground planes on the top and bottom side of the little board form the ground connection between the resistor groups and should help transfer the heat away from the resistors and into the air. A diode and capacitor at the other end of the board provide for measurement of the RF voltage across the dummy load resistors.

The picture below shows the resulting dummy load which I call the SMT Soldering Practice Dummy Load. The board is 0.75 inches wide and 1.9 inches long. I figure the cost of the PCB at about \$3, the BNC connector at about \$4, the diode and capacitor at about fifty cents and all forty-four of those 2.2k, SMT resistors at twenty-two cents. The bottom line is it sounds like this would be a neat little \$10 kit. The task remains to make sure the SWR looks good over the HF bands.





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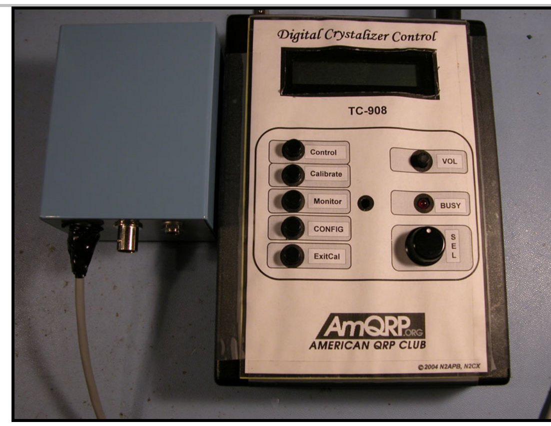
Steve Holton, N1NB

The TC908 Temperature Controller

or … Taming the Atlanticon 2005 Crystallizer

Here's a way to use the Micro908 to serve as a closed-loop temperature controller, thus providing for extremely stable oscillator operation in the Crystalizer Kit. Steve demonstrates the basics of software feedback control, and educates us along the way on thermister operation.



The announcement of the Crystalizer as the Atlanticon 2005 kit somehow piqued my interest in a way that previous Atlanticon kits had not. Not knowing much beyond some very basics about the either oscillators or temperature compensation I started looking around for some information. I found two sentences on page 10.23 of the 2005 ARRL Handbook that got my attention:

> *Recently, oscillators have appeared with built-in digital thermometers, microprocessors and ROM look-up tables customized on a unit-by-unit basis to control a tuning diode via a digital-to-analog converter (DAC) for temperature compensation. These digitally temperature-compensated oscillators (DTCXOs) can reach 0.1 ppm over the temperature range.*

Now this sounded like something I could do. I immediately thought of using the Micro908 to implement this. As I had just finished working on the AF908 software to support the KK7P DSPx daughter card on the Micro908, I was familiar with the platform and the development environment. Studying the schematic and looking at the HCmon support code for the Micro908 I was able to determine that there were available Analog-to-Digital Converter (ADC) pins available. However, the HC908 does not have any digital-to-analog converter (DAC). So, I took a quick look at the PIC-EL to see if it had both ADC and DAC capability – it didn't so I settled on using the Micro908.

I needed two things beyond the normal junk box parts: a thermistor for a temperature sensor; and some form of DAC. To make a nice package I decided to connect the Crystalizer to the Micro908 utilizing the Micro908's 8-pin mini-DIN connector which already presents both +5V and Gnd. So as part of a Digikey order I included a Keystone 10K ohm NTC thermistor accurate to 1^{o}C. (RL0503-5820-97-MS, DigiKey KC003T-ND) and an 8-pin mini-DIN In-Line plug (CUI MD-80, DigiKey CP-2080-ND).

Looking for a solution for digital to analog conversion I came across a "Digital Potentiometer" from MicroChip. This device attaches to the SPI bus, It just so happens that the Mico908 has an SPI bus, and further, I had done the programming to support the SPI bus attachment of the SEEPROM chip that is used for storing the DSP programs for AF908 (and in the future for Antenna Analyzer scans). This was particularly interesting to me as there has been discussion of attaching additional storage, such as an SD card, on the Micro908's SPI bus. In fact, it was by volunteering to help in that effort that lead to my doing AF908. Therefore, I was quite interested to see how easy it would be to attach a second SPI bus device to the Micro908. I ordered an MCP41100 Single 100K ohm Digital Potentiometer from Microchip. The MCP41100 operates in a straightforward manner utilizing the SPI bus. Once the chip is selected a single byte to sent to it over the SPI bus. This byte – a value between 0 and 255 – will position the wiper of the 100K pot. between 0 and 100K ohms once the chip is deselected.

While waiting for the parts to arrive, I learned a bit more about thermistors – enough to realize that perhaps my choice of a 10K ohm thermistor was not ideal. Two important parameters for thermistors are its time constant and its dissipation constant. The time constant for the thermistor I had ordered was 15 seconds which is typical. The thermal time constant for a thermistor is the time required for a thermistor to change its body temperature by 63.2% of a specific temperature span (see: http://www.betatherm.com/tc.htm). This meant that some care in packaging the Cystalizer would be needed to isolate it from large rapid temperature swings. The thermal dissipation constant of a thermistor is defined as the power required to raise the thermistor's body temperature by 1°C in a particular measurement medium. The D.C. is expressed in units of mW/°C (see: http://www.betatherm.com/dc.htm). This is, in effect, a measure of the self-heating effect of the thermistor. This is useful in certain applications, like flow measurements, where the flow rate is determined by the cooling effect of the flow counteracting the self-heating of the thermistor, but it is not useful in simple temperature measurement applications where you want to keep the current through the thermistor below 100 µa. The dissipation constant for the thermistor that I had ordered was 1.4 mW/°C. Quick calculations indicated that a 10K thermistor was not a good choice. Consequently, I added a 100K ohm NTC thermistor (Keystone RL0503-53.36-122-MS, Mouser 527-503-100K) to my next Mouser order.

Once the initial parts order arrived I assembled the Crystalizer and installed it in a small 2x3x3¾ aluminum case. I decided I was not going to resort to any elaborate insulating scheme and just see how effective the digital control could be. I did want to mount the Crystalizer PCB on stand-offs near the center of the case. The only stand-offs I had on hand were some 3/8" plastic Radio Shack ones. After some thought I decided to use them in a "double-decker" configuration so I mounted a piece of Plexiglas slightly larger than the Crystalizer PCB with 4 stand-offs. Then mounted the PCB with another pair of stand-offs on the Plexiglas with the component side facing the Plexiglas – see figure 1. I believe that this "sandwich" of the PCB and the Plexiglas enclosing the Crystalizer components added additional dampening in response sudden changes in temperature.

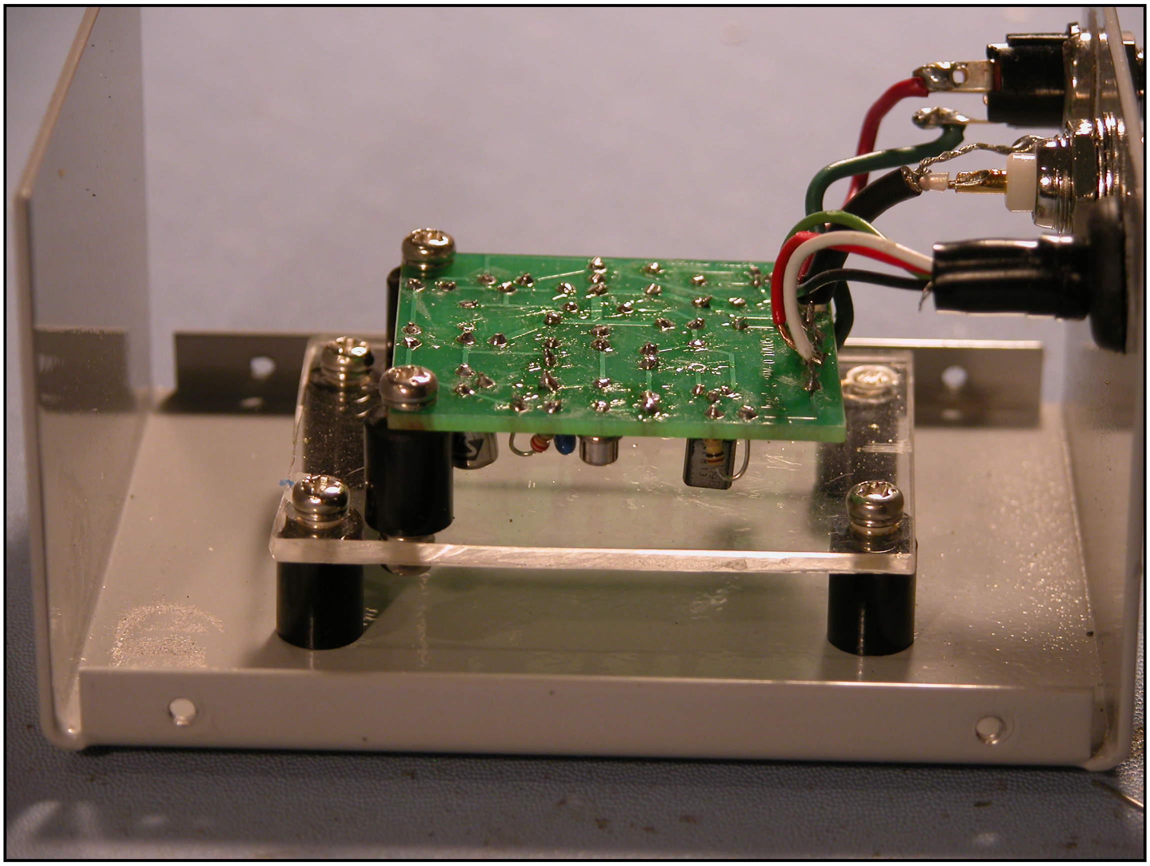
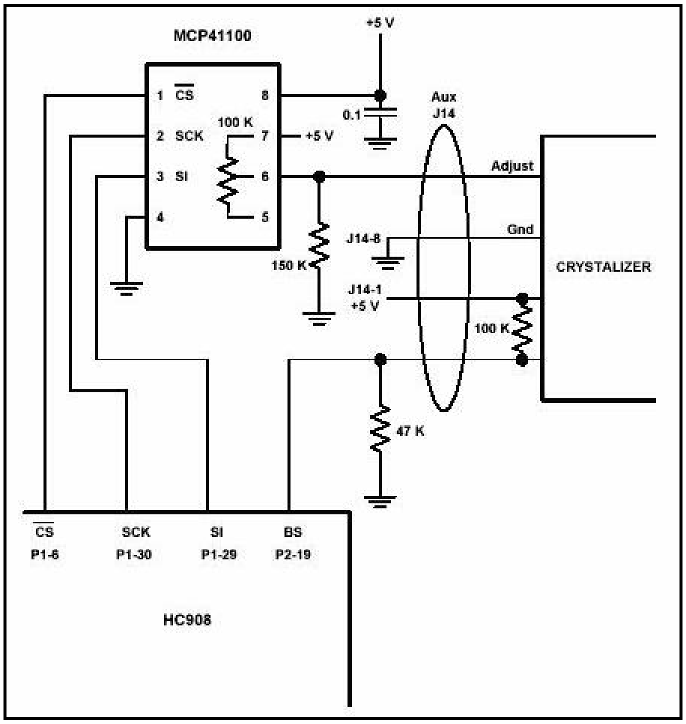


Figure 1 – Crystalizer mounted in 2x3x3¾ aluminum case

The initial testing quickly showed that the Crystalizer, as built, oscillated 2.2 KHz below 10 MHz and with the Adjust voltage at 5V it still was low by 1.8 kHz. Removing C5 and replacing L1 with a wire jumper moved the unadjusted frequency to within 750 Hz of 10 MHz and provided a swing of 1 kHz with 0-5V of Adjust.

I built an initial circuit as shown in the schematic below with the exception of the Adjust voltage where I used the 100K digipot to divide the entire voltage range of 0-5V. With this configuration I developed the basic software and made some basic tests including gathering some calibration data. The software and the calibration will be discussed below. It quickly became apparent that dividing the full 5 V range for the Adjust voltage was a mistake. With 256 steps in the digipot that works out to about 20 mV per step which was not fine enough to meet 0.1ppm or better control. I changed to the circuit shown in the schematic with the digipot dividing the range 3-5V or about 8mV per step which was satisfactory.



TC908 Schematic

The assembled circuit in the Micro908 can be seen in figure 2 with the digi-pot IC used as a “dead bug” located in the lower right center of the picture.

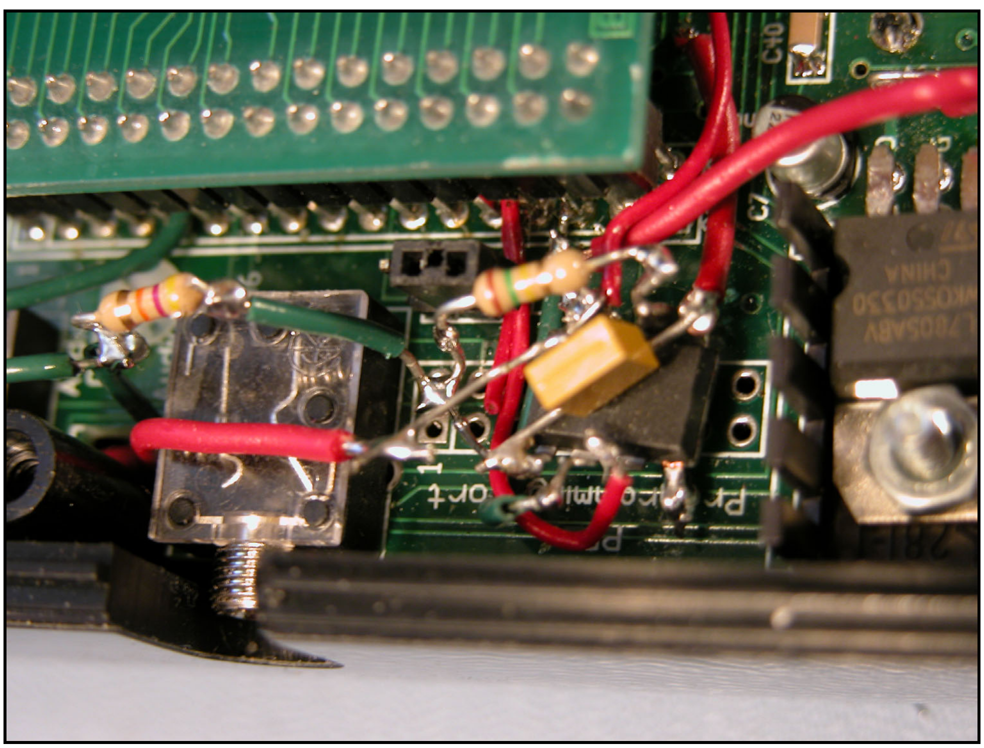


Figure 2 – Micro908 additional components

Calibrating to WWV

I had recently acquired a well used HP8640B Signal Generator and Frequency Counter. Before it could be used I needed to find accurate it was. I setup the crystalizer so that its output was connected to HP8640B. To my K2's antenna input I connected one of my wire antennas to receive WWV as well as a wire to pickup the Crystalizer's signal. The audio output from the K2, in CW mode, was sent to Spectrogram running on the PC. Thus the carriers of WWV and the Crystalizer's signal will appear in the audio spectrum near the K2's BFO frequency with the K2 tuned to 10 MHz. I could then observe both WWV and the Crystalizer on Spectrogram while monitoring the frequency counter. The accuracy of the transmitted WWV signal is about 0.1ppm or 1Hz at 10 MHz due to propagation effects. By altering the Adjust voltage to the Crystalizer it was possible to "superimpose" the two signals in the Spectrogram output. Any error in the soundcard's oscillator cancels out as both signals are processed concurrently and subject to the same errors. With this setup I was able to determine that the HP8640B's readout after suitable warmup was 4Hz low and didn't move thereafter. Further, since you can get 0.2Hz resolution with spectrogram it is possible to measure the drift and temperature variation of the Crystalizer output over time more precisely than you can determine the accuracy of the WWV signal. (Any drift or temperature variation in the soundcard's oscillator should be minimal after a suitable warm-up as its oscillator frequency is divided down so many times that any error in the oscillator is reduced in the process.)

Measuring temperature compensation data

The excellent ARRL book *Experimental Methods in R.F. Design* describes something called an "Oven for Drift Compensation" on page 7.42. It uses a light bulb, for a heat source, a 12V fan in a Styrofoam cooler to measure temperature drift. While I was prepared to use such a setup I decided to try something simpler first which turned out to be sufficient. I had a Styrofoam container of approximately 1 cubic foot capacity with 1 ½ inch thick walls and a close fitting top. Cutting a notch in the Styrofoam just large for the cables from the Crystalizer case, I could heat the Crystalizer enclosure with a heat gun and also warm the interior of the container and then seal it tightly. It would slowly cool down over a period of several hours. After initially closing the container the temperature recorded by the thermistor inside the Crystalizer would continue to climb for several minutes by as much as 20^o C as the temperature within the case equalized. Once the temperature stabilized and started to very slowly decrease it was possible to take data. I had put a crude calibration assist in the software such that I could change the value of the Adjust voltage with the Micro908 dial and when I was happy with the resulting output frequency as displayed by Spectrogram or on the frequency counter I could push the dial pushbutton and it would record the Thermistor temperature value and the Adjust value for the digi-pot in a table in the Micro908 memory. I could then dump out the table when done and use the data to build a table in my source code for the control loop. Similarly for the other end of the scale, I cooled down the Crystalizer and the Stryofoam container outdoors and gathered data as it warmed up to room temperature. With this process I gathered data for the temperature range of 10^o C to 70^o C. Combining data from several runs and interpolating between data points and extrapolating at the extremes I obtained a 256 byte table of digi-pot Adjust values for each possible thermistor temperature value. If I had the capability to get the measured frequency from the frequency counter into my PC or the Micro908 serial port then the calibration could easily be automated with software. This is, or course, how it is done commercially.

Software

You must understand that the software which I dubbed TC-908 was never intended to see the light of day. It was in the “just enough to get it to work and no more” school of programming – not the same quality of my code in AF908! Nevertheless the entire TC908 software package is included. The essential code to perform the control of the Crystalizer is very simple and is shown below:

```
CHAN_TC equ     5           ; Thermistor ADC channel port number
        jsr     POT_Init    ; Initialize SPI bus for Digi Pot

TC_loop:
        lda     #CHAN_TC    ; Set ADC channel to read
        jsr     Read_ADC    ; Read thermistor voltage value into Acc
        clrh                ; Set H:X to thermistor voltage value
        tax                 ;   for use as index into Adjust value table
        lda     Pot_tab,x   ; Load Acc with Adjust value from table
        jsr     Set_pot     ; Send value in Acc to Digi Pot
        jsr     wait500ms   ; Wait for 1/2 second
        bra     TC_loop             ; Keep doing it forever

Pot_tab:
:--- a 256 byte table of Adjust digi pot values
;---     for each possible Thermistor value
```

The subroutines POT_Init and Set_pot are part of TC908 and initialize the SPI bus for the digi-pot and send a one byte value to set the digi-pot respectively. The subroutines Read_ADC and wait500ms are self-explanatory and are part of the AA908/AF908 support routines.

The complete code used in TC908 for the control loop is in module PB1.asm. There is a lot more code there for a number of reasons:

1. The code starts running when PB1 is pushed and stops when PB1 is pushed again

2. The digi-pot is set only when the thermistor value changes and remains changed for 2 successive readings. This removes some “jitter” when the thermistor is right a transition point between two ADC values

3. The loop displays on the LCD: the thermistor measured temperature in degrees Centigrade; the actual thermistor ADC value in hex; and the corresponding Adjust digi pot value in hex. By far the largest amount of code in the module is devoted to this function.

4. The support code for the digi pot.

5. Two data tables relating thermistor ADC values to Adjust digi pot values and thermistor ADC values to degrees Centigrade.

The code for TC908 was created by taking a working copy of AF908 and hacking out some but by no means all of the AF908 code. Code was then written to implement the Crystalizer parts and was "welded" into the remains of AF908. Not pretty, but it worked for the one time "bake-off" at Atlanticon 2005.

In addition to the control function in TC908 I included a number of other capabilities. As mentioned above there was a calibration assist. Pushing PB2 "Calibrate" starts calibration. You vary the adjust value with the dial and push the dial push button when you wish to record a temperature/Adjust value pair in the table. The temperature and digi-pot adjust value in hex as well as the measured adjust value in Volts is displayed. Again the code is crude – no check is made to keep the Adjust voltage within the values 3-5V which is all the circuit allows. If you run the dial outside that range it simple truncates the value to 8 bits…… Pushing PB5 will exit calibration and you can then dump the data with the debugger.

PB3 "Monitor" simply monitors and displays the temperature and Adjust value (in hex.) You exit by pushing PB3. PB4 "CONFIG" allows you to enter the debugger (via Software Load) to retrieve calibration data or re-load AA908 or AF908.

The complete TC908-Crsytalizer is shown in Figure 3

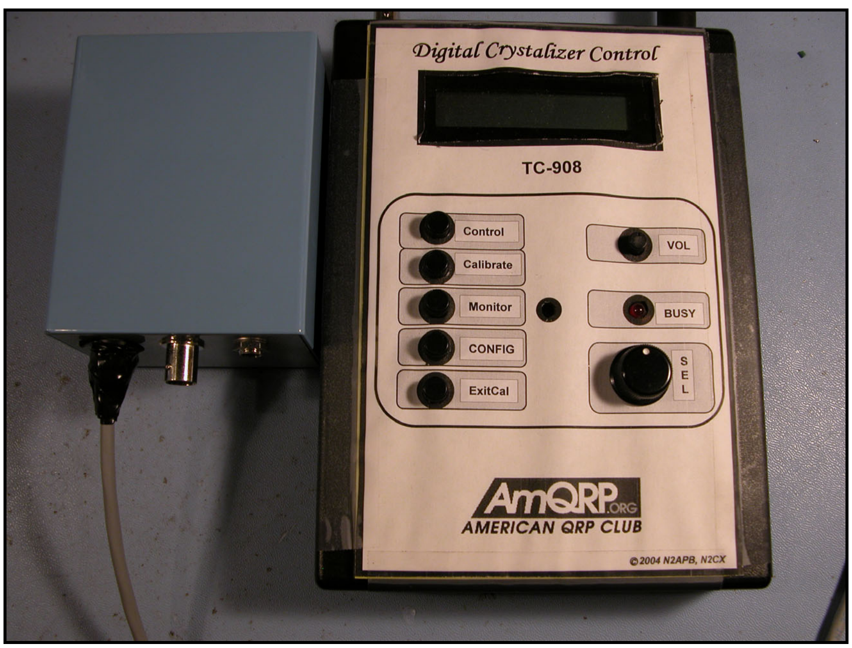


Figure 3: Crystalizer and TC908

The Results

Several measurement runs were made before Atlanticon covering the range from 10^o C to 70^o C. A few anomalous data points were detected and corrected. The result was that over the range 10^o C to 70^o C my frequency counter readout remained constant. It reads to 1Hz (that is 0.1 ppm). The observed range of frequency via Spectrogram appeared to be even better. In both cases you are approaching or have reached the limits of the measuring environment. I had contemplated a number of refinements that would improve performance – some of which are described below, but I was satisfied with the 0.1ppm performance. I neither the time, nor the necessary measurement equipment to pursue them further.

The results I had observed were confirmed at the Atlanticon "bakeoff'. The test environment at Atlanticon used a hair dryer and a frequency counter to test the entries. From room temperature to about 50 ^{o} C (that was when Joe, N2CX gave up and wanted to move the next entry) the TC908 entry didn't move the frequency counter from 10.000000 MHz – which proved to be the winner.

Opportunities for Improvement

One of my initial thoughts on learning about thermistor time constants was that I might have to take into account the rate of temperature change in my compensation algorithm. One can envision tracking the rate of change recorded by the thermistor and during periods of rapid change "looking ahead" in retrieving Adjust values from the compensation data table. This did not prove to be needed and is probably best dealt with packaging that dampens the rate of change seen by the oscillator components.

In observing the output of the Crystalizer, I could see some the frequency jump at times when the temperature changed - though this was well within 0.1ppm. More granularity in the Adjust voltage could improve the results. I had already changed the circuit to have the 256 steps of the digi-pot cover on the range 3-5V versus 0-5V to get the results I obtained. It turns out that the range of the Adjust voltage needed to compensate for the temperature range of 10^o C to 70^o C is just over 1.15V. Therefore, by adding a resistor and changing another in the voltage divider surrounding the digi-pot, the 256 steps of the digi-pot could be "moved" to just cover the required range for Adjust. This would improve the tracking by up to a factor of 2.

Further reading

In addition to the excellent presentation by Joe N2CX at Atlanticon – see the proceedings after returning from Atlanticon I discovered 2 additional valuable sources of information. One is an article in the June 2003 issue of RadCom titled "Accurate Frequency Measurements." Which includes up to date discussions regarding the use of PC based audio spectrum analyzers (thanks to Frank N2FF for a copy). The second is a venerable 1976 book by Martin Frerking; *Crystal Oscillator Design and Temperature Compensation*. This provides a comprehensive discussion of the topic including digital control. As you might imagine, digital control in 1976 involved "pound" of hardware versus what today is a single chip and a few discrete components. Reminds on of how far technology has come, yet the basics are still with us.

Steve Holton, N1NB sholton@optonline.net

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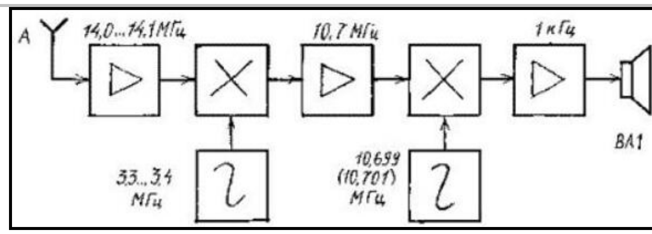
Victor Besedin, UA9LAQ

20-meter Receiver from Tyumen

This small receiver project was developed to commemorate the 50th anniversary of the first Radio Amateur Station to air from our Tyumen region (Western Siberia, Russia)!



This receiver was for me a surprise. It was stable and not sensitive for the value of supply voltage. Two old AA - galvanic elements were enough to hear the hearts-dear Morse music out of the receiver's loudspeaker. As every receiver does, this one works better when it is connected to a full-size matched antenna. The dynamic range of the CW receiver is not so high, but it is improved with the increasing supply voltage and is not so annoying because of portable field, QRP DXpedition or rancho application. Other variants are possible (other bands) at better IF-choice or at extra-VFO application. RX contains only three active components: two NFETs and a multi-purpose IC analog to MPF102 and A283 (TDA1083), respectively, explores two quartz resonators: one as IF filter and the other one in BFO.

This RX is predestinated to receive CW signals in 20-meter band between 14.0-14.1 MHz, its sensitivity is 1 μV (Pout = 5 mW, Vss = 3 V, standby consumption 11-12 mA). Selectivity to adjacent channels depends on the Quartz filter. Signals on mirror-frequencies are good, suppressed according to grand interval between ones and desired frequencies. The dynamic range depends on supply voltages; the range of them can be 3-9 V (maximum, with some FETs and ICs at 2-12 V).

Figure 1 represents block schematics. The desired signal (in 14.0-14.1 MHz range) from antenna comes to an RF amplifier, then goes to signal input of the mixer; LO voltage (3.3-3.4 MHz) comes to either input of the mixer. The combined (difference) signal (10.7 MHz) goes then to the IF amplifier and improved comes to decoder, to input of which comes the signal from BFO (10.701 or 10.699 MHz). The beat AF signal (1 kHz or so) comes then through AF amplifier and improved to loudspeaker (or headphones). Acoustic signals come to our ear. That's all.

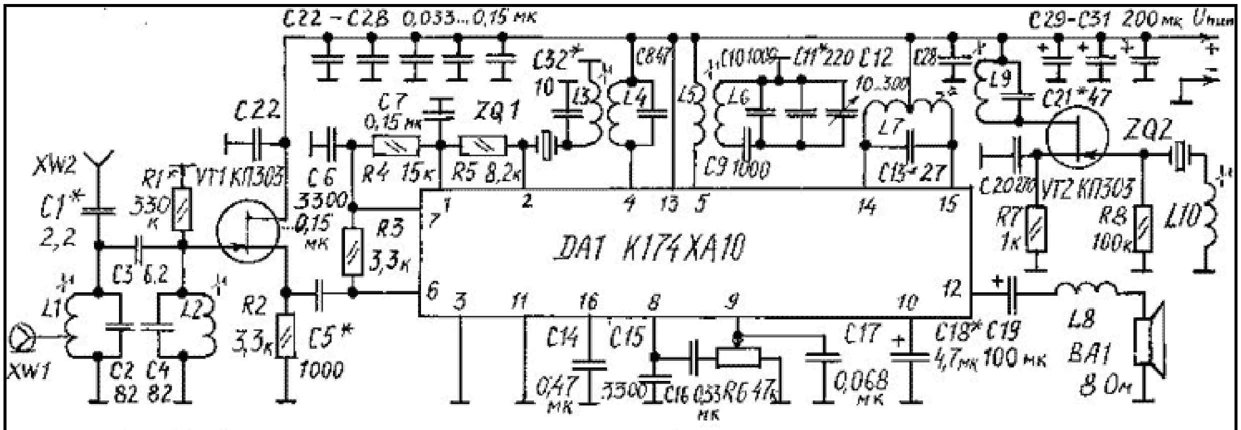


Рис. 2. Экспериментальный приёмник. Схема принципиальная электрическая.

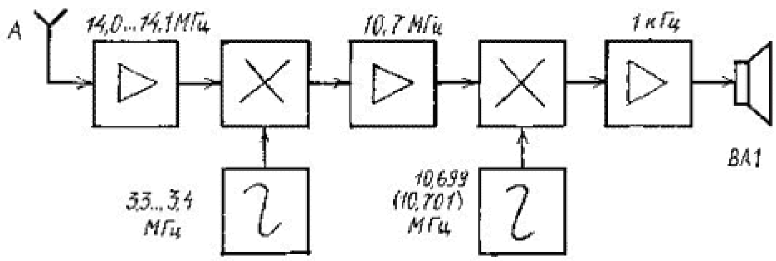


Рис.1 Экспериментальный приёмник. Схема функциональная электрическая.

The main schematics can be seen in Figure 2. The desired signal comes to XW1 socket from matched (with coax feeder) antenna. Then it goes to the part (tap for matching) of the coil L1 of the parallel tank circuit L1/C2. The alternative portable substitute of a good antenna can be plugged in to XW2 socket, C1 is a small value so as to not detune the tank circuit L1/C2 greatly.

For RX selectivity to be improved, a Bandpass-Filter (L1/C2/C3/L2/C4) is applied. The signal (14.0-14.1 MHz) goes through this filter and comes to RF amplifier VT1, which is working in common-drain (source follower) configuration mainly for decreasing the low impedance influence of the following IC input on BPF.

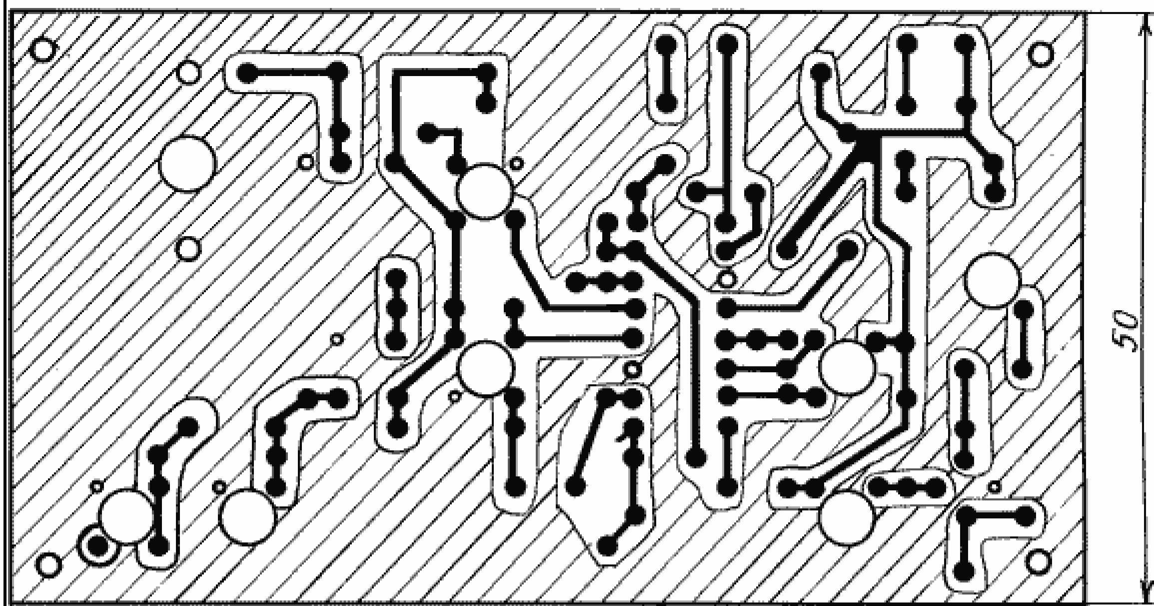
The RF amplifier output is aperiodic, broad-band. The signal filtered in BPF and amplified in VT1 is put to multi-functional IC DA1 input (pins 6, 7) to internal mixer's signal input. L5 is connected to pin 5 of DA1 for internal LO to be tied to its tank circuit L6/C9/C10/C11/C12, which is frequency definable (here: 3.3-3.4 MHz). The IF signal 10.7 MHz is selected from mixture in tank circuit L4/C8 at mixer output (pin 4 DA1) and comes to IF input (pin 2 DA1) via L3 and Q-filter ZQ1, common is here connected to pin 1 DA1.

The improved in IF multistage amplifier 10.7 MHz signal is put to IF AMP load tank L7/C13, which is connected to pins 14 and 15 DA1 symmetrical (balanced) referenced to ground to be right phased for decoder. The same tank (inductance L7) is used to put supply voltage to IF AMP. The same tank is slightly bound to BFO tank L9/C21, which explores VT2. The decoded (detected) IF signal appears on pin 8 DA1 and after filtration from HF components comes to volume control (pot R6), then it comes to AF-AMP input (pin 9 DA1). The amplified AF signal goes to the speaker for conversion to acoustic waves.

R1 can be omitted, it is shown as an element of DC conductivity in VT1 gate-chain during tuning (alignment) procedures, when the “hot” end of L2 is cut off. It is also to define characteristics of BPF, helpful for its balancing. R2 presents DC and RF load for VT1. R3…R5 are the elements of DC control of IC. R7, R8 are BFO elements. C1 defines how close is the alternative antenna tied to tank L1C2 and this way defines (a bit) Q and detune of it at connecting such an antenna. C2…C4 - tank capacities in BPF, C5, C16 are to conduct RF and resist against DC-conductivity. To the same category will be applied the following capacitors C6, C7, C15, C17; C22-C28; C29-C31, but we are used to naming them blocking. C8 – tank capacity of the mixer load, C9-C12 – the same, but for LO, C12 is here the variable cap to tune RX across the band. C13 is a tank cap of the IF amp load. C14 defines the time constant of the AGC system (the smaller C14 the less is the time constant – fast AGC is used). C18 defines the lower frequency of the AF Amp, it is functionally equal to cap put parallel to emitter, source or cathode load. The negative feed-back in IC DA1 AF circuit without this cap is equal to 100%. C19 is blocking DC in LS chain. C20 is blocking the negative feedback on HF, makes BFO freely start and is suppressed for BFO-subharmonics, and parasitics. C21 is a tank BFO cap. C32 is a matching cap in Q-filter circuit. L1, L2 are BPF inductances. L3 defines the tie to Q-filter, L4 is a tank coil on mixer output. L5 is to tie LO tank to LO transistor which is inside of the IC, L6 is a LO tank coil. L7 is a tank coil on IF Amp output, L8 improves the quality and the stability of functioning of IC and can be omitted. L9 is a tank inductance of BFO. L10 serves to detune BFO/Quartz frequency relative to central frequency of the Q-filter pass-band to produce an AF beat of 1 kHz (or so) to be able to receive CW code.

The receiver is situated on a pc board 90 x 50 x 1.5 mm. The foil on the parts side acts like screen and common ground, while the foil on the other side is used mainly for connections that are in isolation from the ground. When there is a necessity to connect the part’s lead to ground, you have to put a piece of wire to connect the foil on both sides of the board through the hole and then to solder part’s lead to the foil at the top side of the board. Leads isolated from ground go through lower holes and are soldered to the foil at the bottom side of the board. The enclosure is better made from conductive materials (or plated by them, for example, inside) for screening. The speaker (if not headphones are not used) is situated on a side of the board so for the magnet to not influence the tanks and so to not cause oscillations. Galvanic or other elements of supply voltage are to put around the speaker magnet system. Tune and volume control knobs can be made as discs partly out from the side of the enclosure. Scale-to-tune of RX can be written to the same disc (control knob) and can be seen through the window in enclosure top cover covered with a piece of glass or lens. Against the speaker WA1 there is to make a number of small holes covered with thin plastic band against moisture. The RX board is secured inside of the enclosure on standsoffs or is soldered to panels of it, if the enclosure is made of plated materials.

Рис3. Экспериментальный приёмник. Эскиз монтажной платы. М 1:2



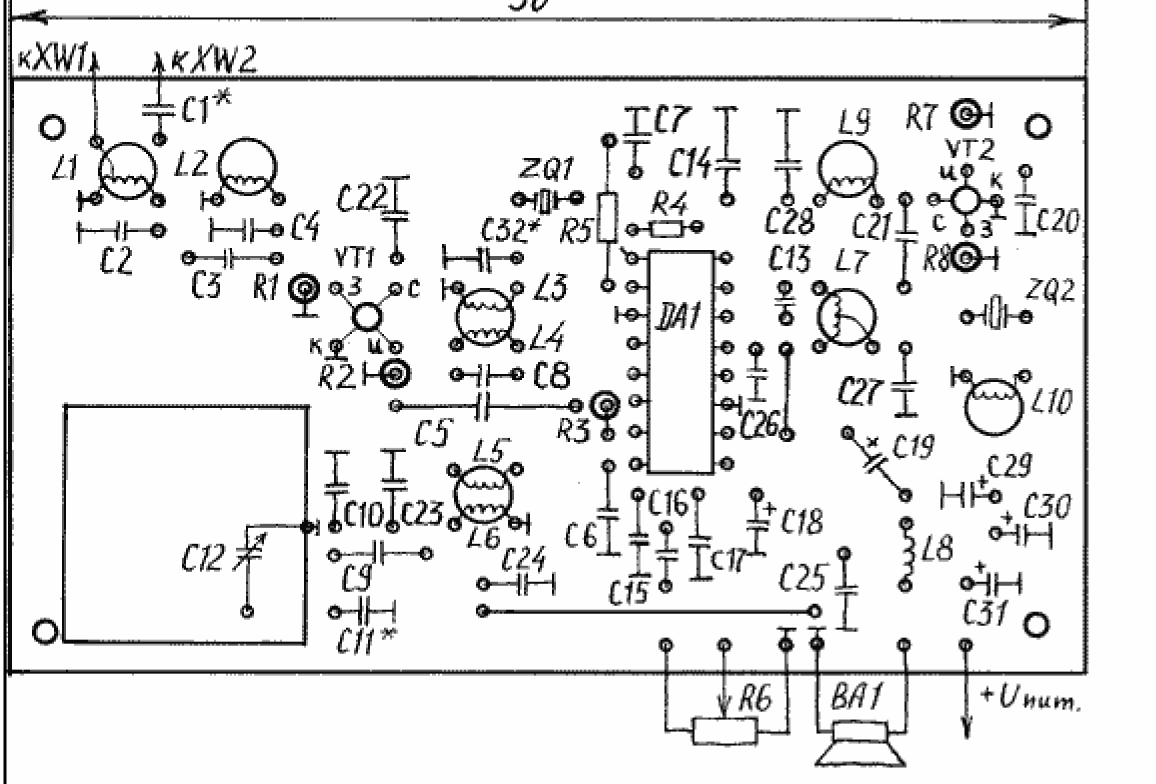


Рис. 4. Экспериментальный приёмник. Эскиз расположения деталей на монтажной плате.

Figure 3 represents the PC board bottom side. Figure 4 is the parts layout.

IC DA1 for HF bands is to be mount with short leads. LO inside IC is able to function to about more than 4 mc, that's why IF will be 10-13.5 MHz, at higher IFs the IC is not reliable upon, but some units can do fine job in more wide band, as an improve, here is mount with short leads and external LO. On these conditions IC can work all over the HF bands. If You put a VHF-converter ahead of this RX, you can receive CW and SSB signals, for instance, in 2 m band. If you switch off the BFO, you can receive AM-signals and with some offset, narrow-band FM signals, too.

In spite of RX simplicity the adjustment procedure must be paid much attention to, otherwise, its sensitivity of 1 µV can not be reached. For adjustment procedure are necessary a signal-generator (SG) (10-15 MHz) and AVO meter (multimeter), maybe a DIP meter. Other equipment like RF scopes, RF Voltmeter, Oscilloscopes and so on are useful but there is usually a lack of them in amateur practice.

On the right mounted RX-board BFO is to be switched off first. This can be done by soldering a piece of wire parallel to R8. Parallel to LS WA1 is to connect an output voltage meter (AVO-meter put to AC voltage metering, max. 1 V). SC is connected first to Pin 2 DA1-IF-input through the small capacitance with short leads (the braid of the SG-cable is connected to common ground). SG is switched to AM 60%. Now is the highest time to power on your freshly-mounted RX. Connect the 3V supply to it. R6 is put to maximum volume. The frequency of SG is put to the value shown on the Quartz-resonator-case (Q-Filter ZQ1 (Fig. 2)) – 10.700 MHz and the output SG-voltage must be enough to hear the AF signal from LS BA1 and see its presence on AVO-meter. If there is no SG-signal to be heard at all, check the AF-amp first touching to Pins 9 and 8 DA1 with a piece of wire taken to your hand. Both cases will produce noise from the supplying net (50 or 60 Hz). If there is no net, so apply an AF generator, microphone or other signal to the AF amp input, the improved sound will be heard from LS BA1. If there is no signal out again, prove that BA1, C19, all leads and wires are okay, if it is so and the supply voltage is connected, but nothing is heard, change the IC DA1.

If SG-modulation signal is heard, turn the ferrite-core of L7 to adjust the tank L7/C13 to maximum value of the output voltage on BA1. If maximum is not reached in lower core position, increase the inductance L7 or/and C13, if the core is out of L7 decrease the inductance L7 and/or C13. When maximum is reached in central position of the core, the tank is tuned to the right frequency. When increasing the RX output voltage at tuning, you have to decrease the SG-signal value, at least to see the peak, because of AGC influence which makes (when at big signal level) the tuning not sharp. Connect SG output to pin 6 DA1, sweeping the SG-frequency, find the signal again, now in much smaller bandwidth.

The following operation is to be taken at very stable SG-frequency settled to center of Q-filter ZQ1 characteristics (SG with AFC, modulated Quartz oscillators or thermally stable SG with VFO (powered on for some hours)). Adjusting the core of L4 in the same manner, put the tank L4/C8 to maximum RX output voltage. Do not forget to decrease SG-signal to neutralize the AGC. Adjust C32 to the most narrow Q-filter bandwidth at max gain and to be free of oscillations. Measurements to help here are: the number of windings of L3, connecting parallel to L3 the resistance (value adjustable). Criteria: to get the maximum signal at minimum noise.

The small wall is situated between input and output terminals of Q-filter ZQ1. Once again is the IF trace to adjust (L3, L4, L7) with accord to max. output signal. Do not forget about the function of AGC. Apply the minimum SG-signal enough to maximum RX output to be measured. If there is an opportunity, use milliammeter with AC 300-500 mV limit. If during the adjustment procedure there were heard some strange signals, cut the lead of L5 off the pin 5 DA1 to switch off the LO and take another adjustment try. Then, the connection is recovered.

SG is put to 14000 kHz, C12 - to the position near to maximum. Improve the SG (connected to RX XW1) output and try to find it's signal (audio in LS BA1), adjusting the ferrite core of L5/L6, LO frequency is then equal to 3300 kHz. Then we'll come to the higher end of the band, putting C12 to near its minimum and find the frequency varying with SG tuning knob. Adjust C11 here if you want the other frequency to be the upper one. Then you'll go to the lower side of the band and correct the tuning to 14000 kHz, then to the upper end, this way for some times until the desired band will be set. If there is muting or oscillation in some positions of C12 it is short-circuit or too small is the inductance of L5. Do not mix the strong signal appearing in SSB sub-band with oscillations; it is 3 times LO frequency put to IF trace, according to the bad choice of IF. That's why RX is prescribed to function in CW-sub-band and is called as "CW receiver" for the most popular mode with QRP operators.

The frequency of that strong signal related to the band is designed easily: take the IF divide it into 3 plus IF and here You are: 10700 : 3 + 10700 = 14266.6666 kHz. IF You want to have the whole band in Your RX, please find a pair of Q-resonators to other frequencies, may be, a bit higher than 10700 kHz. Strong undesired signal (3 x LO) will then go away from SSB sub-band. The application of a Q-resonator as an IF filter permits the homebrewer to introduce his own choice of IF, independent of standard conventional Q-filter frequencies.

After setting the band of LO (VFO) put SG to the middle of the desired band (for instance, - 14050 kHz, if only CW). Find SG-signal working with the RX tune knob and set SG output signal minimum enough to check the adjustment (do not forget about AGC). Then adjust the cores of L1 and L2 of the BPF L1/C2/C3/L2/C4 to the max RX output signal decreasing every time the SG output. Instead of L1 tap, there can be a coil of 1-2 windings above L1, at optima this coil is to be fixed after finding the strongest RX output signal at minimum of noise. C1 is small capacitance for not to detune L1 greatly, it can be adjusted individually for the portable –type antenna [7]. The criteria are the same: max. signal @ min. noise.

AM RX is now adjusted. To convert it to CW/SSB, a BFO is needed. BFO is made on NFET VT2 with the second 10700 kHz Q-resonator ZQ2. The schematics of BFO is tested by UA9LAQ in [3] and [4] and has shown good results. The frequency is stable, non-sensitive to supply voltage (only slight change in a voice in SSB-mode at 3-9 V change of Vcc), no parasitic modulation. Though there is BFO output voltage drop at Vcc change, it is not fatal and BFO is to have no supply regulator. For AGC not be able to block the receiver, BFO-signal is led to IF output and must be screened max, from IF input. IF notches are not present here. IF signals from the RX input are fairly good suppressed with BPF and IC-mixer.

Take the short-circuit from R8 off. SG-voltage (10700 kHz) can be put to the gate circuit of VT2; the low output impedance of SG did not let ZQ2 to oscillate. SG-voltage can be connected to source of VT2 via C20, one lead of it is cut off from common ground, in such a case the short-circuit parallel R8 can be let without the touch. Having connected SG-signal to VT2, we'll adjust the tank L9C21 to maximum according to AC-voltmeter scale; it is enough to put one of it’s leads near the tank’s “hot” end. Maximum voltage of tuned to 10700 kc tank L9C21 can be tested also by means of RF-voltmeter, resonating selective equipment, DIPs and so on, or by means of DC milliammeter (10 mA full scale) (blocked with the capacitor 3300-10000 pF), which is connected between the cut off (after switch off of the RX supply voltage) from ground lead of R7 and the ground. The adjustment will go by turning the core of L9 to minimum measured value, because the impedance of the tuned to the resonant frequency tank is the highest value. The point of resonance can be identified according to the minimum of noise of RX or at measuring it’s AGC DC voltage (between pin 8 DA1 and ground).

After all connections restored and without the short-circuit parallel to ZQ2 BFO with supply voltage applied will oscillate freely. SG output is to connect to XW1. RX is tuned to its carrier (now AM mode is off) to be situated in the center of Q-filter ZQ1 characteristics. Turn the core of L10 to get the usual offset (for more pleasing AF CW tone 1 kHz or so. If there will be also the SSB receiving, so connect antenna to the receiver, switch it on and tune it to one of the functioning SSB signals. Then turn the core of L10 to maximum distinct voice with middle audio frequencies in the signal, thus the needed side band will be set automatically. CW will be received then like in usual SSB equipment. For do not let the BFO signal come to IF input, the constructive cap is made in such a manner: solder to pin 15 DA1 the piece of insulated wire put it in the near of hot end of L9 and glue it to the board. The length of the wire is adjusted to the good one-tone sound of (small level) SG carrier for one hand and to minimal suppression of the desired signal by BFO (compromised). If You want to solder a piece of wire to the drain of VT2 and put it near pin 15 DA1 You have to screen the IF input and BFO for its signal not to spoil the sensitivity of RX muting it by AGC. Adjust the detuned tanks (with L7, maybe, L9 cores) when you put the constructive cap to them. It can be that constructive conditions of your board will not permit the use of constructive cap: the BFO signal is already huge. Check the track BFO signal comes to the decoder, if it is through the IF-input, the IF-trace will be muted by AGC not allowing to have maximum sensitivity. The means to cure here are: to minimize metal leads and wires connected to IF input, voltage supply blocking, the “nearer to surface” mount of the parts, the smaller surface of “hot” terminals and screening. The last procedure of adjustment is to be made thoroughly, turn once more all the cores to maximum and fasten them with some “gluing” material (for example, with one produced by bees).

Receiver coils’ data:

All the inductances (except L8) are wound on corps with 5 mm Dia. with RF ferrite core inside. ПЭВ-2 is enameled wire, ПЭЛШО is enameled and covered with silk wire.

Inductance	Turns	Wire (enam.)	Notes
L1	16	ПЭВ-2 0,41 mm	Tap at 2 w. from cold termination
L2	16	ПЭВ-2 0,41 mm	
L3	12	ПЭЛШО-0.18 mm	Above L4
L4	40	ПЭЛШО-0.18 mm	

L5	12	ПЭЛШО-0.18 mm	Above L6
L6	35	ПЭЛШО-0.18 mm	
L7	21 x 2	ПЭЛШО-0.18 mm	Two layers with heavy twisted
L8	7	ПЭВ-2 0,41 mm	Without corps, internal dia. 4 mm
L9	40	ПЭЛШО-0.15 mm	
L10	50	ПЭЛШО-0.15 mm	

Note: all the inductors are closely wound. The end of one wire of L7 is soldered to start of the second (bifilar wound).

IC К174ХА10 (DA1) can be replaced with A283, TDA1083. VT1, VT2 can be substituted with any small power NFETs good for functioning at HF and at these supply voltages. You apply to them (КП303 – КП307, КП312 as for Russian types, MPF102 or equivalent as for other types). All resistors are 1/8 or ¼ watt, caps - КМ, К10-7, КД or equivalent RF, oxide caps – К50-16 or equivalent without specialities. Speaker WA1 is a small-size type with 8 Ohm impedance. R6 - any type rotary small - size 30-100 kOhm pot with switch. Q-resonators were taken from an old-type bridge Q-filter (non-monolitic) They can be substituted with any good quality resonators for 10700 kHz or so (for this choice of IF). The screening enclosures of coils are made from copper foil band (18-20 mm) by winding 1-3 w. on 10 mm corps and soldered along the screen. There is a protective winding from Teflon band inside the coil screens. After the screen is put to its place around the coil, it is soldered to the foil of the board in 2-3 points on the parts side. The core of coils are put into openings which are present on the board (they permit two side of the board adjustments of coils).

To have the improved characteristics of the receiver, Victor, UA9LAQ has put to IF a single high quality Q-resonator instead of usual Q-filter. The second Q-resonator to the same frequency was needed for BFO (one old Q-filter has 4 pairs of crystals, so You can do 4 receivers out of one Q-filter). The application of one crystal as an IF-filter improves the IF-choice and makes the construction of RX more compact. The choice of IF was done as shown to have good sensitivity and selectivity not only against the adjacent channels but also against the mirror one at single conversion. If You want to improve the selectivity of IF, You may apply the simple bridge circuit to neutralize the Q parasitic capacity. The dynamics of the receiver is not so high but is improved with the improving of supply voltages. If You have Your neighbor operating rig, the supply voltage is better to use 6 V or more. The minimum supply voltage for RX to function is 2,7 V (for some copies of IC it is lower) and is good for field application when the batteries go down. LS permits to here CW-music not having RX in hands: they are free for other work. Supplying voltage is received from minimum of two AA galvanic elements (or three rechargable); other sources can also be applied.

When RX is powered from AC net, take care of connecting parallel to rectifying diodes a cap (for each) 3300-6800 pF for decreasing the so called “multiplication” noise. According to the test of supplying blocks with regulators [5] and [6], the RX sensitivity was decreased with [5] about one fourth, as compared to [6], which is equal to supplying from battery. The multiplication noise decoded controls the AGC which decreases the gain, as for the second case, there were no such a noise according to filtration caused by above mentioned caps parallel to diodes. After caps C13 and C18 values were changed (Fig. 2): C13 - 82 pF, C18 – 68 µF x 16 V.

RX is tested at "on-duty" all the time: day and night. All continents were received with a dipole antenna. When I hear a DX, I take the microphone of self-constructed 2m FM station and make an announcement on our TRAN (Tyumen Radio Amateur Net) that I founded in 1987. All who are present switch their Big Gun PAs and DX is "in the pocket".

CHERIO! 73,

Victor Besedin, UA9LAQ ***ua9laq@mail.ru***

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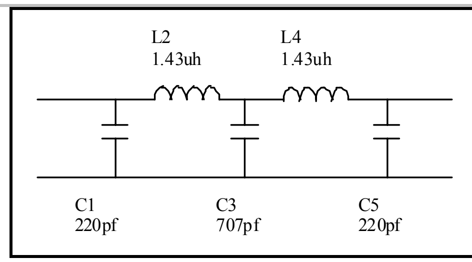
AmQRP.ORG HOMEBREWER

Phil DeCaire, WB7AEI

Low Pass Filters for QRP Transmitters

Learn about those pesky output circuits we all use, and how to optimize them!

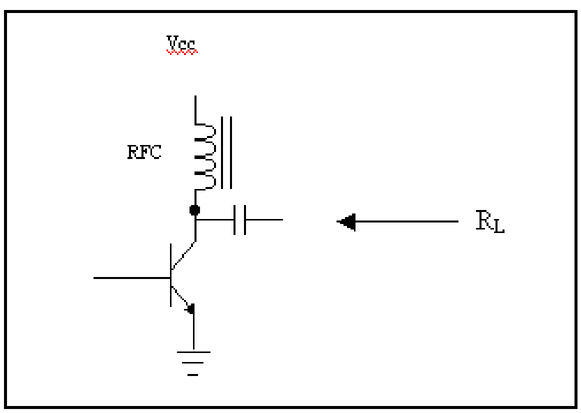


Sometimes the simplest circuits turn out to be the most complex in behavior. That certainly applies to the common "low pass filter" used at the output of most QRP transmitters. Maybe you've built a rig that didn't perform the way you thought it should. I've put together many breadboards that didn't give the output power I thought they should, and so I've spent a little time figuring out why. What I've found is that the filter, which is often something that gets slapped on at the end of the design/construction, plays a very key role in how well it works.

Expected Class C amplifier operation

The expected power output of a class C power amplifier can be calculated from a simple equation:

$$Po = VCC^2 / 2*RL$$



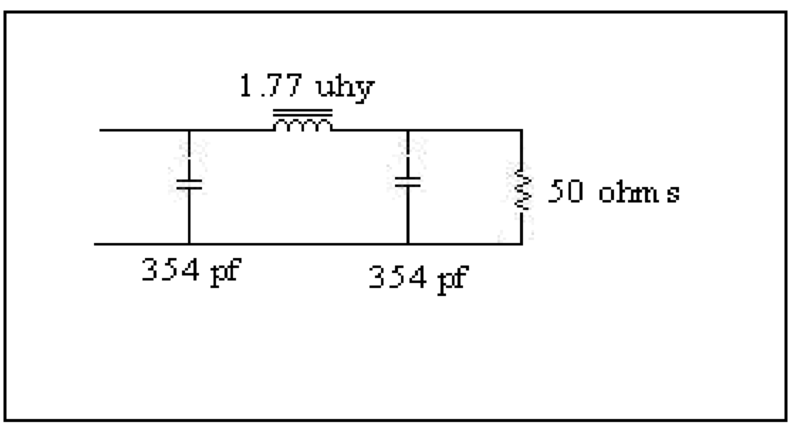
Where VCC is the transistor collector supply voltage and RL is the load resistance presented to the transistor by the antenna or dummy load. This assumes the transistor is saturating and acting as a switch (and that it can handle the necessary currents and voltages). Of course, the transistor may not pull the voltage all the way down to zero, and there may be an emitter resistor, so VCC may have to get adjusted by a volt or two. If the amplifier is under-driven, then the transistor won't saturate and the output will be less. For the 1 watt class of amplifiers I like to play with, if RL is 50 ohms and VCC is about 12 volts, you get about 1 watt output (1.44 watts per the calculation) without any impedance matching at the output. The filter is there solely for harmonic attenuation.

Note that as RL changes, the output power changes. Also note that the impedance the transistor sees is NOT your 50 ohm load, but rather the impedance the filter network presents. We commonly think of filters being designed for 50 ohms, but the impedance they present to your final amplifier may differ significantly from 50 ohms!

I found the answer to my problem when I started calculating out the impedance of my filter at the operating frequency. I was astounded by the numbers; I hadn't realized that filters behaved like this. There are many ways to figure out the impedance. You can do it by hand, starting with the 50 ohm load and working backwards to the input, using the relations for combining parallel and series resistances and reactances (see sidebar #1 for an example). An easier way is with some sort of circuit analysis program such as Cadence's PSPICE Student Version or Ansoft's Serenade Student Version. These programs take a schematic input and do all the work for you. You can get plots of impedance (both real and imaginary) vs. frequency so you can see what the filter really does. You could also set up a spreadsheet program to calculate the impedance vs. frequency; the recent versions of Excel do complex number math quite well. I often use a programmable calculator to calculate filter impedance at a specific frequency.

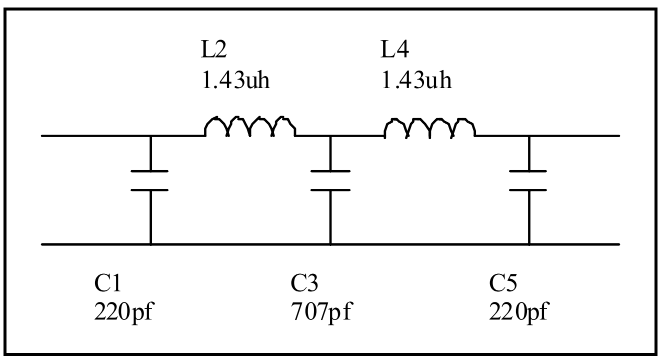
Lessons learned about low pass filters

Don't use a filter with too low a cutoff frequency! A 40 meter rig with a filter that cuts off at 7.2 MHz will have considerable loss (and a bad input impedance) at 7.040 MHz. The "cutoff" frequency of simple filter designs is often the –3 dB point. You need to allow some room between the operating frequency and the filter cutoff frequency. Don't use a cutoff below about 9 MHz for a 40M rig. You're in a bind because you want harmonic rejection, but you also want to get some output power. Let's look at a 3 element Butterworth filter with a cutoff of 9 MHz.



The ideal values are 354 pf for the capacitors and 1.77 uh for the inductor. Analysis of this filter shows 1.0 dB of loss at 7.04 MHz (you only get 794 milliwatts out with 1 watt at the input!), but even more importantly the input impedance isn't even close to 50 ohms. The real (resistive) portion at 7.04 MHz is 120 ohms, and the imaginary portion is –j25.7 ohms. This is the load the transistor sees and that you need to plug into the power equation, so obviously you're not going to get 1 watt out of this rig! You'd expect about 330 milliwatts per the numbers. What to do? If the filter cutoff were shifted up to about 13 MHz the impedance would be much better, but obviously you're not going to get much filtering at the 14 MHz 2nd harmonic.

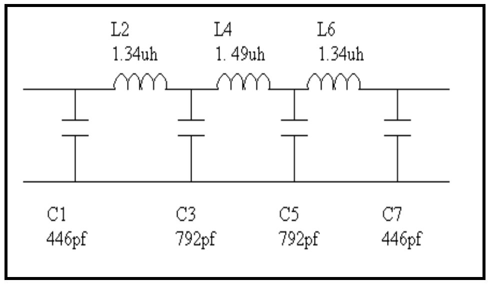
Simpler is not always better! The literature is full of transmitters that use simple 3-element low pass filters. This scheme can work, but there are some pitfalls. Of course, simpler filters also have less harmonic rejection, and a 3 element filter usually isn't adequate even for a QRP transmitter. What I've found is that 5 element (or more) filters have more stable impedances below cutoff. The above filter calculated as a 5 element design below shows a loss of only 0.4 dB with an input impedance of 37 +j21 ohms at 7.04 MHz, which isn't 50 ohms but is closer.



Whereas the first example gives low power output and low collector current, the 2nd may give more than the expected output power with higher collector current (and more heat!).

Not all filter types have the same impedance variation across the passband. There is some magic in the Chebyshev design. If you analyze a Chebyshev filter and plot the impedance data on a Smith Chart (Serenade will do this quite nicely for you), you'll find that up to the cutoff point the impedance remains very close to 50 ohms. As the frequency rises, the impedance starts changing but curves back around in a loop to stay close to 50 ohms. This is indeed the nature of the Chebyshev design. The response in the passband is not flat, but in exchange for this you get sharper cutoff and more stable impedance. A 5 element 0.1 dB ripple Chebyshev design (470 pf, 1.4uh, 820pf, 1.4uh, 470pf, in standard values) shows an input impedance of 47 –j6 ohms at 7.04 MHz, which is a pretty close to 50 ohms. The filter has less than 0.1 dB loss (theoretical) on 40M and a rejection of 30 dB at the 2nd harmonic. In fact, the –1 dB point is 8.3 MHz, and the –3 dB point is 8.8 MHz. Now this is more like what we want from a filter!

Another thing to keep in mind is component tolerances. Those capacitors are not really 470 pf; they may be +/-5%, or even as much as +/- 20%. The inductors likewise may be +/-10%, and if you wind your own toroids they may vary depending on how the winding is spread out on the core. This is ok, it's the real world, but it means not to push the cutoff frequency too close to the operating frequency, because you don't know what the cutoff frequency really is (unless you're lucky enough to have a network analyzer to check it out).
If you need more harmonic attenuation for a given cutoff frequency, add more elements. A 7 element 0.1 dB ripple Chebyshev low pass filter for 40M (446pf, 1.34uh, 792pf, 1.49uh, 792pf, 1.34uh, 446pf ideal values):



gives 45 dB of attenuation at 14 MHz with less than 0.1 dB at 7 MHz, with the cutoff frequency still at 9 MHz. The impedance at 7.04 MHz is very good at 58 –j3. For most QRP work however, a 5 element filter will be sufficient.

Filter "design" is easy these days. All you need is the filter coefficients from a book and you can calculate values for any frequency and impedance. See sidebar #2 for an example.

One exception to the simple filter = bad impedance rule is the so-called "half wave filter". The three element values are calculated for 50 ohms reactance at the operating frequency, giving 450 pf for the capacitors and 1.13 uh for the inductor. It has negligible loss in-band (due to a response peak at the operating frequency). The impedance is good at 50 –j0.1 ohms (essentially a perfect 50 ohm match). But the 2nd harmonic rejection is only about 10 dB, not enough to clean up a typical QRP transmitter to meet FCC requirements. That's why we usually use "fancier" filter designs.

There are other technical tricks that may be used to reduce the requirement for filtering or to apply specific filtering. A push-pull amplifier tends to cancel even harmonics and reduces the need for filtering. A linear (Class A, AB, or even B) amplifier generates lower harmonic levels and needs less filtering. A very simple solution for the 2nd harmonic, although it degrades the filtering at higher harmonics, is to resonate the inductor(s) in the filter with a capacitor that tunes to the 2nd harmonic. This makes an elliptic notch filter that can add lots of dB at a specific frequency(ies).

To Summarize

Even simple filters have complex behaviors. The filter input impedance can vary wildly both below and above the cutoff frequency. The ability of a simple transmitter to develop output power depends on the load impedance the transistor(s) sees, and what it sees is the filter input impedance. This impedance can be analytically determined by either hand or computer analysis, and the numbers can answer the question of why the rig doesn't work right.

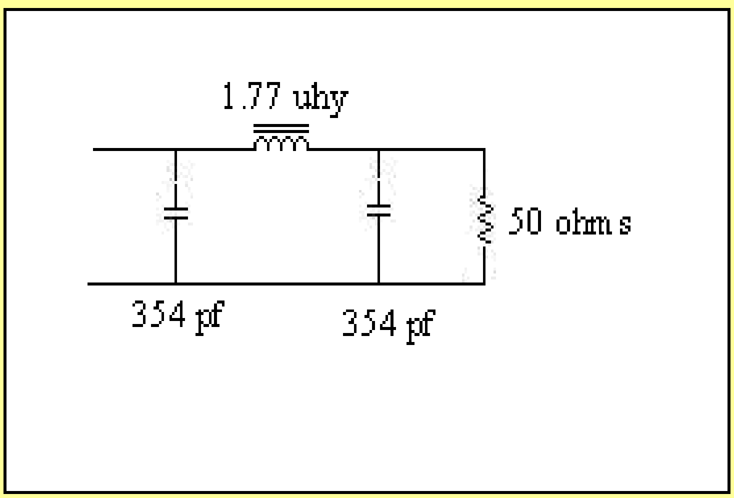
Don't set the filter cutoff frequency too close to the operating frequency! Filters with more elements tend to have more stable impedance below cutoff and higher harmonic attenuation, so stick with the 5 and 7 element filters rather than the 3 element type. Chebyshev filters in particular show a flatter impedance below cutoff.

I find that when I use 5 element 0.1 dB Chebyshev filters designed for a cutoff comfortably above the operating frequency (8.5 to 9 MHz for 40M), things work well and I get what I expect from the rig.

Sidebar #1
Calculating the impedance of a filter

If you've never done this before, here's an example of how to go about calculating the input impedance of a filter. It really helps to have a calculator that will do complex math, and I'm assuming you do. Otherwise it gets a lot messier! We're going to assume a 50 ohm resistive load on the output. We start with the load and work backwards. We calculate the impedance of parallel elements by converting them to admittances and adding them. An admittance is just 1/(impedance). We calculate the impedance of series elements by simply adding the impedances. The calculations will all have real (resistive) and imaginary (capacitive or inductive reactance) parts.

Here's what our circuit looks like:



We're going to analyze it at 7 MHz (7e6 in scientific notation). The 354 pf capacitors (354e-12) have XC = 1 / (2 * pi * 7e6 * 354e-12) = -j64.2 ohms. The inductor (1.77e-6) has XL = 2 * pi * 7e6 * 1.77e-6 = +j77.8 ohms.

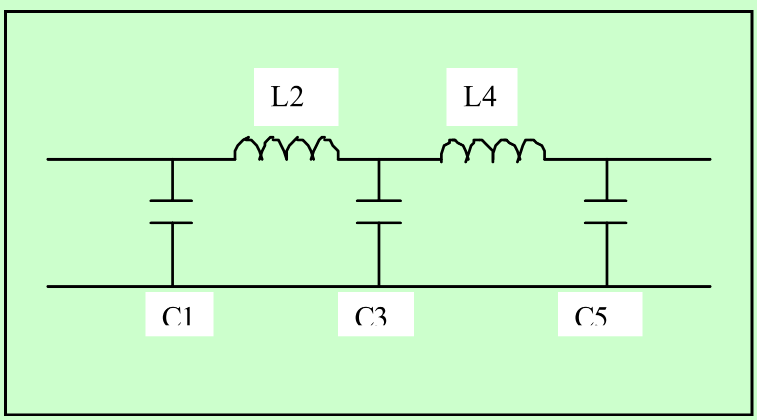
Start by combining the 50 ohm load and the last capacitor. Remember these are complex numbers and you can't treat them like regular numbers! 1/(1/RL + 1/-jXC) = 1/(1/50 + 1/-j64.2 = 31.1 –j24.2.

We've converted this result back to an impedance, so we can just add the inductive reactance to the number, 31.1 –j24.2 +j77.8 = 31.1 +j53.6.
Now we have a parallel combination of the impedance and the first capacitor, which we handle the same as before. 1/ (1/(31.1+j53.6) + 1/ -j64.2) = 119 –j23.5. And that's the impedance at this frequency looking into the filter (this is the Butterworth design we talked about earlier).

You can do a 5 or 7 element filter the same way, it just takes more numbers and calculating. Doing this for a lot of different frequencies is a lot of work! Better to put the computer to work and have it do all that math! Its hard to fill a page or two full of numbers without making an error somewhere.

Sidebar #2
Designing a filter

You need to know what type of filter you want, what the cutoff frequency will be, and how many elements you need. The only other thing we need is the filter coefficients. Look them up in the handbook or filter design book. Given that data you can design any low, high, or bandpass filter that you need! Let's say we want a 0.1 dB ripple Chebyshev low pass filter with a cutoff of 5 MHz and 5 elements. The generic schematic of a 5 element low pass filter looks like this:



You'll get the following numbers from the table for a 0.1 dB Chebyshev filter:

C1 = 1.3013
L2 = 1.5559
C3 = 2.2411
L4 = 1.5559
C5 = 1.3013

You'll notice of course that the filter is symmetrical, and the last two values are the same as the first two. This is always the case for these filters, so you only need to calculate 3 of the 5 values. These are the only values you'll ever need for any 0.1 dB ripple 5 element Chebyshev filter!

Here's how you calculate the L and C values.

C = Cn / (2 * pi * Fc * Z), where Fc is the filter cutoff frequency and Z is the design impedance. So C1 will be
C1 (& C5) = 1.3013 / (2 * pi * 5e6 * 50) = =8.28e-10 or 828 pf
L = Ln * Z / (2 * pi * Fc), so L will be
L2 (& L4) = Ln * Z / (2 * pi * Fc) = 1.5559 * 50 / (2 * pi * 5e6) = 2.48e-6 or 2.48 uhy

And following the same procedure as for C1 & C5, the C3 value will be 1430 pf.

Of course, the values will usually not be standard values for components, so round them up or down to the nearest standard value and go with that. Its always a good idea to double check your filter design by running it on a circuit analysis program to make sure you like what it does. That's also a good way to find any calculation errors. And of course after you've built the filter, you could measure it by connecting a 50 ohm load to the output and measuring the input impedance with an MFJ "SWR Analyzer", Autek RF Analyst, or even a noise bridge.

Phil DeCaire, WB7AEI ***pedecaire@email.msn.com***

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Rich Arland, K7SZ

TUNING UP!
The Birth of "Digital Dickey"

K7SZ describes how an analog guy in a digital world manages to survive in a world of ones and zeros.

I sat through the terrific presentations at Atlanticon 2005 thinking: "Man, I sure wish I could do some things like that!" I am, of course, referring to the superb papers presented by notables like Lyle Johnson, KK7P and Jim Kortge, K8IQY on digital QRP, DDS etc.

Confession time: I am an analog guy in a digital world. I have come to accept that mantel and wear it humbly in the presence of digital gurus like George Heron, N2APB, Joe Everhart, N2CX and others. I just shut my big mouth and nod agreeably when anyone starts talking digital. My old English professor Ken Holloway once told me: "Arland, its better to keep your mouth shut and allow people to think you are an idiot than to open it and remove all doubt!!" Ken, God Bless him, had me pegged pretty well, especially when it came to digital stuff.

So what's the big deal about digital? All it is, in reality, is a bunch of "ones" (1s) and "zeros" (0s). Things couldn't be much simpler than that, could they? OK, OK, so its ones and zeros….but those "ones" and "zeros" are "doing things"…..really weird things like controlling radios, making magic talking box work….hmmmmm. At the very least digital is not normal. It's against Nature's laws. It could even be construed as ***UNHOLY***! I mean, talking over great distances without wires is weird enough but to have "ones" and "zeros" controlling all aspects of our very existence, including our ham radio hobby, well, it's just ***NOT RIGHT***! Aaaaaaaaaarrrrrrrrrrggggggggggghhhhhhhhhhh! (As the Peanunts ™ character, Charlie Brown, would say upon occasion.)

Wow! I am much better now that my meds kicked in! Why am I so intimidated when it comes to digital communications? What is it that is so mystifying about digital? All you really have is a bunch of "ones" and "zeros" floating around out there in the "ether" and they are being manipulated by a software program that makes them do things. Ah, yes, ***software***. Software breeds ***programmers***. Programmers are not of this world! Hmmmm…things are beginning to take shape. It is the "***Alien Factor***" at work. I must notify **MUFON** immediately.

The Birth of "Digital Dickey"

Shortly after Atlantacon 2005, a deal was struck with His Royal Digital Highness, Heir to the Digital Realm, Purveyor of the Digital Rift, His Excellency King George I of Heron. In exchange for an undisclosed amount of coin of the realm, I was presented with a New Jersey QRP Club Micro908 kit, complete with instructions! As I look back over my shoulder, I can still see the event horizon of the digital black abyss over which I crossed some months ago: A place beyond which things were “normal”. Ahead of me, down the long swirling cyclone of utter blackness is the Worm Whole of Digital Salvation, the place I am striving to enter, irrespective of my inability to really understand, let alone comprehend, any of this digital stuff at all! Digital Dickey is in the digital birth canal…like it or not!

Flash back to mid-afternoon of March 6, 1946, to the hospital room at St. Ignatius, in Colfax, Washington, where my poor sweating, screaming mother, is experiencing the final throws of birthing her one and only son, yours truly. My birth was complicated. No, I wasn’t a breech baby. Nor was I entangled in the umbilical cord: no, nothing quite that simple.

In fact, I was desperately clinging to a Hallicrafters receiver on my way down the birth canal. I would not give it up, much to the pain and anguish of my sainted mother. Finally, after an interminable pain wracked birthing, I lay on the bed beside my mother, still clutching the S-38. We were a family. Dad came in beaming proudly, as only a new father can, and immediately proclaimed “It’s beautiful!”, referring, of course, to the S-38, not his pink, gooey, little newborn offspring. And so it started; my life long love affair with radio….***ANALOG*** radio!

So, now that you know the ancient family secret…..you can better understand my total lack of self-confidence in exploring this new world of digital communications. When it comes to digital comm, you have to throw out all your preconceived ideas regarding analog radio. It is, quite literally a whole new world. A world littered with pitfalls and unexpected set backs for the unwary digital neophyte. On the other side of the coin, when things go well, they go extremely well. So well, in fact, that the digital newcomer starts to think that he/she did something wrong! This leads to a lively round of “second guessing” which leads to making some stupid assumptions, which leads to …..Well, you get the picture!

Digital Dickey and the Micro908

All things being equal, I should have been born in the 1980s. Starting a kit, especially a kit with about 95% surface mounted parts at my age (almost 60) with less than perfect eyesight is a real experience; not necessarily a good experience, either.

Thankfully, I can still solder well, something that I learned from many years in ham radio and the military communications. When assembling a SMT kit like the Micro908, it is paramount to have a well lighted, ***CLEAN***, stable work surface that you can lay parts out upon without the danger of losing or dropping anything. A good soldering station, capable of variable heat, is an absolute “must have”. My reliable old Weller soldering station was purchased over 10 years ago on sale for about $100. It was a bargain, believe me! Although the Micro908 kit comes with solder, I prefer using my own: Kester “44” rosin core, .020 diameter. I buy this in one pound rolls and a roll last me quite a while. This is extremely small diameter solder designed specifically for small densely populated circuit boards (like the K2, KX-1, etc) and SMT projects. The soldering station temperature is set at about 2/3 full pot rotation, and provides plenty of heat. I really don't know the temperature of this setting, but it works well, so I use it at that setting. Too much heat is a bad thing, especially when working with SMT devices.

The Micro908 kit is very well done. Instructions are clear and concise, leaving little to the imagination. George has done a terrific job in trying to anticipate problems with this kit and has a very comprehensive troubleshooting section at the end of the manual.

As you undertake this kit, keep in mind two things: 1. you are working with extremely small, highly "losable" parts; watch what you are doing and don't get careless, 2. Speed kills; slow down and enjoy the building experience.

The instructions take you through the various steps in building the Micro908, including using the enclosed flux pen to pre-treat all soldering pads on the circuit boards prior to placing and soldering any SMT parts. One must be extremely mindful of the fact that many of the capacitors, resistors, inductors, diodes, and transistors used in the kit are about the same size as the decorative cake "sprinkles" that your spouse uses on your favorite birthday cake! Use a jeweler's loupe or, in my case my "E-Bay Goggles", to provide the necessary magnification to properly identify parts and parts placement.

A good light source for this project is one of the many 10X magnifying lamps available for between $30 and $100 at places like Harbor Freight and Jameco Electronics. These lights have a circular (halo) fluorescent lamp that encircles the magnifying lens. This provides very flat lighting, ideal for assembling a kit like the Micro908.

As I assembled the kit I found that placing the ultra-small SMT components on the pads was relatively easy. Holding them there while trying to solder them in place was another story. I finally settled on a method of putting a small "blob" of solder (and I mean a ***REALLY*** small blob) on the tip of my iron, and applying it to one side of the SMT component, while holding the component against the circuit board with the point of a pair of very fine nosed tweezers (mine are made of stainless steel and I got them at a ham radio flea market many, many years ago). After the blob adheres to the component and the PC board and cools, I then tack down the opposite end of the component without holding it in place. This method worked very well and the kit went together without any problems over a couple of days plagued by irregular building sessions.

One problem that cropped up was that while I had received the DDS VFO chip, I didn't receive the PC board (called a daughter card) or the upgrade kit (grand-daughter card) that makes the digital VFO perform as advertised. This was conveyed to George, and within a few days, a proper kit of parts was in my hands. The DDS VFO board was constructed, modified according to the upgrade instructions, and placed inside the box.

Check out of the completed Micro908 kit preceded and everything was going fine up to the point of checking out the DDS VFO and calibrating the antenna analyzer. It seems that the DDS VFO was not working, or, if it was, the digital bits of "ones" and "zeros" were streaming off into the "ether" never to be seen again!

This is where the very complete troubleshooting section of the manual that was previously discussed comes into play. After completing all the suggested checks as outlined in the troubleshooting portion of the manual, things still didn't seem to work. Digital Dickey was in a deep purple funk.

I put the almost-completed Micro908 kit into the filing cabinet drawer and decided to back away from the project for an undetermined amount of time. Sometimes it takes a long pause like that to mentally divorce your psyche from the problem at hand, and allow clear thinking to come to the forefront. Such was the case with my Micro908 kit. After about 4 weeks of exile in the bottom drawer of the filing cabinet, I retrieved the errant kit and started back on the troubleshooting track. Soon I had pinpointed the cause; a poor solder connection on one of the jumper wires that connected the grand-daughter DDS VFO board to the DDS VFO daughter board. It is absolutely amazing what a poor solder connection can cause. Once repaired, check out and calibration was resumed with no further problems.

Necessity is the Mother of Invention…or…Invention is a "Muthar"

The New Jersey QRP Club's Micro908 kit has taught Digital Dickey a couple of valuable lessons. First, you **can** teach an old dog new tricks. Having never attempted a surface mount component kit prior to the Micro908, I had my reservations as to whether or not I could accomplish something of this nature with my less than perfect eyesight. Not to worry, mate….good to go!

Second, you don't have to know how to program the Micro908 kit in order to use it nor do you have to understand the programming steps in order to appreciate the beauty of digital communications electronics. Suffice it to say this kit has changed my mind regarding digital comm technology and how to employ same in the ham radio hobby. It is ***not*** all that intimidating, once you make a few inroads and enjoy some successes.

Finally, the Micro908 project is a great little learning platform that can be made to do a multitude of things around the shack….just change the programming! As it initially comes from the NJ QRP Club, the 908 kit is configured as an antenna analyzer for the HF bands. However, just change the software programming and you have a digital audio filter; all from one box, with one set of boards! Software defines what the box does, all you do is sit back, relax, and let the box do the work. Life is good!

Tweak the software and you have a digital VFO/Local Oscillator (LO) for other projects around the shack. Using the digital read out on the front of the box, it is possible to set this "black box" up as a very stable RF generator for testing and aligning receivers. Again, all from one box with one set of board; just change the software.

Did I drop out the end of the Digital Worm Whole of Salvation a seasoned programmer? ***Hell NO!!*** As far as I am concerned they (programmers) are still under alien influence and must be carefully watched at all times. What did happen when I dropped through the Worm Hole was I became conscious of the extremely versatile world of digital communications. A world that is unique and full of surprises for those who want to attempt the journey. Is the digital realm without conflict or tribulation? Hardly. However, you can troubleshoot and succeed if you follow some precise steps, just like the little “ones” and “zeros” do when they are under the influence of a software program.

Digital Dickey is going to hang around a spell. While I still dearly love my old S-38 with all its scars and imperfections, there is room in this ham radio hobby for a digital radio (a software defined radio?)….one that I will be obtaining in the future, one that will be every bit as good and provide as much fun and excitement as my old faithful S-38 Hallicrafters.

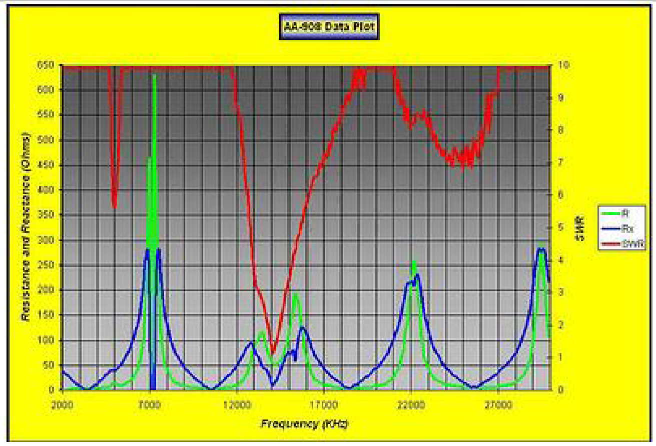
72, Rich K7SZ

AmQRP.ORG HOMEBREWER

Al Gerbens, K7SBK

New & Improved!

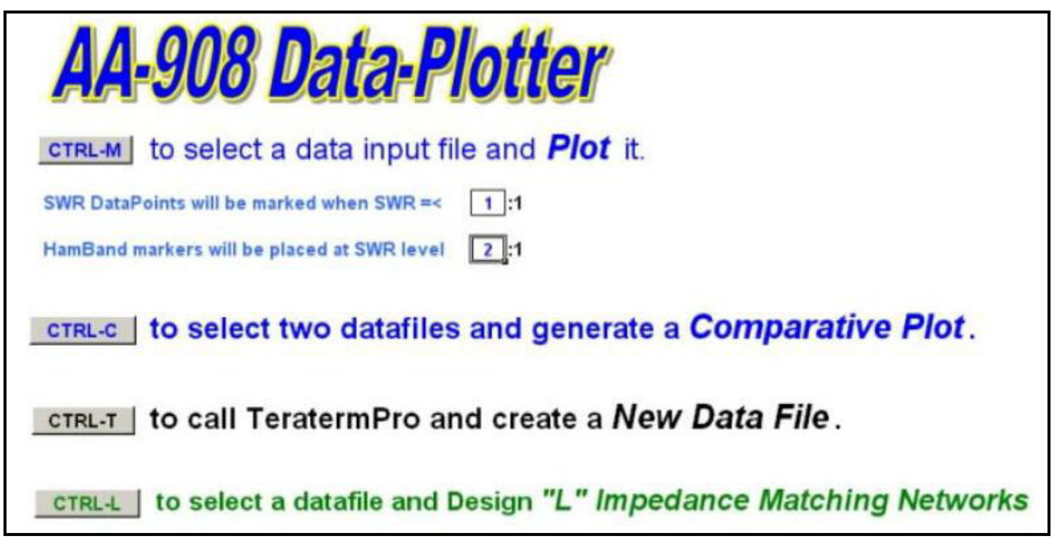
Excel Plot Generator for "Antenna Analyst "



In the last issue, K7SBK described a useful little Excel spreadsheet "macro" that accepted the data file from the Micro908 Antenna Analyst instrument and displayed some real useful SWR and impedance plots on your PC. Well, he's been hard at work since then and has added a ***ton*** *of additional features!*

The Excel based Plot Generator described in the last issue of AmQRP Homebrewer can be used to locate and import an existing AA908 data file captured using the TeraTerm program on the PC, and then generate a frequency value for each data point and plot a graph of the 3 parameters SWR, resistance and reactance versus frequency.

There were at least several bugs in the original program and while working them out I began thinking about enhancing and expanding the program. Several AA908 users also made suggestions along the way and the result is Rev G of the tool.



The new opening page of the AA908 Data Plotter

The latest version of the AA908 Data Plotter (rev G) has three major functions:

CTRL-M	Plot Generator with additional features.
CTRL-T	Generate a Data File using TeraTermPro and the AA908.
CTRL-C	Comparatively Plot two data files on the same chart.
CTRL-L	L network impedance matching datapoints to Coax

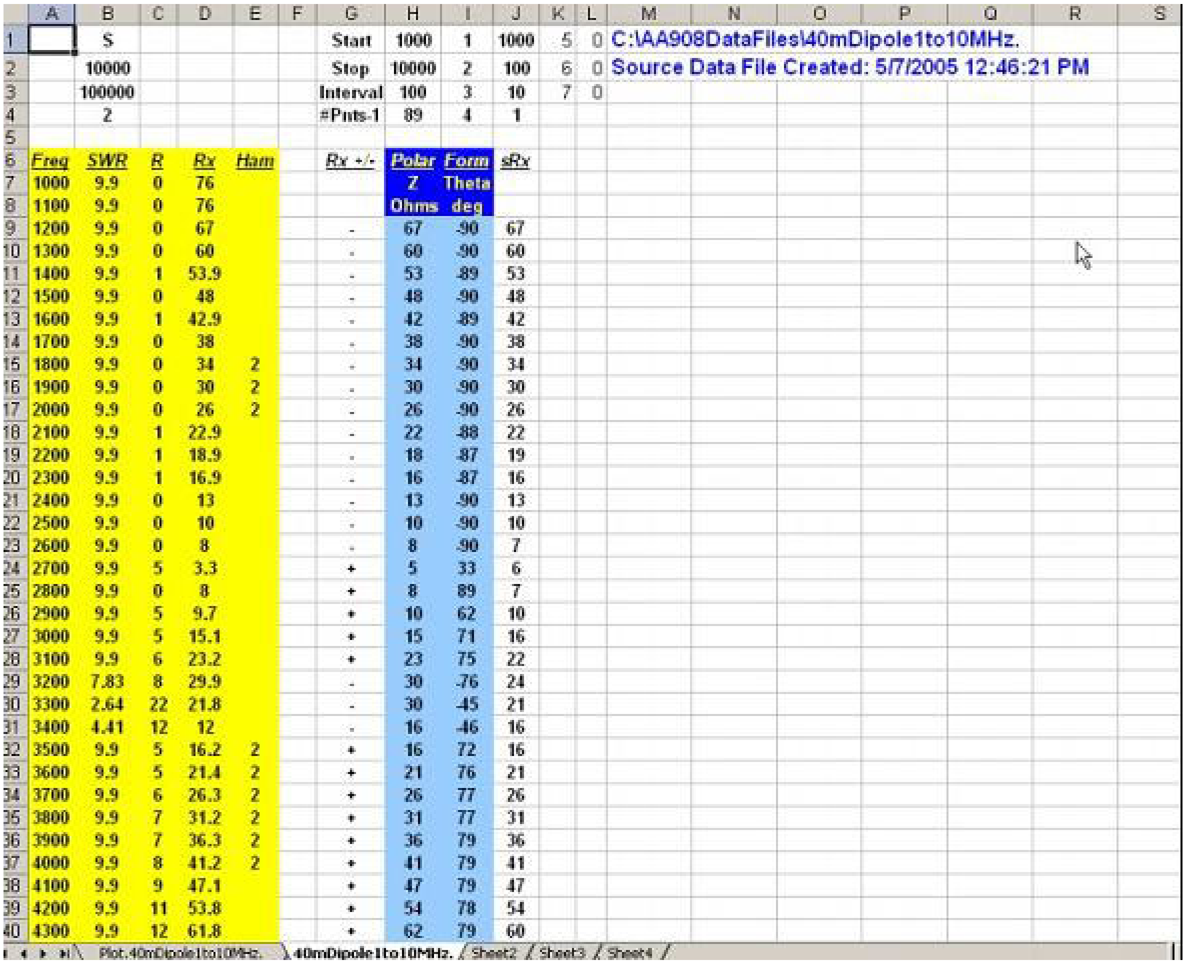
Plot Generator macro (CTRL-M)

The TeraTermPro data file pathname and date of creation have been added to the data sheet. This was done to help in keeping track of the source of the data on the Datasheet and its associated Chart. The file name was added to the Chart Title to associate the Plot with the data. Finally, to further support documentation, the two sheet TABS (one for the data sheet and one for the plot sheet) are given names containing the TeraTermPro file name.

Yep, those are clickable control buttons you see on the opening page. You can now either go to the keyboard and press the CTRL and M keys simultaneously or click the CTRL-M button.

Below the CTRL-M command button are two new features for the Plot Generator. There are two boxes (each is just an Excel spreadsheet cell) in which you can optionally change information before doing the CTRL-M thing. The first deals with SWR data points on the graph to be generated. By default it is set at 1:1 which means that no SWR data points will be marked on the SWR curve because there are no SWR values less than 1:1. Set it at 2:1 though and every data point on the red SWR curve will be marked with a tiny white circle embedded into the red SWR line at SWR levels less than 2:1. Hovering the mouse pointer over a data point can result in the freq and SWR for that point being displayed in a little box near the point. Using this feature you can see where your individual data points lie on the SWR line below an SWR level that you select. Note that if you have collected hundreds of data points per inch of SWR line those little white circles embedded in the SWR line are not going to look much like little white circles. The intent of this feature was originally to have a method for indicating a critical (acceptable) SWR level. I like seeing the individual data points on which the smoothed SWR curve was based so I left the function in place even though we have another option for indicating critical SWR level.

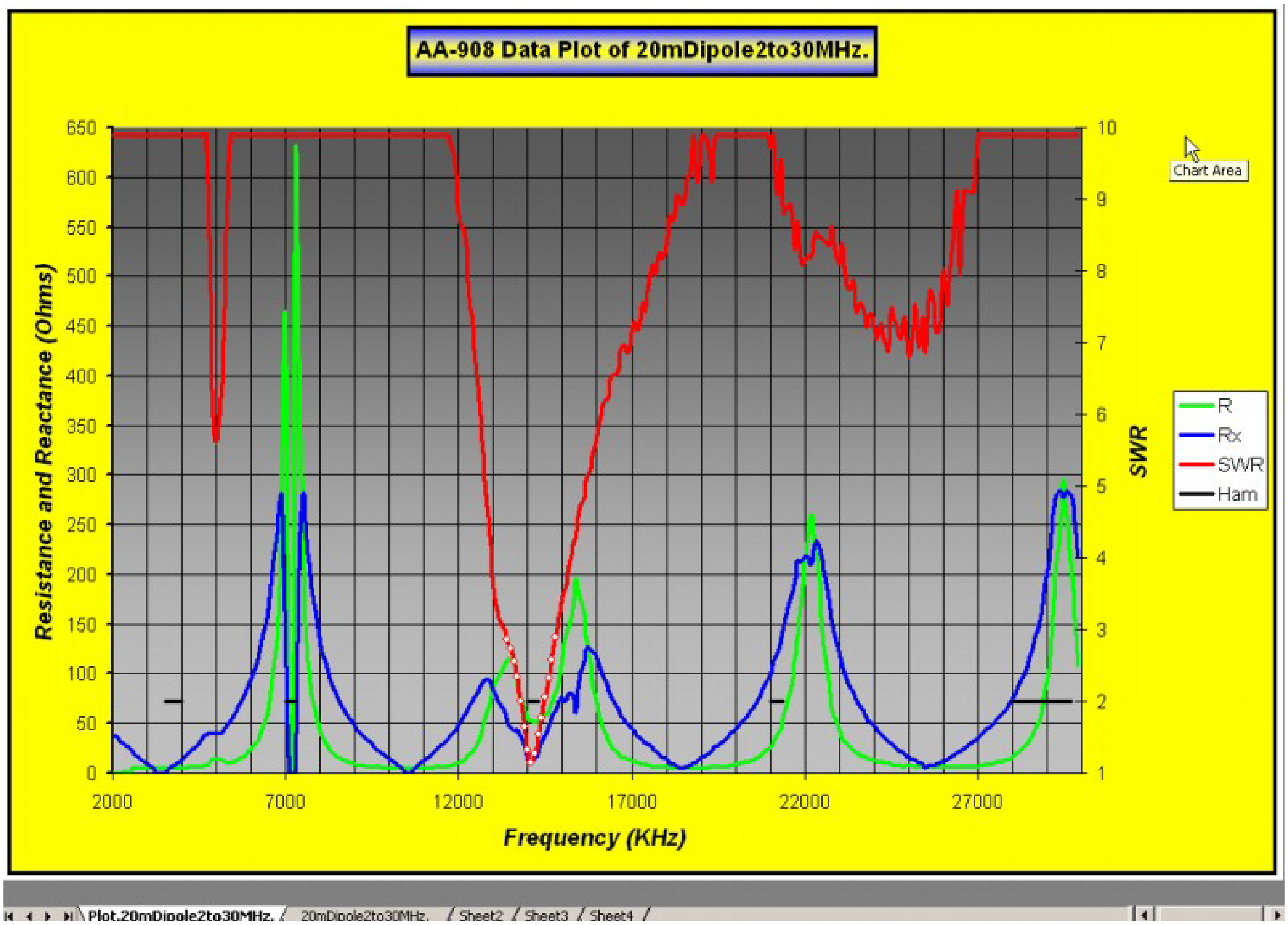
The second box is associated with ham band frequency markers. The intent here is to provide an indication of ham band frequencies, as unobtrusively as possible. To do this I created a fourth data series which is eventually displayed as a single thick black horizontal line on the chart. This line appears on the chart only when there are data points that lie within a ham band. The SWR level you enter into the second box on the front page is the vertical (SWR) level at which you would like to have these ham band indicators appear on your graph. Don’t want them? Just set the SWR level at 1:1, the default is 2:1. This is another way in which you could indicate a critical SWR level. You can see the ham band series on the data sheet, the cells are blank if a datapoint lies outside a ham band and contains the vertical level you specified if the datapoint lies within a ham band.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1		S					Start	1000	1	1000	5	0	C:\AA908DataFiles\40mDipole1to10MHz.
2		10000					Stop	10000	2	100	6	0	Source Data File Created: 5/7/2005 12:46:21 PM
3		100000					Interval	100	3	10	7	0	
4		2					#Pnts-1	89	4	1			
5													
6	Freq	SWR	R	Rx	Ham		Rx +/-	Polar	Form	sRx			
7	1000	9.9	0	76				Z	Theta				
8	1100	9.9	0	76				Ohms	deg				
9	1200	9.9	0	67			-	67	-90	67			
10	1300	9.9	0	60			-	60	-90	60			
11	1400	9.9	1	53.9			-	53	-89	53			
12	1500	9.9	0	48			-	48	-90	48			
13	1600	9.9	1	42.9			-	42	-89	42			
14	1700	9.9	0	38			-	38	-90	38			
15	1800	9.9	0	34	2		-	34	-90	34			
16	1900	9.9	0	30	2		-	30	-90	30			
17	2000	9.9	0	26	2		-	26	-90	26			
18	2100	9.9	1	22.9			-	22	-88	22			
19	2200	9.9	1	18.9			-	18	-87	19			
20	2300	9.9	1	16.9			-	16	-87	16			
21	2400	9.9	0	13			-	13	-90	13			
22	2500	9.9	0	10			-	10	-90	10			
23	2600	9.9	0	8			-	8	-90	7			
24	2700	9.9	5	3.3			+	5	33	6			
25	2800	9.9	0	8			+	8	89	7			
26	2900	9.9	5	9.7			+	10	62	10			
27	3000	9.9	5	15.1			+	15	71	16			
28	3100	9.9	6	23.2			+	23	75	22			
29	3200	7.83	8	29.9			-	30	-76	24			
30	3300	2.64	22	21.8			-	30	-45	21			
31	3400	4.41	12	12			-	16	-46	16			
32	3500	9.9	5	16.2	2		+	16	72	16			
33	3600	9.9	5	21.4	2		+	21	76	21			
34	3700	9.9	6	26.3	2		+	26	77	26			
35	3800	9.9	7	31.2	2		+	31	77	31			
36	3900	9.9	7	36.3	2		+	36	79	36			
37	4000	9.9	8	41.2	2		+	41	79	41			
38	4100	9.9	9	47.1			+	47	79	47			
39	4200	9.9	11	53.8			+	54	78	54			
40	4300	9.9	12	61.8			+	62	79	60			

Plot.40mDipole1to10MHz. / 40mDipole1to10MHz. / Sheet2 / Sheet3 / Sheet4

The screen capture above is the data sheet for a 40Meter dipole scanned over a frequency range of 1-10 MHz in 100 KHz increments and generated using the CTRL-M command. Notice that the polar form the impedance with sign of the angle has been added. I generated the sign using simple averaging to smooth out the rough spots. This is a good place to experiment with sign determination algorithms since all the functions in Excel are available. The sRx column is the smoothed Rx and the sign of Rx is simply based on whether or not sRx is increasing in value (-) or decreasing in value (+) as frequency increases. This is pretty much how the AA908 code does it, but over a larger frequency step and without the smoothing. You can create your own algorithm, generate a column of data using autofill and evaluate how effective it is.



Above is the new chart format, notice the white data point markers below SWR level 3 and the black intermittent horizontal line at SWR level 2 indicating the presence of data points within a ham band.

GENERATE A DATA FILE (CTRL-T)

CTRL-T, the new "generate a data file" capability, is a non graphical function which allows you specify an AA908 Frequency Band range, a Path/FileName for your dataset and then initiate a data scan executed by the combination of TerraTermPro and the AA908 Antenna Analyst. The front page remains unchanged during this process, so after generating as many datafiles as you like a click on CTRL-M, another click on the file of your choice and you're quickly looking at a Plot of your newly generated dataset.

Why have a file generator function? Well, it's a step toward integration and frankly it's really handy to be able to initiate a data scan over a frequency band without leaving Excel, starting TerraTermPro (TTP) , pushing the scan button on a third component the AA908 to generate the file, closing TTP and then back into Excel The CTRL-T macro makes it possible to do all this from within Excel. You'll still have to change the frequency increment from the

AA908 front panel though, there may be a way to do this from outside the AA908, but I didn't find it.

How does the CTRL-T macro work? It first checks for and creates if necessary a folder called C:\AA908DataFiles. Then it opens that folder and asks you for a name for your data file. Your data file will be placed in the C:\AA908DataFiles folder.   I changed the CTRL-M plotter macro to always open the file query in this folder also. It makes it easy to create a file and retrieve it from the same folder.   Anytime that folder is not there, the CTRL-T file generator macro is going to create it for you. (hint: move all of your existing data files into this folder, use subfolders if you like). Your can choose a different folder for your data file while specifying the datafile name but by default the macros will always choose the AA908DataFiles folder.

Once you've entered a path/filename the program checks to make sure that TerraTermPro (TTP)   is in the C:/program files/TTERMPRO folder, if TTP is not there the program will ask you where it's at and accept your input, but it'll do this everytime you run this macro so it's a good idea to have TTP in that location . Next this data-file generator (CTRL-T) pops up an input box where you input the frequency range over which the AA908 will determine impedance and SWR. The first four options (numbers 1 thru 4) are code for the scan ranges 1-10, 10-20, 20-30 and CUSTOM , the remaining options are simply the ham band name, meaning 40 for 40 meters etc. Now, the data-file generator (CTRL-T) macro creates a TTP macro and places it in the TTP folder. The name of this TTP macro is AA908MACRO.ttl and it contains the frequency scan range code, an instruction telling TTP to look for an incoming "E" indicating the end of the data from the AA908 and then execute a close TTP instruction which kills the TTP application. Now the CTRL-T Excel macro is ready to call TTP and it does that using the Visual Basic Object "Shell" which starts a parallel process (TTP running it's own macro) within Windows. Commands passed from the CTRL-T macro to TTP include an instruction to execute Macro AA908MACRO and to log all data to the path/filename you designated.

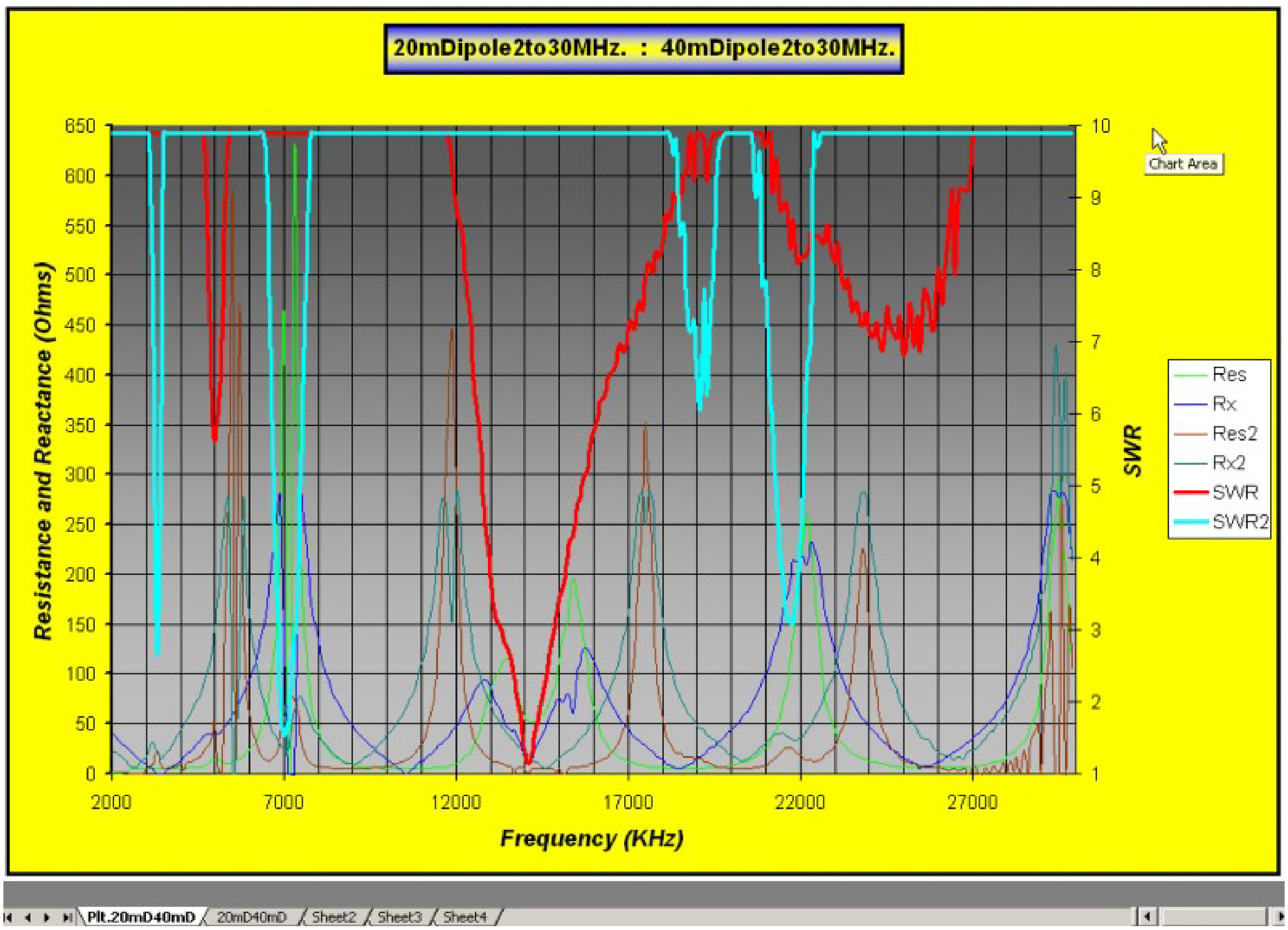
In short, CTRL-T creates a TTP macro, then starts TTP, TTP sends freq band data to AA908 and tells it to start scanning. TTP stores the data in a file and kills it's own incidence when detecting the end of file.

That's it, hit CTRL-M , locate your new data file and plot it, or use CTRL-T to generate another data file.

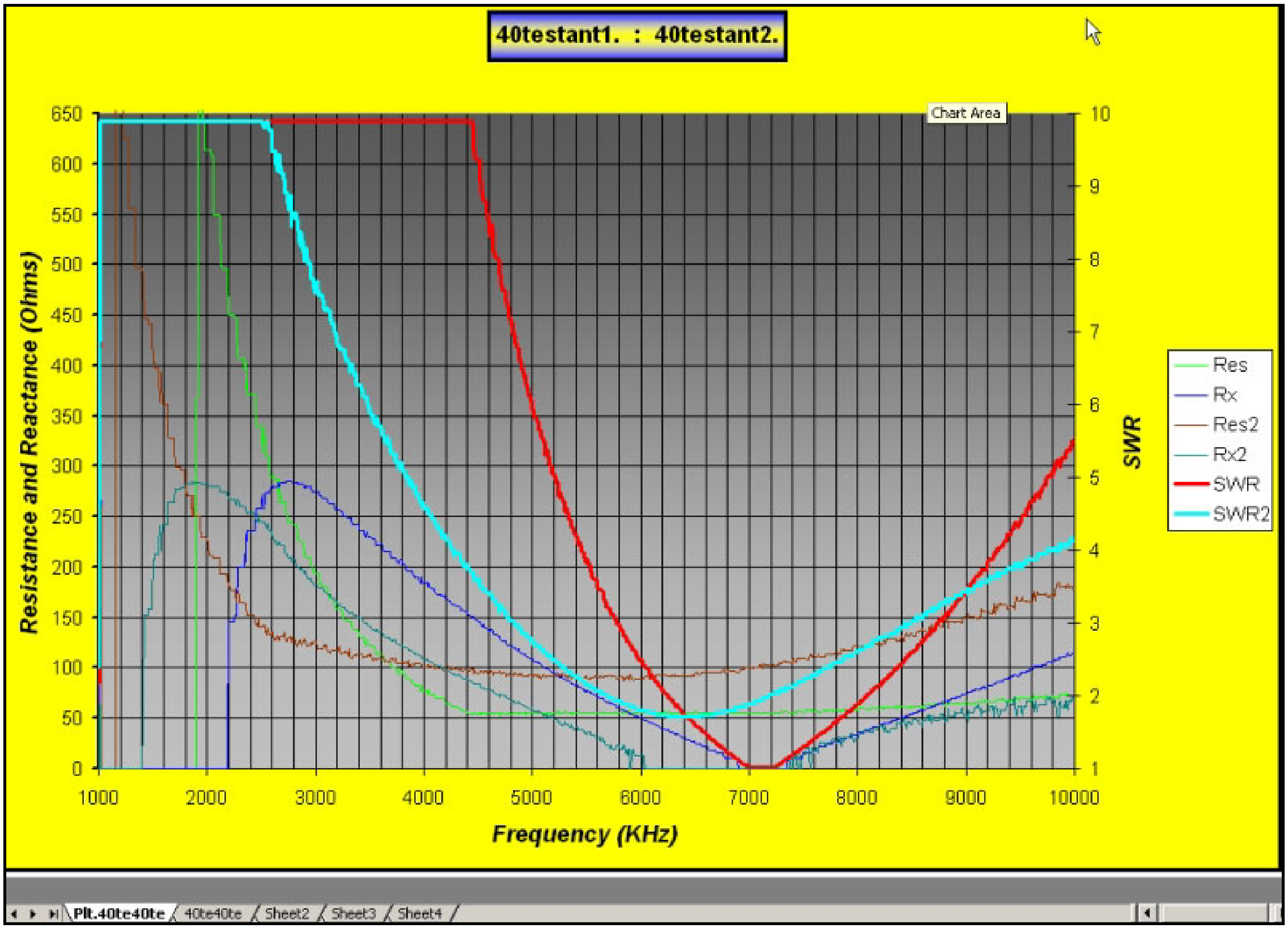
COMPARATIVE PLOT FUNCTION (CTRL-C)

The third function is a comparative plot function (CTRL-C). Operation is simple, just enter two path/filenames on demand and both datasets get plotted on a single graph. These graphs are basically XY scatterplots and so it's possible to arrange them so that all six parameters are plotted against frequency (X axis). The program uses the minimum frequency of the two data sets as the minimum and the maximum frequency of the two data sets as the maximum in determining the frequency range of the graph. So if you plot two 40 meter datasets they'll look pretty good in comparison , if you plot a 160 meter dataset and a 10 meter dataset, you're not going to be too happy with the result. (not too likely you'll want to do that anyway).

Because there's so much going on with 6 parameters being plotted on the same graph I eliminated the hamband indicator and SWR data point marker options. The SWR and SWR2 curves are wide lines for emphasis and the Res, Res2, Rx and Rx2 lines are very thin to help the observor maintain sanity. As you're looking at any of the graphs, remember that your inside of Excel and all of its functions are available to you. For example if you would like to remove a plotted line, use your mouse to select that line, right click on the mouse and edit that series to eliminate the line, change its color, change its width, add datapoint markers etc etc. When you've got it looking right, just save the workbook with your own path/filename.



A comparative plot of a 40 meter dipole and a 20 meter dipole over 2-30 MHz is shown above. Both file names are exhibited in the chart title and referenced in the data sheet. The tabs contain the first 4 elements of both filenames (file #1 first).



Above is a comparative plot using a test antenna circuit consisting of RLC mounted on a BNC connector. I held the circuit firmly between thumb and forefinger when generating the second dataset. You can clearly see the downward shift in resonant frequency and the reduction in circuit Q. (I'm not sure whether to call this phenomenon the "Pinch Effect" or the "Finger Effect".)

Evaluating the effect of antenna modifications using before and after AA908 data scans and overlaying them using the CTRL-C macro should be very interesting.

L-NETWORK IMPEDANCE MATCHING (CTRL-L)

This fourth new function designs an impedance-matching L network for each data point in the data file you select. The input to the L network is 50 ohms resistive and the other end of the network is the complex impedance of individual data points.

There are 8 possible L configurations, most matching problems can be solved with two of the 8 and the two most desirable are the so called 'low pass' configuration. These are the two primary solutions given by LNET a third alternative (TYPE B) is also calculated and presented whenever it'll work. A single L network configuration cannot solve all matching problems.

Determining the sign of the reactance turned out to be a source of error. Some of the limitations result from not being able to sample the reactance outside of the data set range, an occasional 'weird' data point (s) and the method itself. This program attempts to smooth the data and remove 'outliers' but could never get all of them.

There are a lot of reactance vs frequency inflection points in many of my data sets.

L Network Design

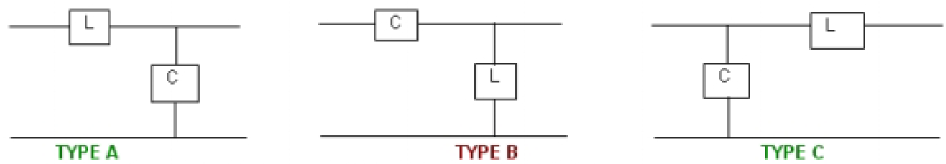
File Name: 20mDipole2to30MHz.

S

20000 2000

300000 30000

2 100 279



Impedance matching L networks: In the above diagrams the input (left) impedance is 50 ohms resistive.

						DESIGN				ALTERNATIVE DESIGN				
Freq	SWR	Res	Rx	RxS	Type	XC	XL	C (picoF)	L (microH)	Type	XC	XL	C (picoF)	L (microH)
2000	9.9	0	38.5											
2100	9.9	0	37	36.5	R<=0 error									
2200	9.9	0	34	33.66	R<=0 error									
2300	9.9	0	30	30.3	R<=0 error									
2400	9.9	1	26.9	-26.93	C	7.1	33.9	9344	2.24					
2500	9.9	1	23.9	-23.69	C	7.1	30.6	8971	1.94					
2600	9.9	5	20.3	-20.46	C	16.6	35.4	3689	2.16					
2700	9.9	5	17.2	-17.2	C	16.6	32.2	3552	1.89					
2800	9.9	5	14.1	-14.43	C	16.6	29.4	3425	1.67					
2900	9.9	5	12	-11.56	C	16.6	26.5	3307	1.45					
3000	9.9	5	8.6	-8.93	C	16.6	23.9	3197	1.26					
3100	9.9	5	6.2	-6.56	C	16.6	21.5	3094	1.1					
3200	9.9	5	4.9	-3.8	C	16.6	18.8	2997	0.93					
3300	9.9	5	0.3	-1.73	C	16.6	16.7	2906	0.8					
3400	9.9	5	0	-0.65	C	16.6	15.6	2821	0.73					
3500	9.9	5	1.65	1.64	C	16.6	13.3	2740	0.6					
3600	9.9	5	3.3	3.71	C	16.6	11.2	2664	0.49					
3700	9.9	5	6.2	5.63	C	16.6	9.3	2592	0.4					
3800	9.9	5	7.4	8.16	C	16.6	6.8	2524	0.28					
3900	9.9	5	10.9	10.43	C	16.6	4.5	2459	0.18					
4000	9.9	5	13	13.69	C	16.6	1.3	2398	0.05					
4100	9.9	5	17.2	16.83	A	16.01	24.1	2425	0.93					
4200	9.9	5	20.3	20.23	A	17.7	42.9	2141	1.62					
4300	9.9	6	23.2	23.26	A	19.87	48	1863	1.77					
4400	9.9	6	26.3	26.63	A	21.95	60.9	1648	2.2					
4500	9.9	6	30.4	30.3	A	24.36	73.8	1452	2.61					
4600	9.9	7	34.2	34.23	A	26.96	78.8	1283	2.72					
4700	9.9	8	38.1	37.33	A	28.95	81.2	1170	2.75					
4800	8.09	10	39.7	39.46	A	30.3	76	1094	2.52					
4900	6.05	14	40.6	39.93	A	31.18	62.4	1042	2.02					
5000	5.6	14	39.5	40.23	A	31.34	63	1016	2					

Plt.20mDipole2to30MHz. / 20mDipole2to30MHz. / Sheet2 / Sheet3 / Sheet4

The screen capture shown above is that of the LNET worksheet. The three network configurations are diagrammed at the top of the page with the 50 resistive input (coax) on the left. The TYPE column indicates the configuration, and the C and L columns contain the capacitance (in picofarads) and inductance (in microhenries) required to build a network matching 50 ohm coax to the complex impedance in your data set Res +/- Rx.

If R =< zero then no design is reported.

Depending on your dataset you'll find an occasional point or small region of points that don't make a lot of sense and in most cases looking at the data set it will be obvious why, generally they'll be connected to a bump in the data that produces a reactance sign transition that possibly is not real or may not be significant to your application.

If you want, for example, to operate your 20 meter dipole on 17 meters you should be able to derive a workable impedance matching network using the designs from this program. Just scan your dipole (including 18 MHz) with feedline, generate the data file, execute LNET, and then select a matching configuration in the 17 meter region of the spreadsheet.

There are several good L network impedance matching tools on the Internet and in HamCalc (see the Software section of this Homebrewer CD) but I thought it would be interesting to see the designs vary by frequency in a spreadsheet format, something none of them can provide. Looking at the design C and design L variation with frequency can be helpful in selecting components you may already have, etc. It turned out that the spreadsheet format provides an overall view of the context for the design of each data point and can allow for construction of a workable L matching network for your application.

In conclusion, the AA908 Antenna Analyst is a wonderful instrument capable of generating lots of useful data. These Excel macros allow us to collect, organize and analyze the data in some different ways while being able to apply the functions and tools of Excel to the data.

Al K7SBK can be contacted at agerbens@msn.com

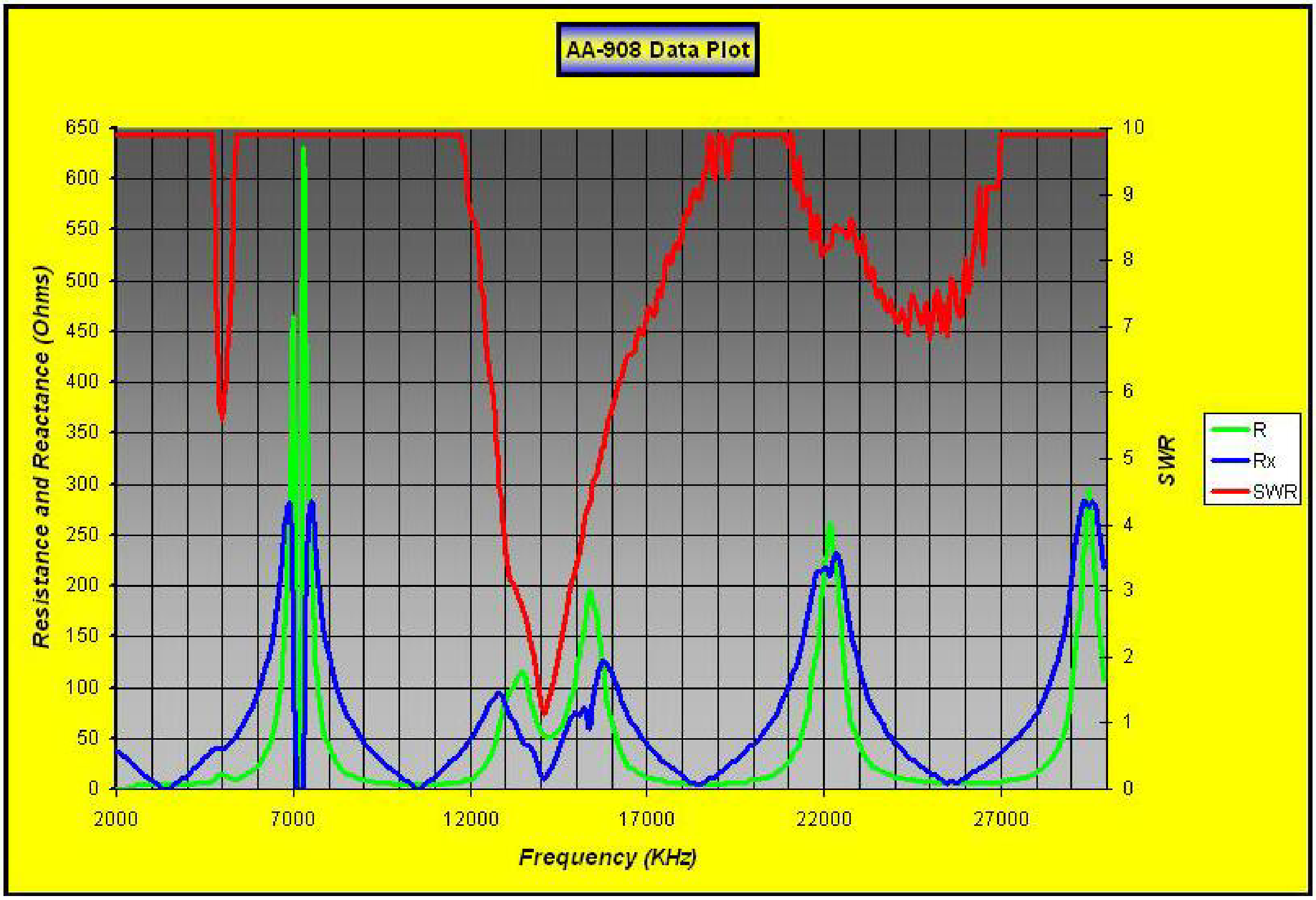
REFERENCE

1) Getting the AA908 scan data into the PC

When you bring up TeraTerm, select "Log" under the File menu and select a filename and location where you want your data file to go. Then just get your scan data from the AA-908 in the normal way ... connect it to the PC with your serial cable, select the Data Option "Send during scan" on the AA-908, and then hit the Scan button! The data sent to the PC and shown on the screen will be saved to the file you specified when you close TeraTerm.

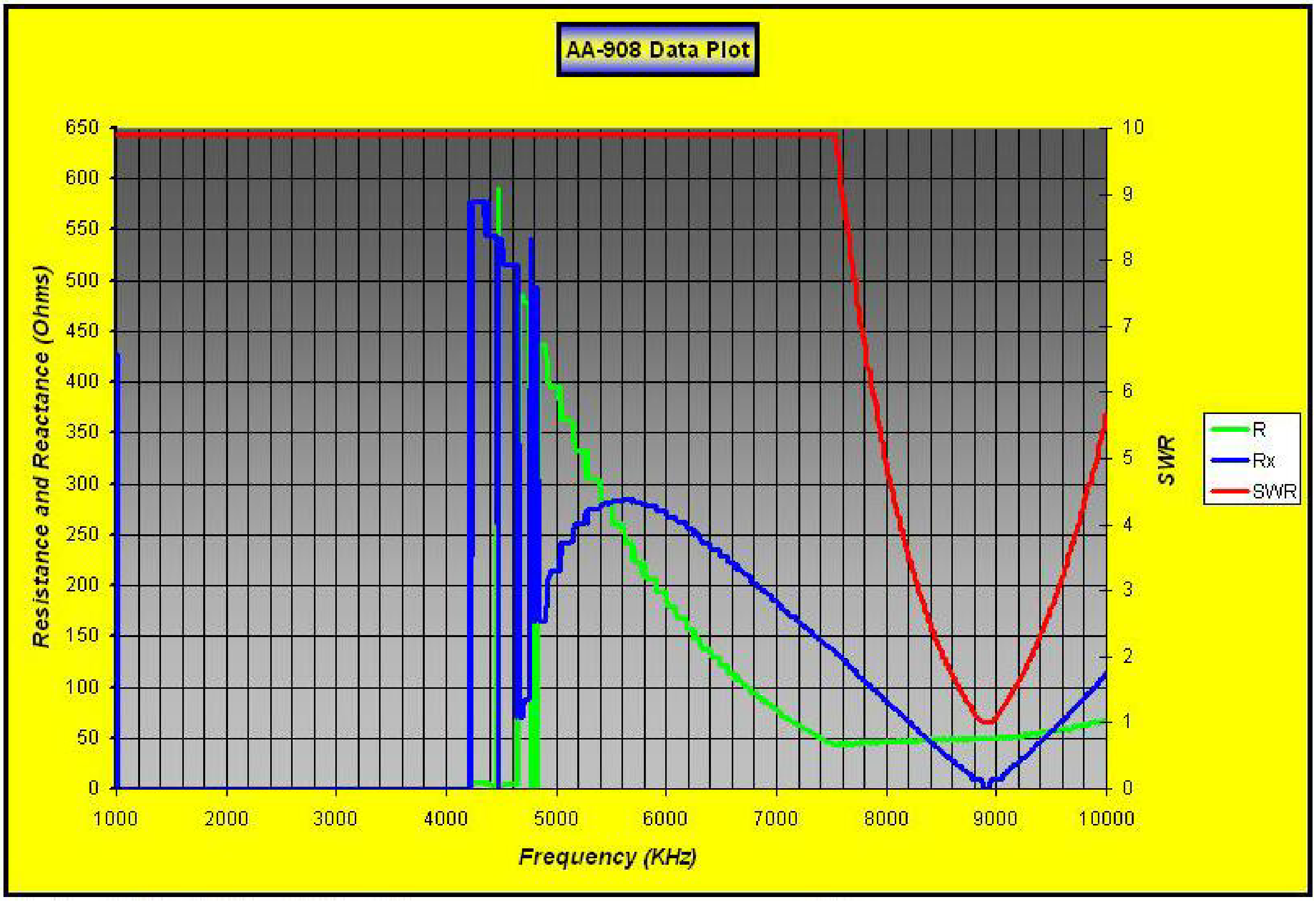
2) Displaying the plot of your antenna scan

Double-click on the AA908plot.xls file on your PC, which will bring up Excel and load the worksheet, displaying the opening screen shown at the top of this article.



2-30 MHz scan of K7SBK multiband dipole using AA-908 and his Excel Plot macro

Note all the useful data shown in the plot: major resonance at 14 MHz, interesting minor resonances at the SWR dips at 5 and 24 MHz, interesting behavior of resistance and reactance at various frequencies, and especially on either side of the resonances.



This is a plot of the dummy antenna that N2APB uses during AA908 development.

Ken Newman, N2CQ

QRP Contesting Calendar

October November December

OCTOBER:

TARA PSK31 Rumble (PSK31 only) ... QRP Category
Oct 1, 0000z to 2400z
Rules: http://www.n2ty.org/seasons/tara_rumble_rules.html

California QSO Party (CW/SSB) ... QRP Category
OCT 1, 1600z to Oct 2, 2200z
Rules: http://www.cqp.org/

RSGB 21/28 MHz Contest (SSB) ... QRP Category
Oct 2, 0700z to 1900z
Rules: http://www.contesting.co.uk/hfcc/rules/r2128.shtml

German Telegraphy Contest (CW) ... QRP Category
Oct 3, 0700z to 0959z
Rules: http://www.agcw.de/english/contest/dtc_e.htm

Adventure Radio Spartan Sprint (CW) * QRP CONTEST! *****
Oct 4, 0100z to 0300z (First Monday 9 PM EDT)
Rules: http://www.arsqrp.com/

Pennsylvania QSO Party (CW/SSB) ... QRP Category and Bonus
Oct 8, 1600z to Oct 9, 0500z
Oct 9, 1300z to Oct 9, 2200z
Rules: http://www.nittany-arc.net/paqso.html

FISTS Fall Sprint (CW) ... QRP Category
Oct 8, 1700z to 2100z
Rules: http://www.fists.org/sprints.html

North American Sprint (RTTY) ... QRP Category
Oct 9, 0000Z to 0400Z
Rules: http://www.ncjweb.com/sprintrules.php

Ten-Ten Day Sprint (All) ... QRP Category
Oct 10, 0001z to 2359z
Rules: http://www.ten-ten.org/calendar.html

Worked All Germany Contest (CW/SSB) ... QRP Category
Oct 15, 1500z to Oct 16, 1459z
Rules: http://www.darc.de/referate/dx/xedcgr.htm

RSGB 21/28 MHz Contest (CW) ... QRP Category
Oct 16, 0700z to 1900z
Rules: http://www.contesting.co.uk/hfcc/rules/r2128.shtml

Illinois QSO Party (CW/PH)... QRP Category
Oct 16, 1700z to Oct 17, 0100z
Rules: http://my.core.com/~jematz/ilqp/ilqphome.htm

RUN FOR THE BACON (CW) * QRP CONTEST! *****
Oct 17, 0100z to 0300z
Rules: http://fpqrp.com

QRP ARCI Fall QSO Party (CW) * QRP Contest *****
Oct 22, 1200z to Oct 23, 2400z
Rules: http://www.qrparci.org/contest.htm

070 Club 160m Great Pumpkin Sprint (PSK) ... QRP Category
Oct 23, 2000 to Oct 24, 0200 (Local Time)
Rules: http://podxs.com/html/160_meter_sprint.html

Zombie Shuffle (CW) * QRP CONTEST *****
Oct 28, Local Sundown to Local Midnight (Any 4 hour period)
Rules: http://www.zianet.com/QRP/

CQ WW DX Contest (SSB) ... QRP Category
Oct 29, 0000z to Oct 30, 2400z
Rules: http://www.cq-amateur-radio.com/awards.html

Ten-Ten QSO Party (CW) ... QRP Category
Oct 29, 0001z to Oct 30, 2359z
Rules: http://www.ten-ten.org/calendar.html

4th Annual Fists Coast to Coast Contest (CW) ... QRP Category
Oct 30, 0000z to 2400z
Rules: http://www.tomochka.com/k7fff/fnw_c2c05.html

ARCBS 2005 Spookfest (CW/SSB/PSK31) ... QRP Category
Oct 30, 1700z to Oct 31, 0300z
Rules: http://www.arcbs.org/ARCBSSpookfest2005.html

NOVEMBER:

HA-QRP Contest (CW - 80 Meters) * QRP Contest*****
Nov 1, 0000z to Nov 7, 2400z
Rules: http://www.radiovilag.hu/haqrp.htm#31.

Ukrainian DX Contest (CW/SSB/Dig) ... QRP Category
Nov 5, 1200z to Nov 6, 1200z
Rules: http://www.ucc.zp.ua/

ARRL Sweepstakes (CW) ... QRP Category
Nov 5, 2100z to Nov 7, 0300z
Rules: http://www.arrl.org/contests/calendar.html?year=2005

High Speed Club Contest (CW) ... QRP Category
Nov 6, 0900z to 1100z and 1500z to 1700z
Rules: http://www.dl3bzz.de/html/hscconte.html

Adventure Radio Society - Spartan Sprint (CW) * QRP Contest*****
Nov 8, 0200z to 0400z (First Monday 9 PM EST)
Rules: http://www.arsqrp.com/

OK/OM DX Contest (CW) ... QRP Category!
Nov 12, 1200z to Nov 13, 1200z
Rules: http://okomdx.crk.cz/

LZ DX CONTEST (CW/SSB) ... QRP Category
Nov 19, 1200z to Nov 20, 1200z
Rules: http://www.qsl.net/lz1fw/contest/

ARRL Sweepstakes (Phone) ... QRP Category
Nov 19, 2100z to Nov 21, 0300z
Rules: http://www.arrl.org/contests/calendar.html?year=2005

HOT Party (CW) ... QRP Category
Nov 20, 1300z to 1500z (40 Meters)
Nov 20, 1500z to 1700z (80 Meters)
(HOMEBREW & OLDTIME - EQUIPMENT - PARTY)
Rules: http://www.qrpcc.de/

RUN FOR THE BACON (CW) * QRP CONTEST! *****
Nov 21, 0100z to 0300z
Rules: http://fpqrp.com

CQ World Wide DX Contest (CW) ... QRP Category!
Nov 26, 0000z to Nov 27, 2400z
Rules: http://www.cq-amateur-radio.com/awards.html

QRP BARBERSHOP QUARTET CONTEST (CW QRP)... QRP Contest!
Nov 30, 2100 EST to 0300 EST
Rules: http://www.io.com/~n5fc/barbershop_contest.htm

DECEMBER:

QRP ARCI Topband CW & SSB Sprint * QRP CONTEST *****
Dec 1, 0000z to 0600z
Rules: http://www.qrparci.org/contest.htm

ARRL 160 meter Contest (CW) ... QRP Category
Dec 2, 2200z to Dec 4, 1600z
Rules: http://www.arrl.org/contests/calendar.html?year=2005

Wake-Up! QRP Sprint (CW) * QRP Contest *****
Dec 03, 0400z to 0600z
Rules: http://www.qrp.ru/sprint_e.htm

TOPS Activity 80 Meter Contest (CW) ... QRP Category
Dec 3, 1800z to Dec 4, 1800z
Rules: http://www.sk3bg.se/contest/topsac.htm

Adventure Radio Society - Spartan Sprint (CW) * QRP Contest *****
Dec 6, 0200z to 0400z (First Monday 9 PM EST)
Rules: http://www.arsqrp.com/

ARRL 10 Meter Contest (CW/SSB) ... QRP Category
Dec 10, 0000z to Dec 11, 2400z
Rules: http://www.arrl.org/contests/calendar.html?year=2005

The Great Colorado Snowshoe Run (40 Mtr CW)... QRP Category
Dec 11, 0200z to 0359z
Rules: http://www.cqc.org/contests/

RUN FOR THE BACON (CW) * QRP CONTEST! *****
Dec 12, 0100z to 0300z
Rules: http://fpqrp.com

RAC Canada Winter Contest (All) ... QRP Category
Dec 17, 0000z to 2359z
Rules: http://www.rac.ca/service/infocont.htm
See http://www.qrp-canada.com/ for more awards from QRP-Canada

Croatian CW Contest (CW) ... QRP Category
Dec 17, 1400z to Dec 18, 1400z
Rules: http://www.sk3bg.se/contest/9acwc.htm
or: http://www.hamradio.hr/modules.php?name=Content&pa=showpage&pid=342

EA-QRP SSB Contest * QRP Contest *****
Dec 17, 1700z to 2000z (10m-15m-20m)
Dec 17, 2000z to 2300z (80m)
Dec 18, 0700z to 1000z (40m)
Dec 18, 1000z to 1300z (10m-15m-20m)
Rules: http://www.eaqrp.com/concurso.htm

QRP ARCI Holiday Spirits Homebrew Sprint (CW) * QRP Contest *****
Dec 18, 2000z to 2400z
Rules: http://www.qrparci.org/contest.htm

Original QRP Contest (CW) ... QRP Contest!
Dec 31, 1500z to Jan 1, 2006 - 1500z
Rules: http://www.qrpcc.de/contestrules/oqrpr.html

Thanks to SM3CER, WA7BNM, N0AX (ARRL), WB3AAL and others for assistance in compiling this calendar.

Please forward the contest info you sponsor to N2CQ@ARRL.NET and we will post it and give it more publicity.

Anyone may use this "N2CQ QRP Contest Calendar" for your website, newsletter, e-mail list or other media as you choose. (Include a credit to the source of this material of course.)

72 de
Ken Newman - N2CQ

N2CQ@ARRL.NET

http://www.amqrp.org/contesting/contesting.html

QRP Contesting "Tips & Techniques"

I may not have anything new in contesting but it wouldn't hurt to review on these points. Anyone with more to add, PLEASE DO, and we'll add your input to the review.

ANTENNAS, ANTENNAS and ANTENNAS. Many would agree that antennas are the first three things to improve our results in contesting for any kind, whether Sprint or Contest.

Sample of the above:

QRP Afield '96 was won easily by AC5AM, Bob Stolzle. Having been in the contest, we wondered how it could be that this guy was S9 the whole contest, and always there sending 950 MW power. Now we know. The complete story was published in the "72" of Jan. '97. Again, antennas. He found the highest point in the area which just happened to have an old, unused broadcast radio tower. He raised two full wave delta loops (20 and 40 meters) and inverted vee's (20/40 mtrs) at the 100' level. A coax switch is used to choose the best antenna for the incoming signals.

The 100' level probably made the difference, being a strong signal from a QRPp station. His point too is that resonant antennas do much better than those with tuners. The idea was to call CQ on the loop. If no answer, call CQ on the Vee, and so on. If answered on a weak signal, switch to the other one if received better.

Now on to the rest of the real QRP World. Not many are going to find an unused 100+ foot tower to raise these types of antennas. Given that for the Contest type of event, the next thing would be the Op.

For the Op, the biggest thing would be the amount of operation time he is having fun with. Very few put in the 24 hours for the QRP ARCI Spring and Fall contests. The ones in the "TOP TEN" list reached that level according to the hours spent, assuming they are more than average stations. How do they do that? First one have to have the desire. It becomes less desirable at the 15 hour level unless you had plenty of sleep before the contest. To stay there, you have to have the necessary operator comforts. You know what they are for you. Things like a comfortable chair and headphones will take you further.

The first thing that took me to longer operating duration was the memory keyer. With this you can be relaxed much longer and your fist won't give out.

In recent years, computer logging will go even further. I use "NA" for the QRCI contests. When calling CQ, you can set a repeat every few seconds. All you need do is listen. If a station is answering, press the "ESC" key to stop the repeats, and enter his callsign. Press the "INSERT" key, and the station is answered and your info is sent. (You can input an RST if you wish). Enter his info and press the "=" key and you have sent an OK and a QRZ. That is it. (Except the log that is printed at the end.) Given that, you could be there a much longer time.

What else for the operator? **Practice, practice, and practice!** The more you do the better you get.

There are some excellent links to more contest tips. I would recommend the K3WWP link first. If you have been in contesting, chances are you worked John. He is using a homebrew QRP tube transmitter with an indoor antenna. If you don't have the antenna like AC5AM had, you can relate to K3WWP. Look for his tips at:
http://home.alltel.net/johnshan/contest_ss_tips.html

After that, you may want to check the tips from the top contesters. Check them out at: http://www.contesting.com. This is not QRP but many of the suggestions will help us all in contesting. This covers the pre-contesting, equipment, operating, and post-contesting. Most tips assume that you are running a KW, beams and contest software.

Anyone have more QRP contesting tips? I'm sure all would like to hear about them and we'll add any that can help us along.

CU in the next 'test!

72/73,

Ken Newman, N2CQ
Woodbury, NJ
n2cq@arrl.net

http://www.amqrp.org/contesting/contesting.html

http://www.n3epa.org/Pages/Contest/contest.htm

Ken Newman, N2CQ

The QRP Homebrewer Sprint

Each spring and fall QRPers have been gathering to compete with others using their homebrew stations … having loads of fun in the process! Here's a collection of the results from the last 5 years of operating the QHB Sprint.

First we show the contest rules, then each of the results from **2005** (fall), **2004** (spring and fall), **2003** (spring and fall), **2002** (spring and fall), and **2001** (spring and fall).

Hope you enjoy this compilation … and join us in the next QHB Sprint!

72, Ken N2CQ [n2CQ@arrl.net]

QRP Homebrewer Sprint

Held on the 4th Sunday evenings of September and March each year.

Put down the soldering iron and get on the air with other QRP homebrewers! The NJQRP and "QRP Homebrewer" magazine are sponsoring this fun, quick and easy QRP sprint ... *with a homebrew twist!* Includes PSK31 mode and multipliers for home-built gear.

Mission: Promote homebrewed & homemade equipment on the air together. PSK31 Warblers too! Anyone with ANY equipment can enter.

Sponsor: New Jersey QRP Club (http://www.njqrp.org)

When: The fourth Monday in March and in September, 0000-0400 UTC (Sunday evening in USA/Canada)

Modes: CW and PSK31. (Both modes considered separate bands)
QRP CW and PSK31 frequencies recommended on 80, 40, 20, 15 and 10 meters.

Exchange: RST - State/Province/Country - Power out

QSO Points:
2 Commercial Equipment
3 Homebrew Xmtr or Rcvr
4 Homebrew Xmtr AND Rcvr or Xcvr
(Kits are okay for homebrew)

Power Mult: The highest power used during the contest determines the multiplier ...
a) >5W = X1

b) 1-5W = X7
c) 250mW - 1W = X10
d) <250mW = X15

Multiplier: State/Province/Country for all bands. The same station may be worked on more than one band for QSO points and SPC credit. CW and PSK31 are considered separate bands.

SCORE: Points(total for all bands)
x SPC (total for all bands)
x power multiplier.

Awards: Subscriptions to AmQRP "Homebrewer Magazine" will be awarded to the top performers. Special certificates may also be awarded.

Results: Sprint results will be published on the NJQRP Web pages and in AmQRP "Homebrewer Magazine".

Logs: Entries must be received by 30 days from the contest. The log sheets and summary should be included. E-mail logs are accepted in text form. (No word processor files etc). Also paper logs are ok.

Include an SASE or E-mail address for the results, if desired. Please include your Soapbox info with your equipment and exploits. Send logs to n2cq@arrl.net, or by snail mail:
Ken Newman, N2CQ
81 Holly Drive
Woodbury, NJ 08096

SPRING 2005 QRP HOMEBREWER SPRINT RESULTS

Call	Mode	QSOs	Points	x SPCs	x PWR	= Score
WN1GIV (Op: N4BP)	CW	93	372	60	7	156,240
K0ZK	CW	69	276	45	7	86,940
W0UFO	CW	64	256	38	7	68,096
N0NTA	CW	60	240	37	7	62,160
W5TVW	CW	43	157	36	7	39,564
N8XI	CW	44	176	26	7	32,032
W5ESE	CW	31	124	26	7	22,568
N0TK	CW	30	120	23	7	19,320
NR7F	CW	29	116	20	7	16,240
VE3XT	CW	26	104	20	7	14,560
K7RMJ	CW	26	104	20	7	14,560
W7GB	CW	26	104	19	7	13,832
N9LTV	CW	24	96	20	7	13,440
W2LJ	CW	25	100	19	7	13,300
NG7Z	CW	17	68	16	7	7,616
K4GT	CW	13	52	13	7	4,732
W1PID	CW	9	36	8	7	2,016

W3DP	CW	7	28	7	7	1,372
K6IMZ	CW	11	22	8	7	1,232
KW4JS	CW	7	28	6	7	1,176
KD5CMN	CW	7	14	7	7	686
N8RN	CW	4	16	4	10	640
N5SPE	CW	4	16	4	7	448
VE3NXB	CW	1	4	1	10	40
Check Log: WQ2RP NJQRP Club (Op: N2CQ)	CW	51	192	35	7	47,040

SOAPBOX REPORTS

WN1GIV:
Club Florida Contest Group
Software: N1MM Logger V5.0.52
Rig : Elecraft K2
Antennas : TH7-DX, 40M Dipole, 80M Dipole
de Bob, (N4BP), Plantation, FL

K0ZK:
Rig: Elecraft K2 s/n 692, 5 Watts.
Activity was pretty good while conditions were generally lousy.
There was a lot of static crashes and signals were mostly weak
although the west coast seemed to come in alright and I was able
to snag Montana, WA, CA, OR, SD AB, AZ and 8P6 on 40 metres.
The antenna was a military 30 foot mast made of 33 inch aluminum
sections. The antenna is a few feet above ground sitting on a
wine bottle insulator with 5 radials. A homebrew antenna coupler
tunes this vertical well on 40, 30, 20, 15 and 10 meteres. It
does fine on DX but just does not work for close-in states.
I can't hear anyone in New England, NJ or nearby NY with it.
I should put up a low dipole for those nearby states.
I used a new key: a Bengali which I love. I never thought
anything could better my Schurr. The Bengali is not better, but
it is just as nice to send CW on it as the German paddle.
72 de Arn, Lebanon, ME

W0UFO:
I was using a K2 at 5W to a TA-33 stuck S.E. on 20M and
a 120 ft zepp on 40M.
de Mert, St. Paul, MN

W0NTA:
Enjoyable contest even after eating too much at the Easter table
with family. I used my trusty K2 and Force 12 Sigma-40XKR vertical
antenna. Band conditions seemed very good, especially on 40 meters.
I worked approximately 3 of the 4 hour contest. Thanks for a great
contest.
73, Dick, Greeley, CO

W5TVW:

Elecraft K1 POWER OUTPUT 5
ANTENNA(S): 135' Zepp at 50' fed with 450 ohm line.
Enjoyed contest. 20 wasn't good, but made a few there. 40 very noisy with QRN but did OK considering. Called and called on 80 and made more multipliers in spite of the heavy QRN. Hope to see everyone next time.
72 to all! Sandy, Hammond, LA

N8XI:
Elecraft K2 XCVR, 5W
40 Meters was in great shape, except for a little QRN
(rain from the south)
72 de Rick, Taylor, MI

W5ESE:
This was my first time to participate with my new call (W5ESE). I was previously 'NJ0E'. I added 80 meters to my collection of kit gear with a Ten-Tec TKIT 1380 (4 watts). Continued using my Ten-Tec TKIT 1320 for 20 meters (3 watts) and my Small Wonder Labs SW+ for 40 meters (2 watts). My antenna is a 300' Horizontal Loop.
72, Scott, Dripping Springs, TX

N0TK:
Rig: K2 #3652 set at 5w Ant: Attic Dipole
Heard WQ2RP, W5TVW and W0UFO on 80m but no antenna up to try to work them. Best signal heard was K0EVZ in the first hour of the sprint. All contacts were on 40m CW.
72 Dan, Highlands Ranch, CO

NR7F:
Station: Elecraft K2 at 5W. Antennas: single-band dipoles.In mid-March I completed my second QRP rig, a K2. Having this radio has generated a lot more interest in QRP events, so when I stumbled upon the QRP Homebrewer Sprint, I could not pass it up. This was the first contest I made a serious effort at. I was not even sure if I would put more than about an hour into it , but at about 6:30 pm the activity on 40 meters was sufficient enough that I decided to make a go of it. de Michael, Bothell WA

VE3XT:
The rig was a K1 to a homebrew vertical running 3W. Conditions were good for the entire contest and it was long enough to enjoy the benefits of shifting propagation to various areas in the south.
Had a great time, thanks.
de Bill, Thunder Bay, ON

K7RMJ:
The receiver I used is a home brew 160 meter receiver with CA3028A mixer, a single MC1350P IF amp and has a 455KHz IF. The receiver is used as a "tunable IF" with an outboard home brew 40 meter converter installed in an Altoids tin.
My workbench power supply smoked on Saturday afternoon, so I had to resort to a 12V gel-cell for the contest. Transmitter is homebrew VXO controlled from the pages of QRP Classics.

Antenna is an inverted el up 25 ft. An electrical storm rolled through the area about 19:00z so had to stop for a half hour in the middle of the sprint, but had a ball anyway.
Let's do it again!!
Regards & 72's, Frank, MURFREESBORO TN

W7GB:
Equipment: Elecraft K1, A3 Tribander, R7 Vertical
Nice contest. Keep up the good work.
73, Don, Moses Lake, WA

N9LTV:
Rig: K-1 & Dipoles 20 & 40m
I always have a lot of fun on these Homebrewer Sprints.
One of these days I'll be able to participate for the entire 4 hours!
de Rod, Carterville, IL

W2LJ:
Equipment used: K2 @ 5 Watts to a G5RV
I got a late start due to Easter company staying on into the evening; but once on the air, I found plenty of staions to work. 20 Meters was dead and 80 Meters had a high QRN noise level, which was a disappointment. It was good to hear a lot of stations on the air on a holiday evening.
I'm looking forward to the next one!
Thanks, Ken!
73 de Larry, SOUTH PLAINFIELD, NJ

NG7Z:
Rig Elecraft K1 @ 5W
I was only able to fit in one hour due to other commitments.
Fun contest. Will look forward to the next one.
73 de Paul, BOTHELL WA

K4GT:
Rig: Elecraft K2 @ 5W
de Jim, Atlanta, GA

W1PID:
Rig: Rig DSW-20 and DSW-40 2 watts ea.
Ant. Windom OCF dipole
Thanks!
de Jim, Sanbornton, NH

W3DP:
Station: K1 at 5W output to G5RV at 25 Feet inverted Vee
NJQRP member #427. I was looking forward to this event, but gave up early due to the heavy QRN crashes. Thought I would turn in a log to show I at least participated.
Hope conditions are better next time.
73, Dick, Camp Hill, PA

K6IMZ:
Operating using a Kenwood TS2000 at 5W into a High Sierra Screwdriver at 15 feet up.

First time in a QRP/CW contest, what a kick! Not a serious effort, just wanted to get my confidence back on CW. Condx and local noise not great but was surprised by reports. I think I am in my own class: LPCA, (Low Power Crummy Antenna)! I hope to have my homebrew 6AG7 osc. and S-38B going by the September contest.
How about a class for homebrew xmtr and pre-1960 rcvr?
A lot of us are re-living our novice days with similar rigs.
Thanks for the opportunity to have so much fun!
de Paul, Surprise, AZ

KW4JS:
Rig: Elecraft K2 running 5 watts into a R7000 vertical.
Big thunderstorms at this QTH which resulted in not vy much sprint.
de John, KINGSTON TN

KD5CMN:
I used a commercial transceiver (FT-817) and ran 5 watts to an 88 foot dipole, so 2 points per QSO. I wasn't aware of which contest it was, I was just cruising around the bands waiting for supper. I could have used my Norcal 20 and doubled my point count.
It's great to hear lots of QRP signals on the air.
Thanks and 73 de Mike, LAKE JACKSON TX

N8RN:
Rig: Sierra operated off a small solar charged battery
Pwr Out: 800 milliwatts
Ant: Inv. Vee up 24 feet
I had to entertain relatives over Easter weekend so I was only able to get late into the contest for around 20 minutes. It was fun while it lasted.
QRP operators are the best. I especially appreciate NR7F way out in Washington state picking up my weak signal. Good ears.
de Roy, Englewood, OH

N5SPE:
Rig: Elecraft K1 @ 5w
Thanks!
de Jim, Brandon MS

VE3NXB:
First time entry in this sprint.
I had only limited time to have fun with my 40 meter unmodified Rock Mite. I only worked one CW fairly strong signal station, WQ2RP. May work 5w multi band next time.
Thanks for the opportunity to enjoy the CW sprints.
de Greg, Kitchener, ON.

WQ2RP: (NJ QRP Club Station, N2CQ opr)
Many thanks for your interest and activity in the Homebrewer Sprint.
The rig here is the K1-4 at 5 watts on 20m and 40m and a Kenwood TS-850sat for 80m. The antenna is a random end fed wire (40m-80m) and TA33jr tribander (20m).

Hope to see you again in the next NJ QRP Homebrewer Sprint on
Sep 26, 2005 0000z
72 de Ken, Woodbury, NJ

FALL 2004 QRP HOMEBREWER SPRINT RESULTS

Call	Mode	QSOs	Points	X SPCs	X PWR	= Score
N9NE	CW	97	388	52	7	141,232
N4BP	CW	78	312	41	7	89,544
K3ESE	CW	68	272	36	7	68,544
K4BAI	CW	85	112	49	7	58,310
K7TQ	CW	44	168	29	7	34,104
K0ZK	CW	42	168	28	7	32,928
W5KDJ	CW	24	96	22	15	31,680
AD6GI	CW	36	144	31	7	31,248
W0UFO	CW	41	164	26	7	29,848
K8DDB	CW	34	136	29	7	27,608
WA8REI	CW	48	96	32	7	21,504
KB2FEL	CW	30	120	19	7	15,960
WA3FAE	CW	27	108	18	7	13,608
NJ0E	CW	22	88	20	7	12,320
KD5UDB	CW	18	74	16	10	11,520
N9LTV	MIX	22	88	18	7	11,088
N7CEE	CW	16	64	14	7	6,272

KH6B	CW	14	56	14	7	5,488
VE7NI	CW	12	48	11	7	3,696
K4AQ	CW	18	36	14	7	3,528
KE2WB	CW	11	44	11	7	3,388
WB7AEI	CW	10	40	8	10	3,200
W0OOW	CW	9	36	8	10	2,880
WB9JTK	CW	11	44	9	7	2,772
N2CX	CW	6	24	5	7	840
W1PID	CW	5	20	5	7	700
NI8W	CW	5	20	5	7	700
Check Log: WQ2RP (Op N2CQ)	CW	56	198	35	7	48,610

SOAPBOX REPORTS

N9NE:
I had quite a day. Up at 2:30 am to drive to neighboring city for 6 am running of 26.2 mile marathon. Dragged across finish line at 11:16 am. (no 2:04 ET for this 61 year-old!). Home to nap and partially recuperate. Up at 5:30 pm to eat and get rig and computer set up for the sprint. Four hours of fun, and finally to bed at midnight.
Rig is K2 @ 5 watts to quad-band beam and 176' doublet. High points: working John, K4BAI, on three bands, and Dean, KH6B on 40 meters.
Nice to work some new calls/faces as well as the regular QRP crowd!

de Todd, Oshkosh, WI

N4BP:
Rig : Elecraft K2
Antennas : 40M Dipole @ 35ft
All antennas taken down for Charley, Frances, Ivan, Jeanne, etc.
Put back up my 40M dipole for the Sprint. 20M usually my best band, but dipole performance not very good there.
de Bob, Plantation, FL

K3ESE:
Setup: multiPIG+ at 5W into an 88' EDZ up 45', on

20M, and a 302' horizontal loop on all three bands, up
about 50', both fed with balanced line and tuned with
a ZM-2.
Very fun event, but...long! Very tired at the
end, about to doze. I've seen better conditions, and
also worse, so it was not too bad, skip-wise. Nice to
work Ken, at the Mothership!
72 es oo, Lloyd, Reisterstown, Maryland

K4BAI:
Rig: Yaesu FT1000MP, 4W. Ant: TH6DXX Beam & Inverted V dipole.
I enjoyed it even though I don't have any homebrew gear.
QRN built toward the end and activity dropped, so I didn't
stay for the last 45 minutes, hi.
73 de John, Columbus, GA

K7TQ:
de Randy, Moscow, ID

K0ZK:
I operated from home QTH using indoor 20 metre dipole on 20
and 40 metres. Elecraft K2 s/n 692. Condx poor until last hour,
but did work KH6B on 20 which was nice.
72 de Arn, Lebanon, ME

W5KDJ:
K1-4 at 249MW, ANTENNA(S): Mosley 7 element.
Bands open to the west, worked KH6B. Had good time but I was to tired
to complete entire contest.
de Wayne, Spring, TX

AD6GI:
Rig: Elecraft K2, 5 watts
Antennas: 15M, 40M and 80M - 40M short dipole up 40 feet
20M - Dipole up 25 feet
Nice cndx for test. Gud openings to east coast. Tnx to all for great
ears and ur patience with me. Looking forward to the next one.
73, Chuck, Sunnyvale, CA

W0UFO:
Used K-1 at 5W to 20M dipole and 40M tuner to 180ft wire.
from cabin at Pine County MN.
Thanks for another good Sprint.
de Mert, Pine County MN

K8DDB:
Rig: Sierra, POWER OUTPUT 5 watts
ANTENNA(S): G5RV at 37 feet
I had a good time in the contest and worked a new state for 80
meters W.A.S. as a bonus. I'd forgotten how much fun my Sierra is!
de Mike, Vulcan, MI

WA8REI:
Operated out in the wilderness on a hilltop using battery
power, but inside my 21 ft motor home. Lots of fun but not
many stations heard in call districts 1, 3, 6 and 7.

W5KDJ's 250MW was FB!
73,72 and oink-oink to all!
Ken, Ogemaw County, MI

KB2FEL:
HW-9 (20-40-80M) 4 Watts.
4BTV vertical and G5RV
de Bob, Valley Stream, NY

WA3FAE:
My rig is an Elecraft KX1 using a 88 foot EDZ at 35 feet with an LDG RT-11 tuner. I forgot this was Contest night! It's very enjoyable to work fellow QRPers. Everybody works hard to dig weak stations out of the mud, seeings how we are all in the same mud pit! Can't wait for next year.
de Forrest, Woodbine, MD

NJ0E:
Rig: ten-tec t-kit 1320 (3W)for 20m,
and a small wonder labs sw40+ (2W)for 40m.
The antenna was an 80m horizontal loop. I was still pooped from my QRP entry in the Texas QSO Party. Many thanks for sponsoring a fun event!
73, Scott, Dripping Springs, Texas

KD5UDB:
Hello all,
Had a great time as usual. I decided to try this Sprint at 1 watt and found that although I had to repeat a few exchanges, everyone I heard, I worked!. Lloyd - K3ESE and Bob - N4BP were "blowing my headphones off" loud into S. Louisiana as usual, and worked them both on 20 and 40 meters. Thanks to everyone who made this possible.
My rig was a K1 on internal batteries and turned down to 1 watt.
The antenna was my usual 20 and 40 meter fan dipole installed about 20 feet high over the roof of the house.
de Chris, Baton Rouge, LA

N9LTV:
Rig: K-1, PSK20 & Dipoles
Worked only 20 and 40. A fun contest! Wish I would have worked the entire time. Worked 2 PSK stations on 20 but they weren't in the contest. Wish there were more.
de Rod, Carterville, IL

N7CEE:
Rig: Elecraft K-2 @ 5W.
Antennas: 170 foot 80 foot end fed wires with 66' counterpoise.
I operated from the Pine Forest Range in NW Nevada during a photo shoot for a book project.
72 de Bruce

KH6B:
Rig: K-2, internal battery, NORCAL paddles, RS PRO-35 headphones.
Antenna: 284' sloping Diamond Loop.
Nice sprint. Worked 'ME' to 'CA' and 'WA' to 'GA'.
I even have 'HI' in my log!

72, Aloha de Dean, Hilo, HI

VE7NI:
Rig is Ten Tec 1340 QRP kit with 5 watts output power.
Antenna is a 40M inverted vee 40' at the apex.
Great fun with QRP as usual and lots of good operators!
de John, Kamloops, BC

K4AQ:
Yaesu FT-897 transceiver operated at 5 watts into an OCF 28-gauge insulated wire stealth antenna up 40 feet in heavy foliage trees next to I-75 in downtown Atlanta industrial area. SGC SG-237 Smartuner. WriteLog 10.48f.
de Matt, Atlanta, GA

KE2WB:
Rig: K2
Operating Time = 1.2 hours
Also used a homebrewed logging program
de John, Augusta, GA

WB7AEI:
Same equipment as usual (HB superhet RX, 1W VFO TX, and all HB accessories) less the 5 watt power amp. Must say I was pleased at how the 1 watt got out, especially with the EFHWA antenna up 17 feet at the highest. The band seemed good actually, although signals weren't strong. Worked more than ever before, although some like N4BP just weren't possible. Highlight was hooking up with WQ2RP, although it must have taken 5 minutes and 50 repeats of my call to get thru.
Thanks for the fun!
72's, Phil, Kent, WA

W0OOW:
Rig: SWL20 POWER OUTPUT 1W.
ANTENNA(S): 3/2 WAVE
Stuck on 20 gggrrrrrrrrr
de Steve, Johnson NE

WB9JTK:
Elecraft KX1, kit.... 3 watt output. Second hurricane went by Saturday. Antenna was a dipole 13 feet in the air in the middle and 5 feet on the ends. Ran rig from a car battery. Glad it had a "logging light" in it! I ordered it right after hurricane Frances. When electricty came back on I built it and had some fun. Then the next hurricane came by. No damage to the house, but no electricity so I was sure glad I had this rig since there was nothing else to do for many days.
73 de Alan, Delray Beach, FL

W1PID:
Rig: DSW 40 2W. Antenna: Windom OCF Dipole
Thanks!
de Jim, Sanbornton, NH

WQ2RP: (N2CQ opr)

Many thanks for your interest and activity in the Homebrewer Sprint.
The rig here is the K1-4 at 5 watts on 20m and 40m and a Kenwood TS-850sat for 80m. The antenna is a random end fed wire (40m-80m) and TA33jr tribander (20m).
Hope to see you again in the next NJ QRP Homebrewer Sprint on Mar 28, 2005 0000z
72 de Ken, Woodbury, NJ

SPRING 2004 QRP HOMEBREWER SPRINT RESULTS

Call	Mode	QSOs	Points	x SPCs	x PWR	= Score
N9NE	CW	91	364	59	7	150,332
K3ESE	CW	71	284	42	7	84,496
W0UFO	CW	63	252	43	7	75,852
AA9NF	CW	54	216	37	7	55,944
K4BAI	CW	56	112	40	7	31,360
W5KDJ	CW	23	92	18	15	24,840
NJ0E	CW	21	84	18	7	10,584
W2JEK	CW	18	72	17	7	8,568
KW4JS	CW	18	72	15	7	7,560
W2AGN	CW	20	80	19	7	6,080
W1PID	CW	14	56	14	7	5,488
WB7AEI	CW	12	48	9	7	3,024
KL7IKV	CW	10	40	9	7	2,520
W2BVH	CW	9	36	9	7	2,268
W5ACM	CW	8	32	7	10	2,240
W0PWE	CW	6	24	6	10	1,440

WA9PWP	CW	7	28	7	7	1,372
W0CZ	CW	5	20	5	7	700
WG1Z	CW	5	10	5	7	350

SOAPBOX REPORTS

N9NE:
Rig: K2 @ 5W to tribander at 55'; 40 meter rotatable dipole at 60';
and a 265' doublet at 55'. Great fun and always good to talk to
old and new QRP friends!
de Todd, Oshkosh, WI

K3ESE:
KX1#11 - multiPIG+#14 - K1#379 - 20/40M RockMites
Loop - EDZ - LW - Begali Magnetic Classic Paddles
73, 72 es oo, Lloyd, Reisterstown, Maryland

W0UFO:
Elecraft K-1 5W. 20m 3el yagi, 40m dipole inverted V coax fed via UFO balun.
Conditions were good and enjoyed working so many of
the regular qrp ops.
de Mert, Ramsey Cty, MN

AA9NF:
Elecraft K2 serial #4074 was born on March 13th 2004,
after one month of construction.
de Pete, Naperville, Il

K4BAI:
Rig: Yaesu FT1000MP, 4W. Ant: TH6DXX Beam & Inverted V dipole.
73 de John, Columbus, GA

W5KDJ:
K1-4 at 245MW, ANTENNA(S): Mosley 7 element.
Slow contest, not many participants. 20M props not to bad,
no props on 40M. CU on the next test.
de Wayne, Spring, TX

NJ0E:
Rig: ten-tec t-kit 1320 for 20m,
and a small wonder labs sw40+ for 40m.
I liked it; haven't been active in contesting but
enjoyed this one. had been doing some work on the
ten-tec t-kit rig for 20m and just got the wrinkles
ironed out sunday. a great chance to put it through
it's paces. thank you all for sponsoring the sprint.
73, Scott, Dripping Springs, Texas

W2JEK:
Rig: OHR-500 5W. Antennas: 20M Gnd Plane(on roof),
40M Dipole & 80M End Fed Hertz
Thanks & 72/73,

de Don, River Edge, NJ

KW4JS:
Elecraft K2, 5W.
de John, KINGSTON, TN

W2AGN:
Power/Rig 5W/Multipig+ (#16)
Antenna: KT34/300' Loop
I was mainly in the FP "Run for the bacon,"
but picked up a few non FPs in the process.
Thought I better send in a log, or AmQRP
will drop this contest, too.
de John, Vineland, NJ

W1PID:
Rigs DSW 40 and DSW 20 2W, Antenna Windom
RTTY was pretty rough on 40. Pretty much shut down the band.
Still made a few Qs there. 20 meters was active, but sigs were
on the weak side. I worked the first hour and had a blast.
Many thanks to all.
de Jim, Sanbornton, NH

WB7AEI:
Station: HB 40M superhet receiver, 1W VFO
xmtr with 5W MOSFET amplifier, homebrew keyer, tuner, SWR
meter, power supply. Antenna WAS (i.e. taken down in the
dark after contest!) temporary end fed half wave, up 17 feet
at high point.

MUCH better conditions than typical for the past year(s)!
40M almost seemed normal, changing markedly over the course,
with low noise levels. It got to ESP at the end. Heard
twice as many as I worked. Tnx to AA1MY and several others
for real good ears! Big signals from K7TQ,W0NTA, K6XR. The
outdoor EFHWA was so great after being on an indoor DCTL for
the past 3 months!
72's, Phil, Kent, WA

KL7IKV:
All QSO's were on 14 mhz cw, using K2 at 5 watts, vertical and dipole
antennas. Not so hot but fun anyway!
Tnx! 73, Lynn, Anchorage, AK

W2BVH:
Rig: K2 @5W, 80m CF Zepp.
de Lenny, Cranford, NJ

W5ACM:
The antenna was a 3-band inverted "V" in the attic. The Elecraft KX-1
arrived in the mail on Thursday, March 18, as a kit. It was fully up and
running on Sunday afternoon, but it wasn't easy! Power output was low due
to minor problem, so I operated from the internal AA batteries and set the
power output level below 1 Watt. It worked VERY well, and I had a great
time on my first Sprint.
72 de Andy, Houston, TX

W0PWE/M
I had to take my daughter back to college on the evening of the sprint. I put my 20M Manhattan SST in the car thinking I would make a few contacts on the way home and then operate 40 for the last hour or so when I got home. Well, it took longer at the college than I expected so 20M was about dead and I never made it to 40M.
Station: 20M Manhattan SST at 1W and a Hamstick on a Honda Odyssey
de Jerry, Mobile in NE/IA

WA9PWP:
Rig: K-1 @ 3 Watts
de Paul, Stoughton, WI

W0CZ:
Elecraft K2 SN 1031 running 5 watts.
Antenna on 20 meters CL-33 beam up 22 ft
Antenna on 40 meters Hy-Gain Hy-Tower
I am not much of a contest operator but I liked this contest because the code speed was not too fast.
I tried PSK31 too but never found anyone in the contest. The bands were poor the first hour but were good the third and 4th hour when I got back on.
73, Ken, Fargo, ND

WG1Z:
Equipment - iCOM IC-775DSP / Spi-Ro D-68 Trap Dipole
Heard more stations soliciting for contact than the 5 I snagged.
Hope to do better snagging them next time.
de Joe, Woburn, MA

FALL 2003 QRP HOMEBREWER SPRINT RESULTS

CALL	MODE	QSOs	POINTS x	SPCs x	PWR =	SCORE
N9NE	CW	97	388	54	7	146,664
K5ZTY	CW	79	316	55	7	121,660
W5TA	CW	63	200	41	7	57,400
W0UFO	CW	56	224	35	7	54,880
W0NTA	CW	51	204	33	7	47,124
VE3XT	CW	44	172	27	7	32,508
W2JLK	CW	35	140	23	10	32,200

W5KDJ	CW	25	100	21	15	31,500
K3ESE	CW	36	144	26	7	26,208
N0TK	CW	31	124	23	7	19,964
K8DDB	CW	31	124	22	7	19,096
KW4JS	CW	34	132	20	7	18,480
K4UK	CW	32	128	20	7	17,920
K0FRP/4	CW	33	132	18	7	16,632
W2JEK	CW	22	88	20	7	12,320
WA1ZCB	CW	22	88	18	7	11,088
W3DP	CW	22	88	15	7	9,240
K1KID	CW	20	80	16	7	8,960
W1PID	CW	22	88	14	7	8,624
KE2WB	CW	13	52	10	7	3,640
N2CX	CW	9	36	8	7	2,016
AE4EC	CW	7	28	6	7	1,176
K2EKM	CW	3	12	3	10	360
N8VW	CW	3	12	3	7	252
WB7AEI	CW	3	12	3	7	252
CHECKLOG:						
WQ2RP *	CW	34	136	24	7	22,848

** NJQRP Club Station, N2CQ op*

SOAPBOX REPORTS

N9NE:
Rig: K2 #1429 @ 5W. Antennas: Triband beam and 88 ft. doublet at 60 feet. Thanks to the NJQRP Club for making the fun possible! Eighty meters was productive here in WI: wish that more ops had been able to get on that band.
de Todd, Oshkosh, WI

K5ZTY:
Elecraft K2, Force 12 C4S. My first QRP contest in a while and it went strictly according to Murphy's Law. Didn't do the last hour. Seemed to be good participation and some pretty good condtions for a change. Had fun while things were working here though. Thanks to Ken and the rest of the NJ bunch for putting this one on again.
de Bill, Houston, TX

W5TA:

20 meters: NORCAL "Red Hot" transceiver (kit, X4), 5 Watts.   Antenna:5/8 wave ground mounted vertical. 40 meters: Kenwood TS-430S (commercial, X2)   Power: 5 watts monitored with Welz SWR/Power meter Antenna: 1/4 wave ground mounted vertical Did better than last year's fall sprint, but not as good as spring sprint. Was a lot of fun anyway.
Very 72, de Dick, Round Rock, TX

W0UFO:
Elecraft K-1 5W. 20m dipole, 40m zepp fed 160' wire. Conditions were good and enjoyed working so many of the regular qrp ops.
de Mert, Cabin in Pine County, MN

W0NTA:
Operated a K2 at 5 watts output to a temporary short G5RV antenna up 20 feet in my backyard. I have antenna restrictions here so I put up this antenna for the contest. It worked very well on 20 meters but not so hot on 40. Many very strong signals here tonight on both bands. Another fun sprint. Thanks to the New Jersey club for organizing it.
de Dick, Greeley, CO

VE3XT:
Elecraft K1 to homebrew all band vertical with 8 AA NiMH battery pack. Good condions and good operators made for a good score.
de Bill, Thunder Bay, ONT

W2JLK:
Small Wonder modified 1W. 40m Dipole up 15m. Hamming since '59 - Homebrewing entire time!
de Jim, Matawan, NJ

W5KDJ:
Good contest as long as you operated 20. 40 next to impossible, nil sigs on 80. Met lot of the regulars and few new folks. Good contest and looking forward to the next one. K1-4 Yagi on 20, LW on 40.
de Wayne, Spring, TX

K3ESE:
Setup was a K1 at 5W into a longwire. I missed the first half hour, while reading "The Long Winter" to my little girls. I also missed the last half hour, as I was falling asleep, and there were no ops out there left unworked, it seemed. But while I was there, it was a load of fun! Thanks to NJQRP once again!
73, 72 es oo, Lloyd, Reisterstown, Maryland

N0TK:
K-1 #545 on 20 & 40 m attic dipoles.
de Dan, Highlands Ranch, CO

K8DDB:
Sierra 5W, G5RV @ 37 feet and LDG Electronics Z11 Auto Tuner, N3FJP's contest software and Dell Latitude laptop computer. Band conditions weren't too good. 20 meters dried up early, 40 and 80 meters were noisey, but so what, I had a good time! Thanks to the sponsors and all of the QRP gang!!
de MiKe, Vulcan, MI

KW4JS:
Elecraft K2, 5W.
de John, KINGSTON, TN

K4UK:
Elecraft K2.
Was able to get in for just a little time due to other Commitments.
de Stan, Moneta, VA

K0FRP/4:
K1 40M ONLY VERTICAL DIPOLE IN THE PINE TREES
de Al, Aiken, SC

W2JEK:
OHR-100A 20m, OHR40 40m & TenTec 1380 80m. Thanks for a nice contest!
de Don, River Edge, NJ

WA1ZCB:
Elecraft K-1 4W. 300' wire loop in 50' tree. My first QRP contest was not what I expected. I had a lot of contacts(22) and 18 new states to add to my W.A.S. award, and all on 40 meters. Had a great time in the sprint. Look for me in the next HB sprint.
de Ed, Fall River, MA

W3DP:
Elecraft K-1 5W #238, G5RV up 25'
de Dick, Camp Hill, PA
-----------9
K1KID:
Elecraft K2 @ 5 W, Antenna = Carolina Windom @ 35 ft. What a blast. 20 Meters closed down shortly after the start of the Sprint. 40 was up and down all evening but was in there long enough to make contacts. 80 meters was in terrible shape but managed to snag N9NE, the only station heard there. Conditions were not the best but the experience under poor conditions is invaluable. Love the Sprints, They are long enough so that you can polish your skills without the marathon effort required for a contest weekend! I hope every one had as much fun as I did. See you all in the next Sprint!
72 de Carl, MA

W1PID:
Rigs DSW 40 and DSW 20 Antenna Windom OCF dipole Many thanks for a fun event,
best, Jim, NH

KE2WB:
de John, Atlanta, GA

N2CX:
Sierra 5w.
de Joe, Bellmawr, NJ

AE4EC:
Elecraft K2,560 ft horizontal loop, gell cell power Lots of local noise here making it difficult at time to pull stations out of noise. Too bad I had to get up early next morning for work or could have stayed on the air longer. Sometimes wish test would start earlier in evening.
de Ed - Carrboro, NC

K2EKM:
HOMEBREW XCR (ROCKMITE), 250MW-1W
de Bill, Springfield, VA

N8VW:
Elecraft K2 5W.
de Pat, OH

WB7AEI:
Station: Homebrew superhet rcvr (BP fltr, NE602, xtal fltr, NE602, NE5532 audio filter & amp), Homebrew TX 1 watt VFO exciter with 5W IRF511 MOSFET amp, homebrew SWR meter and tuner, homebrew keyer (K1EL

with skin resistance paddle), 40M full wave stealth loop with 2 sides at 6 feet and high point 17 feet. At least conditions were better than for QRP Afield (?). Signals here were at the "hold your breath while you copy" level. Anyone who worked several hours of this deserves a special award for perseverance under awful conditions! The guys above have real good ears! Thanks for the fun, 72's

Phil WB7AEI, Kent, WA

WQ2RP:

Thanks to all for your interest and activity in the sprint. RIGs: Elecraft K1 4w, 8 AA batteries, Portable zepp. Good band conditions in general. It was great to QSO the "Ususual Suspects" and several with milliwatt power. Look for the Spring QHB Sprint on Mar 22, 2004, 0000z. CU THERE!
72 de Ken N2CQ Opr - Woodbury, NJ

SPRING 2003 QRP HOMEBREWER SPRINT RESULTS

Call	Mode	QSOs	Points	x SPCs	x PWR	= Score
N4BP	CW	107	428	57	7	170,772
W5TA	CW	82	214	48	7	71,904
K5ZTY	CW	61	244	36	7	61,488
KD7AEE	CW	84	168	48	7	56,448
W0UFO	CW	57	228	33	7	52,668
KE0G	CW	63	252	28	7	49,392
WB8RTJ	CW	33	132	19	10	25,080
K4BAI	CW	30	60	21	7	8,820
W2AGN	CW	18	72	14	7	7,056
WB6BWZ	CW	23	46	18	7	5,796
K4AVX	CW	19	76	10	7	5,320
W2JEK	CW	15	60	12	7	5,040
NB7F	CW	16	64	11	7	4,928
K4GT	CW	15	52	10	7	4,200
W0PWE	CW	10	40	9	10	3,600

K8KFJ	CW	12	48	8	7	2,688
K3NG	CW	9	36	6	10	2,160
VE7NI	CW	7	28	7	7	1,372
WB7AEI	CW	6	24	4	7	672
AB6UI	CW	4	16	4	7	448
AL7FS	CW	1	4	1	7	28
Checklogs:						
WQ2RP *	CW	55	190	32	7	42,560

** NJQRP Club Station, N2CQ op*

SOAPBOX REPORTS

N4BP:
Elecraft K2 @ 5W, TH7-DXX @ 65ft, 402BA @ 50ft, 80M Dipole @ 60ft. 20M was dead in less than 1/2 hour. Other bands were marginal, no strong signals - but did work several miliwatters.
de Bob - Plantation, FL

W5TA:
20 meters: NORCAL "Red Hot" transceiver (kit, X4), 5 Watts. Antenna: 5/8 wave ground mounted vertical. 40 meters: Kenwood TS-430S (commercial, X2). Power: 5 watts monitored with Welz SWR/Power meter. Antenna: 1/4 wave ground mounted vertical
de Dick - Round Rock, TX

K5ZTY:
Elecraft K2 - Force 12 C4S. I had to leave the contest after the first hour and 45 minutes, but conditions were pretty good while I was in there. Fun to work those MW stations on 40 meters. Those guys have guts. Hope I can stay for the whole party next time. Thanks Ken for doing it again. Good to work the contest manager on 2 bands.
de Bill - HOUSTON, TX

W0UFO:
K2@5W. 20M TA33@45'. 40M Inverted V resonant dipole, coax feed with UFO balun, apex at 35" 80M 120' zepp fed wire sloped 20' to 40'. 20M was lousy but 40M and 80M quite good. Thanks to all for an enjoyable Sprint.
de Mert - St. Paul, MN

KE0G:
Homebrew Rig.
de Dan - Rochester, MN

WB8RTJ:
K1-1W. Force 12 C4SXL@50'. Couldn't stay until the end but was fun while I was playing.
72s to all, JIM - Amherst, OH

K4BAI:

FT1000MP@ 5W, TH6DXX and dipoles.
de John - Columbus, GA

W2AGN:
NORCAL Sierra, NC-40A. KT34 & 300' Loop. As always, fun, in spite of poor conditions. Gave me an excuse to break out the old Sierra and NC40A.
de John - Vineland, NJ

WB6BWZ:
Yaesu FT-817 QRP xcvr, 5 watts into a 5-MHz OCF 28-ga insulated wire stealth antenna up 40 feet in trees next to I-75 in downtown Atlanta industrial area. SGC SG-237 autotuner. WriteLog 10.40j, manual logging and post-modified for QRP Homebrewer Sprint (based on ARS Spartan Sprint module), no CAT interface.
de Matt - Atlanta, GA

K4AVX:
Worked only on 40 meters at two watts, with a Small Wonders Lab DSW-40.Forty had long propagation, with no close in stations. Only able to participate for about an hour, but enjoyed the Sprint.
73/72,John - Hazard, KY

W2JEK:
OHR 500 at 5 w. Ten-Tec 1380 @ 3w & HW-8 @ 2w.Groundplane on 20, Dipole on 40 and End fed hertz on 80.
Thanks & 72/73, Don - River Edge, NJ

NB7F:
K2 to sloping dipole. 7040 was murder - we need to SPREAD OUT !!! (IMHO)
de Lee - Portland, OR

K4GT:
Elecraft K2-5W.
de Jim - Atlanta, GA

W0PWE:
Rig: NN1G Xmtr (1w) with Iowa CSS Rcvr, both Manhattan built. Ant: Trap Inv Vee. I was only able to operate the contest briefly and forgot to get my log turned in. Thanks Ken, you guys do a great job with the contests and promoting homebrew.
72 Jerry - Johnston, IA

K8KFJ:
K1 #01194, ground mounted vertical. 5W. Got a late start (1 hour) because of company. Was surprised to find no activity on 20m. Went to 40m where I stayed for the duration (no 80m in the K1). Found activity rather sporadic but conditions seemed fairly good. Top dog here was W0UFO in MN who was 599+. Didn't hear any QRPp stations with the exception of WN7T in WA who I don't think was participating in the Sprint. Didn't make many Qs but wanted to submit my log to show my participation and thanks to the NJ QRP Club for their sponsorship of the Homebrewer Sprint.
de Garie - St. Albans,, WV

K3NG:
I didn't intend on operating the contest as I was planning a 'meltsolder' night. I casually operated awhile and had some fun. 20 meters was dead and all I could hear on 80 meters was WQ2RP, but I couldn't make contact. Hopefully next time I'll plan ahead and operate this seriously. Nice little contest.
:-) 72, Goody - Lehighton PA

VE7NI:
Rigs used were Ten Tec 1340 and 1320 transceivers built from kits with 5 watts output power.
73, John - Kamloops, BC

WB7AEI:
Given the conditions, I was surprised to make this many QSOs. 40M was obviously open to UT! There weren't many contesters heard, and the ones not worked were at the noise level. I'll bet the higher bands were better - I need to get some HB gear up on 20M. All contacts with homebrew 40M superhet receiver (new, replacing the old faithful DC receiver) and 1 watt VFO exciter with 5 watt MOSFET power amplifier. Battery power / homebrew battery charger. Antenna is a full wave 40M loop with two sides along a fence top at about 6 feet and the high corner at about 17 feet at the house eaves (obviously homebrew!). Antenna tuner and VSWR meter also homebrew. Used a vibro brass racer instead of my homebrew keyer this year. (And no, wouldn't dream of running my Pixie Deluxe in this!) Thanks for the excuse to get on and work some other QRP homebrewers!
de Phil - Kent, WA

AB6UI:
NORCAL 20, 5W. R7-vertial.
20M was active at the start of the contest but went dead early. Took dinner break and came back to silence. Finally worked one more then gave up. Was using solar charged gel cell to power the NORCAL 20 and ZM-2 antenna tuner and NB6M paddle. (HB)
de Brian - Torrance, CA

AL7FS:
I only worked N4BP with my K2(5w) on 20 meters. No other stations were heard during my time on the air. I was using my KLM KT-34A at 40 feet.
73, Jim - Anchorage, AK

WQ2RP:
Thanks to all for your interest and activity in the sprint. RIGs: Elecraft K1 (40, 20M), Kenwood TS-850s on 80M. Ant: Mosley TA33jr & doublet. Look for the Fall QHB Sprint on Sept. 22, 2003, 0000z.
72 de Ken N2CQ Opr - Woodbury, NJ

FALL 2002 QRP HOMEBREWER SPRINT RESULTS

Call	Mode	QSOs	Points	x SPCs	x PWR	= Score
N4BP	CW	106	424	53	7	**157,304**
K5ZTY	CW	87	348	47	7	**114,492**
AK7Y	CW	79	316	44	7	**97,328**
K1EV	Mixed	58	233	33	7	**53,823**
K0ZK	CW	53	212	36	7	**53,424**
N2APB	CW	40	160	27	10	**43,200**
N0RC	Mixed	45	185	31	7	**40,145**

N0JRN	CW	42	168	27	7	**31,736**
W2JEK	CW	36	144	25	7	**25,200**
W5TA	CW	21	84	16	7	**9,408**
N4UY	CW	15	60	14	10	**8,400**
KF4FHS	PSK	23	46	14	7	**4,508**
K8CV	CW	20	40	13	7	**3,640**
K0UE	CW	11	44	10	7	**3,080**
K8KFJ	CW	11	22	11	7	**1,694**
AE4EC	CW	6	24	6	7	**1,008**
K4GT	CW	6	24	4	10	**960**
W0UFO	CW	5	20	4	7	**560**
W2TAG	PSK	4	20	3	7	**420**
AB1AV	CW	2	8	2	10	**160**
K5QLF	CW	1	4	1	7	**28**
Checklogs:						
WQ2RP *	CW	67	268	36	7	**67,536**

** NJQRP Club Station, N2CQ op*

SOAPBOX REPORTS

N4BP:
Elecraft K2 @ 5W, TH7-DXX @ 65ft, 40M Dipole @ 35ft, NA v10.57. Condx very good on 20M, even the MW stations were loud.
de Bob - Plantation, FL

K5ZTY:
Elecraft K2 - Force 12 C4S and G5RV. Never did hear anything on 10 or 15 but 20 meters started off with a bang. Good signals until a little after 9pm local. Moved to 40 and had another pretty good run. Good to hear N4BP in the hunt and good to work the contest manager on 20 and 40. Thanks for putting on another good one Ken.
de Bill - HOUSTON, TX

AK7Y:
K-1 5 Watts. End fed 40m halfwave up 15'. Since I was visiting my 86 year old Mother during the contest period, I thought I would just give out a few contacts. My joke of an antenna worked better than expected so I

worked the entire contest. Fun as usual but I miss my ole KLM Tribander on 20 meters. I plan to be home for the Spring HB Sprint.
73 & TNX, Greg - Portable in Grand Rapids, MI.

K1EV:
Elecraft K2 @ 5W, 40/80 Inv Vee at 35 feet, Wilson System 33 at 50 feet (Tribander with 40 meter driven element). Enjoyed my first NJ QRP Club Sprint - thanks for a great contest. It was nice to hear all the QRPers, but I might as well have gone to bed after the third hour when things slowed way down and the noise levels came way up. I kept checking 10 & 15 meters all evening, but didn't hear a peep; heard only 1 peep on 80; worked 1 station on PSK and he wasn't even in the contest.
73, Bill K1EV - Gales Ferry, CT

K0ZK:
K-2 5 watts, Attic dipole. A surprise to work Montana on 40m with the attic dipole.
72/73 de Arn - North Lebanon, ME

N2APB:
Conditions were good and had great time meeting up with the familiar calls from QRP-L. Did lots of work on the bench while listening to the frequencies from across the room. Just slid over to catch a Q, then slid back to the bench for more prototype homebrewing. Sort of a modified S&P approach (solder & pounce, or "slide and pounce")! Sierra, GAP Titan vertical, 1W.
de George - Forest Hill, MD

N0RC:
RIG: K2, PSK-20, Attic Dipole. Fun time and good band conditions. Things a little slow on PSK but still bagged a few.
de Rod - Fort Collins, CO

N0JRN:
K-1 at 4w.
I had a great time!
de Jerry

W2JEK:
OHR 500 at 5 w. Groundplane on 20, Dipole on 40 and End fed hertz on 80. This was a great contest - really enjoyed it.
Thanks & 72/73, Don - River Edge, NJ

W5TA:
NorCal "Red Hot 20" Transciever built as Kit, 5 watts out. Home Brew 5/8 wave vertical; ground mounted 8 radials. This contest turned into to be a learning experience on my new logging program. Next time will work at making Q's. Did get my first QRP DX. I really enjoy these QRP Sprints.
de Dick - Round Rock, TX

N4UY:
Elecraft K-1, 40m and 20m dipoles. Minimum K-1 power -- 300 Milliwatts. Enjoyed the sprint. I turned my K-1 down to minimum power -- read .1 watt on the K-1 display -- 300 mw on OHR QRP wattmeter.
Antennas were dipoles at about 25 feet.
73 de Jake - Vienna, VA

K0UE:
Elecraft K1, St. Louis Vertical, LDG Z-11 antenna tuner. Bands went dead right after last QSO - would have kept going otherwise! Thanks for a great contest!
72 de Skip,K0UE/QRP

K8KFJ:

Had company over for the 49er/Redskin game so could only run into the shack occasionally and make a contact or two. Some breaks from the Sprint were over an hour in duration but I still wanted to make some Qs and show my participation & support for this FB operating event. Even though I was only able to manage a handful of contacts due to this rowdy football bunch, I did have fun and condx sounded good. Next time I hope to be one of the "afield" guys with a homebrewed rig. Equipment was an Icom706MKIIG @ 5w and a very old 14AVQ ground mounted vertical.
de Garie - St. Albans, WV

AE4EC:
K2 USING HB PADDLE - 4 WATTS. INVERTED VEE DIPOLE
Only had time for about « hous of operating as I had to get up early To go to work on Monday.
de Ed - Carrboro, NC

K4GT:
K2 at 900mW. Force 12 C3S @ 38'
de Jim - Atlanta, GA

W0UFO:
I was intending to work a serious session in the HB Test but found that the noise level in my neighborhood was so bad that I only worked a few loud ones before giving up. I think there is some new noise problem in my neighborhood that I need to get fixed because It wasn't like this when I was fox hunting. Of course, I just came home from QRP AFIELD where conditions were superb.
72, de Mert - Saint Paul, MN

W2TAG:
I was hoping more Warblers would show but only talked to one. The band conditions were not very good but the contacts I did make were solid. I cut the time short because of work the next day and it didn't seem that it was going to make any difference in my score anyway.
Equipment: NJQRP Warbler @ 3W output, 80 Meter Doublet
de Ted - Moorestown, NJ

AB1AV:
Equipment: Homebrew transceiver, 600 milliwatts.
Transceiver still on breadboard, powered by one 9v battery. Antenna is 140 ft end-fed wire via modified Rainbow Tuner.
My second contest in my third day of operating! The xcvr can actually be heard! Thanks to both ops for tolerating my clumsy fist and slow ears. Only managed to squeeze in an hour between kids' bedtime and my own, but had a good time and nice chats. Still need to work on T/R headphone thumps (MPF102 has too big a cutoff voltage to use for muting, I guess) and receiver noise.
de Bill

K5QLF:
Equipment: K2 into a doublet fed with 450-ohm twinlead via a ZM-2 tuner.
73, Fred, K5QLF..

WQ2RP:
Thanks to all for your interest and activity in the sprint.
RIG: Elecraft K1 (40, 20 & 15m).
Ant: Mosley TA33jr & doublet.
Look for the Spring QHB Sprint on March 24, 2003, 0000z.
72 de Ken N2CQ Opr - Woodbury, NJ

SPRING 2002 QRP HOMEBREWER SPRINT RESULTS

CALL	MODE	QSOs	POINTS	x SPCs	x POWER	= SCORE
K5ZTY	CW	97	388	50	7	135,800
N2NC	CW	87	348	50	7	121,800
W0PWE	CW	49	196	29	10	56,840
W0UFO	CW	52	208	33	7	48,048
K3WW	CW	51	204	30	7	42,840
AB0RS	CW	38	152	28	10	42,560
N0RC	Mixed	52	189	31	7	41,013
W1HUE	CW	35	140	23	10	32,200
K5HK	CW	35	140	21	10	29,400
KI0II	CW	29	116	25	10	29,000
AD6GI	CW	37	148	27	7	27,972
W5KDJ	CW	27	108	22	10	23,760
K2UD	CW	32	128	18	10	23,040
K4BAI	CW	46	92	31	7	19,964
K7PVT	CW	36	144	18	7	18,144
NK6A	CW	29	116	20	7	16,240
W2AGN	MIX	26	112	20	7	15,680
W3DP	CW	25	100	16	7	11,200
KE1L	CW	23	92	14	7	9,016
VE3SMA	CW	13	52	10	15	7,800
W3ZMN	CW	15	60	13	7	5,460
W1PID	CW	17	68	11	7	5,236
KW4JS	CW	15	60	11	7	4,620
N7CEE	CW	11	44	9	10	3,960
KG4LDY	CW	9	36	8	10	2,880
K4AVX	CW	11	44	8	7	2,464
NK9G	CW	16	32	11	7	2,464

KF4FHS	PSK	14	28	11	7	2,156
AG4PJ	PSK	8	40	7	7	1,960
VE3IGJ	CW	10	40	7	7	1,960
KC0GXX	CW	9	36	7	7	1,764
KC8LTL	CW	8	32	7	7	1,568
N2CX	CW	8	32	7	7	1,568
W2BVH	CW	9	36	5	7	1,260
AB9CA	CW	7	28	6	7	1,176
KB3AAG	CW	6	28	6	7	1,008
KA2UPW	PSK	6	30	4	7	840
K2HPV	CW	4	16	4	10	640
WB7AEI	CW	2	8	2	7	112
Checklog:						
WQ2RP	CW	93	356	48	7	119,616
(NJQRP Club Station, N2CQ Opr)						

SOAPBOX REPORTS

K5ZTY:
Elecraft K2 - Force 12 C4S and G5RV. Well it was a good night for a contest except 15 and 10 meters didn't come out to play. Had a good run on 20 for about an hour and a half then went to 40 and fought the QRN and the radar or whatever that horrible noise was that blanked the band. Tried 80 but the QRN was 5 over 9 or better. Made 2 contacts there. Sorry to those who I just couldn't pull out of the noise level. All that aside, it is always a good contest if it is QRP and you get to work the contest manager. Thanks to Ken for scoring this one again.
de Bill - HOUSTON, TX

N2NC:
My first QRP contest. Was only planning to fool around for a few minutes, but got sucked in and stayed with it until until 0315Z. Running a K2 at 5W and dipoles on 20, 40 and 80. The 80m dipole is fed with open wire through a tuner. Sent everyone 599 reports because of the software I was trying to use. Will have to try and find something better for next time.
John - N2NC, Howell, NJ

W0PWE:
20 and 40 meters were the only bands open here. I have HB rigs for those bands so I ended up with an almost all HB station. Rigs: 20M Manhattan SST, 40M CSS Rcvr and NN1G Xmtr, both Manhattan style. Other HB items: PIC memory keyer, Power supply, remote antenna switch, and the antennas (trap and open sleeve dipoles). The contest was great fun. There were lots of nice QRP and QRPp signals on the bands.
Jerry - Johnston, IA

W0UFO:
Rigs: Red Hot NC-20, Red Hot NC-40. Antennas: 3EL 3BD Yagi, Inverted v dipole. Again, as last Fall, has an MS-15 ready but heard nothing on 15. Good fun on 20 and 40.
de Mert - Saint Paul, MN

K3WW:
I bought a K2 last year, but decided I was missing something, so bought a K1 KIT at Dayton and built it. Recently upgraded to the 4 band module. I had other committments Sunday night, but got in a few hours of the sprint. I was pleased with the activity, the K1 is working great. Antennas: 2 el Cushcraft 40 at 75 feet... pair of Bencher Skyhawks on 20. Used my laptop for logging... manually calculated the score, hope I did it right.
de Chas - Perkasie, PA

AB0RS:
Elecraft K2 - 900mW
de Richard - St. Paul, MN

N0RC:
RIG: K1, NC20, PSK-20 5 Watts. ANTENNA(S)__Attic Dipole. Nice activity, enjoyed it. Will be back for more in the fall!
Rod, Fort Collins, CO

W1HUE:
40M - Modified Norcal 40A - Inverted Vee
20M - Modified Norcal 20 - 450' longwire
15M - Modified MFJ Cub - 450' longwire
de Larry - Idaho Falls, ID

K5HK:
Equipment: SST 20M AT < 1W. (XCVR WILDERNESS KIT) SMK-1 40M AT 500MW. (XCVR NORCAL KIT) ANTENNA: LIGHTNINGBOLT 5-BAND 2-ELEMENT QUAD AT 38FT. I USED SAME ANTENNA THROUGH A TUNER ON 40M.
de Carl - RENO NV

KI0II:
HB Xmtr & Rcvr <1W. Didn't have a chance to try any PSK but is a fun event!
Ron - Littleton, CO

AD6GI:
Elecraft K2, 5 watts, 40M, 15M = dipole at 40'; 20M = dipole at 25'. S + P was not working well due to band conditions and found that QRZ? filled the bill. Increased my contact count near 10% over last Sprint and had great fun learning a different approach. My thanks to all the operators for their good ears and a special thanks to Ken Newman and the NJ QRP Club for another fine Sprint.
73, Chuck

W5KDJ:
Elecraft K1/4band Xcvr. 7, 14 & 21 Mhz
Mosley PRO57b. 7Mhz - DX-88 Trapped vertical.
de Wayne - Spring, TX

K2UD:
2N2/40 HB xcvr (<1W), Camcorder battery, end-fed-halfwave ant. Been absent on the air, good chance to get on. 40M was the ticket, 20M dead in the east, 80M not so hot. Dig that VE3SMA w/200mW, EEEEH! That's punishing!
de Howard - Amherst, NY

K4BAI:

FT1000MP (5W), TH6DXX, Dipoles. Long skip on 20m to NJ. Not enough activity. Maybe everyone was on PSK31?
73, John - Columbus, GA

K7PVT:
Wilderness SST-20 >1W, KT34XA tribander up 60'. All in just an hour of operation. Didn't have any more time. XYL was 8-(as it was!
de Robert - Langley, WA

NK6A:
Rigs: K2 at 5W to a Force 12 C4 at 40' and K1 at 5W on 40M.
Don - Mar Vista, CA

W2AGN:
Rigs: K2, PSK80 "Warbler. Antennas: KT34 Tribander, 300' Horiz Loop, 80/40 Trap Dipole. Rather poor conditions, but gave new Trap Dipole a good test. Even got RI for new state, and worked AL on 80M PSK. (He was running Warbler).
de John - Vineland, Nj

W3DP:
Elecraft K1 (5W), G5RV, K20 Keyboard, battery power. 40M band conditions were very good. Best skip was W0PWE in Iowa at 559 running 1W. The usual QRO stations around 7040 oblivious to the QRP event! I am impressed with the K1 filtering. I could copy very weak signals just 200 HZ away from S9 plus QRO stations with no problem. They just disappeared! This was in the 250 HZ F3 filter position. Great little rig! Was amazed to work 16 states in one hour. Good participation from all over.
72 all, Dick - Camp Hill, PA

KE1L:
What a struggle! The bands, they were not so good. Then they got worse. I took a break a bit after 9, and when I came back, 40 meters had been invaded by some sort of Woodpecker-ish interference, centered right around 7.040! It later went away for a while, but the band never seemed to recover from the insult. The closing bell hasn't quite rung as I write this, but I've had enough. The rig was K2 #1984 (Big Brother is listening) with all currently available options, set for 5W output. The antenna was a 40 meter inverted vee; the apex is anchored to the chimney of my house, about 40 feet up. 40 was the mainstay band, what with the antenna being set up for it, but I did manage to eke out a few QSOs on 20 and 80 as well. (The KAT2 will tune almost anything!) I heard KD1JV at one point, but I wasn't able to work him. Darn. I would have liked to snag an official melted-solder Q.
Mark - Dorchester, MA

VE3SMA:
Homebrew 200 mW output direct conversion xcvr, HB keyer and Bencher paddle, HB antenna tuner, 26' verical ant. Started out at a good rate, but some time after 0100z the skip got very long, which made the rest of the contest tough going for a flea-powered station!
Steve - Cambridge, Ont.

W3ZMN:
Elecraft K2, Dipole on 80 and 40, R5 vertical on 20.
de Conrad - Bethlehem PA

W1PID:
40 meters Emtech 5W, 20 meters MFJ Cub 2W, Antenna Off Center Fed Dipole 40 meters was dynamite. Operated for 45 minutes. Had a ball. Many thanks to all operators and organizers!
Jim - Sanbornton, NH

N7CEE:
Station: Elecraft K1, ATU, end fed 80 foot wire with counterpoise, 10 cell AA NiMH pack, 1.5 watt solar. I operated on the fourth night of a six day backpack trip in Arizona's Blue Range Primitive Area. Considering that I

was set up in the bottom of a 2,000 foot deep canyon, the bands sounded pretty good. Thanks to N2CQ and the NJ QRP Club for organizing this fine contest!
73, Bruce - Strayhorse Canyon, AZ

KG4LDY:
SW-40 home built Xcvr at 1 watt, all 40 meter CW. Noisy night on 40 meters with lots of QRM. Strange propagation. Heard a station in Venezuela calling CQ around 7050 about the time the Sprint began. Called him but my one watt just wouldn't make it.
73, Jim - Woodstock, VA

K4AVX:
Nice contest. Only got on on 40 meters about halfway through. Had lots of QRN, SSTV and SSB QRM, and shifting band condx. Used my DSW-40, a gelcell battery, and ant tuner with an 80 meter dipole. Qso's tough to make during the last hour.
73, John - Hazard, Ky.

NK9G:
Rig: Yaesu FT-817, Antenna: Cushcraft R7 Vertical, 5 Watts. Activity could have been better, W5KDJ with 900mw has good signal into SE WI.
Rick - Cudahy, WI

KF4FHS:
Man, I've got new respect for you QRP guys. This is the first contest I've done using 5 watts and it was definitely a challenge. I was using an old Kenwood TS-520 with nothing but SSB filters and a dipole up 70 feet, not the most ideal setup, but I must say I had a ball. I can't wait until the next one. Thanks for a great time & 73,
Bernie - Yelm, WA.

AG4PJ:
Warbler running 5 watts into 65' End-fed Zepp up 35'. Static rolled in about 02:00, making things tough. Still, a lot of fun! (Sure would like to know what kind of antenna K6EIL was running!)
Regards, Dave - Mobile, AL

VE3IGJ:
POWER 5 WATTS, ELECRAFT K2 TRANSCEIVER, AND 20M INVERTED V DIPOLE
IAN - OTTAWA, ON

KC0GXX:
2N2/40 (Jim Kortge's design. 2W), HB Keyer based on 3 "555" IC's, Dipole up ~40', MFJ941E tuner. Lots O' Fun.
Thanks, Tom - Lincoln, NE

KC8LTL:
Rig: K2 #2030 at 5 w. I almost didn't participate because the 40 M dipole was broken (used coax fed 80 M dipole and atu for 40) and the bands were crap in the afternoon, but gave it a short go anyway.
de Ken

N2CX:
Rig - HB Sierra at 3W Antennas : 40m inverted vee and 20m PAC-12 vertical. 40 and 20 meter operation
de Joe - NJ

W2BVH:
RUFF CONDX!
de Lenny - Cranford, NJ

AB9CA:
RIG: SWL SW 40+ Ant: Homebrew 40m vertica. This is my very first contest. Had a great time. Wish I could

have worked more. Heard WQ2RP a couple of times but was never able to be heard.
de Dave - Loxley, AL

KB3AAG:
Small Wonder 40 meter xcvr built by friend (One hand operator) I enjoyed the contest and will be back even if I am still slow! (Ed: Go for it Frank! Hope to hear you often!)
de Frank - Waynesburg, PA

KA2UPW:
I operated PSK31 exclusively on eighty meters with my Warbler. Where was everybody? Not on eighty meter PSK31. It sure didn't LOOK like a contest was going on. After hastily constructing an eighty meter dipole and erecting it at about five feet, I made six PSK31 contacts. Rig: PSK31 Warbler (80 m) about 2 watts out. Antenna: 80 m dipole at five feet. CPU: Pentium with Digipan
de Doug - NJ

K2HPV:
Ten Tec 1320 (20 meters only). 900 mW. Gap Titan vertical. Sorry I couldn't do better....that heterodyne on 20 meters was devastating.
de Herb - Clarksboro, NJ

WB7AEI:
Here's my entry. The bands were pretty bad, and only managed a couple contacts on 40M the last half hour of the event. (the only band I heard any signals on all day). Think maybe the "recovery" was better on the East coast since the sun had been gone longer. Gear: Homebrew DC Rcvr, 1 watt VFO rig and 5 watt amp, tuner, swr meter, keyer, battery charger, antenna (random horizontal/vertical invisible wire). Still didn't run my "Pixie Deluxe" in this. Its a great event and hope the ionosphere Gods are in a better mood next time. Not many signals, not very strong, more "agn?" than an SOC contest. Thanks for the excuse to get on the air. Did I mention the conditions were a little rough?
72's, Phil WB7AEI - WA

WQ2RP:
Thanks to all for your interest and activity in the sprint. 40 meters was GREAT as long as Woody Woodpecker took a rest. RIG: Elecraft K1 (40, 20 & 15m) and Kenwood TS850 (80m). Ant: Mosley TA33jr & doublet. Look for the Fall QHB Sprint on Sept 23, 2002 0000z.
72 de Ken N2CQ Opr - Woodbury, NJ

FALL 2001 QRP HOMEBREWER SPRINT RESULTS

Call	Mode	QSOs	Points	X SPCs	X PWR	= Score
K5ZTY	CW	83	332	47	7	109,228
AK7Y	CW	84	336	46	7	108,192
K7RE	CW	82	328	45	7	103,320
K0EVZ	CW	70	280	38	7	74,480
W0PWE	CW	45	176	35	10	61,600
N0TK	CW	50	200	33	7	46,200
NQ7X	CW	40	160	28	7	31,360
AA1MY	CW	40	160	26	7	29,120

W2AGN	Mixed	28	116	23	10	26,680
AD6GI	CW	34	136	23	7	21,896
W0UFO	CW	27	108	20	7	15,120
N7CEE	CW	19	76	15	10	11,400
N0RC	CW	31	62	21	7	9,114
KW4JS	CW	19	76	16	7	8,512
AA3SJ	CW	17	68	11	10	7,480
KA3WMJ	CW	18	72	14	7	7,056
W1PID	CW	18	72	13	7	6,552
K4GT	CW	15	60	12	7	5,040
N3MK	PSK	12	60	11	7	4,620
N2APB	CW	12	48	9	10	4,320
N2CX	CW	14	56	10	7	3,920
W3BBO	CW	10	40	9	10	3,600
NA5N	CW	17	34	13	7	3,094
W4NJK	CW	11	44	7	7	2,156
K1SWL	CW	12	24	9	7	1,512
WB7AEI	CW	6	24	4	7	672
KD7CTF	CW	4	16	4	7	448
WC7S	CW	5	10	4	7	280
N1EI	CW	2	6	2	7	84
W6EMD	PSK	1	5	1	7	35

Checklogs:

WQ2RP	CW	74	288	42	7	82,320

(NJQRP Club Station, N2CQ Opr)

SOAPBOX REPORTS

K5ZTY:
Another good NJQRP Club contest. Condx were good even though we had quite a bit on QRN here in TX from thunderstorms in the area. Thanks to those who stayed with me thru several repeats when the noise got bad. Thanks to Ken for promoting and scoring again. WQ2RP was loud.
Bill

AK7Y:
Thanks for another great QRP HB Sprint. I am sure glad that you posted to call for logs. I have been putting off the entry, working on a new SW-30+ kit, and time slips by when building new rigs!
Greg

K7RE:
Good conditions and very nice turnout too. No 15M activity found this time around. I did CW only. Rig: K-2, 3 el trapped tribander at 35 feet, half square on 40M. Fell short of the Spring contest totals by 18 QSo's Sure enjoyed myself, I also got to try out my new 40M Half Square antenna before the rest of the contest season begins.
Brian

W0PWE:

Rigs: 20M Manhattan SST, 40M CSS Rcvr and NN1G Xmtr both Manhattan sytle. 15 and 80M TS140S. Antennas: Multiband dipoles. 20M was fun while it lasted. 40M and 80M had summer like QRN.
Jerry

N0TK:
NC20 and K1 built by N0TK. Attic dipole antennas for 20 and 40.
Dan

K0EVZ:
Will be interested in seeing how this log compares to the top scorers. Usually I don't send in logs, but may change as I get more familiar with computers and keyboards.
Doc

NQ7X:
GOOD PROPAGATION AND PARTICIPATION, BUT AS USUAL I ONLY GOT LESS THAN 2 HOURS OP TIME. FUN THOUGH AND THANKS TO KEN N2CQ AND THE NJ CLUB FOR SPONSORING.
Floyd

AA1MY:
Propagation seemed good, but turnout seemed light... maybe 'cuz I missed first two hrs? The skip zones were clearly visible when plotted on a map, esp. on 20m. Odd, but NA5N's unmistakable sound is usually heard/worked at the end of my 'tests. Thanks to NJQRP for running this great event... cu nxt sprng!
Seab

W2AGN:
An real challenge doing without my trusty K1 or K2 and using the SST and NC40A. PSK-80 Warbler was a gem though, but where were the NJQRP PSK31 stations?
John

AD6GI:
Great group of operators! Good ears and very patient with my occasional bad keying as I got excited as my exchange rate increased. Still lots of funand am already planning for next year. See you then. Many thanks to Ken and the NJ Gang for their effort. It is much appreciated.
Chuck

W0UFO:
Had an MS-15 ready for 15 but heard no signals. Lots of noise with sigs on 40. Had fun on 20 but it was a cold nite at the cabin so quit early. Used an NC-20 and Red Hot NC-40 with 20m dipole & longwire on 40.
Mert

N7CEE:
Elecraft K2 running 1 watt into a 40 meter vertical.
Bruce

N0RC
Sure miss my K2 for these events, but had to yield to economic realities. BUT NEXT TIME I'LL BE USING MY K1 (recently acquired)!!! ;-) Looking forward to the Mar 2002 event! Rig: KNWD 570D(G) @ 5W - Ant: Attic Dipole @ 20ft
Rod

KW4JS:
Elecraft K2 - Homebrew Xcvr - Pwr 5 Watts
John

AA3SJ:
I just completed this rig last week and decided to give it a try. The direct conversion receiver made it difficult to

use in contesting. Using 700mW, my final was a 3N3904 (Hi!). Band conditions were also rough. At my QTH I have a strong shortwave station that comes on at about 11:00 PM each evening and it overwhelms the rcvr. Overall this was a lot of fun, but definately a challenge. This is the first contest that I actually worked for a score. Thanks NJ QRP for sponsoring it.
Ed

KA3WMJ:
Really enjoy these Sprints with the K2 but I need to improve my antennas for close in stations. Thanks for all your help.
Ken

K4GT:
Elecraft K2 - 4W
Jim

N3MK:
Fair condx but not a lot going on on PSK. Ran PSK-31 only with PSK-20 and Warbler. Rig: PSK-20 and Warbler into MFJ 934 tuner into dipole
Don

N2APB:
Short time spent, and correspondingly small score, but I had a great time. It's always exciting to hear and QSO with the various calls we see on the Lists, the hamfests and the QRP weekends. Most notable experience during the sprint was hearing N2CX waaaay down in the noise with a ton of people trying to get him. During my repeated tries for him as well, a dog wandered over to the SLVPV antenna and relieved himself on the base ... I was too busy trying to get Joe and just decided to let the dog go. I ultimately bagged N2CX and attributed it to the added ground conductivity of the antenna. Homebrew setup here: Wilderness Sierra running 1W, NorCal BLT Tuner, St. Louis QRP Society "Vest Pocket Vertical" antenna, and scratch-built W9GR DSP-1 audio filter. Location: local school soccer field in Forest Hill, MD.
George

NA5N:
I only ended up able to work about an hour and a half, from about 0200-0400UTC with a couple of interuptions. Blew a water pump in the car saturday, so spent sunday dropping the new one in ... which of course took far longer than planned :-(Remember when you could change a water pump WITHOUT having to relocate a hundred hoses, pull the radiator, oil coolers, transmission lines, etc.? Geez! So sorry I wasn't able to participate longer, and with local sunset kicking in, propagation was sadly mostly out west. Although I did work WQ2RP and Sean AA1MY with fairly good signals. Still had fun though, and a nice way to wind down after playing master mechanic. (which I ain't) I like the Sunday and the time slot. Keep it.

LOCATION: From the house, about 15 mi. N of Socorro, NM
RIG: SG-2020 (just fixed for a friend) running 5W
PWR: A Wal-Mart 12V lawn mower battery
ANT: Full-length G5RV and St. Louis Tuner (homebrew)
KEY: Homebrew paddles (not a kit)

72, Paul NA5N

W4NJK:
Rig K1 # 49; G4ZPY minipaddles;40M halfsquare wire from CA,near San Jose. Second time with the K1 and great participation noted on 20 and 40. Lots of QSB and odd condx on 20; but 40 was excellent once it got to the West Coast. Heard WQ2RP most of the night and K0EVZ for a while but no luck getting through. Very enjoyable, thought I would hear more stations at less than 5W but Condx may have kept them to local QSO's TNX NJQRP and all for good operations all around.
72, Charlie, W4NJK

K1SWL:
Thanks for managing this event! Good conditions and activity levels, but had to QRT about an hour into the

Sprint- our son called to say his car had died- that took 2 hours to square away. I really regret not having an antenna up for 80M - the 'Warbler' is sure feeling neglected! Rig: FT-840/battery- 5W - 20M dipole @40 ft
72- Dave- K1SWL

WB7AEI:

The conditions didn't seem bad on 40M, but QRP'ers were weak and piled on top of each other. There weren't many standout signals, except for the encroaching QRO QRM, and of course Doc K0EVZ. Run my Pixie in this - no way! This was all 40 meters with my homebrew DC receiver, 1 watt VFO transmitter, and 5 watt MOSFET amplifier. For that matter, my keyer, battery charger, tuner, SWR meter, and antenna are homebrew also.
72's and tnx for some fun - Phil WB7AEI

KD7CTF:

K2 at 5W into ground-mounted Hustler vertical. Bands were vy noisy here.
73's, Lee, KD7CTF

WC7S:

With this much fun, in only half hour of operation, look for me in next test for sure!!
Dale

N1EI:

XMTR: Sorta TT2. This is actually a Little Joe built on a TT2 board and mounted in a tuna can. The keying transistor is mounted on it's own little board and is hidden inside the can under the main board. Power out is about 1.25W using a 2N4401 oscillator transistor and 2N5321 final PA. A seven element external 40M low pass filter was used in addition to the 3 element filter on the board.

VXO: Sorta Doug DeMaw design. The oscillator stage is a JFET source follower VXO right out of one of his books with a two stage buffer/amp from another one of his designs grafted on to it. Impedance matching between the VXO and the Sorta TT2 was handled by an MFJ long wire antenna tuner. Frequencies covered: 7.039 - 7.043.

Keyer: An Oak Hills board kit (designed for the 2 band Classic maybe?) mounted in it's own little box.

RCVR: I wanted to use my 2 tube regen (built from the QRP Power article by Dave Newkirk.) But the VXO's poor shielding put out such a strong signal when turned on that regen detector pulling prevented my from zero beating the receiver to my xmtr. So I used my back up rcvr - a Hammarlund HQ-180. Got to shield that VXO better. Maybe putting a bottom on the box would be a good place to start. :-)

XMTR antenna tuner: ZM-2.

Antennas: 80M doublet at 50' for the xmtr, and 85' wire at about 20' for the rcvr.

My unoptimized setup here kept me from putting in much of a contest effort. I had to turn the VXO on and off for each call (so I could hear anyone on the off chance that they called me back) and the itty bitty switch that I put on it wasn't really designed for that. Hope to make a better effort next time.

Thanks for a fun contest!

Charlie Fitts, N1EI

W6EMD:

My gear: Rig..Small Wonder Labs PSK-20
Ant..KLM KT-34A at 30'
Software...Digipan
Computer...586 running Win98SE
72, Dave, W6EMD, Redwood City, CA

N2CX:
Rig: Sierra with window line fed 40M dipole/ZM-2 tuner.
Joe

WQ2RP:
Rig: Elecraft K1 on 40 and 20, Kenwood on 80m, TA33jr tribander & center fed Zepp. Thanks for the activity, Folks! I hope you enjoyed it. Look for the Spring QHB Sprint on March 25, 2002 0000z.
72 de Ken N2CQ Opr

SPRING QRP HOMEBREWER SPRINT 2001 RESULTS

CALL	MODE	QSOs	QSO PTS	SPC MLT	PWR MLT	FINAL SCORE	
K5ZTY	CW	128	512	73	7	261,632	
K7RE	CW	100	400	60	7	168,000	
WQ2RP	CW	100	374	64	7	167,522	N2CQ OPR.
AK7Y	CW	105	382	61	7	163,114	
N9NE	CW	96	384	55	7	147,840	
W2AGN	MIXED	74	301	51	7	107,457	
W0PWE	MIXED	63	256	40	10	102,400	
WU0L	CW	75	300	48	7	100,800	
N0RC	CW	71	284	48	7	95,424	
W0RSP	CW	65	260	41	7	74,620	
W1HUE	CW	51	204	34	10	69,360	
AD4J	CW	46	184	33	10	60,720	
N3AO	CW	47	188	32	10	60,160	
W0UFO	MIXED	56	226	38	7	60,116	
KC2AFK	CW	47	188	32	7	42,112	
K1TS	CW	28	112	20	7	15,680	
W1PID	CW	26	96	19	7	12,768	
AB0GO	CW	21	96	14	7	9,408	
N0MCX	CW	21	72	18	7	9,072	
AB5XQ	CW	19	76	16	7	8,512	
K8KFJ	CW	29	58	20	7	8,120	
N1BQ	PSK	18	90	12	7	7,560	
W4NJK	CW	18	72	14	7	7,056	
KM5VY	CW	16	64	15	7	6,720	
VE3SMA	CW	11	44	9	15	5,940	
N5OBC	PSK	11	55	10	10	5,500	
KR4IP	PSK	13	65	12	7	5,460	
N0HRL	CW	16	64	12	7	5,376	
K3NLT	CW	13	52	10	10	5,200	
WA5BDU	CW	15	60	11	7	4,620	
K7GT	CW	16	64	10	7	4,480	

N0OCT/8	CW	12	48	9	10	4,320
NA3V	CW	14	56	11	7	4,312
N7CEE	CW	11	44	9	10	3,960
AE5K	PSK	10	50	9	7	3,150
KG4FSN	CW	4	16	4	7	448
NU3E	PSK	3	15	3	7	315
KH6B	CW	2	8	2	7	112
W6ZZZ	PSK	0	0	0	7	0

SOAPBOX REPORTS

Rig=Homebrew Elecraft K1 W/KAT1 installed @ 5 Watts
Ant= Attic dipole cut for 20/40 meters

This was a great test of my K1, first contest event since I installed the KAT1. I did not get to operate the entire contest, but still had a ball. Highlight was working G3IGW at 5 W on my Attic Dipole, He was QRO! Thanks for sponsoring a great contest, looking forward to the next one.

72 de Bill, AB5XQ

Rigs: DSW-20, DSW-40
Antennas: 66' doublet, 33' doublet (perpendicular to 66 footer) both fed with 300 ohm twinlead, tuned with Emtech ZM-2 and MFJ-949E

This was my first Homebrewer Sprint. Four hours is just the right length. W9JOP/4 had a very nice signal for 350 mW as did WD3P with 500 mW. Having perpendicular antennas on 20 meters was very helpful in making the marginal QSOs. It was good to hear W0RSP on giving out South Dakota QSOs.

Jim, AD4J

Band: 80 Meters (ONLY), Mode: PSK31 (ONLY), Equipment: Warbler.
Antenna: Radio Works Carolina Beam 80 (wire ant.), Output power: 2 watts

First QRP contest for me, heard several 1's and 2's but QRM and band conditions did not allow contact. Think most of us had a tendency to exchange more than required information in our QSO's (speaks of the spirit of QRP and PSK31, not good for scores). At least half stations worked were using Warblers, plus several more heard but not worked. Looking forward to the next one! --

AE5K (Don) in the boondocks of the northern Arkansas Ozarks
(12 miles south of Yellville, AR).

Used my new K1 (#605) running into a loop antenna for both 20 and 40 meters. Seemed to work pretty well. Next contest I need to spend more time in the chair.
Thanks for a fun event!

73,
Marc, K1TS

Transceiver: Elecraft K2 <5W   Antenna: Yagi and G5RV

Worked many stations on multiple bands. Good conditions and lots of players. Good contest. Thanks to Ken and the NJ club for putting this one on. I'm looking forward to doing this one agn.

Bill, K5ZTY

Cedar Mesa UT.   Elecraft K1.
Not too bad for coming in very late...

73 Allan K7GT

Elecraft K2 at 5 Watts

What a blast. Band conditions were really excellant.
I wish that I had entered into the 1W class, as there were plenty of nice strong under-5W stations worked. High points were being called by RA3ID, DL1CC, and KH6U. If I had more time, I would have tried PSK-31 as well, but a week full of my wife's Spring Break Honey DO's made this old body somewhat less contest compliant than usual. Thanks to Ken and the fine folks at the NJ club for putting on this very fine event.

Brian, K7RE

Emtech NW 8020 running 4 watts. Antenna: Dipole in my attic.
This was my first contest. Next time will be better.

73s
Juan - KG4FSN

Equipment: K2 with internal battery and Hy-Gain 14AVQ trap vertical antenna.
Got in the event at the tail-end. Almost forgot the thing entirely.

Dean, KH6B

QTH: Tijeras, NM, Rig: K2 #398, Power = 4W, Ant = random wire
Fun contest! Thanks

Tom, KM5VY

EQUIPMENT : PSK - 80 WARBLER at 3 WATTS POWER OUT
ANTENNA :   80 Meter Dipole UP 60 Feet

Keith, KR4IP   COVINGTON GA

K1 20m/40m running 5W to attic dipole.

First attempt at a sprint, lots of fun. Highlights were working K5ZTY on two bands within just a few contacts, and copying W9JOP/4 at 350mW from VA. Nice to hear lots of calls that I have seen on the e-mail list.

Ken, N0HRL   Plymouth, MN

This event was great fun, a classic QRP blast. I was operating from
my car parked on my favorite local hilltop, at Loretto Heights Park
in southwest Denver. I started out on 20m CW with the SST, and
later on switched to 40m CW with the 706. Antennas were mobile
whips on the Jeep hood.
Many thanks to K5SA for putting up with my incomprehensible attempts at
sending "559-CO-4W" while fixing a loose key cable, to the NJQRP outfit
for putting together a fine event, and to everybody who played! I'm
looking forward to next time....

73/72 es CUL, Tom - N0MCX

I was on vacation with my family, on our way to Washington, DC
for Spring Break. I was operating /8 from Martinsburg, WV, with 20'
of wire sticking out of the 2nd storey window on the west side of the hotel.
Not ideal. Rig was NC-20 running 0.95W, which was the first contest
for this rig, as I just finished building it [okay, so I'm slow].

73, Jim NØOCT

Rig: K2 #286 @ 5W   Ant: Attic Dipole @ 20ft

Had a great time, hope you we do it again next year!

73, Rod N0RC   Fort Collins, CO

NJQRP Warbler running 2 watts to G5RV. IBM Thinkpad 365XD Digipan 1.5
One band only 80m PSK

N1BQ, Brian

K2 at 1 Watt. 5-Element tri-band beam & Windom at 38 feet.

It sure was fun! Next time I'll try for the whole 4 hours...
73/72,

Carter N3AO

Power: 900 milliwatts   Station: Elecraft K2, 40 meter horizontal loop up
50 feet.

I was only able to operate the first hour but had a good time. The K2 mojo
seemed to be working overtime, as I worked every station I called, but one,
even at 900 mW. Thanks to Ken and George for putting this one together.

73, Bruce - N7CEE   Flagstaff, AZ

Elecraft K2 #1429, triband beam at 60 ft.; 18AVT vertical; 80 meter zepp.

This was my first NJ Sprint, and I thoroughly enjoyed it!
Lots of good QRP operators out there. After 43 years of hamming,
thought I knew Z time but miscalculated and started almost an hour late.

CU next test!

73, TODD, N9NE   OSHKOSH, WI

NJQRP Warbler kit @ 3 Watts, homebrew 6-band trap dipole in attic

I got busy and didn't remember the contest until after 10 PM. But I enjoyed the short time I was on.

73,   John NU3E

Equipment:
Manhattan built single band transceivers for 40 and 20M.
Warbler for 80M PSK. Trap dipole for 40 and 80M,
open sleeve dipole on 20M. Qrpdupe logging.

Thanks NJQRP for sponsoring a fun contest. Always nice to hear so many homebrew signals on the bands.

Jerry, W0PWE   Johnston, IA

Equipment:
Transceiver: K2 built from a kit.
Antennas: GAP Voyager vertical and 450-ft long wire.
Keyer: Super CMOS III built from a kit.

It's great to have a CQ answered by a JA when you're only running 900 mW! :)

Larry, W1HUE   Idaho Falls, ID

Equip: DSW-20, DSW-40, FT-817 (on 80 and 15 meters)

W1PID, Jim   Sanbornton, NH

HB Transceiver(s) Mode:CW/PSK31 Power: 5 W

This was a fun contest. Worked N2APB for first time. Could have wished more PSK31 activity.
Did give me a chance to try out my "Warbler" but only 5 QSOs. Concentrated on CW. Some unbelievable QRPp signals!

John, W2AGN   Vineland, NJ

Station K1 40/20 @5W/3W, Whiterook paddlette, on lead acid battery
(this is my traveling station except I throw up a 20M dipole)
ANT 15M half square at 25 feet

My first entry with a transceiver I actually built and what a blast! Lots of stations heard but condx on 20 went out then back in the last hour. My received RST reports varied from 579 to 339 and 519... TNX to WQ2RP for hearing me as next to last contact. Next year I will use two different antennas and probably try 1 Watt. I was impressed with several I heard especially W0PWE at 900MW and K0FRP at 1W, so I know it can be done. Thanks to NJQRP and the organizers for a great idea and event.

73,72 Charlie W4NJK Los Altos, CA

Equipment is a Warbler with a homebrew 80m dipole antenna.

Due to other constraints I was only able to operate for a short time from 3:30-4:00 z.
I like the idea of this sort of QRP homebrew contest.
FYI - this sprint is rather early in the day for good propagation for us West Coast Warbler (80m) folks. I'm not complaining, just bringing up a fact.

Marc, W6ZZZ

Equipment:
2N2/40 to 180 foot dipole fed with 450 ohm ladder line via a Johnson Matchbox.

Enjoyed the contest. Worked more than I expected to, just fooling around. Only have a decent homebrew rig for one band at the present. Band conditions (40 meters) were good.

72 & Tnx--Nick, WA5BDU

My rig is a home designed, scratch built 2 band transceiver.
It operates on 20M and 40M.. Features 10.5 MHz IF and crystal filters, KC-1 for keyer and audio frequency annunciation, SWR bridge, Vackar vfo, and IRF510 PA.
My antenna is a GAP vertical ground mounted.

WU0L----Mark Golden, Colorado

Equipment:
Homebrew direct conversion tranceiver using one transistor, one voltage regulator IC and 7 CMOS digital chips, homebrew keyer (bigger than rig!), vertical antenna. 150 mW out.

Many thanks to all who strained to copy my weak signal, especially to KA3WTF who never quite got everything through the QRM despite a most valient struggle.
Operated only about half the Sprint but enjoyed and picked up two new states (NJ,CO) at the 150 mW level.

VE3SMA, Mark Cambridge, Ontario

Equipment:
40m OHR 100 & 80m Emtech NW80 at 5W out. Ant 130' doublet.

I dusted off two old rigs I haven't used in a year. Forgot how well they worked! Spent a little over an hour in the contest. Very nice and lots more activity than I expected.

Jim, NA3V

Equipment: Elecraft K2
This is my first participation in one of the Sprints, found it fun.
The only problrm was that not everyone was aware of the Sprint and I ended up with a ragchew. Ragchewing is more what I enjoy

the most, so I was easily distracted. Also did not have full time available. Will hope to set aside more time for the next one.

73 de Russ K3NLT

Equipment:
MS-15, NC-20, NC-40 @ 5w & PSK-80 @ 3w. TA-33 @ 45', 120' ZEPP.

Thanks to all for the fun!

Mert W0UFO   St. Paul, MN

Equipment:
Both rigs are homebrew original designs built way back when.
20m D.C. Xcvr, 2N5913 final, 1.8w output.
40m D.C. Xcvr, "420XC" (CQ, Oct, 1978) 2N5590 final, 5W output.
G5RV antenna up 48ft

This was a great SPRINT! Maybe the best so far! QRN was a pain on 40 but managed to copy everyone eventually. Operating with the D.C. xcvrs reminded me of how easy it is these days with superhets and sharp filters!

72, Ade - W0RSP

Equipment:
15m Index Labs QRP++, 20/40m Elecraft K1 (5 Watts),
KLM Tribander @ 22', Butternut Vertical roof mounted, WM-2 Power Meter

AK7Y, Greg   Alpine, AZ

Equipment:
K-1 40/20 & Knwd TS850 80/15 (5 Watts).
Center fed Zepp. TA33jr Tribander @ 40'