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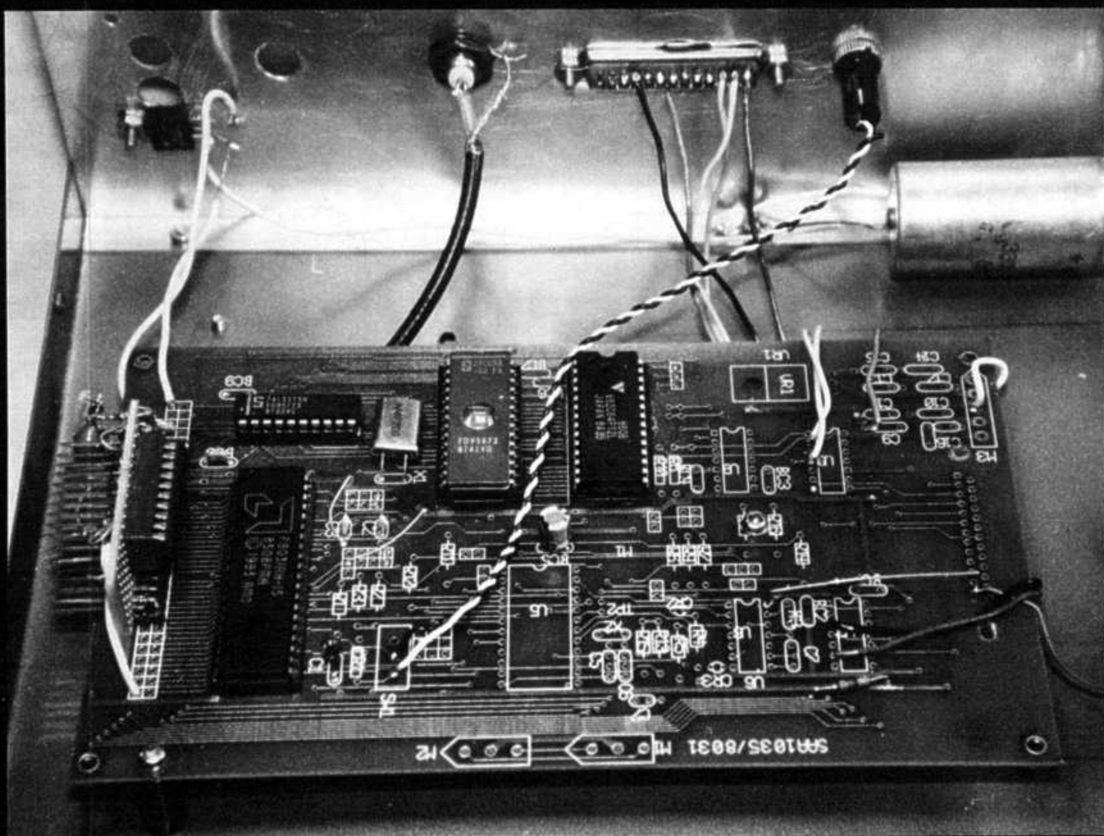
July 1993



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About the Cover:

AA6FJ and NS6Z used this surplus microcontroller card, but you can easily build their PC add-on oscilloscope from scratch.

137

Features

Columns

July 1993 QEX Advertising Index

Purpose of *QEX*:

1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio field
3) support efforts to advance the state of the Amateur Radio art

All correspondence concerning *QEX* should be addressed to the American Radio Relay League, 225 Main Street, Newington, CT 06111 USA. Envelopes containing manuscripts and correspondence for publication in *QEX* should be marked: Editor, *QEX*.

Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and doubled spaced. Please use the standard ARRL abbreviations found in recent editions of *The ARRL Handbook*. Photos should be glossy, black and white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

Any opinions expressed in *QEX* are those of the authors, not necessarily those of the editor or the League. While we attempt to ensure that all articles are technically valid, authors are expected to defend their own material. Products mentioned in the text are included for your information; no endorsement is implied. The information is believed to be correct, but readers are cautioned to verify availability of the product before sending money to the vendor.

Empirically Speaking

ALE to the Fore

In this month's issue of *QEX*, you'll find the first of a six-part series on automatic link establishment (ALE) radios. ALE is perhaps the most significant new technology in years for HF radio communications—at least, the HF communications of the federal government. Its development, which is outlined in this initial article, was done for the government, but it should be of interest to amateurs as well.

For *QEX* readers, of course, the technology itself is of interest, as our readers are interested in a wide range of radio technologies. But there is a more substantial reason why we decided to bring this series of articles to you in *QEX*. That reason is the increasing need for close cooperation between US amateurs and the disaster-relief agencies of government at all levels. One possible form of that close cooperation is the production and use of interoperable radio systems.

Why should amateurs *want* interoperability with government (and commercial) systems? Simply because the communications needs in an emergency situation require the maximum possible use of every available communications medium, amateur and other, and interoperating systems maximize the utility of communications.

Of course, the primary drive to introduce technology into Amateur Radio will always be amateurs' day-to-day communications needs, and ALE promises much for those purposes. Today we have rudimentary digital communications systems that link up automatically (or partly so, in some cases), but we really don't have automated linking systems that automatically adapt to changing HF propagation well. ALE promises just that, and adopting it will let amateurs concentrate on developing better ways of communicating at HF.

While the first article of the series discusses the background against which ALE is developing, the upcoming articles will look into some of the details of ALE protocols and implementations. As you read them, consider how ALE can bring new possibilities to your HF communications.

This Month in *QEX*

Robert Adair, KAØCKS, David Peach, and ARRL TA Dennis Bodson, W4PWF, present the first of a six-part series: "The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)."

Dave Lichtenstein, AA6FJ, and John Nemec, NS6Z, present a simple board that connects to your IBM PC printer port and acts as a digital oscilloscope for audio in, "Turn Your PC into an Oscilloscope."

In an article reprinted from the DARC (German) journal, *cq-dl*, Hartmut Päsler, DL1YDD, describes "DTMF Deluxe," a full-featured DTMF signalling and messaging system.

Finally, Zack Lau, KH6CP/1, provides in his "RF" column complete details of his latest design: a no-tune 220-MHz transverter.—*KE3Z, email: jbloom@arrl.org (Internet)*

The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)

Part I: The National Communications System, The Federal Standards Development Process, and the Basic Definition of Federal Standards 1045 through 1054

Significant interest and activity are rapidly developing in the HF ALE radio arena. Equipment and knowledge of the technology are becoming available which allows experimentation and use of this new mode.[1] Stand-alone ALE controllers (modems) are now available to amateurs interested in ALE. The use of ALE is an exciting new technique for passing digital traffic in parts of the spectrum which are typically unusable for voice traffic. Operating "down-in-the-mud" can be fun!

Robert T. Adair, KAØCKS, David F. Peach, PE and Dennis Bodson, W4PWF

Introduction

The development and implementation of Federal Standard 1045 (FS-1045), "HF Radio Automatic Link Establishment" has revolutionized HF radio communications by utilizing automated, digital signal transmission techniques.[2] This standard provides the foundation for an entire family of HF radio standards which functionally, specifies the automation of these radios. The features included in this family of standards make these radios automatically adaptive to the ever-changing HF propagation conditions—thus the radios are termed adaptive HF radios. The HF Radio Automatic Link Establishment (ALE) functions are standardized in FS-1045. FS-1045 provides the standardized functions for a linking process, including the emission of a call, a response, and an acknowledgement signal. The emission waveform contains address information that will selectively alert a station and will trigger a response from that station if the station is operational (either scanning or monitoring a specified frequency). The "functional standard" specifies the required protocols, timing, and technical definitions, but leaves implementation to the innovation of the equipment manufacturer. The technical details of this standard are described in the May 1992 issue of *QST*.[3]

A significant national effort is focused on developing and testing a family of functional standards for automated HF radio systems. When fully developed and implemented, these standards will substantially improve radio communications efficiency and interoperability within and among civilian Federal agencies, emergency preparedness organizations, Amateur Radio operations, and the US military departments. These standards will also enhance competition and promote new product development in the US telecommunications industry, which should advance the vendors' positions in the world trade market. This will also lower the cost of radios and will make them more affordable by amateurs.

A series of articles has been written for publication in *QEX* by various individuals involved in the development, writing, and testing of the Federal Standards for adaptive HF radios. The titles and basic contents of this series are detailed in Table I.

Basic ALE Radio Functions

By now you may be wondering, what can ALE radios do and how do they work? Fig 1 illustrates the similarities

[1]Notes appear on page 8.

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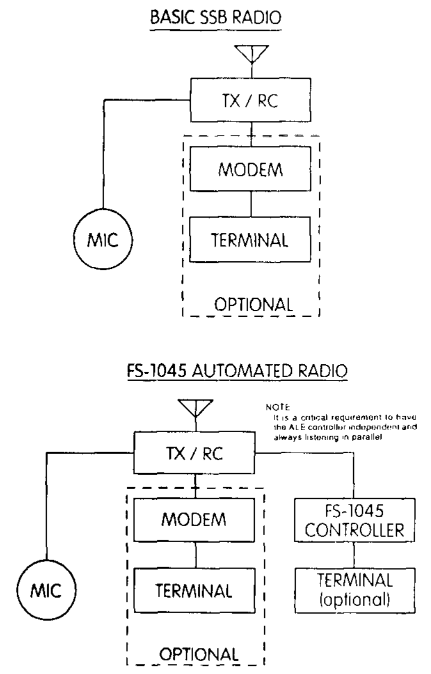

Fig 1—Basic SSB radio with optional terminal compared to an FS-1045 automated radio with optional terminal.

and differences associated with a typical single sideband (SSB) HF radio and a Federal Standard 1045 capable radio. The FS-1045 controller is basically a robust modem which controls the HF SSB radio to which it is attached.

The basic ALE unique functions are summarized in Table II. Automatic Link Establishment is accomplished by passing 8-ary FSK (8 audio-frequency tones) through the audio passband of a programmable SSB radio. ALE radios can be programmed to scan up to 100 frequencies, but typically 10 frequencies are more than adequate to cover the HF band. The calling radio stays on each frequency for only 200 milliseconds which means that all ten frequencies can be scanned and a successful link made with a scanning receiving station in much less than a minute. This will greatly reduce the HF spectrum "pollution" of calling CQ, CQ, CQ... and then trying it over again manually on various other frequencies until a suitable link is made.

The remaining functions are being developed and will be implemented in future standards within the HF radio family of proposed Federal Standards (pFS) as shown in Table III. Further information on these standards will appear in later articles in this series.

ALE Operating Rules

ALE radios must obey strict operating rules in order to function properly. The following specific ALE operational rules are listed in order of precedence. These rules must be strictly adhered to for the ALE radios to successfully interoperate.

1. Independent ALE receive capability (in parallel with any others) (critical)
2. Always listens (for ALE signals) (critical)
3. Always responds (unless deliberately inhibited)
4. Always scans (if not otherwise in use)
5. Never interferes with active ALE channels (unless priority or forced)
6. Always exchanges Link Quality Analysis (LQA) with other stations when requested (unless inhibited), and always measures the signal quality of others
7. System responds in preset/derived/directed time slot (net/group/special calls)
8. Always seeks (unless inhibited) and maintains track of connectivity with others
9. Linking ALE stations employ highest mutual level of capability
10. Minimizes time on channel
11. Minimizes power used (as capable)

The Standardized Levels of HF Radio Interoperability

Fig 2 illustrates the standardized levels of HF radio interoperability and the Federal Standards with which they are associated. The higher the standardized level number (on the diagram) the more advanced and difficult the level of automation which is required to achieve that particular function. The diagram also contains a representation of the families of Federal Standards which encompass these functional standardized levels. It is difficult to divide these functional levels into distinct, separate numbered standards. The listed functional levels interact in several instances and cannot be clearly delineated in software and hardware during implementation. The MITRE Corporation in Washington, DC, performed considerable research and development on this subject over the period of several years.[4,5,6] This has formed a strong foundation for the development and standardization of advanced technology adaptive HF radios. HF radios which embody the Federal Standard 1045 functions are capable of performing the standardized levels 1 through 4 and a portion of level 7.

Improved Operating Efficiency

ALE HF Radios which embody Federal Standard 1045 do not require well-trained, experienced operators to allow rapid, high-quality communications. These radios are capable of scanning up to one hundred preprogrammed frequencies, analyzing the quality of the propagation path over each to the desired station or stations and automatically linking in a matter of seconds or minutes. These radios have been shown to link successfully and pass data over channels with S/N levels 10 dB below detectable voice levels.[7] These capabilities provide for a much more efficient use of the crowded frequency spectrum. Further details of the ALE waveform and the linking process appeared in May 1992 *QST*. The standardized radio functions also result in equipment cost reductions, and predictable interoperability among different brands of equipment, which can save an estimated 25% procurement cost per radio. The technological and economic impact assessment of this standard was performed by NTIA/ITS.[8] This document illuminates

Table I

The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)

Part I:	The National Communications System, the Federal Standards Development Process, and the Basic Definition of Federal Standards 1045 through 1054.
Part II:	A Compact Disc for Testing HF ALE Radios.
Part III:	Where are the Federal Standards for HF ALE Radio Networking Going?
Part IV:	Network Simulation for the Radio Amateur.
Part V:	An Amateur's Practical Approach to HF ALE Systems.
Part VI:	Federal Standard 1049: The Future of HF ALE Operation in Stressed Environments.

the response from government and industry and summarizes the pertinent facts. The common use of radio systems utilizing the FS-1045 family of Standards will greatly enhance the nation's telecommunications infrastructure for both routine and emergency traffic, and will eventually enhance amateur communications.

Current Activities

Three proposed Federal Standards are currently in the process of final approval and publication: 1) FS-1045A, 2) FS-1046/1, and 3) FS-1049/1. FS-1045A is a revision of FS-1045, which provides updating and enhancement to the original standard. FS-1046/1 is the basic automatic networking "building block" of the family, and FS-1049/1 provides the protection function for ALE radios during the linking process. A technological and economic impact assessment of these three proposed standards was performed by NTIA.[9]

Background Information

The National Communications System was established on August 21, 1963, by a Presidential Memorandum entitled "Establishment of the National Communications System."[10] On April 3, 1984, President Reagan signed Executive Order (E.O.) 12472 "to provide for the consolidation of assignment and responsibility for improved execution of national security and emergency preparedness telecommunications functions."[11] This Executive Order supersedes the August 21, 1963, Presidential Memorandum. It was again updated by the President as E.O. 12656 on November 23, 1988.[12]

The NCS is a confederation in which Federal departments and agencies participate with their telecommunications assets to assist the President, the National Security Council and the Director of the Office of Science and Technology in meeting their need for National Security and Emergency Preparedness communications for the Federal Government under all circumstances, including crisis or emergency.

The principal assets of the NCS include telecommunications networks of the following Departments and Agencies: Departments of State, Defense, Health and Human Services, Justice, Treasury, Agriculture, Interior, Commerce, Energy, and Transportation (which includes networks of the Federal Aviation Administration and the United States Coast Guard) Veterans Affairs, the Federal Emergency Management Agency, the US Information Agency, the National Aeronautics and Space Administration, the General Services Administration, the Central Intelligence Agency, National Security Agency, and the National Telecommunications and Information Administration. There are also four participating Agencies: the Nuclear Regulatory Commission, United States Postal Service, Federal Communications Commission, and the Federal Reserve System. Fig 3 illustrates these relationships.

The Concept: A Coherent National Telecommunications System

These assets comprise the bulk of the long-distance telecommunications resources of the Federal Government. Telecommunications facilities are planned, funded, and operated by the parent agencies to satisfy their respective mission requirements; however, through joint planning, standardization, and other coordinated management activities of the NCS, they are available to satisfy national requirements transcending those of the individual operating agencies. The objective is to ensure that essential federal telecommunications resources are improved progressively, and can be inter-operated so that the aggregate functions as a coherent system under all conditions, particularly those of crisis or emergency.

Policy and Management Functions

Policy direction for the development of the NCS stems directly from the National Security Council, as set forth in Executive Order 12472, and National Security Decision Directive 97 (NSDD-97), "National Security Telecommunications Policy."[13] The Director of the

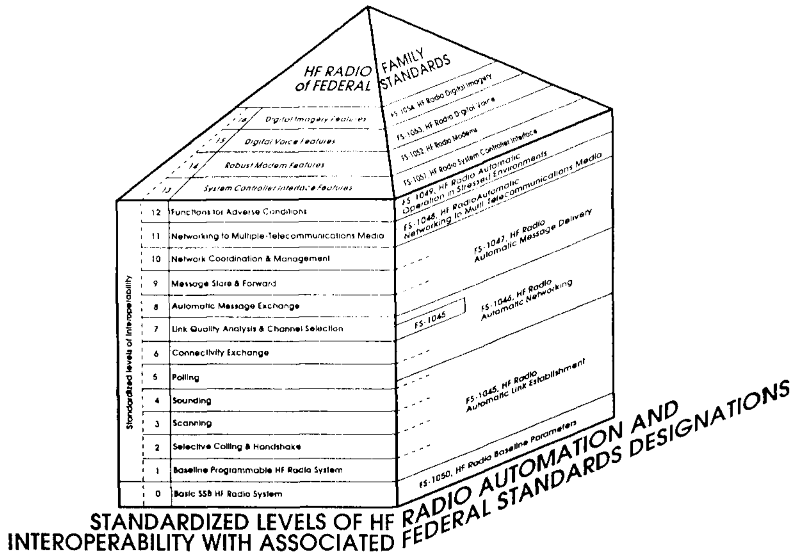

Fig 2—Pictorial diagram illustrating the standardized levels of HF radio interoperability and the federal standards with which they are associated.

Table II

Summary of HF Radio ALE Functions

1. ALE Protocol Tones Pass Through SSB Radio Audio Pass Band
2. ALE Digital Modem Provides a Low Speed, Robust Device For Selective Calling and Data Transmission
3. ALE Modem Automatically Selects "Best Available" Channel Based on Link Quality Data Stored in ALE Memory
4. ALE Radio Automatically Establishes and Confirms Links Upon Operator Command
5. ALE Radios Can: Transfer Data, Do Error Checking, Do Networking, Relay Messages, and Other Special Functions

Office of Science and Technology Policy (OSTP), Executive Office of the President, is responsible for directing the exercise of the war power functions of the President under Section 606 of the Communications Act of 1934, as amended. E.O. 12472 designates the Secretary of Defense to serve as the Executive Agent for the National Communications System. NCS is responsible for ensuring that unified operations and technical planning are conducted to afford a highly effective and responsive system to meet the needs of the Federal Government. The major functions delegated to the Manager-NCS by the Executive Order include those pertaining to coordination, planning, standards, test, and evaluation.

The Secretary of Defense has designated the Director of the Defense Information Systems Agency (DISA) to serve as the Manager of the NCS. In order to carry out the NCS management responsibilities, an Office of the Manager-NCS, was established. This office is separate and unique because its authorities emanate directly from the Executive Office of the President to the Executive Agency, NCS. NCS is also unique within the Federal Government because considerable personnel support for the office is provided by the member organizations of the confederation (see Fig 3). The member organizations select members of their staff to work full time for the Office of the Manager, NCS, and detail them for a minimum of two years.

Table III

The HF Radio Family of Federal Standards

Standard Number	*Title*
FS-1045	Telecommunications: High Frequency Radio Automatic Link Establishment.
pFS-1045A	Telecommunications: High Frequency Radio Automatic Link Establishment (revision of FS-1045).
pFS-1046/1	Telecommunications: High Frequency Radio Automatic Networking, Section 1: Basic Networking - ALE Controller
pFs-1046/2	Telecommunications: High Frequency Radio Automatic Networking, Section 2: Advanced Networking - ALE Controller.
pFS-1046/3	Telecommunications: High Frequency Radio Automatic Networking. Section 3: Advanced Networking - Network-Layer Controller.
pFS-1046/4	Telecommunications: High Frequency Radio Automatic Networking, Section 4: Optional Advanced Networking Features.
pFS-1047/1	Telecommunications: High Frequency Radio Automatic Message Delivery, Section 1: Automatic Message Exchange.
pFS-1047/2	Telecommunications: High Frequency Radio Automatic Message Delivery, Section 2: Automatic Message Exchange with Store & Forward.
pFS-1047/3	Telecommunications: High Frequency Radio Automatic Message Delivery, Section 3: Network Coordination and Management.
pFS-1048	Telecommunications: High Frequency Radio Automatic Networking to Multiple-media.
pFS-1049/1	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 1: Linking Protection.
pFs-1049/2	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 2: Anti-interference.
pFS-1049/3	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 3: Encryption.
pFS-1049/4	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 4: Adaptive Operation.
pFS-1050	Telecommunications: High Frequency Radio Baseline Parameters.
pFS-1051	Telecommunications: High Frequency Radio System Controller Interface.
pFS-1052	Telecommunications: High Frequency Radio Modems.
pFS-1053	Telecommunications: High Frequency Radio, Digital Voice.
pFS-1054	Telecommunications: High Frequency Radio, Digital Imagery.

Working Relationships: Operating Organizations' Roles

The Operating organizations of the NCS play a central role in the formulation of telecommunications policy and the solution of mutual problems by means of representation in NCS study groups, ad hoc committees, and permanent committees formed by the Manager, NCS. Depending on the nature of the task, the Operating Agencies provide personnel with the needed skills to serve on the working groups and committees along with members of the Manager's permanent staff. The Federal Telecommunication Standards Program (FTSP) is among functions assigned by E.O. 12472 in support of the mission of the NCS. The FTSP is clearly vital to the successful accomplishment of this particular aspect of the NCS mission by its emphasis on the development of standards to facilitate interoperability of the NCS component networks.

The Federal Telecommunication Standards Program

The Federal Telecommunications Standards Program (FTSP) was initi-

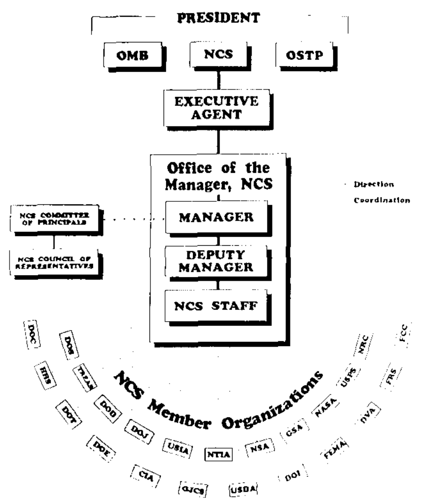

Fig 3—Organizational chart of the National Communications System showing the direct authority from the Executive Branch of the government.

ated in 1972.[14] The scope of the NCS's assignment under the Federal Standardization Program is to develop Federal standards which either contribute to the interoperability of functionally similar Federal telecommunications networks or to achieve a compatible, efficient, and economical interface between such networks and appended computer terminals. The emphasis of the FTSP is on the development of standards to facilitate interoperability of the NCS member networks. All standards resulting from the FTSP are coordinated, approved, and published in accordance with the GSA-managed Federal Standardization Program, or the National Institute of Standards and Technology (NIST) Federal Information Processing System (FIPS) publications program, whichever is appropriate to the particular standard in question. The Manager of the NCS has the overall responsibility of the FTSP, however the Assistant Manager for NCS Technology and Standards is assigned the daily management of the FTSP.

The Federal Telecommunications Standards Committee

The Assistant Manager for NCS Technology and Standards also Chairs the Federal Telecommunications Standards Committee (FTSC) (see Note 14). The FTSC consists of senior telecommunications staff members from participating Federal Agencies. This committee, which meets monthly, determines the relevance and priority of standardization proposals, recommends positions which should be supported by Federal Government members of national and international standardization committees, and rules on the technical adequacy of draft Federal Telecommunications Standards for formal coordination with Government Agencies and industry. The NCS Office of Technology and Standards also provides leadership and members for a number of interagency, industry, national, and international standards committees. These committee members (and officers) consist of NCS staff members and program support staff from other government agencies such as the NTIA/ITS. The committees are actively engaged in the identification and development of concepts and ideas which may be accepted in whole or in part as Federal Standards.

The HF Radio Subcommittee & Its Working Groups

The FTSC has generated several Subcommittees which develop Federal Standards to fulfill specific areas of need. Fig 4 illustrates the method by which the HF Radio Subcommittee functions. Working members were solicited from the 23 Federal Agencies. The subcommittee developed the infrastructure which consists of three Working Groups (WGs): 1) the Statement of Requirements WG (SORWG); 2) the Test and Evaluation WG (TEWG); and 3) the Standards Development WG (SDWG).

Federal Standards Development, Coordination, & Approval Process

The NTIA/ITS staff has conceived a rather detailed Federal Standards Development Procedure which works very well in the development of "Advanced Technology Standards." Fig 4 depicts the functions and relationships of the HF Radio Subcommittee and its three working groups. The Statement of Requirements Working Group (SORWG) functions first in this process, to determine the requirements which must be met in the finished standard. These requirements are gathered from the government departments and agencies which will be the users of the equipment that is built to conform to the standards being developed. Significant attempts are made to determine the real programmatic requirements from the organizations which will be the users of the equipment for the next decade. These requirements are then transformed into technical definitions from which prototype hardware can be built. The Test and Evaluation Working Group (TEWG) functions to develop procedures for a set of minimum-but-adequate tests. These tests are de-

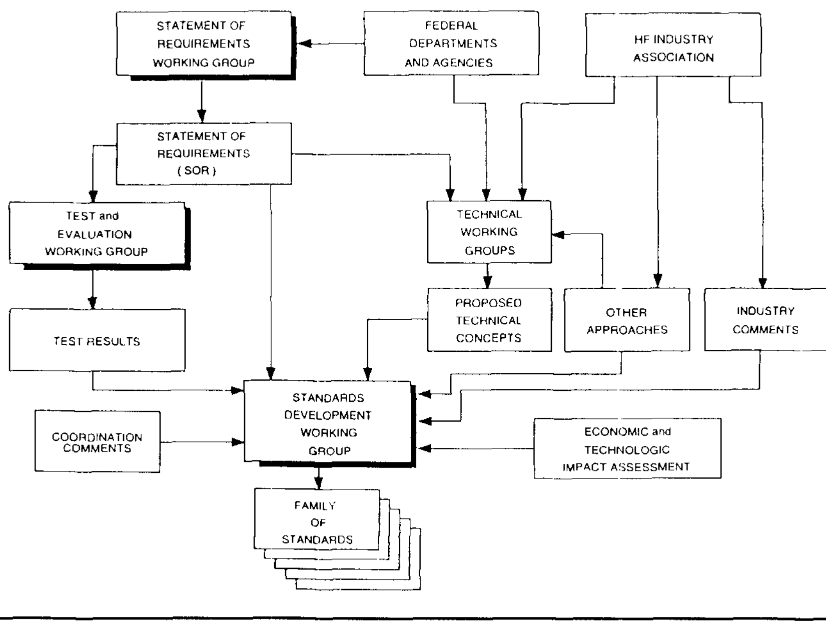

Fig 4—Diagram of the HF Radio Subcommittee Process illustrating the functions of the Working Group.

signed to determine the feasibility of implementing the standard and to prove the concept of the written standard. The test program is intended to uncover any problems within the standard and the process of embedding it into practical, interoperable hardware. The results of the testing program are studied and summarized in the form of a report which is then utilized by the Standards Development Working Group (SDWG). The SDWG then develops a "functional" standard which can be used by industry to build hardware that conforms to the standard and is therefore inter-operable with equipment constructed by other manufacturers. A functional standard specifies key features, but allows room for the vendors to develop and install their own innovative features in addition to those specified. This tends to stimulate competition and enhance the product lines into user friendly highly capable hardware. The SDWG develops a draft standard based on the requirements, the test results, and a technologic and economic impact assessment. This draft standard is then announced (after approval by the FTSC) via the Federal Register to obtain comments from public, industry and Government representatives over a 90-day comment period. Comments of substance are resolved and incorporated into the final draft standard which is then submitted to the FTSC for approval and final submission to GSA or NIST (as appropriate) for final approval and publication.

Summary

A national need was identified for the continuous and interoperable communications for the Federal Government under all conditions. The National Communications System was formed to provide and coordinate that capability. The development[15], testing (see Note 7), and publication (see Note 2) of Federal Standards providing interoperability has been one of the primary means of achieving this mission.

The forthcoming parts of this series of articles will continue to present information on other aspects of the family of Federal Standards for automated HF radios. Further details on the availability and application of ALE in the amateur radio service will be presented.

Acknowledgements

This work was supported by the National Communications System, and the National Telecommunications and Information Administration, Institute for Telecommunication Sciences (NTIA/ITS). The authors would like to express their sincere appreciation to all those who had a hand in conceiving, developing, testing, and improving the nation's telecommunications infrastructure through the development, implementation, and use of the Automated HF Radio Standards and equipment described in this series of articles. This work of many engineers, technicians, and operators has revolutionized the field of HF Radio Communications. The authors would also like to thank John Harman and Bill Ingram for the graphics which appear in these articles.

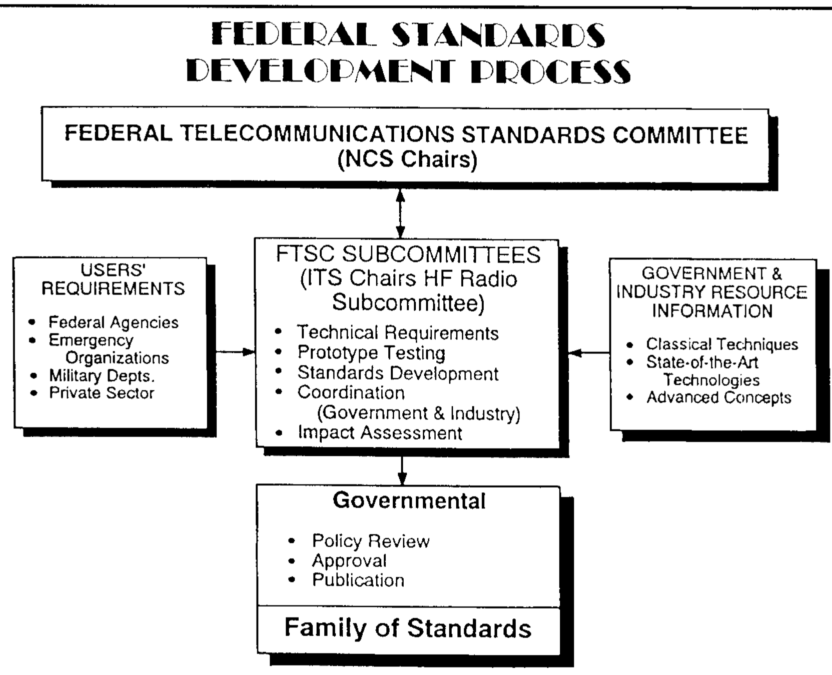

Fig 5—Diagram illustrating the methodology by which the HF Radio Subcommittee functions.

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Turn Your PC into an Oscilloscope

Display audio waveforms on your PC screen, or modify for higher frequency, higher resolution use.

Dave Lichtenstein, AA6FJ and John Nemec, NS6Z

Introduction

As most experimenters know, an oscilloscope is a very convenient tool for viewing signals and making measurements. However, a reasonably good oscilloscope costs about $500, and if you only use it a few times a year the investment may not be worth it. With a microcontroller and a few logic components, a personal computer (PC) can be turned into an effective tool at very moderate cost. In fact, the PC's power to manipulate and display data can sometimes prove to be a better analysis tool than an oscilloscope.

An oscilloscope can be used to analyze various signal types. Extremely fast rise time digital signals or transmitter RF signals may require sophisticated instruments having bandwidths up to 1 GHz. For this low-cost project, we decided to stay with something simple that would provide a good tool for audio work. The design goals were to make a PC interface that would provide an oscilloscope function with a bandwidth up to a few hundred kilohertz using low-cost components and a minimum of critical construction.

Design Overview

There were several design issues to consider. The most critical item was the selection of the A/D converter. The requirements were a device that was inexpensive, used few external components, and was easy to apply. The best choice was the ADC0820 half-flash A/D converter. The flash method of conversion requires no external sample-and-hold amplifier and the digital interface is very simple. No conversion clock is required and data is assured to be valid after a specified delay. The conversion rate is comparable to the I/O access rate of most microcontrollers and is in the range of our desired performance. The 8-bit resolution yields a dynamic range of 48 dB. The byte-wide conversion results are easily transferred to an 8-bit microcontroller. While the dynamic range is not sufficient for demanding analysis, where 14 bits would be desirable, it is suitable for general-purpose use.

The next consideration was the interface logic for the A/D, memory and PC. Since the design goals for this project were sample rates in the hundred kilohertz range and simplicity, the entire module function was implemented using a microcontroller. With instruction execution times in the order of 1 µs, a simple microcontroller can perform the A/D control, data movement to memory, sampling timing, start and stop control and communication with the PC. The entire circuit requires only five chips: A/D converter, microcontroller, static RAM, latch, and an EPROM.

There are two strategies for controlling the A/D converter. The first is to employ a variable sampling rate that would be user programmable. This is similar to what we are used to doing when adjusting the timebase of an oscilloscope. While this approach allows a longer time history of slow wave forms to be captured for a given amount of memory, there are several disadvantages. First, changes in the sampling rate have to be communicated to the A/D module and a new time history converted and stored in memory. Second, one-time events are lost. Finally, analysis time is spent waiting for the collection of new data for a better view or for moving to a new trigger point. Since static memories for these speeds are inexpensive, we decided it made more sense to have a large amount of memory for storing a long-time history and then use the data manipulation power of the PC to exam-

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ine the data and display it as desired.

Given this approach, the circuit was designed to run the A/D converter as fast as possible. Data is converted and stored into RAM until the RAM is completely filled. The conversion is then stopped and the RAM becomes available to be read. Since the conversion time for the ADC0820 is 2.5 µs maximum, we were able to write microcontroller assembly language code in a tight loop which starts the ADC0820 conversion, reads the data when the conversion is complete, writes the result to RAM, and starts the next conversion. Based on the maximum rate of the A/D converter, the design should approach a sampling rate of 400 kHz. With 8-kbytes of RAM, the time history stored is 20-ms maximum. This is certainly adequate to observe signals down to the 100-Hz range.

Detailed Hardware Design

Since the conversion time of the A/D converter is about the same as a microcontroller instruction cycle, sensing the completion status of the A/D is not necessary. The design samples the conversion result at a fixed time after the start conversion pulse is asserted. This fixed time is determined by the instruction delays and must be larger than the guaranteed conversion time of the A/D. The ADC0820 is operated in the stand-alone mode. (Refer to the data sheet on this device for the various operating modes.)

The software loop for starting the conversion, reading the data, and moving the data to the external RAM is listed below, with the entire microcontroller program shown in Fig 4. This code is for an 80C51 microcontroller. Each instruction executes in one machine cycle except for MOVX, INC DPTR and JZ which each execute in two machine cycles. The whole loop therefore takes thirteen machine cycles.

```
STRT: CLR   adwr             A/D conversion
                             start signal low
      SETB  adwr             A/D conversion
                             start signal high
      NOP
      NOP                    wait until conver-
                             sion is complete
      MOV   A,adresult       conversion result
                             to accumulator
      MOVX  @DPTR,A          put result into ex-
                             ternal RAM
      INC   DPTR             increment the
                             RAM address
      MOV   A,DPH            put RAM pointer
                             into accumulator
      ANL   A,#maxaddress    check if RAM is full
      JZ    STRT             if not full, do an
                             other conversion
```

The microcontroller uses a 20-MHz crystal which means that a machine cycle is 600 ns. (A higher frequency can be used, but a high-performance version of the microcontroller would be required. This is an option for the builder.) Given this, the CLR, SETB,

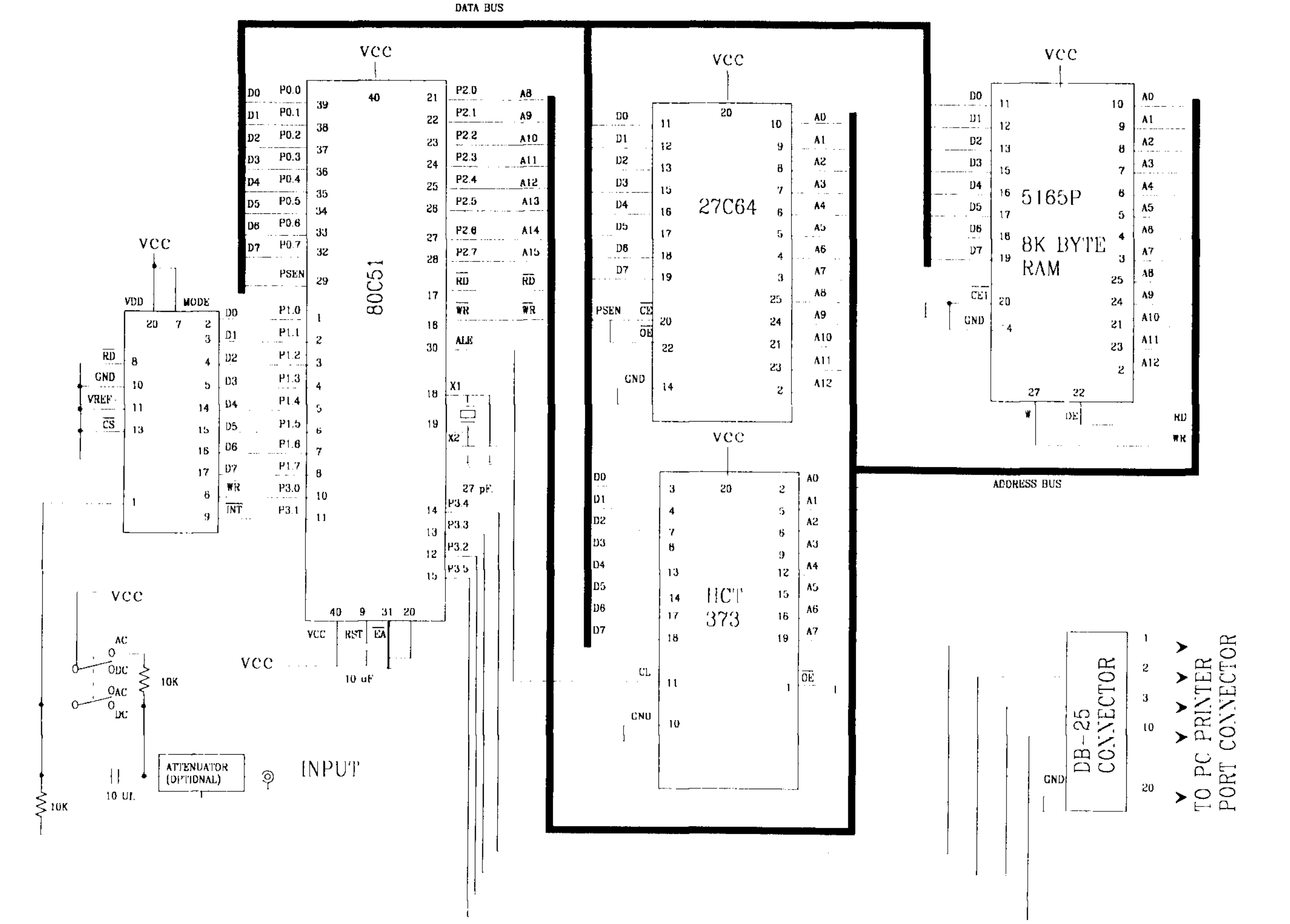


Fig 1—Schematic diagram of the PC oscillosope A/D module.

NOP, NOP sequence is 2.4 μs which is about equal to the A/D conversion time. NOPs must be added or deleted depending upon the actual microcontroller instruction speed. With these parameters the loop takes 7.8 μs and the sampling rate is about 130 kHz. This is short of the 400-kHz maximum achievable but perfectly suitable for the design target of the project. Increasing the microcontroller speed can help, and playing some tricks with the code could help also. (Instead of a NOP, perform some task like INC DPTR, but be careful about the order of the operations. Certain other adjustments will be required.) With the 130-kHz sampling rate and an 8-kbyte memory, signals up to about 50-kHz range can be observed and a 60-ms time history can be stored. Adding RAM to the system can increase this number.

If the intended use is only for audio, the sampling rate can be lowered to any desired value. This is accomplished by adding a time delay in the sampling loop. For example, the code below replaces JZ STRT.

```
      JNZ  DONE         jump out if
                        memory full
WAIT: JNB  TF0,WAIT     loop here until
                        the timer flag
                        is set
      CLR  TF0          clear the timer
                        flag
      JMP  STRT         not full, do
                        another
                        conversion
```

Timer 0 of the microcontroller must be enabled prior to entering the sampling loop and the timer overflow rate is adjusted according to the desired sample rate.

A schematic of the A/D converter system is shown in Fig 1. There is nothing critical about the construction other than using good digital design practice and following the grounding and decoupling recommendations given in the ADC0820 data sheet. The design was actually constructed using an 80C51 system board obtained on the surplus market. The board already contained the microcontroller, crystal, EPROM socket, address latch, and RAM connected in the standard 80C51 configuration as given in the 80C51 manufacturers data sheet. All other unnecessary components were removed and the ADC0820 was connected to unused I/O ports of the microcontroller. A small daughter board was used to mount the A/D converter. This construction approach saved considerable time since all of the standard configuration wiring was already present and less than twenty connections were required for the ADC0820, the PC interface and the power supply.

The final part of the design is the PC interface. This can be done in several ways: RS232 serial, printer port serial and printer port parallel. The RS232 serial method is a good choice but it does require two RS232 interface drivers and additional plus and minus 12-volt supplies. The parallel printer port speeds the upload of data and is easiest from a software view, but modification of the standard PC printer port is required to make the byte-wide data path output drivers tri-state. For this project the serial printer port method was chosen. It uses the printer port as is and employs the printer port status lines to send serial data from the A/D converter system to the PC since these lines are bidirectional. Other lines are used for the serial communication handshake. Details are described below in the software section.

Software: A/D Converter Module Firmware

The A/D converter module firmware consists of three simple parts: triggering, data collection, and data transfer to the host PC. The A/D converter module remains idle until triggered. Once triggered, it performs the data sampling and then the transfer of the data to the host PC. After this, the module remains idle until triggered again. Triggering is accomplished by setting port bit P3.2 of the microcontroller to a logic 0. This may be done under control of the PC or it may be connected to the circuitry which is the source of the signal to be examined. In this design, the trigger is PC controlled—a reasonable choice unless one-time events are to be captured.

Once the system is triggered, the tight sampling loop is entered. The microcontroller starts the A/D process by asserting the WR (write) input of the ADC0820. After the appropriate delay, the conversion result is read into the microcontroller and transferred to the external static RAM. The loop continues until the RAM is full. Once the sampling cycle is completed, the routine to transfer the data to the PC is entered. The communication to the PC is done serially through the printer port. Serial data is placed on the microcontroller port P3.5. The communication handshake is accomplished by two signals: ACK and RDY. ACK is a one-way signal from the PC to the A/D module (microcontroller) that indicates that the PC has accepted the data. ACK is sensed on the microcontroller port P3.3. RDY is a bidirectional signal communicated through microcontroller port P3.4.

The microcontroller also uses ACK and RDY as a reset input. Should the communication sequence between the microcontroller and the PC get out of synchronization, the PC can assert ACK and RDY simultaneously. When this is recognized by the microcontroller, the communication loop in the A/D module is reset.

PC Interface: A/D Converter Module Interface

A double handshake is necessary to align the actions of two systems (host PC and A/D module) running at very different rates. This is effected by the RDY and ACK signals. RDY is communicated via the printer port STROBE signal (bit 0, address 2FAH for printer port 2) and ACK is communicated via the printer port DØ signal (bit 0, address 2F8H for printer port 2). The serial data is communicated using the printer port ACK signal (bit 6, address 2F9H for printer port 2). Note that the RDY signal undergoes a net logic inversion from the A/D module and the port as read inside the PC host. In the PC host software, another inversion is added by the use of the NOT operator. In the discussion below reference will be made to the RDY signal as it is in the A/D module.

After power up reset, the A/D module clears the RDY bit (RDY = 0). The PC host software examines this bit and if the bit is not 0 assumes the A/D module has inadvertently advanced in the program. The PC host software then invokes the clear procedure which forces ACK and RDY to 0 simultaneously. Recognizing this state, the A/D module returns to the start of the communication loop.

Under normal conditions clearing is not required. Upon power-on reset, the A/D module stops awaiting a trigger input to start the conversion process. Once the trigger is detected, the conversion loop is entered and an entire set of data is collected. The communication loop is then entered. Simultaneously after the trigger, the host PC enters the communication loop which calls the procedure GETBYTE. From power-on reset through the data collection, the RDY signal has been held at 0 by the A/D module. When the first bit of data is ready to be communicated to the PC host, the A/D module places this data bit on the printer port input line. Then the RDY signal is set to 1. This indicates to the host PC that valid data is present. The host PC reads the data and asserts ACK (ACK = 0) indicating to the A/D module that the data has been received. Recognizing ACK = 0, the A/D module clears RDY (RDY = 0) and waits for ACK to return to 1. Recognizing RDY = 0, the PC host deasserts ACK (ACK = 1) thereby completing the handshake cycle. The A/D module recognizes ACK = 1 and obtains the second bit of data to be communicated. This cycle is repeated until all of the data is sent.

Display

The PC display software is simplified by using Borland's *Graphics Toolbox for Turbo Pascal*. This is an older software package which may still be available through some sources. The acquired data is left unscaled as an integer value from 0 to 255 and stored in an array called ADRESULT. The abscissa is a true time value calculated from the known conversion rate of the A/D module. The time between sample points is a constant for the A/D module and is denoted by TIME in the program. When the display portion of the program is entered, inputs are requested for the desired start and end time of the display. The defaults are 0 and the end time of the available data points . A check is made to determine if the values entered are legitimate and if they are not, the program branches back to the point where the requests are made (DSPLY). With these values, World(1) is defined which has an ordinate range of 0 to 255 and an abscissa range of T_s (the starting time) and T_e (the ending time). The graphics are initiated and the appropriate axis is drawn using World(1) and Window(1). (Refer to Borland's *Graphics Toolbox for Turbo Pascal* for details.) Window(2) is then selected to force the plotting of the data points to be within the drawn axes. A "for" loop and the DrawLine function plot the data as directed. The display remains until KeyPressed becomes true, at which time the graphics routine is exited and the program returns to normal mode. The last part of the program examines the character returned when KeyPressed became true. If an R was pressed, the program branches to DSPLY, where the user can enter new time values for the limits of the display. This permits the user to zoom in or out on any portion of the entire time history of collected data. If a T was pressed, the program branches to SCAN, where the A/D module is retriggered to start a collection of new data.

Using the System

With the host PC and the A/D module powered up, connect the two units with a DB-25 male/female extension

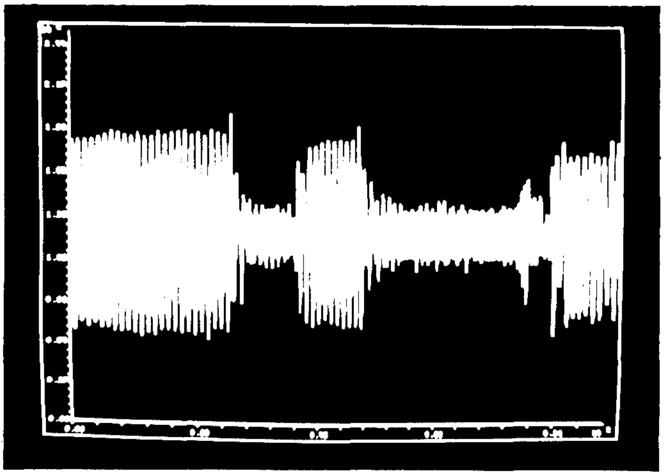


Fig 2—Example "trace" displayed on the PC screen.

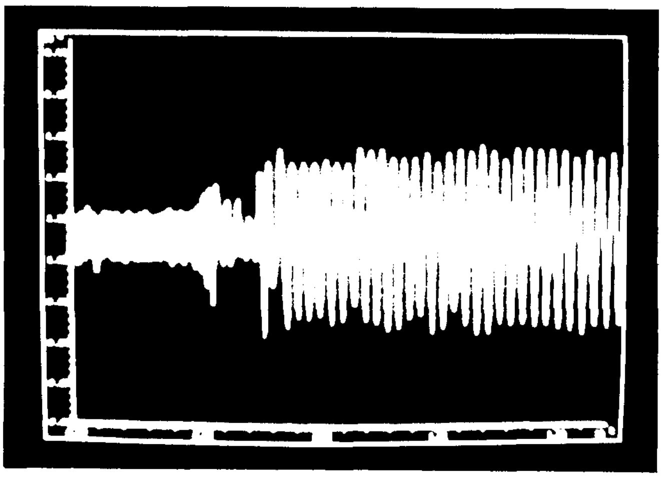


Fig 3—A zoomed-in section of the trace of Fig 2.

```
;
;
;  Primary controls
$MOD51
$TITLE(A to D)
$DATE(DEC-10-88)
$PAGEWIDTH(80)
;
;  Constant declarations
;
maxaddress        DATA     0E0H;    8k of data
;
;
;  Variable declarations
;
; A to D INTERFACE
adwr     BIT      P3.0
adint    BIT      P3.1
trig     BIT      P3.2
adresult          DATA     P1
;
;   COMMUNICATION PORTS
ack      BIT      P3.3;               DB-25 pin 2
rdy      BIT      P3.4;               DB-25 pin 1
sdata    BIT      P3.5;    DB-25 pin 10
;
;
;
;
         ORG      0H
         CLR      rdy
TLOK:    JB       trig,TLOK
         MOV      DPTR,#0
STRT:    CLR      adwr
         SETB     adwr
         NOP
         NOP
         MOV      A,adresult
         MOVX     @DPTR,A
         INC      DPTR
         MOV      A,DPH
         ANL      A,#maxaddress
         JZ       STRT
;
DONE:    CLR      rdy
HCND:    JNB      ack,HCND
         MOV      DPTR,#0
COM:     MOVX     A,@DPTR
         MOV      R0,#8
SEND:    RLC      A
         MOV      sdata,C
         SETB     rdy
REL:     JNB      rdy,REL;  wait if held by external hdwr
HAND:    JB       ack,HAND
         JNB      rdy,DONE;                 restart communication
         CLR      rdy
HBND:    JNB      ack,HBND
         DJNZ     R0,SEND
         INC      DPTR
         MOV      A,DPH
         ANL      A,#maxaddress
         JZ       COM
         JMP      TLOK
         END
```

Fig 4—Source code for the A/D module 80C51 program.

cable. Select ac or dc coupled as appropriate and apply the signal to be observed to the input of the A/D module. Without an attenuator, the input must be between 0 and +5 volts, if dc coupled, and no greater than 5 volts peak-to-peak if ac coupled. The input impedance of the A/D module is 5-kΩ to 10-kΩ, therefore a low-impedance signal source should be used. Start the program on the PC by typing "atod" <CR>. The program will prompt for input of the printer port selection (1 or 2) and then for the time between data samples. (Normally these values would be constants in the program. The number of sample points is fixed at 8192, the size of the A/D module RAM.) After the entry of this data, the module will immediately start collecting a time history of data and as soon as this is completed will upload the data to the PC. The PC will then display the prompt: "Enter start point of display, mS." Press <CR> to select the default value of 0. The PC will then display the prompt: "Enter end point of display, mS." Press <CR> to select the default value of the maximum time of the data collected. The data will then be displayed on the screen. A typical example is shown in Fig 2. The left vertical scale is the value of the converted data (0 to 255). The horizontal axis is the time axis in milliseconds. Note that the horizontal axis is labeled using scientific notation (the numbers contain only one digit to the left of the decimal point). At the extreme right of the horizontal axis is a 10 raised to a power. This is to be applied to all numbers on this axis. Take note of some region of interest on the display and note the start and end times of this region. Press R, and the plot will disappear and the prompt: "Enter start point of display, mS" will appear. Enter the number just noted. Respond accordingly to the next prompt for the end time of the display. The program will now zoom in on the specified section of the data with the horizontal time scale expanded to the values just entered. The expanded data is fully displayed for this time interval as shown in Fig 3. R can be pressed again to zoom in or out on various sections of the data. Note that the data is the originally captured data. To trigger the A/D module and capture a new time history of data, press T while the present set of data is displayed on the screen. The program will return to the start.

Initial Circuit Checkout

The easiest way to verify the operation is to connect the A/D module to a PC. Using the source code listings provided, remove the graphics display portion of the code. Write small routines to check out the various portions of the operation. The first thing to look at is the RDY input. Holding the microcontroller in reset will force RDY to be a logic 1. This will be read by the PC as a logic 0 (net inversion, for this signal only). Keeping the trigger input at logic 1 and then releasing the microcon-

```
program atod;
{$I typedef.sys}
{$I graphix.sys}
{$I kernel.sys}
{$I axis.hgh}
type data = array[0..8191] of byte;

const points:integer = 8191;
      pad2:integer = $278;
      pad1:integer = $378;
      tfactor:real = 452.0;

procedure getbyte(var bd:byte;pad:integer);
var xin,xmask,ab: byte;
    i,j: integer;

label retry, relook;

begin
ab := 0;
for i := 0 to 7 do begin
    retry:xmask := 0;
    j := 0;
    while xmask = 0 do begin
          xin := port[pad+2];
          xmask := (NOT xin) AND $01;
          delay(1);
          j := j + 1;
          if (j > 256) then begin
             writeln('No response from A/D module.');
             halt;
             end;
          end;
    xin := port[pad+2];
    xmask := (NOT xin) AND $01;
    if (xmask <> 1) then goto retry;  {debounce}
    xin := port[pad+1];
    ab := (ab shl 1) OR ((xin shr 6) AND $01);
    port[pad] := $FE;
    relook:xin := port[pad+2];
    if ((NOT xin) AND $01 = 1) then goto relook;
    port[pad] := $FF;
    end;
bd := ab;
end;

procedure clear(pad:integer);
begin
port[pad+2]:=$FE;
port[pad]:=$FE;
delay(1);
port[pad+2]:=$FF;
port[pad]:=$FF;
writeln('Cleared.'):
end;

var adresult: data;
    d,ds,sp,pad: integer;
    bd: byte;
    r:char;
    time,ts,te:real;

label scan, dsply;

begin
write('Enter printer port number 1/2: ');
readln(d);
if(d = 1) then pad := pad1 else pad := pad2;
writeln;
time := 0.0078;
write('Enter time between samples, mS: ');
readln(time);
port[pad+2]:=$20;
port[pad]:=$FF;
scan:bd := port[pad+2];
bd := (NOT bd) AND $01;
if (bd=1) then clear(pad);
port[pad]:=$FD;    {apply trigger}
delay(1);
port[pad]:=$FF;
writeln('Triggered.');
d := 0;
repeat begin
       if (d > 1000) then begin
          writeln('A to D Module not ready.');
          halt;
          end;
       bd:=port[pad+2];
       bd:=(NOT bd) AND $01;
       d := d + 1;
       delay(1);
       end;
       until (bd<>0);
writeln('Reading Data.');
for d := 0 to points do begin
    getbyte(bd,pad);
    adresult[d] := bd;
    if((d MOD 200) = 0) then write('*');
    end;
writeln;
ts := points;
ts := 0.0;
dsply:write('Enter start point of display, mS: ');
readln(ts);
write('Enter end point of display, mS: ');
te := time*(points-1.0);
readln(te);
sp := TRUNC(ts/time);
ds := TRUNC(te/time);
if ((ds>=8191) OR (ds<=sp) OR (sp<0)) then goto dsply;


InitGraphic;
DefineWorld(1,ts,255,te,0);
DefineWindow(2,4,0,XMaxGlb,YMaxGlb-5);
SelectWorld(1);
SelectWindow(1);
DrawAxis(5,-5,0,0,0,0,0,-5,false);
SelectWindow(2);
for d:=sp to ds do DrawLine(d*time,adresult[d],(d+1)*time,adresult[d+1]);
repeat until KeyPressed;
LeaveGraphic;

read(KBD,r);
if (r = 't') then goto scan;
if (r = 'r') then goto dsply;
end.
```

Fig 5—Source code for "atod," the PC data acquisition and display program.

troller reset will cause the start of execution of the stored program in the EPROM. RDY will be cleared (logic 0), and since the program will stop at the point waiting for the trigger, RDY will remain at logic 0 (read in the PC as logic 1). Note that the ADC0820 need not be connected for this test to be successful since the ADC0820 is purely passive; it is advisable to set some of the microcontroller Port 1 pins to ground (see schematic) to have some "data" to examine in subsequent debug tests. This test verifies that the RDY signal interface is probably correct and that the microcontroller is executing the first few instructions. If the test is not working, examining RDY with a meter or logic probe from the microcontroller to the PC printer-port connection will aid in isolating the problem. Be aware that the 80C51 microcontroller port outputs do not have a strong pull-up. A low-impedance meter may pull these outputs down.

Once this first check is completed, the next step is to trigger the microcontroller. Add code to the debug software used above to apply the trigger pulse after sensing that the RDY at the microcontroller is at logic 0 (read as logic 1 in the PC). The code should continue to monitor the RDY signal input and display it. You should observe RDY at logic 1 (read as logic 0 in the PC) in much less than one second. This verifies the data collection loop within the A/D module and the entry into the communication loop. Next add the communication loop software to the debug code for the PC. Add "traps" (repeat until KeyPressed) at selected points in the GETBYTE procedure so that the DATA and ACK signal paths can be traced from the PC the A/D module with a logic probe or meter. Observe the RDY and ACK signal exchange and the data transfer as the serial communication advances. If nothing seems to be working in the microcontroller section, it may be advisable to write stand-alone microcontroller checkout code that will verify the basic functionality of the A/D module board before continuing with the PC interface debug. One approach is to make a simple software counter that writes the counter value to an output port. Put this program into an EPROM and verify that it functions in a known good board. Then put this EPROM into the A/D module. Observing the port bits toggling is a clear indication that the microcontroller is working and that the microcontroller to EPROM interface is correct.

Additional Features

Many additional features such as cursors, measurement windows and auto-zoom can readily be incorporated into the PC software. The hardware could also be enhanced by adding more memory to provide a longer measurement period. Another hardware option is to run the processor faster and use a faster A/D converter or even use a 10-14 bit A/D for greater resolution. While this circuit may not have all of the bells and whistles available in a state-of-the-art oscilloscope, it is a practical way to obtain the advantages of a useful measurement tool at minimal cost. □□

DTMF Deluxe

Reprinted from August 1992 cq-dl.

"Deluxe" is hardly sufficient to describe this do-all calling and messaging system!

Hartmut Päsler, DL1YDD

Introduction

In the last few years, a lot of transceivers have been sold with DTMF transmitting and/or receiving capability. This type of transceiver supports only a limited DTMF operation. The selective calling facilities are normally very limited, sometimes showing the code number of the caller on a small display. Transmission of messages was not possible until Kenwood brought out the TH-78. As a side note, the original *cq-dl* article was in production and several prototype models of DTMF Deluxe were undergoing testing when the first announcement for the TH-78 came out in Germany.

Kenwood did not respond to my requests for their DTMF protocol, so DTMF Deluxe had to be developed without a "Kenwood mode"—perhaps DTMF Deluxe is compatible with Kenwood HTs, perhaps not, who knows? I do not have the money to buy a Kenwood HT just to test how their DTMF system works! However, DTMF Deluxe is compatible with the system from Standard, meaning that the paging functions can be used with one another, but DTMF Deluxe has many more features:

- the sender of a message is displayed in plain text (eg, call sign)
- 1000 participants are possible in one network (expandable on demand, but then no longer compatible with the Standard system)
- 100 pre-defined messages are available (expandable on demand)
- alphanumeric display (LCD), either one line of 20 characters or 2 lines of 16 characters, plus several combinations of illumination and display type
- high-precision real-time clock, all messages are time-stamped
- 8 independent switching outputs
- two relays on board for PTT and speaker switching
- built-in keyboard with 16 keys for easy operation in conjunction with the LCD
- simple configuration via an RS232 interface (computer/terminal)
- stand-alone operation, no terminal nor computer needed for normal use
- DTMF transmitter integrated; 20 DTMF memories available;
- built-in DTMF repeater
- message passing system—you can walk around with your standard HT and get all calls which your DTMF Deluxe receives
- designed using CMOS wherever possible for low-power operation
- battery-backed RAM for user-defined data
- easy software updates: just back up your data (provided for by DTMF Deluxe) and change EPROMs

History of DTMF Deluxe

DTMF Deluxe was initially developed to call the attention of local club members to VHF openings without the need to listen on the sometimes very busy club frequency or repeater. Therefore it had to be possible to also transmit short messages. Group calling would have been fine, but some display of the sender of the message was mandatory. DTMF Deluxe was designed with these requirements in mind. Many additional features not previously considered were added as the author's spare time allowed.

Some DTMF Deluxe builders found other uses for it. In Berlin, where traffic jams are common, people use it to signal home from the car (for example: "will arrive 1 hour late, traffic is terrible"). It is also possible to omit some expensive parts like the keyboard, the LCD, the clock and/or the DTMF transmitter. Then the unit is usable as a sophisticated remote switching unit.

Neuwerkstrasse 3
45665 Recklinghausen
Germany
email: DL1YDD@DBØIZ (packet)
CompuServe: 100272,2642

Possible Application

The use of DTMF Deluxe is described here with an example:

Let's suppose that DL1YDD would like to signal to DH1YAG that there are quite good DX conditions on 23 cm. Unfortunately, DH1YAG does not respond to a voice call by DL1YDD. Hence, DL1YDD would send the DTMF sequence 872*08023. This could be done either via the DTMF Deluxe unit or any transceiver equipped with DTMF transmitting capability.

Now let's take a closer look at the sequence 872*08023. DH1YAG's DTMF address is 872, DL1YDD's is 080. The asterisk between the two addresses is necessary to remain compatible with the Standard system and carries no further information. The "23" at the end of the sequence was previously defined to mean: "Attention, good Condx on SHF."

Because it is quite difficult to remember all the message numbers, let alone all the addresses on a major network, DTMF Deluxe translates all numbers into plain text. In our examples, the display of DH1YAG's unit would show: "Mo 15:29 DL1YDD, Condx 23 cm >YAG." The first two groups are the time stamp, followed by the sender of the message and finally the message. In the version with the 2×16 display the group that was called is displayed, too. In our example, it is DH1YAG's personal address, but it could be "DX," "VHF" or even "SOS" for other groups. More on groups and emergency use later on. It is possible to scroll through the last 50 calls with the built-in keyboard.

By now, DH1YAG's DTMF Deluxe has received DL1YDD's call, but DL1YDD does not know whether the call was received or not; perhaps DH1YAG is not QRV at all. For that reason DTMF Deluxe can issue an acknowledge signal to the sender. This can be a single DTMF tone, a predefined DTMF sequence or even the received DTMF sequence itself.

The latter has a specific background: Imagine DH1YAG is working in his basement on his latest transverter system. DL1YDD's transmitter can't reach his HT directly, but DH1YAG's DTMF Deluxe receives DL1YDD's message, and confirms it by resending it. DH1YAG can of course hear his own shack transceiver and his HT reacts with beeping—Standard HTs even display the sender on the display. If DH1YAG wants to answer DL1YDD, he can use the repeater feature of DTMF Deluxe; all sequences with a trailing # are repeated without the #. So it is possible to answer to hidden stations with a normal HT. In our case, DH1YAG can walk to his shack and start a QSO.

Another important application of DTMF Deluxe is emergency use. If all members of an ARC or emergency organization were equipped with DTMF Deluxe, surely no emergency call would ever be lost again. It is possible to activate a loud horn in case of an emergency call. The alerted ham could initiate steps to help the caller.

It is also possible to define different

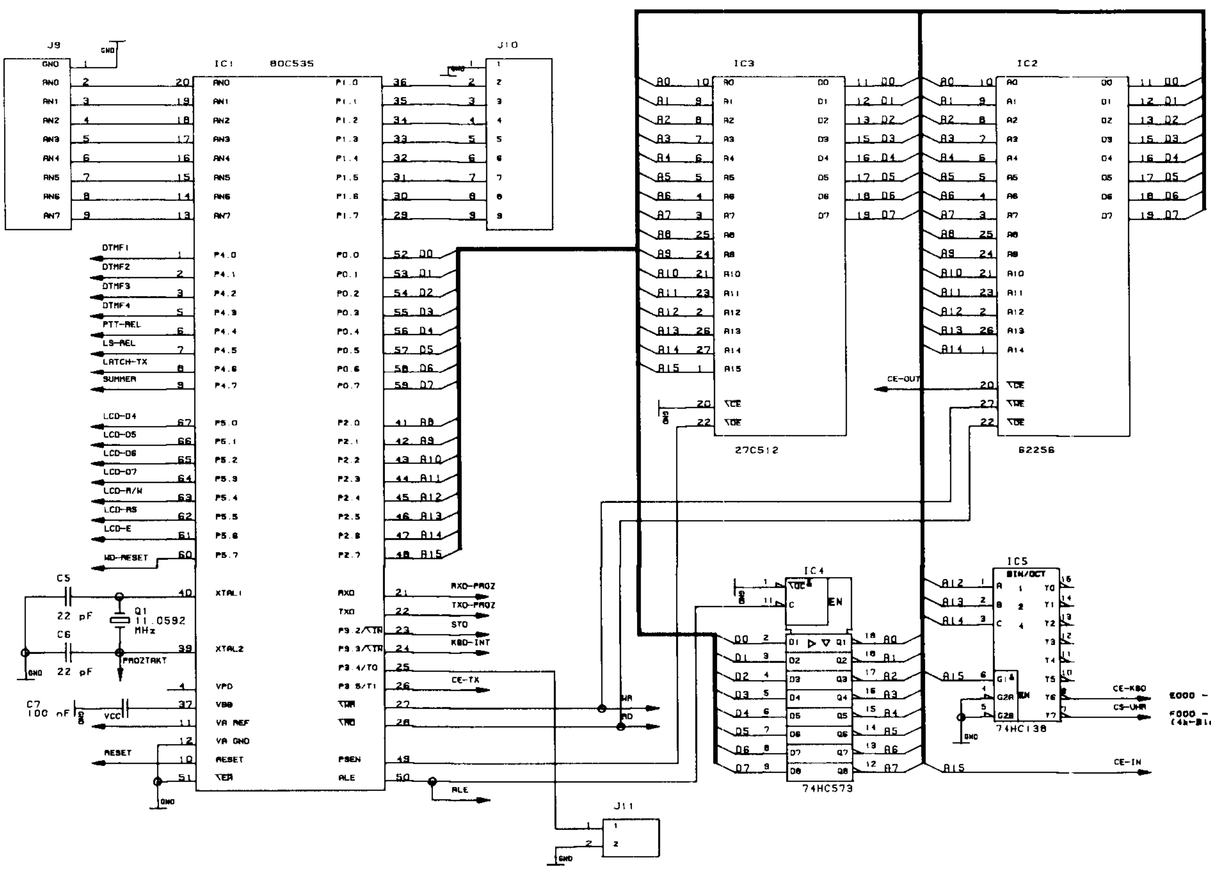


Fig 1—Schematic diagram of the processor unit

priorities for different calling groups. DTMF Deluxe can be programmed via the built-in keyboard in such a way that it responds to all calls during the day, but only to certain calls at night, so you can be undisturbed but emergency calls would still come through. All other calls are displayed and stored, but there is no alert and no confirmation. Priority levels from 0 to 9 allow great flexibility.

Configuration

A device of this complexity must be configured. This is done via the RS232 interface with a terminal or via the built-in keyboard and the LCD display. Because the keyboard and the display are not needed in all applications, all adjustments can be performed via the RS232 interface. In this case the built-in keyboard is used only to modify the behavior of DTMF Deluxe during operation.

In most cases a computer will be used as terminal. This computer can be any brand, the only requirement is an RS232 interface and a suitable terminal program. A "recycled" mainframe terminal works well; even an Atari Portfolio pocket computer is used by some. If you are QRV in packet radio, you are already equipped with a terminal. The interface speed is selectable between 19200 and 1200 bauds to satisfy C64 users too.

I would like to stress at this point that it is not necessary to use a computer or terminal for the day-to-day operation of DTMF Deluxe! The computer or terminal is needed only to configure the unit. All data (configuration, addresses, reaction when called, etc) are stored in a battery-backed RAM. Even when the unit is switched off for a long period, all data remains in memory, and the clock continues running.

Circuit Description

The entire device is controlled by a Siemens 80C535 CMOS one-chip controller. The current drain is about 60 mA. It is possible to use the slightly cheaper NMOS 80535, but then the current drain rises to approximately 300 mA. In this case, the heat sink of the voltage regulator must be larger.

The 80(C)535 can address 64-kbytes of RAM and 64-kbytes of ROM. (Harvard architecture; in this configuration it is not a Von Neumann machine.) The program is contained in an EPROM of 64-kbytes capacity. Of the 64 kbytes, approximately 45 kbytes are occupied, so there is still room for later enhancements. A 32-kbyte RAM chip unit is buffered by a small rechargeable NiCd battery. It is used both as working memory and as memory for the addresses and call signs. The rest of the RAM area is usable as I/O space and is organized into 4-kbyte blocks. Since only two of the eight chip-select lines from the 74HC138 decoder are used thus far, plenty of spares remain available for later expansion.

The clock oscillator is integrated into the controller chip. A crystal and two ceramic capacitors are all that is needed to complete the clock circuitry.

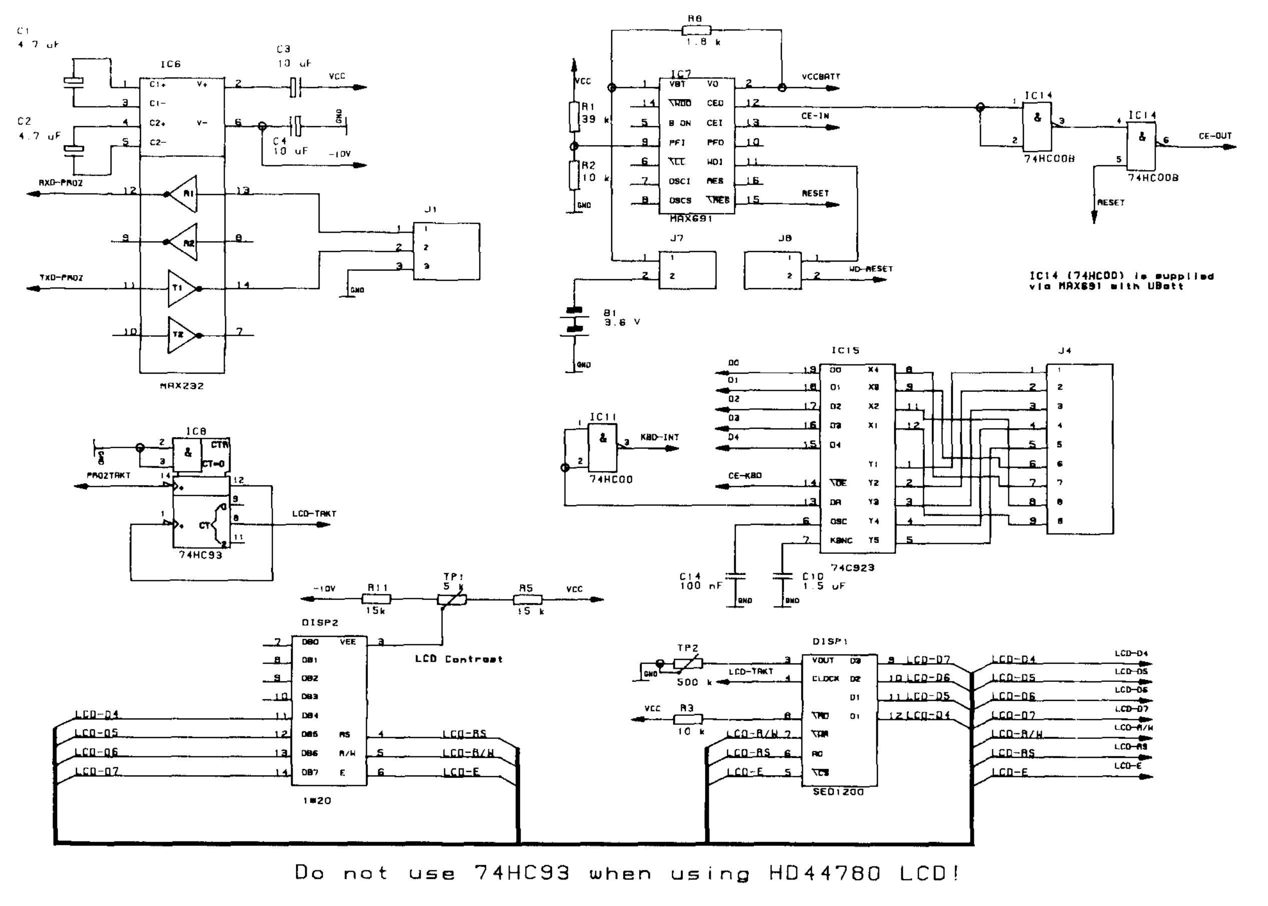


Fig 2—LCD, watchdog, keyboard, and RS232 circuits

To guarantee reliable reset behavior of the system, a special "Microprocessor Supervisory Chip" (MAX691) is used. It serves several purposes. First, it provides a well-defined reset pulse to the whole circuitry. The reset pulse is also generated if a certain pin of this IC does not change level at least once every 1.6 seconds. It is the processor's and the program's task to generate this transition on a regular basis. If this transition does not occur within 1.6 seconds, the MAX691 concludes that the system has either crashed or the program is in an endless—or at least very time consuming—loop. Since proper operation of DTMF Deluxe would not be guaranteed in either case, the MAX691 generates a reset pulse to restart the unit. Naturally, the contents of memory remain intact.

Furthermore, the MAX691 assures the accurate switching of the RAM and the clock between the normal power supply and the battery. Considering that reconfiguration may be quite time consuming, this function is very welcome! The battery has a capacity of 60 mAh and provides back-up power for the RAM and the clock for nearly six months. It is recharged during normal operation of DTMF Deluxe. Based on the assumption that the unit will be more or less in continuous service, the charging current was calculated so that overcharging the battery is very unlikely. When DTMF Deluxe is seldom used, the charging current should be increased, otherwise there could be too little charge available to power the memory and the clock. *Warning: if the current is increased, there is no overcharge limiting!*

The real-time clock (RTC) is also maintained by the battery. This IC is directly attached to the processor bus. It needs no external components and is very accurate. Timed events are possible, but not yet implemented in the software.

Configuration is performed mainly via the RS232 interface with a terminal (PC, C64, etc). A special interface IC, MAX232, is used to supply the standard RS232 levels. By using this IC, only a single +5-V power supply is necessary. The MAX232 is based on the principle of the charge pump. One RS232-to-TTL and one TTL-to-RS232 converter are available for expansion.

DTMF Deluxe displays calls and messages on an LCD (liquid crystal display). LCDs of the HD44780 and SED1200 type are supported by the software. Each type is connected with a different plug due to the differing requirements.

LCDs of the HD44780 type are widely available with different viewing angles and alternate types of illumination (LED, EL or none). The author recommends "Top View" types when the display is used in the shack since they are easier to read than the normal types, although are they more expensive and harder to get. All types can be illuminated, either with a set of LEDs or by an electroluminscence foil. The latter looks very good, however a dc-dc converter must provide the 80 V for illumination. The author had severe problems with the electromagnetic pollution caused by these converters.

All in all, the more expensive the dis-

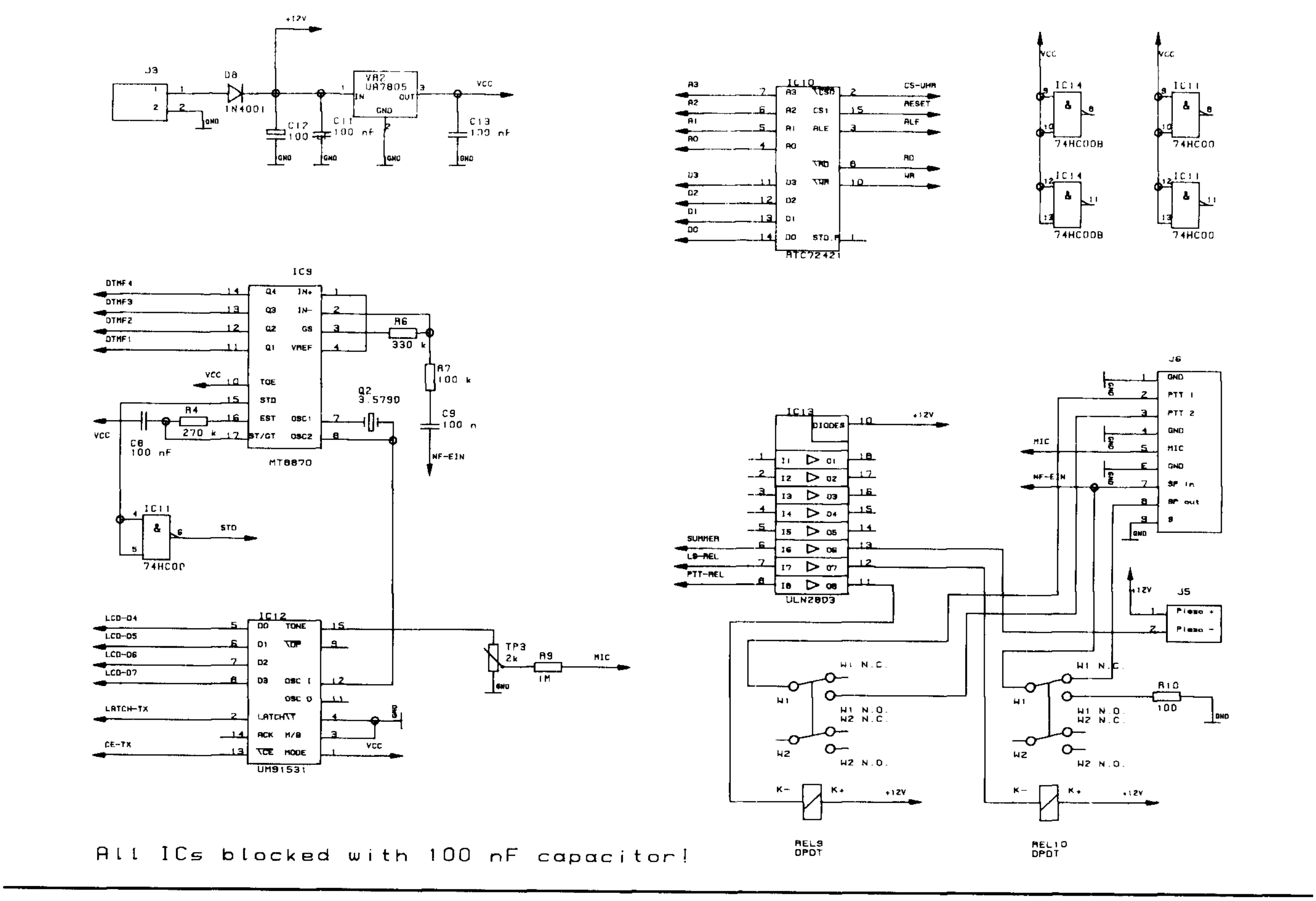


Fig 3—DTMF-RX and -TX, relays, and clock

play the better it is—except for the dc-dc converter. The author recommends that you initially use the LCD included with the kits. If you think you need a better display, contact your local dealer; he will supply you with the display type you like. But be warned that it is not at all cheap.

The two display types mentioned require different types of firmware. It's not sufficient merely to change the display; another EPROM is also required. The author provides both types of firmware. Updates will be available generally for both types.

The SED1200 types need an external clock signal which is derived from the processor clock by a TTL divider. If you use the HD44780 type, omit the divider IC 74HC93.

The LCD contrast is adjustable with a trimmer. If you plan to use DTMF Deluxe in extreme climatic environments, you should make the contrast pot accessible from outside the cabinet, otherwise the LCD contrast may be too weak. When used in a normal environment, such as in the shack or in the car, this is not needed. In this case it is sufficient to adjust the trimmer only once at the initial set-up of the unit.

The section for decoding and encoding the DTMF bursts consists basically of two ICs. The decoder is the well known MT8870, while the encoder is a UM91531 which is often used in inexpensive telephones. Both need a clock signal of 3.579 MHz, so one crystal is sufficient for both ICs. The clock signal is generated by the MT8870 and the crystal and then fed to the clock input of the UM91531.

The MT8870 decoder chip needs an input voltage level that corresponds roughly to a moderately adjusted loudspeaker. The input of DTMF Deluxe can be directly connected to the external speaker jack of the transceiver. The MT8870 is relatively tolerant of variations in input level. If significantly different input levels are present, it is possible to change the amplification factor of the first operational amplifier inside the MT8870. The feedback elements are external and thus changeable.

When the MT8870 recognizes a valid DTMF burst that is present for at least the period of time which is determined by R4 and C8, it applies the binary equivalent of the DTMF code to the output pins Q1 to Q4 and then sets the output STD to a high level. This signals the processor that a valid DTMF burst has been received and that the binary equivalent is available at the output

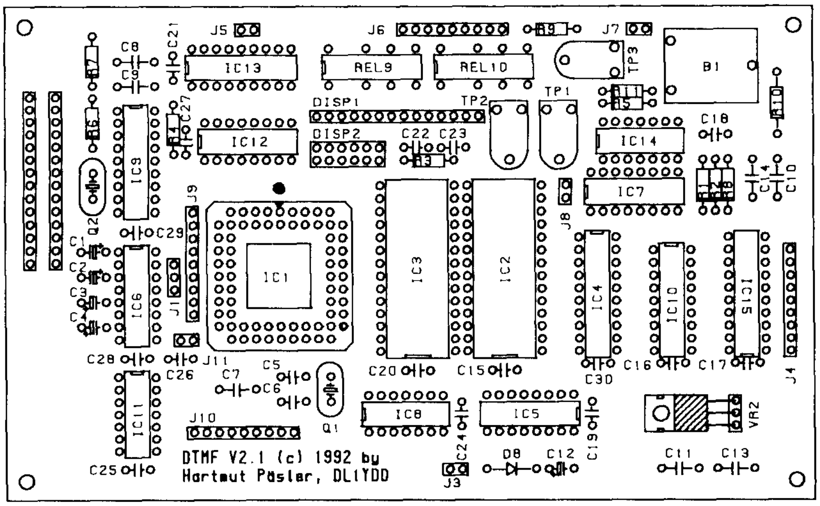


Fig 4—Component placement diagram

pins of the 8870. Both the minimum duration of the DTMF burst and the minimal pause between two DTMF bursts can be adjusted as needed. The timing was chosen so that bursts from simple DTMF hand transmitters for telephone answering machines, and also from automatic transmitters found in modern HTs, are readily recognized. Limits to the maximum time allowed for the whole sequence are determined by the microcontroller software.

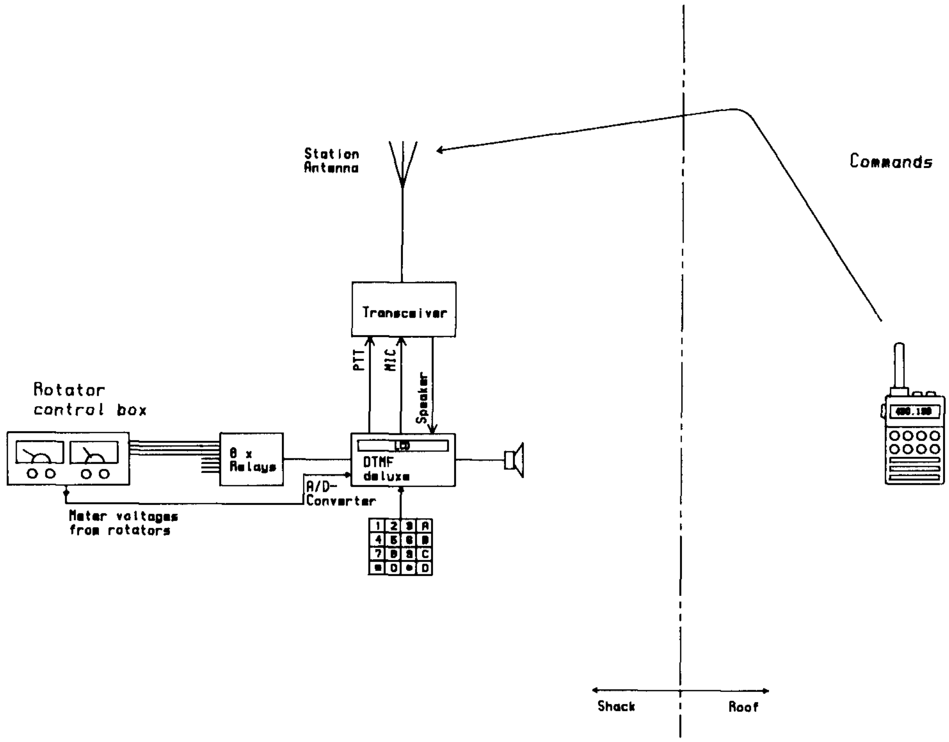
To make do with fewer processor I/O ports, the DTMF transmitter is switched in parallel to the LCDs. Since LCDs and the DTMF transmitter each need a separate enable signal, this works readily without restrictions. The DTMF transmitter produces standard 70-ms DTMF bursts. It is possible to lengthen these bursts with a software trick, but it is not possible to shorten them. Without exception, all test receivers that were accessible by the author reacted correctly to the 70-ms bursts. Some HTs reacted incorrectly when the pause between the bursts was too short, so the inter-digit pause may be set by the user. The output of the DTMF transmitter is sufficiently sinusoidal. The output level of the DTMF generator is set with a trimpot in the output from the IC. The output of the UM91531 DTMF transmitter can be connected directly to the transceiver microphone input. To avoid hum pickup a 1-M resistor is inserted in the signal path.

Since a 12-V or 13.8-V supply is available in most shacks rather than a 5-V supply, there is a voltage regulator on the PCB. This regulator can be supplied with a dc voltage in the range of 8 to 30 V. The temperature of the heat sink will not rise significantly when DTMF Deluxe is equipped with the CMOS processor, but when the NMOS processor is used, it gets quite warm. When additional 5-V loads are connected to the regulator you should be aware that the maximum possible load on the regulator is 1 A; however the allowable current draw from the device is determined by the maximum power dissipation of the regulator. The size of the heat sink must then be increased. To protect DTMF Deluxe from reverse polarity, a protection diode is provided.

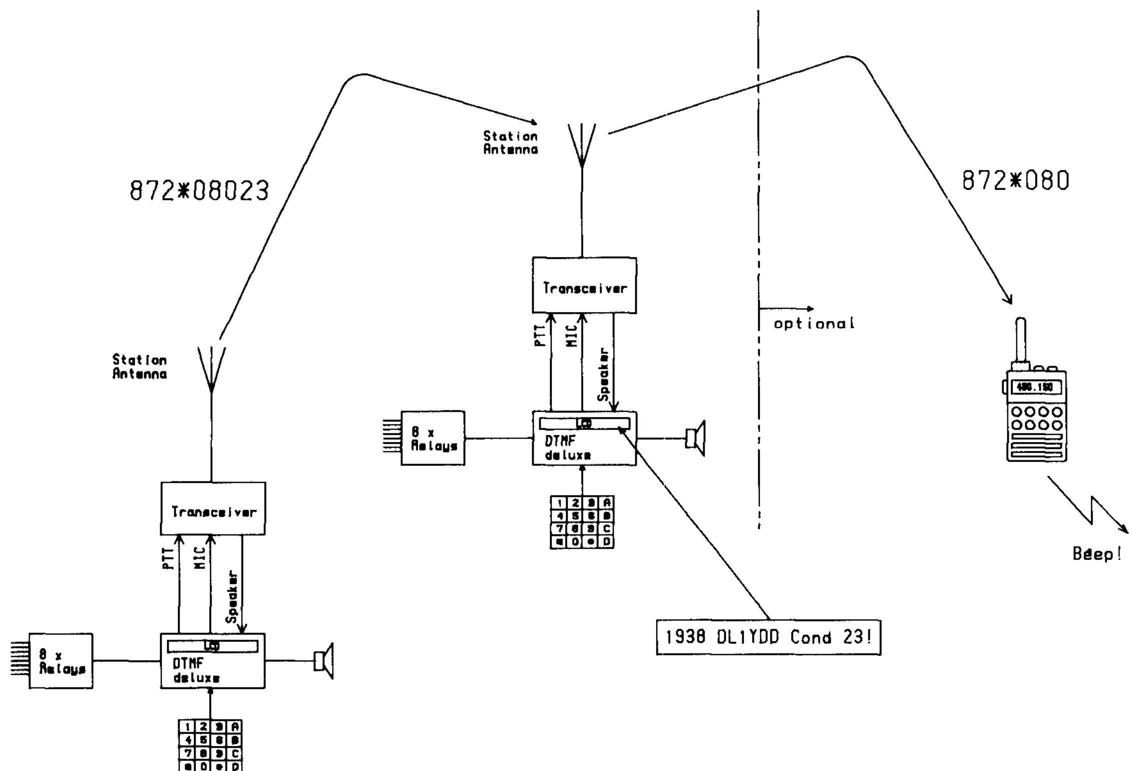
In addition to the two relays on the main PCB (speaker and PTT), DTMF Deluxe features another eight switching outputs which are routed to a 9-pin connector strip. The user can attach relays via suitable drivers to these outputs. A suggested circuit is shown in Fig 6. The ULN2803 is quite universal; it can switch relatively heavy loads and features built-in surge protection diodes in case electromechanical devices are attached.

It would have been possible to design a PCB for the relay section. There are at least two reasons for not doing so:

- Almost every user has his own thoughts on the number of contacts per relay, their maximum load, the mechanical design, etc. Some relays can be driven without external drivers, some need an external driver like the ULN2803. Other users may want to use electronic relays.
- The processor port, which is prima-



(A)



(B)

Fig 5a—Principle of rotator control via DTMF Deluxe. Fig 5b—General principle of DTMF Deluxe

rily designed as an output to eight relays, can be partially reconfigured as an input port by changing the firmware programming. It is thus possible to read in up to eight on/off states. To permit further expansions to the system, the author has left the use of this port up to the user. As default, the port is programmed as output.

DTMF Deluxe can thus be used for other purposes such as controlling an FM repeater or something similar as the computing power is sufficient for this application. Of course, the firmware must be changed in this case.

To sound an alert when a message comes in, a connector is provided for a piezo beeper on the PCB. If such a beeper is mounted on an outer wall of the case, the volume is usually very high. The beeper is driven in intervals of 5 short beeps and then a pause. It can be heard loudly in the author's home even when he is not in the room.

An extremely short beep of the piezo beeper is emitted when then user depresses a button of the built-in keyboard. This is designed as feedback when pressing keys and can be disabled by the user.

Prospects

One possible expansion of the unit is for remote control of an antenna system. This could be very handy when doing maintenance work on the antenna. It would thus be possible to turn the antennas with a simple command from a HT.

This application would require feeding the rotor meter voltages to the A/D converters in DTMF Deluxe. After an initial calibration, DTMF Deluxe would know where the antennas are pointing. When necessary, it could actuate one of the relays connected to the buttons on the rotator control box.

The user has two ways to issue commands for this kind of operation: first, he defines a specific DTMF sequence for antenna operations and appends the direction(s) to where he wants to turn the antennas to "080*999270045" would turn the system to the west with 45 degrees elevation. The second method is momentary contact, meaning that the rotators run as long as you press a certain button of your DTMF transmitter (2 for "up," 8 for "down," 4 for "left," 6 for "right"—look at your HT's keypad, you'll understand it immediately).

This feature is not yet implemented but may be by the time you read this. As the author is personally interested

Table 1

```
***************************************************************
* DTMF Deluxe Version 921121, (c) 1992 Hartmut Päsler, DL1YDD *
*                                                             *
* Commercial use requires written permission of the author    *
***************************************************************

dtmf> dtmf> help


          *** DTMF Deluxe, V2.1, Firmware V921121 ***

ACKnowledge:    Set type of acknowledgement
BEAcon:         Beacon transmission time
BTEXT:          Content of beacon transmission
CALIbrate:      15 s transmission to adjust microphone level
CALLs:          List last 50 messages
COMmands:       Define commands
DATE:           Set date
DEFine:         Define call signs
HELP:           This help
MSG:            Define messages
PRIOrity:       Set priority
QRES:           Reset memory to default value
REPeater:       Set repeater on/off
RUN:            Start DTMF Deluxe, leave COMMAND mode
SELcals:        Define own selcals
SEND:           Transmit DTMF sequence entered via the terminal
SHort:          Define DTMF memories
TIME:           Set time
TXM:            Transmit DTMF memory


CTRL-C switches from RUN mode to COMMAND mode

dtmf> calls

4 messages stored:

Di  17:42  DL1YAR QRV?          >YDD
Sa  18:19  DH1YAG #STANDARD#    >YDD
So  12:30  DL5DAA QRV?          >YDD
So  14:26  DF5DP TROPO!         >UKW

dtmf> beacon
*** BEACON every 35th minute of the hour

dtmf> btext
*** BEACON TEXT: 080

dtmf> com
  Nr. Code      Relay     Action     Priority  Comment
=====================================================
   1  1234        1         1           7      PREAMP ON
   2    4321      1         0           7      PREAMP OFF

dtmf> com 7 497513 5 30 3 30_SEC_LIGHTS
dtmf> com
  Nr.  Code     Relay     Action     Priority  Comment
=====================================================
   1    1234      1         1           7      PREAMP ON
   2    4321      1         0           7      PREAMP OFF
   7    497513    5        30           3      30 SEC LIGHTS

dtmf> date
*** DATE Sa, 17. Apr. 1993

dtmf> time
*** TIME 17:51:01   <- will be changed to US format

dtmf> def
    Nr.   Call Sign
=======================
   000    DLØCRE
   018    DL1YAR
   080    DL1YDD
   195    DF5DH
   218    DG2YF
   383    DL5DAA
   435    DL1DBY
   514    DF5DP
   732    DB5YY
   872    DH1YAG

dtmf> msg


Number    Message
-------------------------
   0      #STANDARD#

  14      CONDX KW!
  23      CONDX SHF!
  60      PSE PHONE
  73      QRV?
  91      ->DBØBS
  92      ->DBØUR
  99      ->CLUB-QRG

dtmf> sel
 Nr.      Selcall   Priority  Comment
--------------------------------------------
   1        080         7     YDD
   2        777         9     EMERGENCY
   3        144         5     VHF
```

Table 2
Parts list

B1*	3.6 V, 60 mAh	rechargeable battery
C1,C2	4.7 µF,16V	electrolytic capacitor
C3,C4	10 µF,16 V	electrolytic capacitor
C5,C6	22 pF	electrolytic capacitor
C7,C8,C9,		
C11,C13	100 nF, 35 V	Foil type, 3/10 inch
C10	1.5 µF,10 V	tantal capacitor
C12	100 µF, 25 V	electrolyte capacitor
C14...C30	100 nF, 50 V	blocking capacitor
D8	1N4001	diode
DISP1*	SED1200	LCD
DISP2	HD44780	LCD
IC1*	80C535	processor
IC2	62256	RAM
IC3*	27C512	EPROM, programmed
IC4	74HC573	Latch
IC5	74HC138	Demultiplexer
IC6	MAX232	Interface circuit
IC7*	MAX691	Watchdog
IC8	74HC93	Counter/divider
IC9*	MT8870	DTMF decoder
IC10*	RTC72421	Real-time clock
IC11	74HC00	4*NAND
IC12*	UM91531	DTMF endcoder
IC13	ULN2803	Relay driver
IC14	74HC00	4*NAND
IC15*	74C923	Keyboard encoder
J1,J3...10	one row	Headers, 61 pins
J2	two rows	Header, 12 pins
Q1	11.0592 MHz	Quartz, HC-18U
Q2	3.5790 MHz	Quartz, HC-18U
R1	39 k, 0.1 W	Resistor
R2,R3	10 k, 0.1 W	Resistor
R4	270 k, 0.1 W	Resistor
R5	1.8 k, 0.1 W	Resistor
R6	330 k, 0.1 W	Resistor
R7	100 k, 0.1 W	Resistor
R8	1.8 k, 0.1 W	Resistor
R9	1M, 0.1 W	Resistor
R10	100, 1 W	Resistor
R11	3.9k, 0.1 W	Resistor
REL9,REL10	SDS DS2E-S-DC 12 V	Relay
TP1	5 k, 0.2 W	Trimmer
TP2	500 k, 0.2 W	Trimmer
TP3	2k, 0.2 W	Trimmer
VR2	7805	Voltage regulator
S1	Piezo buzzer	

Miscellaneous

- Heat sink for voltage regulator, TO-220 style
- IC sockets, precision types recommended:
  1 PLCC68*
  2 28 pin DIL
  2 20 pin DIL
  3 18 pin DIL
  4 16 pin DIL
  2 14 pin DIL
- 16-key keyboard*, matrix style, alternatively 16 single pushbuttons
- 1-inch ribbon cable 14 wires
- 1 PCB "DTMF Deluxe 2.1"*

in this feature, it is quite likely that he will change the firmware to get DTMF Deluxe to steer his antennas.

The Firmware

Table 1 shows a sample set-up procedure. It does not show all of the possible commands, but the principle is the same for all commands. The aim is to show the principle, not how DTMF Deluxe is to be configured. You can read this in the manual which has approximately 50 pages. The use of every command is explained and supplemented with an example.

Table 1 is a capture file of the terminal program supplied with DTMF Deluxe (IBM PC only).

All commands are command-line oriented and can be uploaded to DTMF Deluxe with a suitable terminal program. There also exists a DUMP command that dumps all user defined settings to the terminal in a form that can be uploaded again without any change. This is quite handy when you want to pass one DTMF Deluxe's data to another unit or simply to back up all data for security purposes or when changing the EPROM in a firmware update.

Reproduction

To make the reproduction of DTMF Deluxe as easy as possible, the author designed a double-sided, plated-through PCB with solder mask and silk screen. Kits in various forms are available through the author, as are programmed EPROMs. The contents of the EPROM will be available via the ARRL BBS (203 666-0578), too.

There are several ways to get DTMF Deluxe, depending on the number of parts available locally:

1. PCB, EPROM, LCD (1 × 20), terminal program
2. "hard-to-get-part kits": like 1 (above), with all parts marked with an asterisk in the parts list
3. complete kit: all parts to get DTMF Deluxe running, except enclosure
4. complete unit in high-quality enclosure, with supertwist LCD (2 × 16), speaker, keyboard; completely built and tested

Items 1, 2 and 3 are available in nearly unlimited quantities, item 4 is available in very limited quantities, please contact the author before ordering anything! The delivery time of item 4 may be quite long.

All prices are calculated strictly on a non-commercial basis, this means that if you start buying all the parts from your local dealers, if may be more ex-

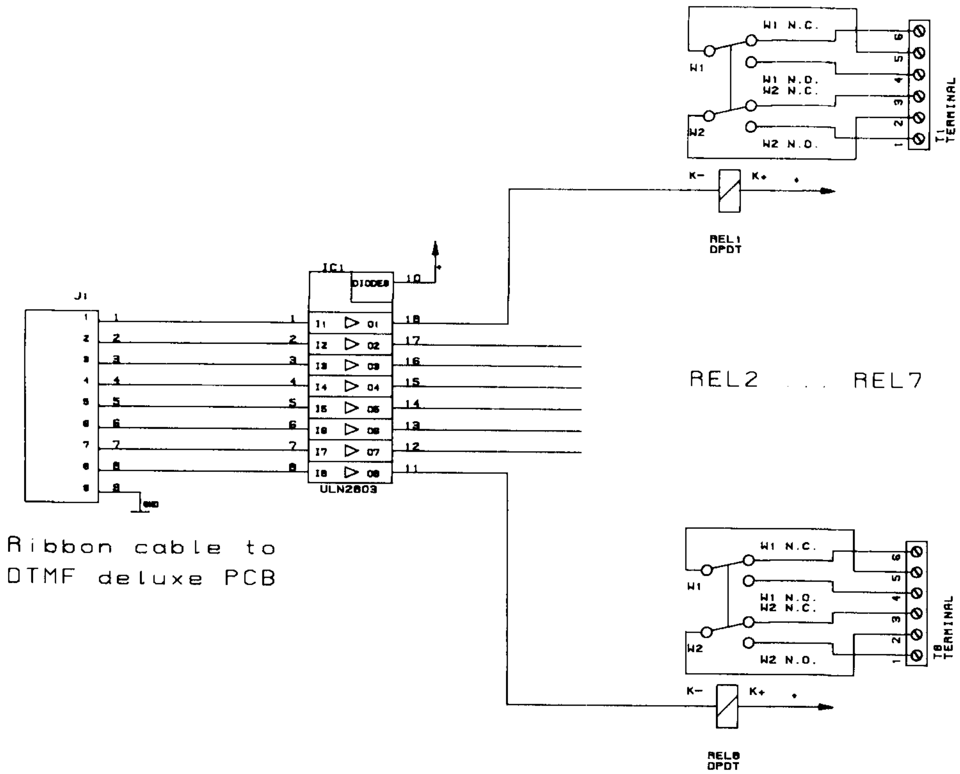


Fig 6—Suggestion for a relay board

pensive than if you buy it completely from the author who can purchase most parts in quite large quantities. The 1 x 20 LCDs are available at a nominal fee because the author obtained many of them from industrial surplus.

Be aware that DTMF Deluxe was designed entirely in the spare time of the author. The kits are put together in a similar way, so please allow some time for delivery. Also keep in mind that it is not possible for the author to keep large numbers of kits and parts in stock. This would readily exceed the author's financial capabilities! The only way to handle this problem is to deliver a certain number of kits and then wait for the money to come in. Orders will be processed in the order they are placed. I am very sorry about this as I don't like to wait for a kit either, but it is the only way to handle the problem.

The author is also very grateful for bug reports, even if there are few of them, because DTMF Deluxe has been in use in Germany for approximately one year now. Updates will be available at cost in the form of EPROMs or disk files. They will be made available via the ARRL BBS and/or Internet.

DTMF Deluxe kits and PCBs are delivered with about 50 pages of documentation plus all schematics and board layouts. Please do not expect step-by-step instructions how to assemble the kits. Here in Germany, and generally Europe, it is not usual to use (or write!) "Heathkit-like" manuals. However, it should be possible for the somewhat experienced builder to build DTMF Deluxe without any problems. It is certainly not a project for the beginner. There is no need for sophisticated test equipment; the only alignment points are the TX audio level and the LCD contrast.

Legal Stuff

Passing along the documentation with acknowledgement of the source is expressly allowed and encouraged. The reproduction and use of DTMF Deluxe is allowed for personal purposes only. Commercial use and marketing requires the written permission of the author who reserves all rights. The circuitry is designed with the utmost care.

The author makes no representation or warranties with respect to the contents hereof and specifically disclaims any implied warranties of merchantability or fitness for any particular purpose. DTMF Deluxe is provided "as is" without warranty of any kind, either expressed or implied.

The author shall have no liability or responsibility to you or any other person or entity with respect to any loss or damage caused by DTMF Deluxe including, but not limited to, any loss of profits, interruption of service, loss of business or consequential damages resulting from the use of such devices.

Acknowledgement

Many thanks to Don Moe, DJØHC, for helping to translate the original *cq-dl* article into English.

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RF

Zack Lau, KH6CP/1

A No-Tune 222-MHz Transverter

No, that isn't a misprint. The wavelength is 135 cm, and the design is a pair of no-tune boards on 1/16-inch glass-epoxy or G-10/FR-4 boards (ε_r=4.8). I was reminded of this idea when I read Bill Olsen's comment in the 1992 *Microwave Update* about tuning a 432-MHz transverter down to 220 MHz. I had been playing around with the idea of bending the lines around the board in a way similar to the idea described by W5KHT in 1971 of using spiral inductors on fiberglass board.[1] What eventually worked, however, was a design analogous to small transmitting loops. One way of looking at the filters on these boards is as small transmitting loops coupled together. (The 1971 article didn't consider the concept of widening the bandwidth and using many filter sections.)

Like transmitting loops, the filters use relatively high-Q capacitors to reduce the size of the resonator. For a manufacturer of kits, these filters represent less risk than "standard" no-tune designs—you can always fudge the design a bit by changing the capacitor values a bit if you get a batch of boards with an unusually high or low dielectric constant. What *is* important is the coupling between the loops: a severely under-etched or over-etched board probably won't work. A few mils error either way is probably acceptable, though.

[1]Notes appear on page 32.

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Newington, CT 06111
email: zlau@arrl.org (Internet)

The Local Oscillator

The LO of Fig 1 uses the same two-transistor Butler emitter follower circuit used in many of the no-tune designs. It produces quite a bit of second-harmonic output, so I merely ran it into a filter, rather than designing a diode doubler circuit. The output of the filter is roughly −1 dBm. Although the loss of the filter is 3 dB, this does not mean that you will see +2 dBm if you connect the oscillator directly to a spectrum analyzer. I'm taking advantage in this circuit of something known as "filter gain," in which a filter and a non-linear circuit (the oscillator) interact to produce more output than expected at the desired frequency. I realize that this conflicts with some people's concept of filters, but that is their problem. The hand-waving explanation is that some of the energy reflected by the filter is converted by the non-linear circuit into the desired harmonic.

Rick Campbell has suggested drilling holes and mounting the crystal on the ground plane side of the board. If the crystal is properly insulated, this can improve the stability of the oscillator. I've not done this with my prototypes, however, since it helps to have one side of the board completely devoid of components when you are doing design development with a work bench that obviously isn't big enough. [*It* would *be big enough if only Zack quit filling it with things he has built!—KE3Z*]

Two stages of three-loop filters provides more than enough filtering for most applications. The 97- and 288-MHz signals are down 63 and 64 dBc, respectively. The splitter network at the output of the board provides marginal low-pass filtering, so the 2nd and 3rd harmonics of the 194-MHz signal are down only 27 and 47 dB, respectively. You could modify the board for extra low-pass filtering, though I don't think this is necessary for feeding diode mixers. As Table 1 shows, you can expect +10 dBm of output for each mixer, which is more than enough for driving an SBL-1 or TUF-1SM mixer. The former is the old standby, while the newer TUF-1SM is easier to use for surface-mount applications. You might also consider modifying the board to accommodate another MAV-11 by adding a hole for the MMIC and gaps in the traces for the dc blocking capacitors. This would provide enough output to drive a high-level mixer.

DC voltage measurements taken using a Fluke 77 multimeter are shown for all three boards in Table 4. The meter invariably detunes the circuit at times, but I made no effort to compensate for this.

The Converter Boards

I elected to use the same printed-circuit board design for both transmit and receive converters rather than develop optimized boards for each. (Although the board design is identical, the circuitry on the two boards differs, as shown in Figs 2 and 3. The most important consideration in the converter design is the amount of filtering to put

Table 1—Power output versus supply voltage of the 194-MHz LO.

V_{cc} (V)	P_{out} (dBm)
9.78	8.0
11.12	9.5
11.97	10.2
12.53	10.2
13.83	11.0

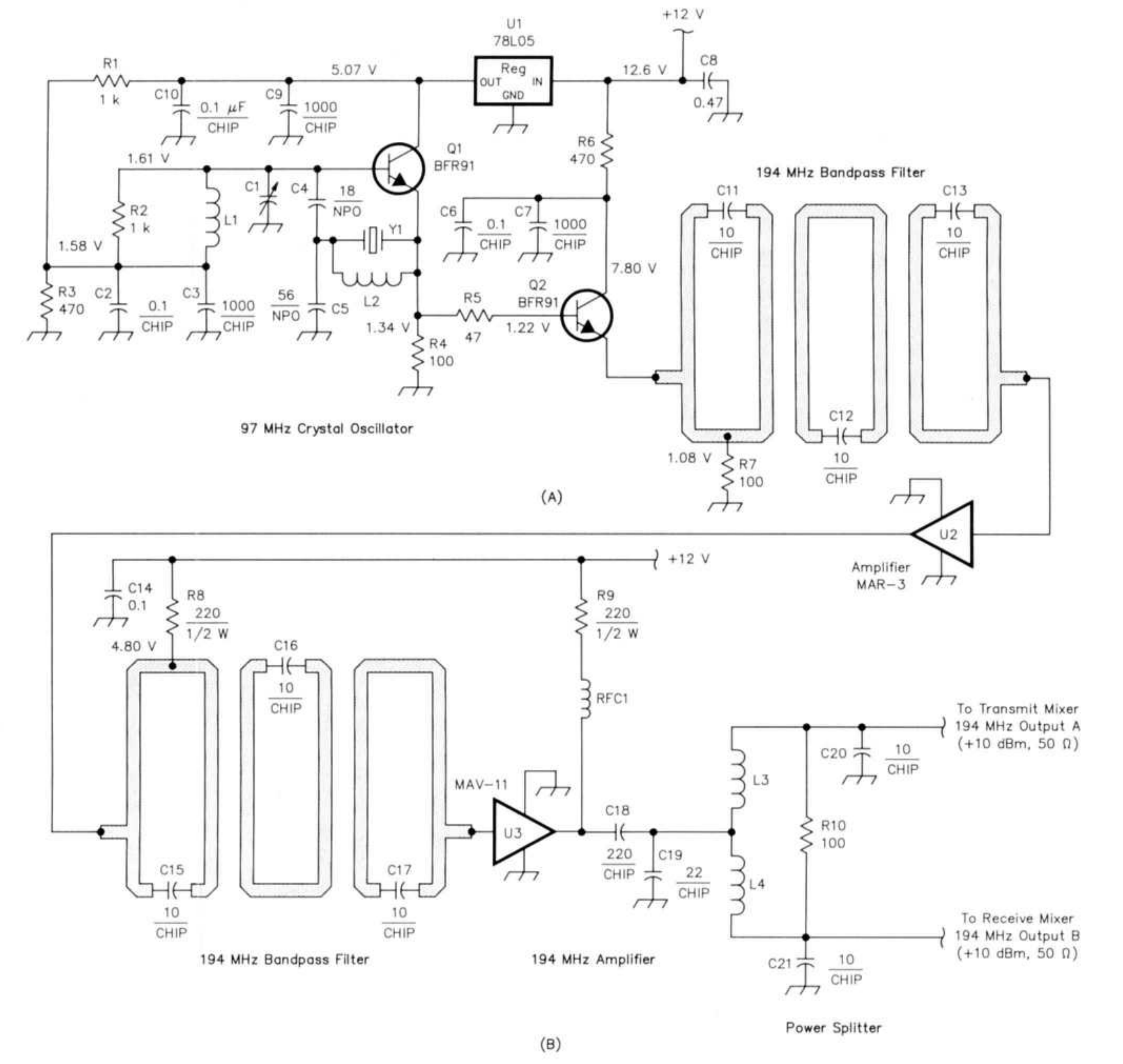


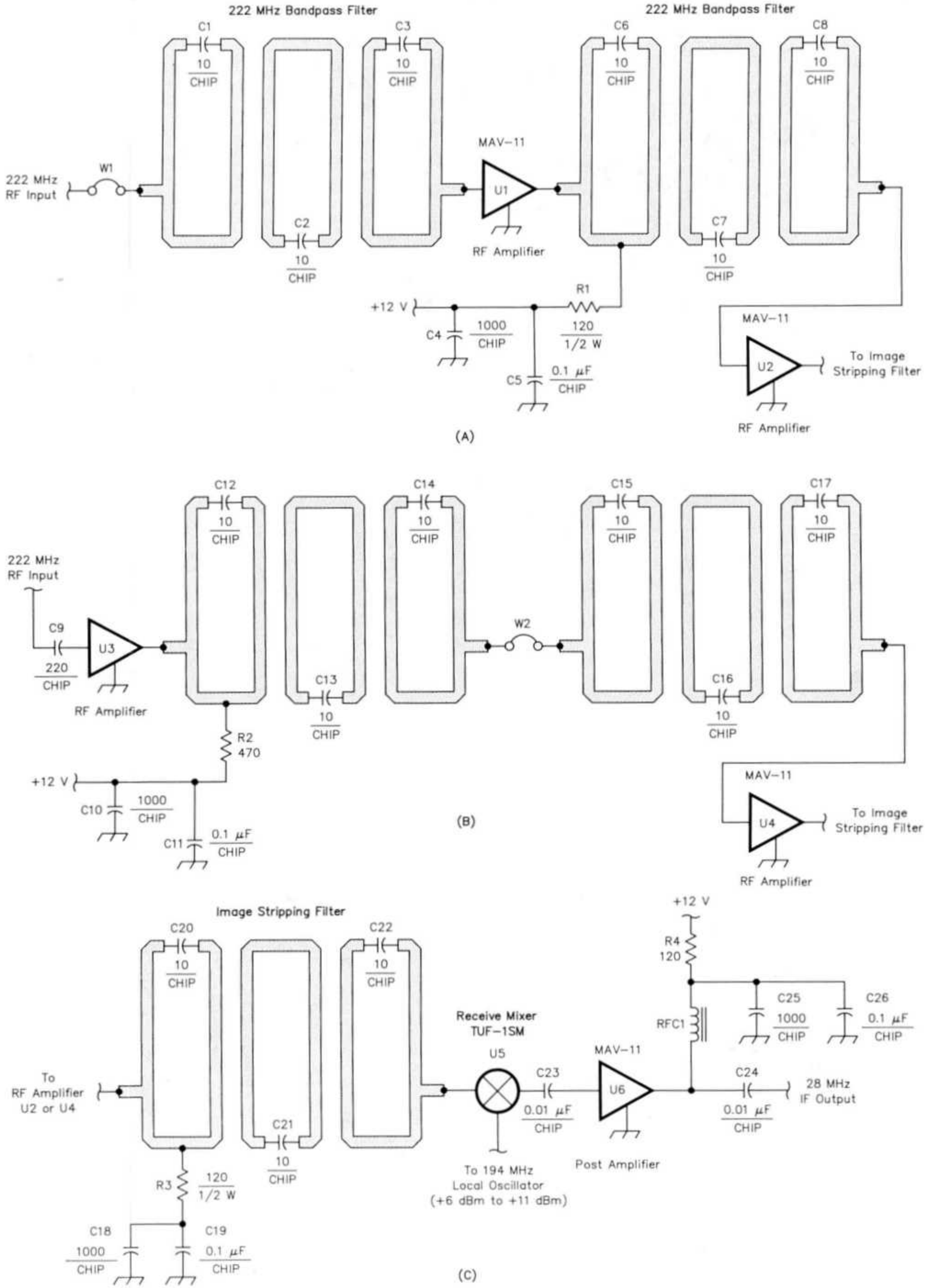
Fig 1—Schematic of the 194-MHz local oscillator.

C1—6-to-10 pF maximum value trimmer capacitor.
C18—Ideally a series resonant capacitor, although anything from 100 to 1000 pF should work just fine.
L1—7 turns #24 enam wire close wound. ⅛-inch drill bit used to form turns.
L2—10 turns no. 28 enam wire on T-25-6 core.
L3, L4—4 turns #24 enam wire close wound. ⅛-inch drill bit used to form turns.
Q1, Q2—BFR-91 or 2N5179 NPN transistor.
RFC1—7 turns #24 enam close wound. ⅛-inch drill bit used to form turns.
U1—78L05 5-volt, three-terminal regulator IC.
U2—MAR-3 or MSA 0385 MMIC.
U3—MAV-11 or MSA 1104 MMIC.
Y1—97.000-MHz crystal. International Crystal Manufacturing part number 473390.

(Fig 2 appears on page 26.)

Fig 2—Schematic of the 222-MHz receive converter. A is the high-intercept front end and B is the low-noise front end. Either of these circuits can be built using the provided board design. The output of one or the other of A and B connects to the input of the circuitry at C.

C9—Ideally a series resonant capacitor, although anything from 100 to 1000 pF should work just fine.
RFC1—at least 4 turns of #28 enam wire on an FT-37-43 ferrite toroid core. The coil I yanked out of the parts bin had about 20 turns.
U1,2,4,6—MAV-11 or MSA 1104.
U3—MAR-6 or MSA 0685.
U5—Mini-Circuits TUF-1SM surface-mount mixer.


222 MHz Bandpass Filter
222 MHz Bandpass Filter
C1
10
CHIP
C2
10
CHIP
C3
10
CHIP
C6
10
CHIP
C7
10
CHIP
C8
10
CHIP
W1
222 MHz
RF Input
MAV-11
U1
RF Amplifier
+12 V
C4
1000
CHIP
C5
0.1 µF
CHIP
R1
120
1/2 W
MAV-11
U2
To Image
Stripping Filter
RF Amplifier
(A)
C12
10
CHIP
C13
10
CHIP
C14
10
CHIP
C15
10
CHIP
C16
10
CHIP
C17
10
CHIP
222 MHz
RF Input
C9
220
CHIP
U3
RF Amplifier
W2
R2
470
+12 V
C10
1000
CHIP
C11
0.1 µF
CHIP
(B)
MAV-11
U4
To Image
Stripping Filter
RF Amplifier
Image Stripping Filter
C20
10
CHIP
C21
10
CHIP
C22
10
CHIP
To
RF Amplifier
U2 or U4
R3
120
1/2 W
C18
1000
CHIP
C19
0.1 µF
CHIP
Receive Mixer
TUF-1SM
U5
To 194 MHz
Local Oscillator
(+6 dBm to +11 dBm)
C23
0.01 µF
CHIP
MAV-11
U6
Post Amplifier
+12 V
R4
120
RFC1
C25
1000
CHIP
C26
0.1 µF
CHIP
C24
0.01 µF
CHIP
28 MHz
IF Output
(C)

on the board. The 222-MHz band actually is a more difficult band for which to make a spectrally clean transverter than are higher-frequency bands, since Part 97 rules require the spurs of a 25-watt transmitter to be at least 60 dB down. With good reason, too, as other services could be adversely affected by a bad amateur transmitter.

While two three-loop filters could be made to work, I decided to be conservative and use three filters. I also decided to use slightly overcoupled filters, with the resulting "double hump" response, placing the lower peak at 222 MHz. This makes sense, since the usual causes of strong-signal interference, such as TV channel 13 and waterways communications, are below 222 MHz. Plus, I didn't want to preclude use of this design up through 225 MHz. You may wonder, "Why not just use a narrower filter?" The disadvantage is that the insertion loss of the filter goes up dramatically as the loaded Q approaches the unloaded Q. The narrower filter would have too much loss, unless a better material than G-10 fiberglass board were used. And I don't think the improved performance would justify us-

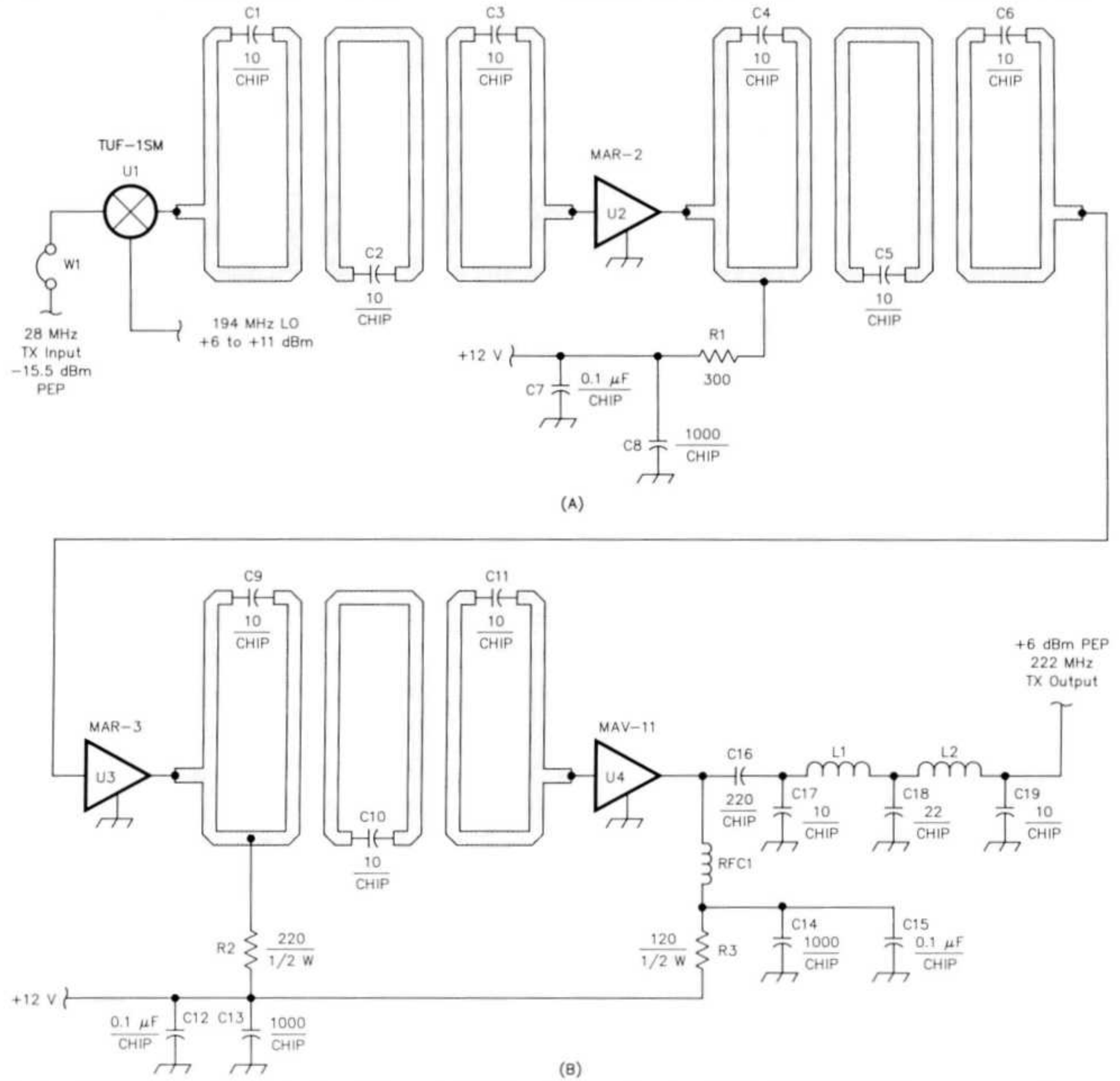


Fig 3—Schematic of the 222-MHz transmit converter.

C16—Ideally a series resonant capacitor, although anything from 100 to 1000 pF should work just fine.

L1, L2—4 turns #26 enam wire close wound. 3/32-inch drill bit used as a temporary form to make coil.

RFC1—8 turns #28 enam wire close wound. 1/8-inch drill bit used as a temporary form to make coil.

U1—Mini Circuits TUF-1SM surface-mount mixer.

U2—MAR-2 or MSA 0285 MMIC.

U3—MAR-3 or MSA 0385 MMIC.

U4—MAV-11 or MSA 1104 MMIC.

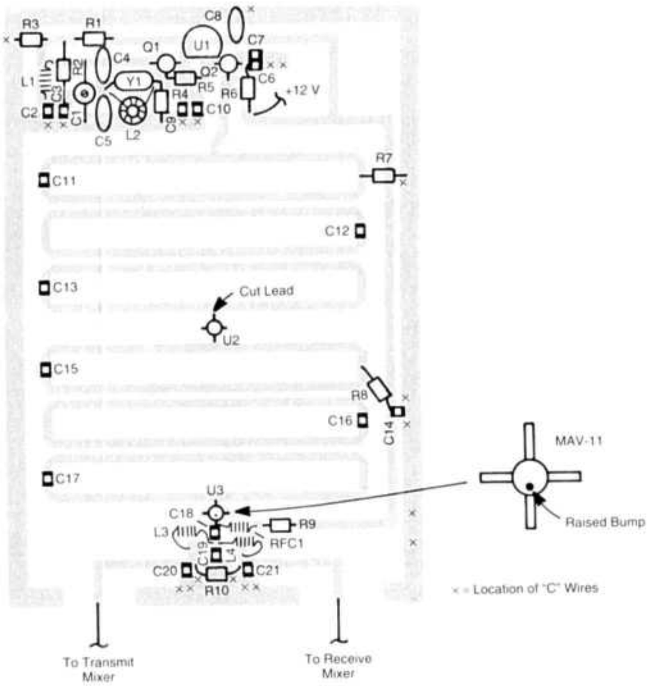


Fig 4—Parts placement for the 194-MHz LO board.

Table 3—Input intercept of the 222-MHz receive converter.

High-intercept version (see text)

Test conditions: Roughly 10 dBm LO injection using the LO board. HP8640A signal generators used to generate two-tone signal. Output viewed on HP 8563E Spectrum Analyzer. Vcc=12.72 volts.

Measured voltages on the input MAV-11:
- input: 1.877 V
- output: 5.51 V

Output at –13.5 dBm (each tone):
- Input = –30.5 dBm each tone (17-dB gain)
- IMD = –64 dB relative to each tone
- +1.5-dBm input intercept

Output at –6.3 dBm (each tone):
- Input = –23.5 dBm each tone, (16.8-dB gain)
- IMD = –46 dB relative to each tone
- –0.5 dBm input intercept

Output at –3.5 dBm (each tone):
- Input = –20.5 dBm each tone (17-dB gain)
- IMD = –40 dB relative to each tone
- –0.5 dBm input intercept

Low-noise version (see text)

Test conditions: +9 dBm LO injection using Marconi 2041 signal generator. HP8640A signal generators used to generate two-tone signal. Output viewed on HP 8563E Spectrum Analyzer. Vcc=12.72 volts.

Output at –5.8 dBm (each tone):
- Input = –33.5 dBm each tone (27.7-dB gain)
- IMD = –44 dB relative to each tone
- –11.5 dBm input intercept
- +16.2 dBm output intercept

Table 2—Measured noise figure of the 222-MHz receive converter.

Low-noise version (see text)

f (MHz)	*Insertion Gain (dB)*	*Noise Figure (dB)*
26	25.04	3.69
28	26.49	3.56
29	26.92	3.51
30	27.34	3.42
33	28.22	3.23

Test conditions: MAR-6 input MMIC, MAV-11 before and after mixer, Middle MMIC traces jumpered with 0.08-inch-wide foil.

High-intercept version (see text)

f	*Insertion Gain*	*Noise Figure*
26	10.10	12.84
28	15.79	10.04
29	16.82	9.48
30	17.57	9.23

Test conditions: +7 dBm LO drive. No MMIC ahead of filters. MAV-11 used after filter and before and after mixer—high intercept front end. See text—noise figures are unexpectedly high.

ing pricey Teflon board instead of G-10.

One advantage to building your own circuits is the ability to tailor them to suit your needs. You can optimize the receive converter for just the amount of strong-signal handling you need. This is particularly important if you intend to use a high-gain GaAs FET preamplifier in an area where strong signals are common, thereby running the risk of front-end overload. A low measured noise figure is pretty meaningless if your receiver is constantly being desensed by blocking! On the other hand, if you are hundreds of miles from any cellular phone site, you can probably get away with dreadful IMD performance and never notice a problem.

What makes the noise figure best is to put a MMIC ahead of the first input filter. But for many people, this is *not* what you want to do. These days, you can expect all sorts of interference from other transmitters. You probably want to sacrifice 2 or 3 dB of noise figure by putting the MMIC *after* the input filter. The noise figure might not look so great, but you undoubtedly will hear more. It can be awfully frustrating trying to pull a weak station out when your receiver is being continually blocked by strong signals.

Tables 2 and 3 give measurements of the two versions of the receive converter: the "low-noise" version and the "high-intercept" version. Comparing the versions shows that you pick up 11 dB of dynamic range by giving up 6.5 dB of noise figure. Besides lacking input filtering, the low-noise design fails to take full advantage of the better input stages because the mixer isn't strong enough. Ideally, the mixer's input intercept would be around +26 dBm. But this

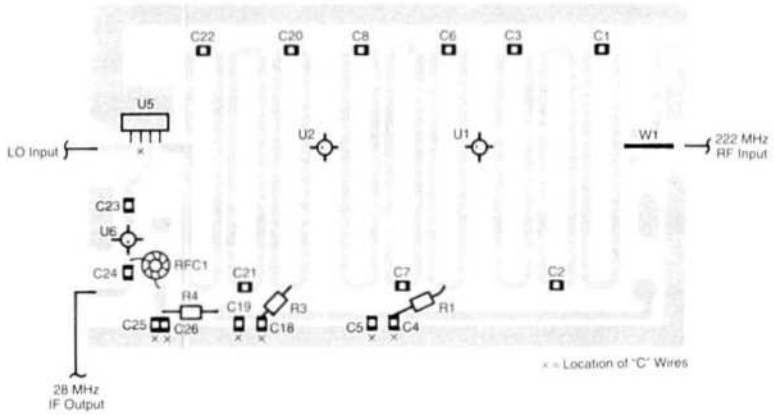


Fig 5—Parts placement for the 222-MHz receive converter board.

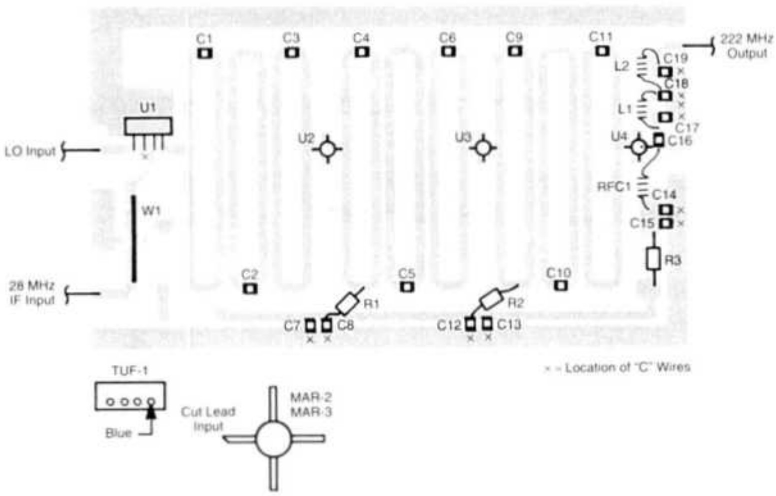


Fig 6—Parts placement for the 222-MHz transmit converter board.

Table 4—Measured MMIC voltages (V_{cc} = 12.6 V).

Transmit boards

	Transmit Board #1		Transmit Board #2	
MMIC	Input (V)	Output (V)	Input (V)	Output (V)
MAR-2	1.596	4.96	1.600	4.96
MAR-3	1.698	4.75	1.682	4.71
MAV-11	1.646	4.66	1.823	5.36

Note: Two different transmit boards were measured to show the variations between components.

Receive board

MMIC	Input (V)	Output (V)
MAR-6	1.533	3.47
MAV-11	1.925	5.78
MAV-11	1.901	5.59

would create a problem for the post amplifier stage! The moral is, while improving individual components helps, the biggest improvements often come via intelligent design. I think that either of these designs is a marked improvement over previous "no-tune" VHF designs.

Like in most other no-tune designs, there is almost no filtering after the receive mixer. It is assumed that the IF receiver will have enough input filtering to remove the local oscillator and VHF mixer products. If this is not a valid assumption for your IF receiver, you can add a filter, such as a 10-meter bandpass filter, between the receive converter and the IF receiver input. (Appendix 2 of *Solid State Design for the Radio Amateur* has a pretty good tutorial on designing real filters.) For example, I have a 40-MHz lowpass filter that I use ahead of the Hewlett Packard noise figure meter, as the HP 8970's filtering isn't adequate. The noise-figure readings in Table 2 were taken with the 5-dB ENR noise source we have here in the ARRL Lab. A high ENR noise source may allow for more accurate readings.

The MAV-11 post amplifier helps to preserve the input intercept of the mixer by providing a broadband termination of the mixer's IF port. While not perfect, it's undoubtedly better than the front end of a typical HF receiver, which is probably the limiting factor to system performance. As I discussed in my article, "Birth of a 7-MHz Transceiver," in March 1993 *QEX*, diode mixers are quite fussy about being terminated properly—a 15 dB reduction in input intercept isn't unusual if properly terminated. While probably inferior in performance to a well-designed and properly tuned passive network, I think this MMIC is a good compromise termination, especially if reliability and ease of construction is taken into account. After all, what good is a high-performance circuit if you can't get it working?

You can expect an MAR-6 to have about a 3-dB noise figure and 20 dB of gain, while the MAV-11 will have about a 4-dB noise figure and 12 dB of gain. The input intercept of the former is around –7 dBm, and the latter +18 dBm. The MAV-11 gets this vastly improved IMD performance by its lower gain and higher current draw, while sacrificing

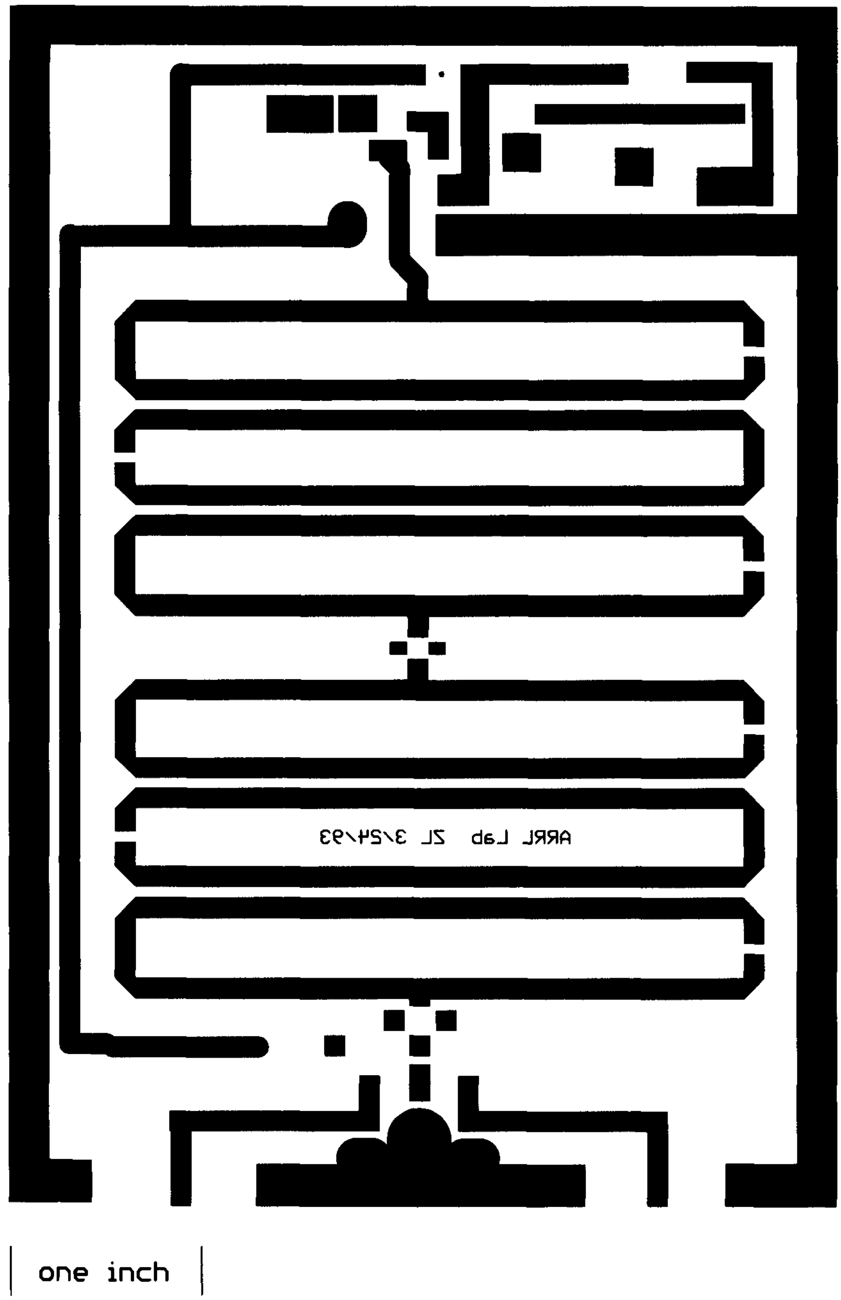


Fig 7—Printed-circuit board etching pattern for the 194-MHz LO board.

a little noise figure. MMICs seem to be pretty consistent up to 2304 MHz, though I have noticed considerable differences at 3.5 GHz, probably because this is above their rated bandwidth. In particular, I have a no-tune 3456-MHz board with 22 dB of gain and a 3.9-dB noise figure, while another had 9 dB of gain and a 6.6-dB noise figure! I'd expect about 13 dB of gain and a 5-dB NF to be perhaps typical.

On transmit, the small-signal output intercept is +30 dBm, which degrades to +27.5 dBm with a +6 dBm PEP output. The local oscillator is 49 dB down, and the signal at the LO+2 × IF is 54 dB down with a PEP output of 4 milliwatts. This is with an unshielded board not in a cabinet. At this frequency, I wouldn't expect to get much more local oscillator attenuation with the mixer and filters on the same board. It should be pretty easy to get the remaining 11 dB of required filtering out of any external amplifiers you intend to add. Of course, at the 4-milliwatt level, the transverter easily meets the numerical FCC spectral purity requirements. (The spectral purity requirement eases as the output power drops below 25 watts.) –15.5 dBm of drive is needed for +6-dBm output, indicating a gain of 21.5 dB. The pads used for the receive post amplifier can be used for a pi-network resistive attenuator on the transmitter version of the board.

I've been asked how critical are the voltages on the MMICs. Generally, they get more critical as the bias resistor value goes down. For example, a low-voltage device, such a MAR-6 or MAR-7, will operate with a pretty wide voltage swing. I'd expect a MAR-6 biased with a 470-Ω resistor to work with supply voltages between 9.5 and 12.5 volts. On the other hand, a MAV-11 biased with a 120-Ω resistor might only be expected to work well between 11.8 and 13.5 volts. At lower voltages, the power output might drop. 110-Ω resistors might be a little more appropriate for battery operation, changing the range to 11.3 to 12.8 volts. These are estimations based on the data sheet nominal specifications and resistor tolerances. A better analysis would include the MMIC variations as well. A low drop out regulator, such as the Linear Technology LT1085, may be worth considering for battery operation. This chip will deliver 3 amps with a input/output differential of as little as 1.5 volts. Previously hard to get, Digi-Key now stocks Linear Technology parts.[2] (Incidentally, while doing some research, I discovered that this company was apparently named after their first project, a digital keyer project that the authors supplied parts for.)

You might also consider reading what Al Ward has to say about MMICs in his paper "Performance Improvements for the Down East Microwave 540 MHz LO Module," published in the *Proceedings of the 38th Annual West Coast VHF/UHF Conference*. Other useful references on powering MMICs from batteries are:

P. Wade, N1BWT, "Improved Battery Regulation for No-Tune Transverters," North Texas Microwave Society *Feed Point*, March/April 1993. ($12 per year, Wes Atchison, WA5TKU sec/treas.)

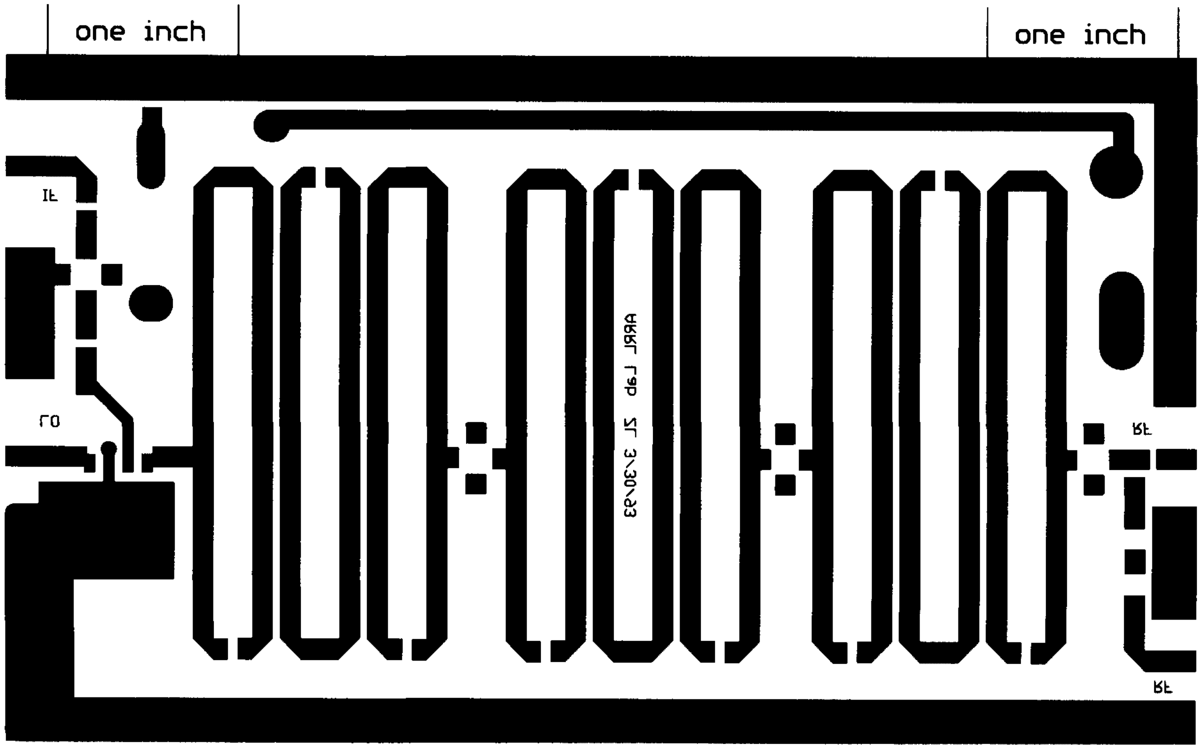


Fig 8—Printed-circuit board etching pattern for the receive and transmit converter boards.

```
*194 MHz Microstrip filter on G-10 board.
*At least 20 MHz bandwidth.
* Good rejection of 97 MHz and frequencies above 290 MHz


W50:109MIL
* 50 ohm stripline
WLINE:109MIL

SPACE:50MIL
*space between coupled lines

HEIGHT:?3064.69MIL?
*length of coupled lines

WIDTH:300MIL
*loop width

CPS:50MIL
*gap for capacitor

LTOP:((WIDTH-CPS)/2)

H1:?1362.39MIL?
*tap point for coupling to loop

H2:(HEIGHT-H1)

CRES:10pf
*resonating capacitance

LSTRAY:0.4NH
*the resonating capacitor has some inductance
*assocated with it.

BLK

   TRL     5 10      W=WLINE P=LTOP SUB1
   BEND   10 15      cut W=WLINE SUB1
*modeling the bends hopefully improves simulation
*accuracy

   TRL    15 20      W=WLINE P=H2 SUB1

   TEE    20 25 1    W1=WLINE W2=WLINE W3=W50 SUB1
*input tap point

   TRL    25 30      W=WLINE P=H1 SUB1
   BEND   30 35      cut W=WLINE SUB1
   TRL    35 40      W=WLINE P=WIDTH SUB1
   BEND   40 45      cut W=WLINE SUB1
   CPL    45 115 130 60 W=WLINE S=SPACE P=HEIGHT SUB1
   BEND   60 65      cut W=WLINE SUB1
   TRL    65 70      W=WLINE P=LTOP SUB1

   SLC     5 70      L=LSTRAY C=CRES

   TRL    105 110    W=WLINE P=LTOP SUB1
   BEND   110 115       cut W=WLINE SUB1
   BEND   130 135       cut W=WLINE SUB1
   TRL    135 137       W=WLINE P=(WIDTH/2) SUB1
   trl    137 140       w=wline p=(width/2) sub1

*A junction was added to look at grounding loops at
*a low impedance point.  Wasn't worth the bother with
*this particular topology.

   BEND   140 145       cut W=WLINE SUB1
   BEND   160 165       cut W=WLINE SUB1
   TRL    165 170       W=WLINE P=LTOP SUB1

   SLC    105 170       L=LSTRAY C=CRES

   CPL    145 215 230 160 W=WLINE S=SPACE P=HEIGHT SUB1

   TRL    205 210      W=WLINE P=LTOP SUB1
   BEND   210 215      cut W=WLINE SUB1
   BEND   230 235      cut W=WLINE SUB1
   TRL    235 240      W=WLINE P=WIDTH SUB1
   BEND   240 245      cut W=WLINE SUB1
   TRL    245 250      W=WLINE P=H1 SUB1
   TEE    250 255 2    W1=WLINE W2=WLINE W3=W50 SUB1
   TRL    255 260      W=WLINE P=H2 SUB1
   BEND   260 265      cut W=WLINE SUB1
   TRL    265 270      W=WLINE P=LTOP SUB1

   SLC    205 270      L=LSTRAY C=CRES


FILT:2por 1 2
end

freq
step 25mhz 900mhz 25mhz
step 97mhz 970mhz 97mhz
step 178mhz 210mhz 1MHz
end


data
sub1: ms h=59mil er=4.8 metl=cu 1.4mil rgh=100uin tand=0.020
end
```

Fig 9—*Microwave Harmonica* circuit description file.

```
MICROWAVE HARMONICA PC V5.5
File: \mh\222\194qex.ckt   20-MAY-93 05:21:14
```

Freq GHz	MS11 dB FILT	MS22 dB FILT	PS11 deg FILT	MS21 dB FILT	MS22 mag FILT	PS22 deg FILT
0.025	-0.0	-0.0	-20.4	-63.34	0.995	-20.4
0.050	-0.1	-0.1	-40.2	-57.54	0.991	-40.2
0.075	-0.1	-0.1	-58.6	-54.11	0.988	-58.6
0.097	-0.1	-0.1	-73.7	-51.46	0.987	-73.7
0.100	-0.1	-0.1	-75.7	-51.08	0.986	-75.7
0.125	-0.1	-0.1	-92.0	-46.97	0.984	-92.0
0.150	-0.2	-0.2	-109.4	-39.20	0.979	-109.4
0.175	-0.6	-0.6	-140.8	-20.82	0.934	-140.8
0.178	-0.9	-0.9	-149.8	-16.89	0.902	-149.8
0.179	-1.1	-1.1	-153.7	-15.44	0.885	-153.7
0.180	-1.3	-1.3	-158.1	-13.91	0.861	-158.1
0.181	-1.6	-1.6	-163.3	-12.32	0.830	-163.3
0.182	-2.1	-2.1	-169.4	-10.67	0.785	-169.4
0.183	-2.8	-2.8	-176.4	-9.01	0.724	-176.4
0.184	-3.9	-3.9	175.6	-7.40	0.640	175.6
0.185	-5.5	-5.5	167.2	-5.93	0.529	167.2
0.186	-8.0	-8.0	159.9	-4.71	0.398	159.9
0.187	-11.6	-11.6	157.6	-3.82	0.264	157.6
0.188	-16.0	-16.0	169.5	-3.24	0.158	169.5
0.189	-18.2	-18.3	-158.9	-2.92	0.122	-158.9
0.190	-17.1	-17.0	-137.3	-2.74	0.140	-137.3
0.191	-16.2	-16.2	-130.3	-2.63	0.156	-130.3
0.192	-16.5	-16.5	-126.5	-2.56	0.150	-126.5
0.193	-17.9	-17.9	-117.6	-2.50	0.127	-117.7
0.194	-19.2	-19.2	-94.1	-2.49	0.109	-94.2
0.195	-17.3	-17.3	-64.4	-2.55	0.136	-64.4
0.196	-13.7	-13.7	-51.5	-2.69	0.207	-51.5
0.197	-10.6	-10.6	-50.1	-2.94	0.295	-50.1
0.198	-8.3	-8.3	-53.6	-3.27	0.383	-53.6
0.199	-6.7	-6.7	-58.8	-3.66	0.463	-58.8
0.200	-5.5	-5.5	-64.6	-4.08	0.530	-64.6
0.201	-4.5	-4.5	-71.0	-4.58	0.594	-71.0
0.202	-4.0	-4.0	-76.6	-4.93	0.633	-76.6
0.203	-3.6	-3.6	-81.9	-5.21	0.658	-81.9
0.204	-3.5	-3.5	-87.0	-5.38	0.672	-87.0
0.205	-3.5	-3.5	-92.0	-5.43	0.672	-92.0
0.206	-3.6	-3.6	-96.7	-5.36	0.657	-96.7
0.207	-4.1	-4.1	-101.3	-5.17	0.624	-101.3
0.208	-4.9	-4.9	-105.1	-4.89	0.566	-105.1
0.209	-6.4	-6.4	-106.2	-4.59	0.481	-106.2
0.210	-8.3	-8.3	-99.1	-4.47	0.385	-99.1
0.225	-0.3	-0.3	-98.2	-25.84	0.961	-98.2
0.250	-0.2	-0.2	-118.1	-45.23	0.982	-118.1
0.275	-0.1	-0.1	-128.7	-60.29	0.985	-128.7
0.291	-0.1	-0.1	-134.0	-78.90	0.986	-134.0
0.300	-0.1	-0.1	-136.8	-75.56	0.986	-136.8
0.325	-0.1	-0.1	-143.6	-64.94	0.987	-143.6
0.350	-0.1	-0.1	-149.6	-62.69	0.987	-149.6
0.375	-0.1	-0.1	-155.2	-61.87	0.987	-155.2
0.388	-0.1	-0.1	-157.9	-61.69	0.987	-157.9
0.400	-0.1	-0.1	-160.4	-61.59	0.986	-160.4
0.425	-0.1	-0.1	-165.3	-61.58	0.986	-165.3
0.450	-0.1	-0.1	-170.0	-61.73	0.986	-170.0
0.475	-0.1	-0.1	-174.6	-61.99	0.985	-174.6
0.485	-0.1	-0.1	-176.5	-62.12	0.985	-176.5
0.500	-0.1	-0.1	-179.2	-62.36	0.984	-179.2
0.525	-0.1	-0.1	176.2	-62.85	0.983	176.2
0.550	-0.2	-0.2	171.5	-63.47	0.982	171.5
0.575	-0.2	-0.2	166.7	-64.28	0.981	166.7
0.582	-0.2	-0.2	165.4	-64.55	0.980	165.4
0.600	-0.2	-0.2	161.8	-65.35	0.979	161.8
0.625	-0.2	-0.2	156.6	-66.81	0.977	156.6
0.650	-0.2	-0.2	151.0	-68.89	0.974	151.0
0.675	-0.3	-0.3	145.1	-72.11	0.971	145.1
0.679	-0.3	-0.3	144.1	-72.79	0.971	144.1
0.700	-0.3	-0.3	138.6	-77.88	0.967	138.6
0.725	-0.3	-0.3	131.4	-87.60	0.963	131.4
0.750	-0.4	-0.4	123.3	-78.02	0.956	123.3
0.775	-0.5	-0.5	114.2	-74.74	0.949	114.2
0.776	-0.5	-0.5	113.8	-74.72	0.949	113.8
0.800	-0.5	-0.5	103.7	-76.69	0.939	103.7
0.825	-0.7	-0.7	91.5	-82.23	0.927	91.5
0.850	-0.8	-0.8	77.2	-56.29	0.910	77.2
0.873	-1.2	-1.2	62.8	-31.72	0.874	62.8
0.875	-1.2	-1.2	61.7	-30.87	0.874	61.7
0.900	-1.4	-1.4	42.3	-26.07	0.856	42.3
0.970	-2.0	-2.0	-4.1	-16.40	0.791	-4.1

Fig 10—*Microwave Harmonica* circuit analysis output.

M. Lee, KB6FPW, "An Adapter for Powering Hand-Held Rigs from 12-V Sources," *QST*, Nov 1989, 17-21.

Getting the Artwork

The printed circuit board artwork is available in Postscript format for those who can use it. You can download it from the ARRL BBS (203-666-0578, filename 220XVTR.ZIP) or via anonymous FTP on the Internet (ftp.cs.buffalo.edu, in the /pub/ham-radio directory). Although I'm on the Internet, it's not really practical for me to mail 1-megabyte files, even though its theoretically possible. If all else fails, send me two DOS 1.44 MB, 3½-inch formatted disks and a self-addressed, stamped return disk mailer, and I'll put the artwork on the disks and mail them back to you.

Converter Board Construction

The holes for the MMICs are 0.161 inches in diameter, suitable for the MAV-11. I used copper foil to connect the component-side ground foils to the ground plane through the MMIC mounting holes. Alternately, you could bend the MMICs' ground leads and solder them directly to the ground foil. 'C' wires are used to couple the by-pass capacitors to ground, though these probably aren't necessary if you choose to connect the top and bottom grounding foils with brass strip or copper foil around the edges of the board.

If you chose to build the high-intercept version of the receive converter, you may improve the sensitivity a dB or two by moving the filter down slightly in frequency. This can be done with 0.4- or 0.5-pF chip capacitors in parallel with the existing 10-pF chip capacitors. In many cases, no improvement will be seen, as the filter will be a little lower than designed anyway due to component tolerances. Still, there are those who insist on tuning no-tune transverters!

References

[1] B. Cooper, W5KHT, "Etch Inductance Band-pass Filters and Filter Preamplifiers for 50 and 144 MHz," *Ham Radio*, February 1971, 6-14.

[2] Digi-Key Corporation
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