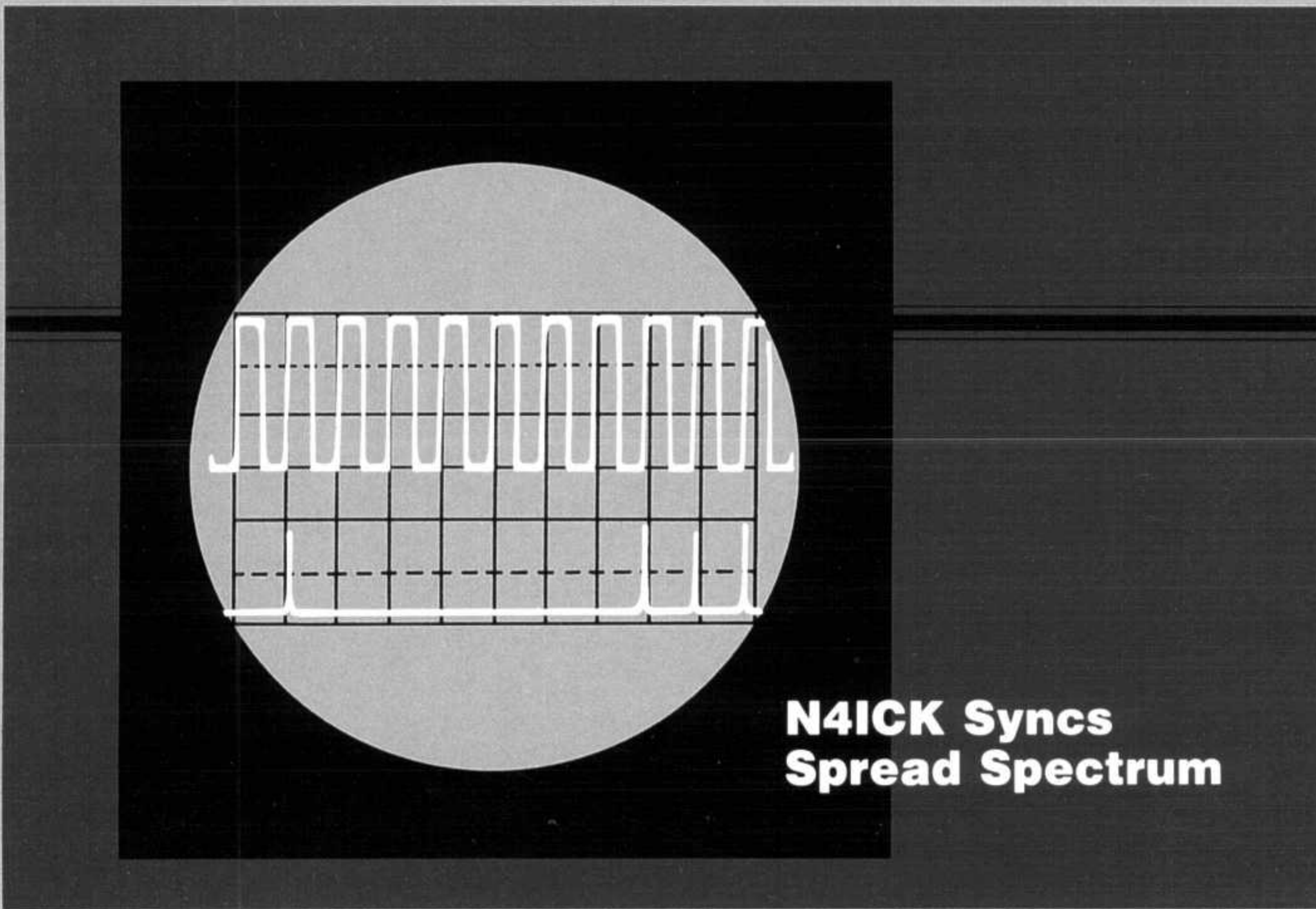
# QEX 88

$1.75

JUNE 1989

ARRL Experimenters' Exchange




**QEX:** The ARRL
Experimenters' Exchange
American Radio Relay League
225 Main Street
Newington, CT USA 06111

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US Postage
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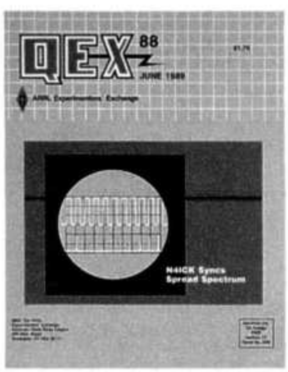

### ABOUT THE COVER

Drawing of what you would see on an oscilloscope when looking at N4ICK's clock-recovery scheme. Synchronous oscillator output is top trace, sync input pulses with 6 missing are at the bottom.


*QEX* (ISSN: 0886-8093) is published monthly by the American Radio Relay League, Newington, CT USA.

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Subscription rate for 12 issues:
In the US by Third Class Mail:
ARRL/AMSAT Member $10, nonmember $20;

US, Canada and Mexico by First Class Mail:
ARRL/AMSAT Member $18, nonmember $28;

Elsewhere by Airmail:
ARRL/AMSAT Member $38, nonmember $48.

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2) document advanced technical work in the Amateur Radio field
3) support efforts to advance the state of the Amateur Radio art.

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Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double 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*.

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## Empirically Speaking. . .

# Creative Consumption

These days it's easy to buy the things that our various whims and fancies are made of. We are a nation of consumers. Want a shiny new electronic watchamacallit? (What ham doesn't?) Visit the nearest dealer (if you're lucky enough to have one in your area), produce your plastic (credit card), sign for your purchase and out you go—the proud owner of a spanking new watchamacallit. No nearby dealer that you can visit? You can take your pick of mail-order companies with 1-800 numbers in *QEX* or *QST* that are eager to supply those electronic goodies. If you're willing to pay a bit extra, you can get your watchamacallit tomorrow.

Am I against this consumption of electronic goods? No way! In fact, I think it's great. Today we have an excellent variety of products and component parts available to meet our needs. When I first became a ham there was an electronics dealer within driving distance. Two of the counter men were hams. I used to go in there with my parts lists and schematics to buy the parts for the projects I wanted to build. The hams at the store would come up with what I needed, and when they didn't stock an item, they'd help me find a substitute. The store still exists, but the hams have retired, and you won't find the kind of helpful advice we used to get for our ham radio projects. Nowadays, I rely on those 1-800 numbers to get the parts and pieces for my ham station and those projects we all love. The selection of ready-to-go units and component parts is better than ever these days. You've probably noticed some of the highly specialized ICs that are on the market.

It's so easy to call that number and order the finished product—you know we can afford it—that we take the shortcut and buy something that we could build. It does save time, and there is something to be said for instantaneous gratification—but what about the joy and satisfaction that comes from the creative act of designing and building that electronic gadget? If you're a regular *QEX* reader, you're probably above average in technical interest and ability. Why not design and build that next project yourself? I'm not talking about a full feature, synthesized, all band transceiver. But you could tackle a QRP transmitter, a simple receiver or an accessory for the shack. Sure it's going to take some time for you to do the research, and the paperwork. After that you'll be building a prototype or two. When you're through you'll know that circuit inside out. You won't have to send it to the factory for repairs either.

As I said earlier, there's a wonderful variety of ICs available today and more appearing all the time. (We never bought such capability in a single active device from that old electronics store.) Do you ever try these new devices? Some imagination and experimentation may lead to unadvertised capabilities in those chips. Perhaps you remember the Simpleceiver (September 1986 *QST*). Author Bruce Williams, WA6IVC, wanted a simple receiver for CW and SSB. He experimented with an MC3359—a chip that is advertised as an FM receiver. Bruce noticed that the broadcast (quadrature) detector looks a lot like a product detector. In fact, through experimentation, Bruce found that it would serve that purpose. The "FM receiver" had become a CW/SSB receiver.

It takes time to design, build and debug a project. You may even spend a little more money in the process—not to mention wear and tear on your soldering iron. In the process you change. You are still a consumer, but you become a creative consumer. You purchase component parts and with your creative abilities and labor you turn them into a finished project. The product might not win a beauty contest but it's yours because you created it.

Can you put your skills and imagination to work and come up with your own project design? I think you can. Don't overlook undocumented capabilities in some of the new ICs. Imagine the satisfaction you'll gain. Think about it. Then call that 1-800 number, use your plastic and order some parts and start work on your own creation. You'll love it.—*K8CH*

# Impedance Bridge

By David L. Hanning, KD4FY
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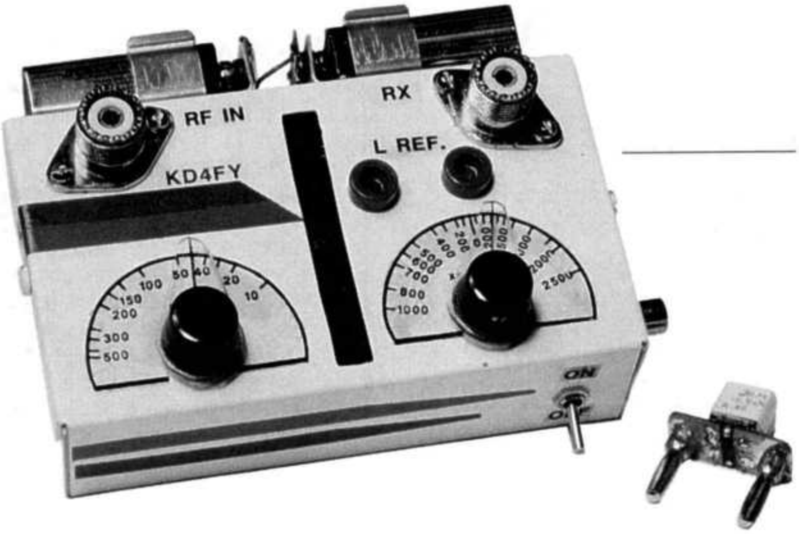
Huntsville, AL 35802




The project that I am about to describe is not new technology, but an application of modern circuit components to a traditional RF impedance bridge design, ie, to a modified Wheatstone Schering/Owen style bridge circuit. The original design and construction article, published by the American Radio Relay League, appears in the *ARRL Handbook* and is called, "The RF Impedance Bridge for Coax Lines." It is still one of the best impedance-measuring circuits designed for providing the radio amateur with a piece of equipment that exhibits reasonable accuracy at a low cost, compared to a commercial impedance bridge at today's prices.[1]

Like most hams, I am not practiced in using theoretical transmission-line equations, the employment of the Smith Chart to solve antenna-matching problems, or calculating the length of coax cable necessary to transform one impedance to another. This is not to say these tools are not important in the understanding of RF transmission theory or that an inexpensive impedance bridge is the ultimate substitute. However, a small easy-to-use piece of portable test equipment that does not cost in excess of $400 and satisfies the basic need to know which way to go in obtaining the desired result in antenna or transmission matching problems is what the average amateur needs.

The direct-reading impedance bridge is one that I most prefer over the use of the more popular "noise bridge," ie, hybrid coil,[2] that we see advertised. One of the basic drawbacks of the noise bridge is its propensity for false readings and the extreme sensitivity of the null readings, coupled with the requirement that you must use a quality communications receiver when you are making the measurement.

Additionally, the noise bridge must compete with RF background QRM and usually aggravates the process of finding the proper null. This is all I will say about the noise bridge because it has its special place in the ham's arsenal of satisfactory test equipment. This article was not intended as a comparison study of the various impedance-measuring devices offered in the marketplace today.

As most hams have discovered in this day and age of high-tech products, the components for a conventional direct-reading impedance bridge are becoming more and more difficult to find. The requirement for a split variable differential capacitor in the correct range will cause most enterprising hams to give up the project immediately. To a lesser degree, finding the proper coil forms to use as the reference inductance can prove difficult, however, this is more of a minor inconvenience. Needless to say, this was sufficient to get the creative juices running on how to approach this problem. As they say "necessity is the mother of invention" and several ideas were considered. One was to substitute the split differential capacitor with two mechanically coupled variable capacitors. However, this was not exactly the solution for a small compact, easy-to-build and very low-cost impedance bridge.

For the past few years, the electronic industry has been using tuning diodes for automatic RF tuner applications, both in low-cost AM/FM car radios, VHF/UHF receiver units and scanners.

The idea was now fixed in my mind: Why not use Varactor tuning diodes to accomplish the task of tuning the three arms of a modified impedance bridge? Using the same concept that has served the hams for so many years, using mechanical devices could be translated into modern Varactor-diode theory. In addition, this concept could open up a number of interesting interface circuits to computers for direct automatic readout of impedance values in complex notation, ie, (R ± j).

First, let me set the record straight for the purist crowd. This was not intended to be the ultimate replacement for a precision, manually operated, direct-reading impedance bridge similar to a General Radio 916A or 821A or a vector phase meter.

### Basic Bridge Theory

The type of ac bridge commonly used to measure complex impedance elements is the modified Owen bridge which is also similar to the Schering bridge.[3] See Figs 1 and 2.

A vast number of combinations of circuit elements can be used to measure direct capacitance or inductive reactance. Moreover, a large number of bridge circuits utilize special balancing circuits across the RF input to the bridge to reduce errors in measurements.[4] We will not go into these various circuits other than to mention them in reference for additional reading and investigation.

One can ascertain, by close examination of Figs 1 and 2 that no one combination of these bridge circuits will fill the

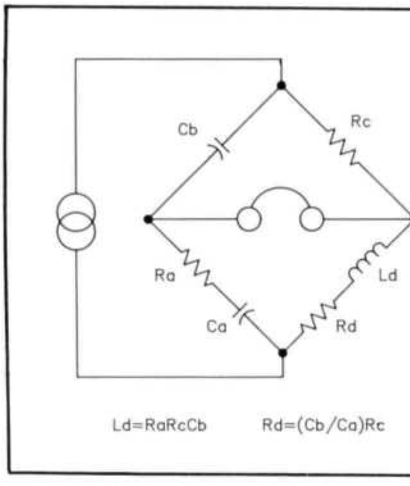



Fig 1—Basic A C Bridge Circuit

[1]Notes appear on page 6.

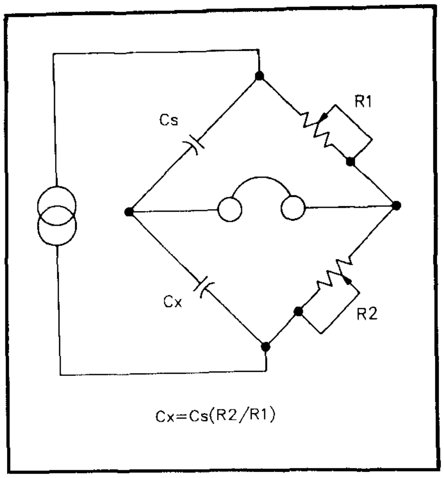



Fig 2—Basic Owen Bridge

bill for the measurement of both capacitance and inductive complex impedance values.

## The Varactor Bridge

Fig 3 shows the completed bridge design. The principle factor in any bridge design is to eliminate the stray capacitance and inductive effects in or near the bridge elements themselves and the stray L and C components caused by external connections to the bridge elements, ie, RF excitation and the output measurement of the unbalance error voltages. These all contribute to errors in calibration between 2 MHz and 30 MHz. This now becomes a major consideration in the use of Varactor tuning diodes because the lead lengths can be kept very short and the Q values are very predictable. One of the most interesting things a well constructed impedance bridge will show is, if very low Q values are used for the standard reference inductance, large offset errors in the positions of the reactive components used in the resistance arm of the bridge will be observed. Special care must therefore be used in the design of the inductors used for the lower frequency calibration points.

The standard coil should have a minimum Q of 100. Q values below 100 are not recommended and litz wire should be used on the lower frequency coils.[5] The Q figure of merit values for the Varactor diodes are typically near 1000 in the mid operating voltage range and as low as 600 for the low voltage range.[6]

I have found null sharpness to be slightly better than the mechanical bridge for the reactance arm of the bridge. Both the mechanical bridge and the Varactor ¼bridge behave very much the same. However, because of the wider control range of the varactor diodes as relates to capacity tuning ratio, a greater range of $X_C$ or $X_L$ values can be measured. The Varactors should be temperature compensated and a stable power supply used

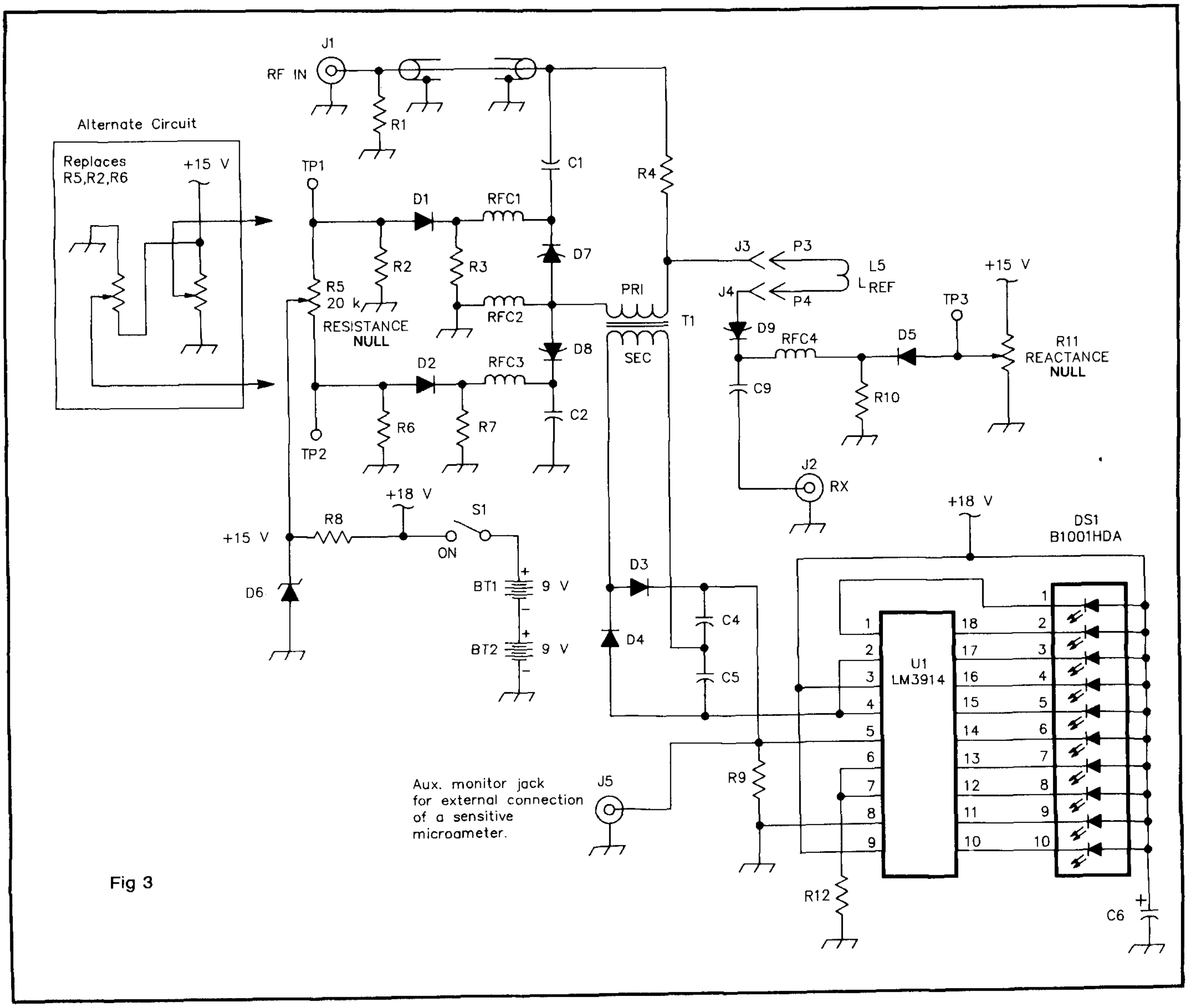
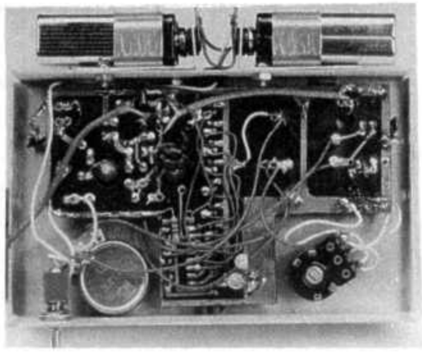



Fig 3

for the control voltages. No attempt was made to refine the drift compensation other than to use a standard 1N914 diode in series with the varactor diodes, with a 20-kΩ resistor to ground to bias the diode at some current level.[7] There has been much literature written on this subject, so I will only reference this for the reader's further investigation. Balance Varactor tracking in the resistance arm of the bridge circuit is quite adequate, however, dual matched Varactor elements can be purchased to help improved the performance. The Varactors used in this design are called Hyperabrupt, and the one chosen for this application is a Motorola MVAM115, a common 50-cent diode.[8] I found the repeatability very good and capacitance tracking between D7 and D8 reasonable. Special mention should be made that the circuit consisting of R2, R6 and R5 can be replaced with a dual linear-taper potentiometer for improved performance.

The bridge output circuit was accomplished by using a wide-band ferrite transformer with a voltage doubler coupled to the secondary winding using 1N34A diodes. One peculiarity of this bridge is the use of high-capacitance low-reactance dc blocking isolation capacitors in series with the Varactors. This provides ideal isolation. If the values of $X_C$ are very low compared to the Varactor impedance of D7, D8 and D9 at 160 m, there is little influence on the bridge circuit elements if capacitance values change with temperature. However, high quality, low dissipation, low-internal-resistance capacitors should be used in the design. RFC1, RFC2, RFC3 and RFC4 are used to isolate the bridge RF circuit from the Varactor dc control voltage circuit. The dc control path provided for D9 is through the wideband output transformers primary winding to ground via the RFC2.

Transformer TI must be wound in such a way that will provide isolation between the primary and secondary windings. This is necessary to eliminate the effects of stray capacitance reactance to ground, causing serious detuning of the bridge elements. The ideal condition exists when R5 will balance the bridge at equal-potential



dc voltages across R2 and R6.

Special mention should be given to the use of the LED bar-graph display and driver in place of a sensitive direct-reading microamp meter. This was strictly a trade-off for those folks who may find the source for a 50-μA meter to be most difficult to find and of a miniature variety. The bar-graph display is very inexpensive and the 10-dot driver can be found in most electronic parts stores.[9]

In the reactance arm of the bridge, D9 is set to a value near 90 pF. This allows a satisfactory range in both capacitive and inductive values to be achieved. This setting depends greatly on the type of Varactor chosen along with the characteristic slope of control voltage verus capacitance values. The resistance arm of the bridge can be experimented with in the selection of the values for R2 and R6 to achieve the desired range. There is a sacrifice, however. You cannot achieve very large values of resistance measurements because of the typical cutoff point for low values of C, ie, the capacitance versus voltage control curve for the particular varactor diode chosen cuts off at around 25 pF at 14 V dc.

### Construction

All the components were mounted in a 5-1/4 inch long by 3-1/8 inch wide by 1-5/16 inch high aluminum box. This makes for a very compact unit that is no larger than most of the present noise bridges offered on the marketplace today.

All the components are mounted on a one-sided printed board, with holes drilled out to accept the RF input connector, the RF load and the L reference inductor. No special consideration was given to the placement of the components, however, all the critical RF bridge components were grouped together with short copper runs. The RF input connection to the bridge was made by a short length of coax cable wired from the UHF connector to the bridge components.

The reference inductors were constructed using shielded coil forms equipped with powdered-iron slugs. I found these coils provided the necessary high Q and reasonable inductance per turn needed to adjust the reference inductance for each different frequency and they were very easy to mount to a small PC board equipped with banana plugs. There is nothing special about using your own method to achieve the same result as long as the Q of these coils is high. Q values above 100 for the lower frequency bands are very difficult to achieve with the small size coil forms, so I would recommend some other coil design below 7 MHz. I found that a ferrite toroidal core works very good, and very high Q values can be obtained, however, tuning these coils is a problem. It is possible to use a tapped coil using a small printed-circuit data switch mounted in a small plug in assembly to switch to various tap positions on the coil to change the inductance for a sharp null.

The RESISTANCE NULL and REACTANCE NULL adjustment potentiometers are mounted such that the calibrated scales are observed from the top of the unit. I found this very convenient, because the bridge output null indicator is mounted flush with the chassis, so you are usually looking down on the bridge while making the null readings. This allows you to see the resultant position of the calibrated dials as you tune the bridge.

As can be seen by the circuit schematic diagram, the bridge requires two 9-volt batteries. This is to allow for the wide swing in control voltage necessary to control voltage obtain the full range of Varactor-diode capacitance.

These are mounted to the outside of the box with the power wires running into the box through a rubber grommet.

One passing suggestion to the builder: I would suggest that a small adjustment

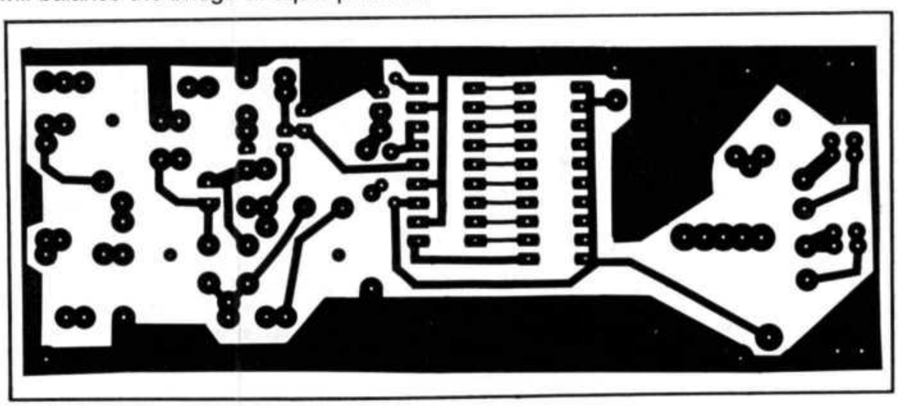


Fig 4A—Varactor bridge circuit board, component side.

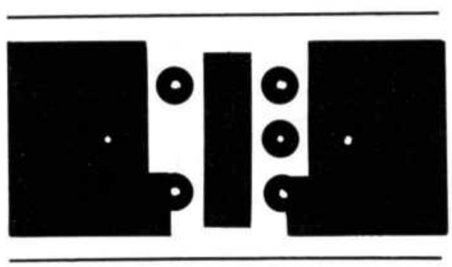


Fig 4B—L5 plug-in templet.

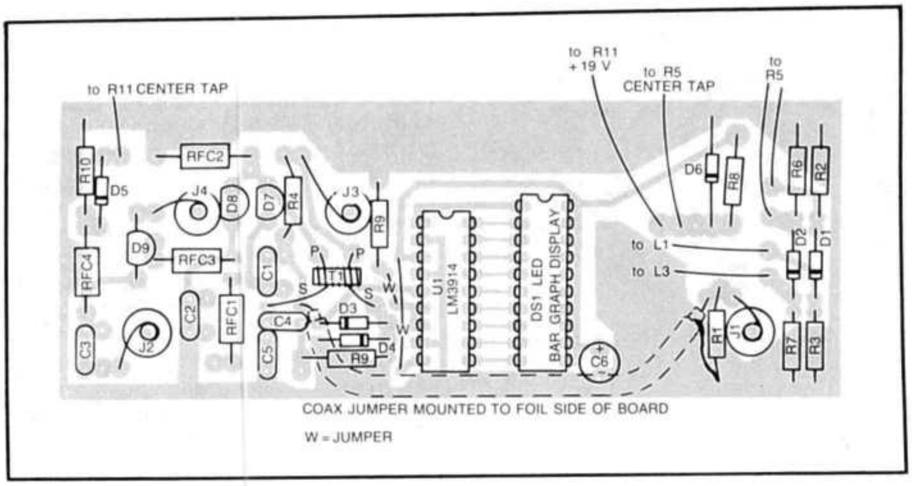



Fig 5—Note: there are no components mounted to the foil side of the printed circuit board

potentiometer be wired from the RF input connection to the bridge to adjust the RF level.

## Bridge Calibration

The impedance bridge is quite easy to adjust and calibrate. The first procedure is to adjust for the 50-ohm calibration position of the resistance arm and the zero-reactance point of the reactive arm of the potentiometers R5 and R11. The resistance arm should be centered by measuring the voltage across TP-l and TP-2. The voltage should equal approximately 2.25 volts when the potentiometer is at the midpoint position. The bridge should null exactly at 50 ohms. Minor adjustments can then be made when the actual resistance standards are placed across the bridge for final calibration.

The reactance potentiometer R11 should be adjusted for a 9-volt dc reading at the tap or the connection to the diode D5 test point TP-3. This is now the center position or the zero reactance position for the reactance adjustment potentiometer.

Calibration of this bridge is the same as used in the *ARRL Handbook*. For those that may not have a copy handy (God forbid), I will take editorial liberties of repeating this procedure, with a flavor slanted to this particular bridge design.

The resistance dial of the bridge may be calibrated by using a number of ½ or 1 watt 5-percent-tolerance composition resistors of different values in the 5-200 ohm range as loads. For this calibration, the appropriate frequency coil must be inserted at J3 and its inductance adjusted for best null reading on the Bar graph meter or external 50 microammeter when R11 is set to the zero reactance position (see text). For each test resistor, R5 is then adjusted for a null reading. Alternate adjustment of L5 and R5 should be made for a complete null. The leads between the test resistor and J2 should be as short as possible and the calibration preferably should be done in the 3.5-MHz band where stray inductance and capacitance will have the least effect.

The calibration of the reactance dial can be accomplished by connecting various reactances of known value in series with a 47-ohm 1-watt resistor connected at J2. Begin the calibration by setting R11 at the zero reactance point (see text). With a purely resistive load connected at J2, adjust L5 and R5 for the best null. From this point on during calibration, do not adjust L5 except to rebalance the bridge for a new calibration frequency. The ohmic value of the known reactance for the frequency of calibration is multiplied by the frequency in MHz to obtain the calibration value for the dial.

## Using the Impedance Bridge

I have measured the minimum power to activate the bar dot display to be less than 0.005 watts. This is slightly more than is required using a 50 μA meter. I would suggest that if a sensitive meter is available, use this when doing the initial calibration of this bridge. Once again I will yield to the excellent write up on the use of this type of bridge circuit, so I will repeat most of the text in its original form, from the *ARRL Handbook*

### Using the Impedance Bridge

This instrument is a low-input-power device, and is not of the type to be excited from a transmitter or left in the antenna line during station operation. Sufficient sensitivity for all measurements results when approximately 0.005 watts of RF signal is applied at J1. This amount of power can be delivered by most grid-dip oscillators. In no case should the power applied to J1 exceed 1 watt or calibration inaccuracy may result from a permanent change in the value of R5. The input impedance of the bridge at J1 is low, in the order of 50 to 100 ohms, so it is convenient to excite the bridge through a length of 52-75 ohm line.

Before measurements are made, it is necessary to balance the bridge. Set the reactance dial at zero and adjust L5 and R5 for a null with a nonreactive load connected at J2. The bridge must be rebalanced after any appreciable change is made in the measurement frequency. After the bridge is balanced, connect the unknown load to J2, and alternately adjust R5 and R11 for the best null.

**Varactor Bridge References**

[1]J. Hall, ed., *The 1984 Radio Amateur's Handbook*, (Newington: ARRL, 1983) Chap 16.
[2]*Reference Data for Engineers*, (Indianapolis: Howard W. Sams, VII Ed), Chap 12-3.
[3]Slurzberg and Osterheld, *Essentials of Electricity*, (New York: McGraw-Hill, 2nd Ed), Chap 6-17.
[4]Henry Jasik, *Antenna Engineering Handbook*, (New York: McGraw-Hill, 1st Ed), chap 34.
[5]Amidon Associates data sheet available from Amidon Assoc, 12033 Ostego St, N Hollywood, CA 91607, tel 818-760-4429.
[6]Motorola Application notes.
AN-55 Tuning Diode Design Techniques.
AN-544A Printed Circuit VHF Tuners Using Tuning Diodes.
AN-847 Tuning Diode Design Techniques.
AN-249 Designing Around the Tuning Diode Inductance.
[7]See note 6.
[8]Motorola data sheet for the MVAM-115 tuning diode.
[9]National Semiconductor data sheet for the LM3914 Dot/Bar display driver.

Circuit boards are available from the author. For prices, send an SASE directly to the author. Please do not call for prices. *QEX* and ARRL in no way warrant this offer.

**Varactor Diode Bridge Parts List**

C1,C2,C3—0.22 μF capacitor Erie CKO6BX224K.
C4,C5—0.10 μF capacitor Erie CKO5BX104K.
C6—2.2 μF tantalum capacitor (Radio Shack 272-1435).
D1,D2,D5—Silicon diode 1N914 (Radio Shack 276-1122).
D3,D4—Germanium diode 1N34A (Radio Shack 276-1123).
D6—1N4744 15-V, 1-W Zener diode (Radio Shack 276-564).
D7,D8,D9—Varactor tuning diode (Motorola MVAM115 NTE #618).
DS1—LED bar-graph display (Radio Shack 276-081).
J1,J2—SO-239 chassis-mount connector (Radio Shack 278-201).
J3,J4—Chassis-mount banana jack (E. F. Johnson 108-0902-001, Digi-Key part J151).
J5—Chassis-mount phono jack (Radio Shack 274-346).
L5—160 m Miller 4207 or alternative part use Toko inductor 154ANS-T1020Z (Digi-Key TK1218).
80 m Amidon Associates L-43-1, 51 turns no. 30 enam wire.
(scramble wound) or alternative part use Toko inductor
154ANS-T1013Z (Digi-Key TK1211).
40 m Amidon Associates L-43-2, 25 turns no. 30 enam wire or
alternative part use Toko inductor 154ANS-T1006Z (Digi-Key TK1204).
20 m Amidon Associates L-43-6, 13.5 turns no. 26 enam wire or alternative part us Toko inductor BTKANS-9449HM (Digi-Key TK1412).
15 m Amidon Associates L-43-6, 9 turns no. 26 enam wire or alternative part us Toko inductor BTKXNS-T1049Z (Digi-Key TK1409).
10 m Amidon Associates L-43-6, 6½ turns no. 24 enam wire
or alternative part use Toko inductor BTKXNS-T1047Z (Digi-Key TK1406). R1—4.7 kΩ ½ W 5% carbon comp.
R1—4.7 kΩ ½ W 5% carbon comp.
R2,R6,R12—1 kΩ ¼ W 5% metal oxide film.
R3,R7,R10—20 kΩ ¼ W 5% metal oxide film.
R4—51 Ω ½ W 5% carbon comp.
RFC1, RFC2, RFC3, RFC4—RF choke 2.2 mH (J. W. Miller 70F223A1).
R8—200 Ω ½ W 5% metal oxide film.
R9—100 kΩ ¼ W 5% metal oxide film.
R5,R11—10-kΩ linear-taper, molded-composition.
S1—SPST toggle switch
T1—Wideband transformer, Amidon Associates FT-37-61. Primary 10 turns no. 24 enam wire. Secondary 20 turns no. 30 enam wire.
U1—LED bar-graph display driver (National LM3914).

# Practical Spread-Spectrum: Clock Recovery With the Synchronous Oscillator

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### Introduction

Clock recovery circuits are usually built around convolvers, such as surface acoustic wave devices, or phase-lock loops such as Costas loops, $\tau$-dither loops etc (see references 1, 2). The formers tend to be extremely expensive and therefore out of the reach of radio amateurs, while the latters can be quite complicated and are inclined to work better when the clock information is present most of the time.

When, however, synchronization information is missing, a large portion of the time (ie, in the presence of heavy interference, or long pseudorandom sequences) most PLLs revert quickly to their free-running frequency, thus producing output jitter.

A simple solution to the above problem is the Synchronous Oscillator (SO), an interesting and simple circuit which can be used for clock recovery. This article describes its principle, as well as a test apparatus designed to evaluate the SO's practicality, ease of use, and performance.

### The Basic Circuit

Referring to Fig 1, the Synchronous Oscillator is basically a modified Colpitts oscillator with an extra transistor in its emitter-to-ground path. It has two positive feedback paths: one from the junction of the two capacitors in the collector tank circuit back to the emitter of the upper transistor; the other one from the junction between the tank coil and the RF choke back to the base of the transistor. The operation of this circuit is described in detail in references 3, 4 and 5. Briefly, the upper transistor is a free-running sinusoidal oscillator operating in class C. It thus conducts only during very short periods of time. Whenever it draws current, it develops a voltage across the bottom transistor, and allows the latter to conduct. Therefore, of all the signals applied to the base of the bottom transistor, only those which appear during that very short "time-window" which is the moment of conduction, can be amplified by the bottom transistor and used to synchronize the upper one. This "coherent amplification" arrangement explains the excellent noise rejection characteristics of the SO. (Such a circuit is used for carrier recovery in my 440 MHz direct-sequence spread-spectrum link, published in the May 1989 issue of *QST*.) Note that, contrarily to what happens in a phase-lock loop, in an SO the input signal directly synchronizes the output signal.

### The Clock Recovery Circuit

Clock recovery circuits do not generally need the ability to work with noisy signals, a quality usually demanded of carrier-recovery circuits, and it is thus possible to further simplify the SO (see Fig 2). The tuned circuit in the collector introduces a flywheel effect which supplies the stability required to produce steady output clock pulses in the momentary absence of input synchronization pulses.

### Practical Application

To put the SO to the test, an apparatus was built which generates an incomplete train of synchronization pulses. (In other words, properly timed synchronization pulses are produced, but some of them are purposely deleted.) The general arrangement is shown in Fig 3, while the actual circuit is shown in Fig 4.

U1, a crystal oscillator operating at 2 MHz is used to drive a seven-stage pseudorandom noise (PN) generator of the kind used in most of my spread-spectrum equipment. The PN generator consists of U2, a 74164 shift register, while two sections of U3, a 7486, are used as an XOR and inverter stage (see reference 6 for a more complete description of the PN generator used). This PN sequence is fed to an "edge-detector" consisting of U4, another 7486 XOR integrated circuit. Three of the four gates are connected in series, and their cumulative propagation delay is put to good use to retard the incoming pulse. This pulse and the original pulse are XORed in the fourth section of U4, and a short output pulse is thus created for each input transition. Since the output of a seven-stage pseudonoise generator presents at times up to six "0" or six "1"

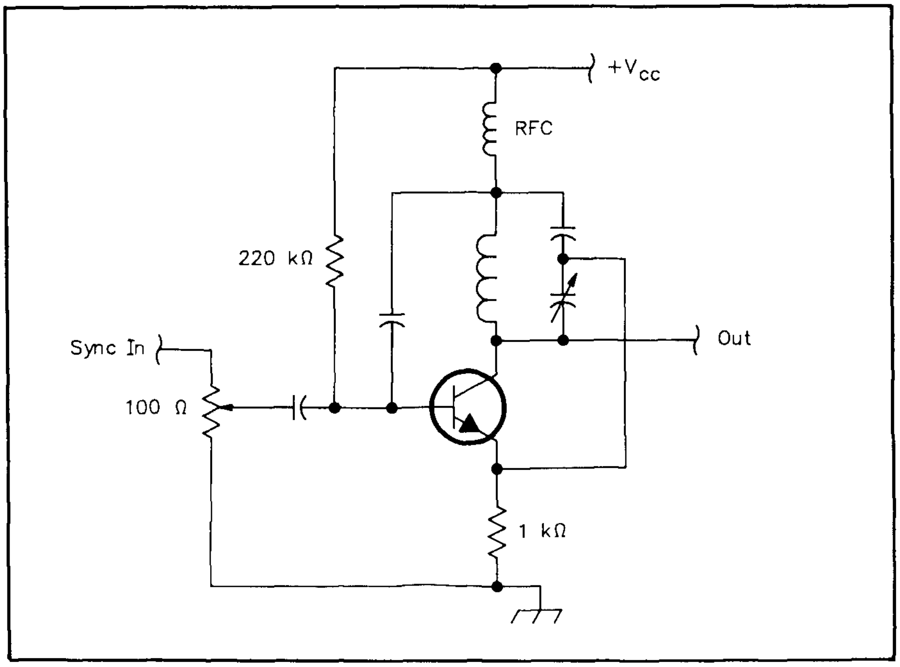


Fig 1—The Synchronous Oscillator. Component values depend on frequency of interest and transistors used.

[1]Notes appear on page 9.

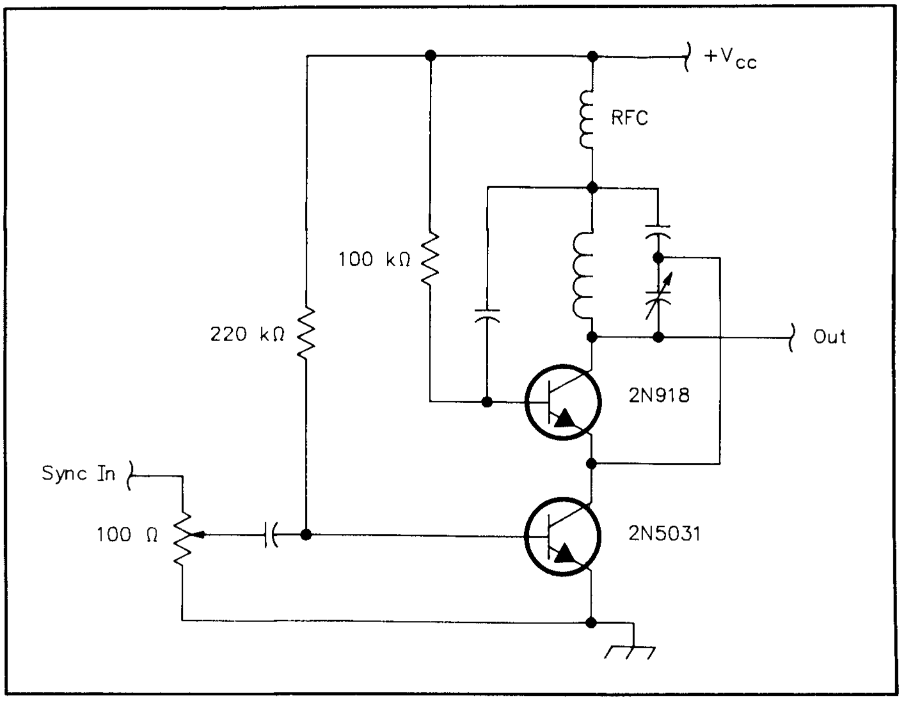


Fig 2—Simplified Synchronous Oscillator for clock recovery.

in a row, the edge-detector will create a pulse train with up to six synchronization pulses missing from time to time.

This latter pulse-train is the synchronization information supplied to our SO. It is displayed on the lower oscilloscope trace of Fig 5. One of the characteristics of the SO, which consists of Q1, is that it is a sine-wave oscillator whose output amplitude is always constant throughout the synchronization range. Since the output amplitude is constant, it is acceptable to feed it to a CMOS Schmitt trigger (U5, a 74HC14) without fear of output jitter. (Which would otherwise result from variable trigger points due to the ceaselessly varying slope of a variable amplitude signal, should such a signal be used.) The output of the Schmitt trigger stage is a 2-MHz square wave shown on the upper oscilloscope trace of Fig 5. Notice that, although 6 synchronization pulses are missing, there is no visible jitter on the traces in the interval between sync pulses.

### Construction

The circuit described above was constructed on perforated phenolic board, using point-to-point wiring techniques and generally following good HF wiring practices, particularly with regard to grounding and decoupling. If it is desired to recover clock frequencies much above 50 MHz, the circuit can be scaled up, but it will be necessary to use Schmitt triggers made of discrete components (such as MPF102 FETs). Similarly, VHF transistors (such as the 2N918) should replace the 2N2222 used for Q1.

### Adjustments

A digital frequency counter is connected to the output of U4 (pin 11). The wiper of R1, the potentiometer used to adjust the amount of sync signal applied to the SO, is first turned all the way down to ground. The slug of L2 is then adjusted to bring the free-running frequency of the SO near the target frequency (in our case, 2 MHz). The variable capacitor C1 is then adjusted until the output frequency, read on the frequency meter, is as close as possible to the target frequency (say plus or minus 5 kHz, or between 1,995 and 2,005 MHz). The input signal is then slowly increased by means of R1. After less than ¼ turn, the frequecy meter will suddenly display the target frequency, as the SO has reached lock.

If a dual-trace oscilloscope is available, connect channel B to the output of the edge-detector U4, connect channel A to the output of U5 and synchronize on channel A. The channel (the upper trace on Fig 5) will display a square wave, while the other trace will be fuzzy. As you slowly turn up R1, the lower trace (channel B) will suddenly synchronize with the bottom trace, as shown on Fig 5.

### Tracing Range

To simulate the effects of a Doppler shift in input frequency (satellite operation, for instance), the crystal oscillator was replaced by a variable-frequency oscillator. Which the values shown on Fig 4 and the circuit adjusted for a free-running frequency of 2 MHz, the tracking range (ie, the bandwidth within which synchronization takes place without returning) extended from 1.986 MHz to 2.015 MHz. This 1.5 tracking range is generally in agreement with measurements reported in references 3 and 4. Several

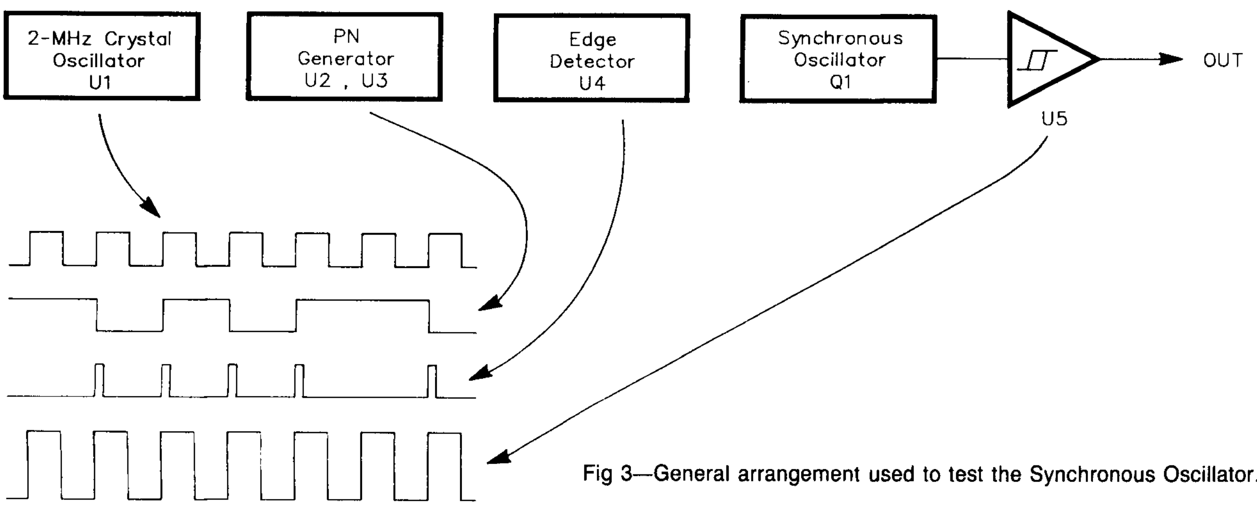


Fig 3—General arrangement used to test the Synchronous Oscillator.

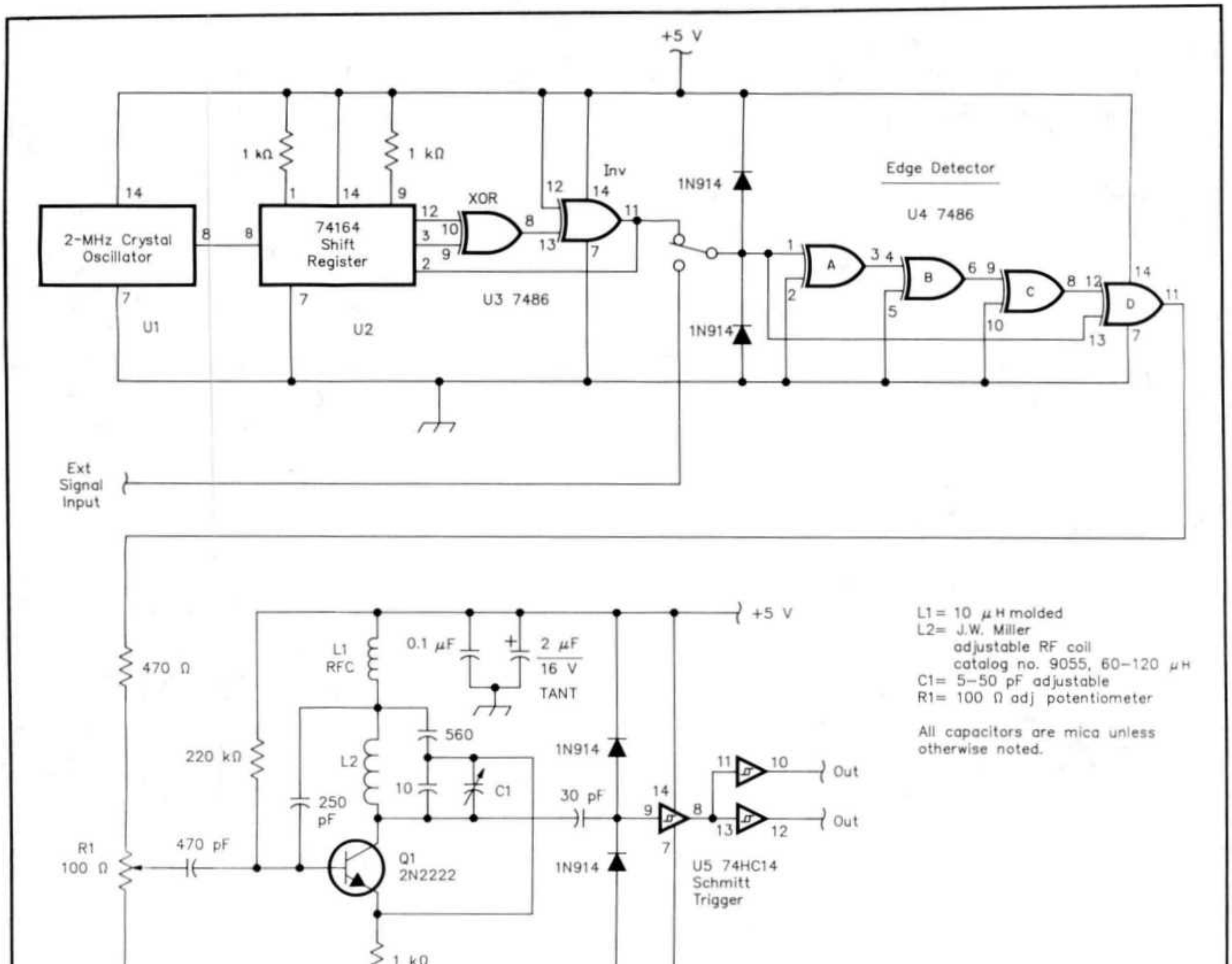


Fig 4—Schematic of the equipment used for test purposes.

typical synchronization curves have been published in reference 3. It should be kept in mind that the tracking range depends on the level of the synchronization signal at the input, and on the Q of the collector tank circuit. (Incidentally, per reference 7, the maximum doppler shift created by amateur radio satellites is typically less than 0.006 which is but a fraction of the tracking range available with the SO.)

## Conclusion

The SO is a circuit remarkable both for its performance and its simplicity of construction. The reader is encouraged to breadboard a SO to appreciate its ease of use. (If a commercial application is contemplated, the reader should note that the SO is covered by several US patents, see note 8.)

I am indebted to Professor Marvin White (of Lehigh University) and Mr. Vasil Uzunoglu (formerly with Fairchild Communications), the co-developers of the Synchronous Oscillator, for their encouragements and stimulating discussions.

### References

[1]R. Dixon, *Spread Spectrum Systems*, (New York: Wiley) 2nd Ed, 1984, pp 186-187 and pp 232-234.

[2]R. Best, *Phase-Locked Loops*, (New York: McGraw Hill) 1984, pp 212-217.

[3]V. Uzunoglu and M. White, "The Synchronous Oscillator: A Synchronization and Tracking Network," *IEEE Journal of Solid State Circuits*, Vol SC-30, No. 6, Dec 1985, pp. 1214-1224.

[4]V. Uzunoglu and M. White, "Some Important Properties of Synchronous Oscillators," *Proceedings of the IEEE*, Vol 74, No. 3, Mar 1966, pp 516-518.

[5]A. Kesteloot, "Extracting Stable Clock Signals from AM Broadcast Carriers for Amateur Spread-Spectrum Applications," *QEX*, October 1987, pp 5-9.

[6]A. Kesteloot, "Practical Spread-Spectrum: A Simple Clock Synchronization Scheme," *QEX*, October 1986, pp 4-7.

[7]M. Davidoff, *The Satellite Experimenter's Handbook*, (Newington, CT: ARRL), 1984, pp 10-3 to 10-5.

[8]US Patents 4,274,067; 4,355,404; 4,356,456.

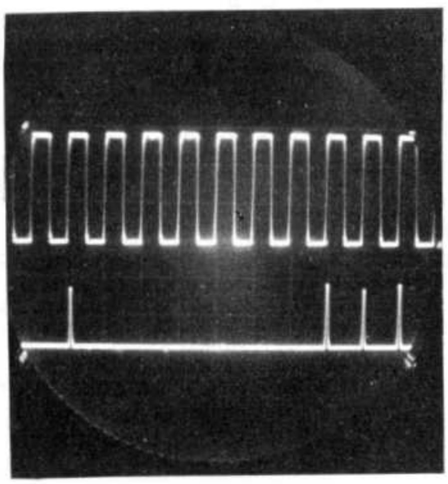

Fig 5—The upper oscilloscope trace shows the output of the Synchronous Oscillator (U5, pin 8) while the lower trace shows the train of synchronization pulses. Note that there is no visible jitter on the output signal in the absence of input signal. Horizontal scale: 0.5 μSec/division.

# Nonlinear Applications Using the Avantek MMICs

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and

Marcus Wagner, N5GEJ
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Aubrey, TX 76227

The Avantek line of monolithic microwave integrated circuits has revolutionized the design of both microwave receivers and transmitters. These low-cost gain blocks have been used both as low-noise amplifiers and in moderate power output applications. Although designed as linear class A amplifiers, these devices can also be used in several nonlinear applications such as oscillators, mixers and multipliers.

Avantek has introduced two lines of MMIC mixers: the MSF-86 series for applications to 1.5 GHz and the MSF-88 series for mixer applications to 4 GHz. These devices are similar to their MSA-06 and MSA-08 counterparts except that they are characterized and tested specifically for mixer applications.

The original application of the devices was as a self-oscillating mixer (SOM), whereby a portion of the output was fed back to the input at the proper phase to sustain an oscillation. At lower frequencies this was accomplished by use of a series R/L/C network, whereas at 4 GHz, as an example, a dielectric resonator plus two microstriplines produced the feedback network. Once the device is oscillating, all that is required to mix is to inject an RF signal at the input port of the device and collect LO ± RF or RF ± LO (depends on high side versus low side LO injection) at the IF port. Of course, due to gain roll-off of the basic device, the mixer provides better conversion gain when used as a downconverter. This device has been used successfully in many C band TVRO block downconverter designs. If desired, the SOM can be phase locked to a stable reference source for increased frequency stability.

This note will cover the use of the MSF-8885 MMIC as a single-ended active mixer. Since the frequency stability of the SOM is not adequate for narrow-band CW or SSB signals, it was decided to try the device as a single-ended mixer with external LO drive. The MSF-8885 is in the inexpensive 0.085-inch-diameter plastic package. The device was tested as a downconverter at frequencies as high as 10.368 GHz and with IFs as high as 2304 MHz. As with any single-ended mixer,

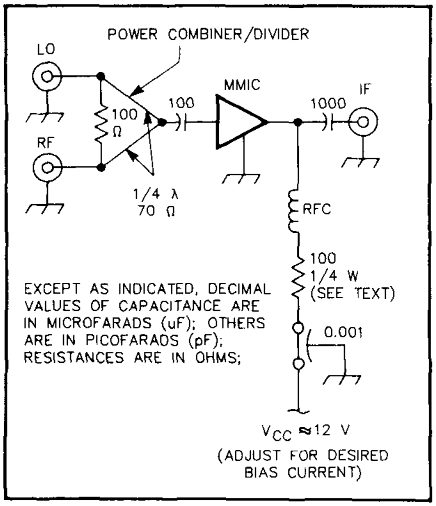



**Fig 1—MMIC Downconverter. RFC is 5 turns, no. 24 wire, 0.125 inch ID spaced 1 wire diameter. $V_{cc}$ should be adjusted for the desired performance, then the bias resister can be optimized for a particular power supply voltage.**

external filters must be used to establish isolation between the LO, RF and IF ports. Typically a low-pass filter is used on the IF port to keep the RF and LO levels below some acceptable level. Remember that the mixer also acts as an amplifier and can amplify the LO drive up to 10 dB! Similarly, band-pass filters can be used at the RF and LO ports to offer image rejection and LO-to-RF isolation.

For the purpose of measuring conversion gain and single sideband noise figure, the simple test setup shown in Fig 1 was constructed. A broadband power divider was used on the input port of the MMIC. This combines the LO and RF signals with a 3 dB loss in each path. The IF was obtained at the output port of the MMIC where the bias decoupling was optimum for VHF frequencies. From the standpoint of stability, it would be best to not incorporate RFC but instead use a larger value resistor at R1, such as 270 ohms. This will limit the maximum current that can be pulled from the power supply but this may or may not be a problem, depending on the frequency of operation. If possible it is best to present the 08/88 series devices with a resistive load to retain stability.

Table 1 summarizes the results for various amateur bands with a 144 MHz IF. These tests were run on an HP8565A spectrum analyzer. Conversion gain was optimized by varying the LO power and the dc bias current. Note the conversion gain of 8 dB at 2304 MHz with a 144 MHz IF. Even at 10,368 MHz the conversion loss is only 3.8 dB. This is still superior to a typical doubly balanced mixer at a fraction of the cost. Note that as the IF is increased the conversion gain decreases. This suggests that the MSF MMIC offers better conversion gain as a downconverter as opposed to an upconverter.

Another advantage of the active mixer is the reduced LO drive requirements. Typically the drive requirements are in the −2 to +3 dBm region for optimum conversion gain.

Noise figure of the active mixer was measured at 2304 MHz by placing a cavity filter in series with the RF port. SSB noise figure of the mixer measured 9 dB. Comparing this to a typical DBM feeding an IF amplifier reveals comparable noise figures but at a fraction of the cost. At 2304 MHz the optimum LO drive for minimum noise figure is about −6 dBm and the optimum bias current is 10-15 mA. Conversion gain decreases to 7.6 dB compared to 8 dB with higher LO drive.

In the actual application, LO drive can be supplied through a 6- or 10-dB coupler which allows the straight through low loss or direct port to be used for the RF port. This increases the LO drive power by a similar amount. If the LO and RF signals are separated in frequency by several hundred MHz, it may be possible to build a diplexer that has low loss in the RF path while still retaining low loss for the LO path. This would help preserve the low LO drive requirements of the MMIC mixer.

Another application of the MMIC is frequency multiplication. The MSF-8835

**(continued on page 13)**

# Correspondence

Everyone interested in HF packet radio should read the two articles by Barry McLarnon starting in the December 1987 issue of *QEX*. These articles explain the characteristics of modems and HF propagation. Then look at the advertisement from HAL on page 105 of the May 1988 issue of *QST*.

Present day HF packet radio ignores past experience with RTTY and AMTOR. The choice of 300 baud with a 200 Hz shift was probably brought on by the availability of telephone modem integrated circuits. This choice results in a signal-to-noise penalty of about 10 dB compared to the old 45 baud 170 Hz shift RTTY system. Now add the multipath problem! The use of the telephone chips also brings up the silly tuning problem.

I suggest that a practical standard for the HF bands be set, such as 100 baud with a 200 Hz shift. The 300 baud 600 Hz HAL system would be a good choice if people would reduce the baud rate to match conditions. These choices would allow the use of plain old ordinary existing RTTY modems. Once you take this step, the tuning problem is gone. You simply look at the oscilloscope like RTTY people have been doing for years.

Higher baud rates will require more bandwidth and more attention to modulation techniques. Multiple tone modems are now available which run 2400 baud on the HF bands. They are expensive ($8000) and are designed to use an SSB voice channel. As digital signal processing comes to ham radio, the price will fall to reasonable levels.

It is time to combine the best of RTTY with the best of packet. I have home-built equipment that will run on any standard. If anyone else would like to experiment with these ideas, please contact me. I can only operate on 80 meters right now, but plan to add 10 meters.—*Charlie Solie, WB5LHV, 1409 Jeanie Court, Las Cruces, NM 88005*

# Feedback

☐ Please make these corrections to "MMICs Mimic Mixer," *QEX*, Mar 1989, pp 3-7. In Fig 2, the characteristic impedance of the horizontal arms of both branch couplers was shown as 354 Ω. This value should be 35.4 Ω. The parts list in the caption of Fig 4 eliminated the identification of these components: U1, U2—Bipolar Silicon MMIC, Mini-Circuits MAR-8 or Avantek MSA-0885; R1—150-Ω, ¼-W carbon-composition resistor; C4—Etched bypass capacitor, 30-Ω open stub, ¼-wavelength at input frequency; L1—0.1 μH (not 0.01 μH as shown). Also, J1, J2 and J3 should have been identified as RF INPUT, LO INPUT and IF OUTPUT, respectively. In Table 2, the first and fourth entries in the second column (Frequency (MHz)) should be 1553, not 1533.—*H. Paul Shuch, N6TX, 14908 Sandy Lane, San Jose, CA 95124*

☐ "Path Selection—Part 1," Dec 1988 *QEX*, pp 11-13. A typesetting error appears in Equation 1. The equation should read as follows:

$$N_0 = \frac{77.6}{T} \times \left( \frac{4810 \text{ U } e_s}{T} + P \right)$$

—*Dennis Haarsager, N7DH, 1171 Border Lane, Moscow, ID 83843*

☐ Rich Measures, AG6K, has drawn our attention to some errors in his August 1988 *QEX* article, "High-Voltage Breakdown Tester." On page 6, second column, fourth full paragraph, the third sentence should read: "An HVBT is more important when the amplifier has more than one vacuum capacitor." Also on page 6, third column, third full paragraph, the words *breakdown voltage,* not *leakage current,* should appear in the fifth sentence. On page 7, first paragraph, the second sentence should read: ". . . but the test for it is simple: Pass dc equal to the diode's forward-current rating through the diode in the forward direction." Lastly, page 7, second column, second paragraph under **R8**, the last sentence should read: "A single 200-kΩ spiral-film resistor . . ."

☐ In "A High-Stability Audio Oscillator," *QEX*, February 1989, p 14, the four references to a DTMF encoder and tones should be changed to read CTCSS encoder and tones.—*Craig Carter, KA9OOP, 23860 W Rolf Rd, Plainfield, IL 60544.*

☐ *Please refer to "A Low-Noise Preamp For Weather Satellite VISSR Reception," QEX*, February 1989, pp 3-9. In Fig 9, C9 should be shown in parallel with C1, and C10 in parallel with C2. Fig 13 contains two scope photos; the caption refers only to the bottom photo. The upper photo represents a spectrum-analyzer display of an actual VISSR signal as received through the LNA on a 16-foot dish with a coffee-can feed.

In Table 2, line four, the word "circuits" shouldn't be hyphenated. If entered into an ASCII file as shown, the presence of the hyphen will cause the analysis program to bomb.

Figs 7 and 8 are miscaptioned. They are stability circles not merely of the input stage, but of the entire cascade (all three stages) after computer optimization. Similarly, the captions for Tables 2 and 4 are somewhat misleading. Table 2 is a circuit-parameter input file of the input stage only. Table 4 was expanded to include all three stages of the casade.—*H. Paul Shuch, N6TX, 14908 Sandy Lane, San Jose, CA 95124.*

# Bits

**MEMORANDUM-OF-UNDERSTANDING**

Boulder, CO, March 19, 1989—AMSAT-Italy and AMSAT-NA signed a Memorandum of Understanding allowing for the co-construction of a Microsat/PACSAT satellite. AMSAT-NA will be sharing its technology by assisting AMSAT-IT in this endeavor. Joint construction of this Microsat satellite will allow for AMSAT-IT to study, observe and learn about all aspects of building an OSCAR satellite from bending metal to integrating it upon a launch vehicle. This represents the first time that AMSAT-IT has attempted to build an OSCAR satellite. The new AMSAT-IT MICROSAT will be known as ITAMSAT-1 and is expected to be finished and launched within two years. The center for this effort will be in Milan, Italy, with Dr Zagni being designated as the program manager for ITAMSAT-1.

# Components

By Mark Forbes, KC9C
5240 Whitney Blvd
Rocklin, CA 95677

## READER SURVEY

I have received several more letters, and they continue to say the same thing: most of you build a variety of projects, or, like me, you go through phases. Several more requests were made for microwave components, so I'll begin to dig a bit deeper in that area. This month begins again with a description of a small-quantity hardware vendor.

### Jameco Electronics

Jameco, like Digi-Key described in April, has been serving the electronic hobbyist for many years and has built a solid reputation for quality parts, shipped quickly, and at a reasonable price. Jameco used to be known as "James Electronics," but apparently outgrew that name.

Their catalog is quite extensive, covering components, tools, PCs and PC products. The only area that Jameco doesn't cover is RF-specific parts. For just about any other project, they can supply chips, resistors, caps, pcb, cabinet, power cord, and just about anything else you might need, including the test equipment to debug your circuit!

Prices are very reasonable too. For example, digital ICs generally range from 15 to 50 cents. The minimum order is $20, and even with that, I can't see how they can make any money!

You can get a copy of their current catalog by writing them at 1355 Shoreway Road, Belmont, CA 94002. Or, you can call and request one via their 24-hour order line: 415-592-8097. They even have a technical-assistance number if you have problems: 415-592-9990.

### Microprocessors Unlimited, Inc

While on the subject of parts vendors, another company which deals exclusively with memory and microprocessors is Microprocessors Unlimited. They describe themselves as "a small company dedicated to excellence." I have had only limited dealings with them, but they seem reliable. They offer a very complete line of static and dynamic RAM, EPROM, and non-68000 family microprocessors.

In addition to normal shipment, they will also Federal Express orders for only $6 for up to four (4) pounds. To prevent damage to ICs from static electricity, they "wear 100% cotton clothing—including their underwear—while working barefoot on a grounded floor mat." Anyone who would ask his employees to work barefoot *must* be sincere about quality!

To get a copy of their small catalog, contact them at Microprocessors Unlimited, 24000 South Peoria Avenue, Beggs, OK 74421. Make sure you're barefoot and wearing cotton underwear when you unpack your order!

### Qualcomm Q2334 Digital Synthesizer

The Q2334 is a dual, direct digital synthesizer (DDS) chip from Qualcomm. Typical applications include frequency synthesis, FM (or phase modulation), and quadrature oscillators. There are two independent DDSs on the chip, controlled from a single microprocessor interface. Through the interface, the operating mode can be selected, as well as control of the phase and frequency of each synthesizer. Frequency and phase modulation are through synchronous inputs.

In addition to the chip, a complete evaluation kit is available. The evaluation kit includes a preprogrammed microcontroller, the DDS chip, a Sony CX20202A-1 10-bit DAC, 3 analog output ports, and RS-232-C terminal port, and switch selectable baud rates. Using the onboard antialias filter port, frequencies from 0.01 Hz to 12 MHz can be generated. The resulting waveform can be output in one of three formats: direct output from the DAC, output from a low-pass filter, or output from a low-pass filter that has been processed by a zero-crossing detector to produce TTL level output.

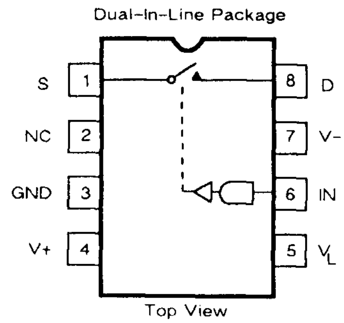
Unfortunately, these parts are quite expensive. In small quantity (less than 100 pieces; 2-piece minimum order), the DDSs are $149 each. The evaluation kit is $545. If you are interested in the part or learning more about it, contact Qualcomm, Inc, 10555 Sorento Valley Road, San Diego, CA 92121-1617.

### Universal Filter Building Block

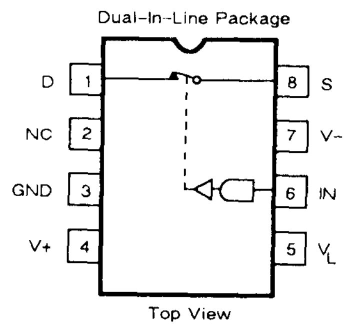
Linear Technology offers a low-noise, quad universal filter building block. Each of the four switched-capacitor filters, together with an external clock and 3 to 5 resistors can provide various second order functions such as low-pass, high-pass, and band-pass filters. The center frequency is easily tuned with an external clock, or a clock/resistor ratio. To learn more about the LTC1064, contact Linear Technology Corp, 1630 McCarthy Boulevard, Milpitas, CA 05035-7487.

### Siliconix Analog Switches

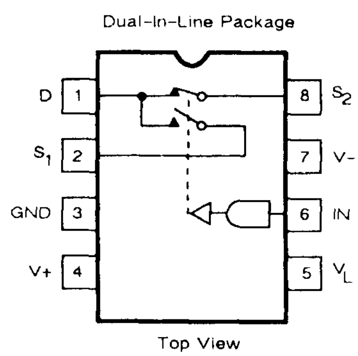
The DG417, DG418, and DG419 monolithic CMOS analog switches combine low power, low leakage, high speed, low *on* resistance, and small physical size




Order Numbers:
CerDIP: DG417AK, DG417AK/883
Plastic: DG417DJ




Order Numbers:
CerDIP: DG418AK, DG418AK/883
Plastic: DG418DJ




Order Numbers:
CerDIP: DG419AK, DG419AK/883
Plastic: DG419DJ

(8-pin mini-DIP, or SOIC). The part is built using high voltage silicon gates, and break-before-make is guaranteed with the DG419 SPDT switch. The switches are configured as SPST (both normally open [DG417] and normally closed [DG418], and the SPDT DG419).

You can request a data sheet, which also contains several useful application circuits, from Siliconix, Inc. Their address is 2201 Laurelwood Road, Santa Clara, CA 95054.

### Motorola One-Time Programmable Microcontroller Kit

Motorola, through Hall-Mark Electronics, is offering a one-time programmable (OTP) training kit. The kit includes a training course manual, a programming/education board with an erasable 68HC705C8S microcontroller, and development software. You interface the training kit through either an IBM-PC® or compatible, or a Macintosh.

An interesting twist is that you may elect to take the "optional OTP test." If you score 100%, you're eligible to win a Mac II; if you score over 90%, you can win a free course. If you want to order one, send $87.54 to Hall-Mark Electronics, Attn: Glenn Whitehead, 11333 Pagemill Road, MS 67, Dallas, TX 75243.

### Photo Cells

You can choose from 16 different types of photocells from Clairex Electronics. Their product line probably has the product to meet your requirement. If you'd like a copy of their catalog, write to Clairex Electronics, 560 South Third Avenue, Mount Vernon, NY 10550.

### Wideband Amplifiers from Mini-Circuits

Mini-Circuits is offering a "designer's kit" of their popular and inexpensive line of monolithic wideband amplifiers. The plastic-packaged parts have 50-ohm input and output impedance, and can be cascaded.

The designer's kit includes 5 of each of their 7 models, for a total of 35 amplifiers. The family of amplifiers features specs of gain up to 33 dB, noise figure of as low as 2.8 dB, and bandwidth of either 0-1000 MHz or 0-2000 MHz. To order the kit or to request more information, write Mini-Circuits at PO Box 350166, Brooklyn, NY 11235-0003. The price of the kit is $59.95.

## Nonlinear Applications Using the Avantek MMICs

(continued from page 10)

device was evaluated as a 1152 to 3456 MHz $\times 3$ multiplier. This device is packaged in the familiar Micro-X microwave package. With a drive level of +10 dBm at 1152 MHz and a device bias current of approximately 7 mA, 0 dBm of 3456 MHz signal was obtained. As with any single-ended multiplier, filtering is required to remove undesired harmonics. The bias current was obtained through a 680-ohm resistor from a 12-volt power supply. Since the gain of the MSF-88 and MSA-08 series improves at lower frequencies, improved conversion efficiencies at lower frequencies should be expected.

Detailed construction information on MMICs can be found in references 1 and 2.

The MSF series MMICs have also been used as frequency dividers with input frequencies as high as 20 GHz with good efficiencies. These are but a few of the many potential applications for the Avantek line of silicon MMICs. What's next?

**Table 1**

Test Results

| *RF (MHz)* | *LO (MHz)* | *IF (MHz)* | *LO* Power (dBm)* | *Bias Current (mA)* | *Conversion Gain MMIC (dB)* | *Conversion Gain MMIC and Power Combiner (dB)* |
|---|---|---|---|---|---|---|
| 2304 | 2160 | 144 | −2 | 26 | 8 | 5 |
| 5760 | 5616 | 144 | +1.5 | 39 | 6 | 3 |
| 5760 | 3456 | 2304 | +1.5 | 39 | −7 | −10 |
| 10368 | 10224 | 144 | +3 | 43 | −3.8 | −6.8 |

*Measured at input to MMIC

### References


[1]A.J. Ward, "Monolithic Microwave Integrated Circuits-Part 1," *QST*, Feb 1987, pp 23-29 & 32.

[2]A.J. Ward, "Monolithic Microwave Integrated Circuits-Part 2," *QST*, Mar 1987, pp 22-28 & 33.


# Bits

**DATASPACE '89** (incorporating RSGB Data Symposium and AMSAT-UK Colloquium) will be held Friday through Monday, July 28-31. The basic program will be as follows:

*Friday 28 July:* Registration at 10 am. Lectures predominantly on data topics.

*Saturday 29 July:* Lectures on data and satellite-oriented topics.

*Sunday 30 July:* Lectures predominantly on satellite topics.

*Monday 31 July:* Satellites in Education Forum aimed at teachers, lecturers and other interested parties.

For more information, please contact: Ron Broadbent, G3AAJ, AMSAT-UK, London, E12 5EQ, Great Britain or RSGB Headquarters, Lambda House, Cranborne Road, Potters Bar, EN6 3JW, Great Britain.