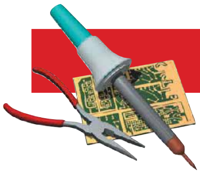

By Alan Bloom, N1AL

A Modern GDO—The "Gate" Dip Oscillator

Building an RF circuit? Use an updated version of an indispensable and legendary piece of equipment to test it—the "dipper."

I still have my first grid-dip oscillator, purchased at a flea market about 30 years ago. It's an Eico model 710 that covers 0.4 to 250 MHz with 8 plug-in coils. It weighs over 2 pounds and must be plugged into the wall to obtain power for its 6AF4 vacuum tube. It still works, although the coil socket has become intermittent over the years, which makes it a bit frustrating to use.

Amateurs have been using grid-dip oscillators (GDOs) at least since 1947.[1] While these days they no longer have a vacuum-tube "grid" to dip, the name seems to have stuck. A GDO is a tunable oscillator with the coil mounted outside of the chassis. The external coil allows you to measure the frequency of a tuned circuit without any electrical connection to it. Just bring the coil close to the tuned circuit's coil and tune the GDO while watching for a dip in its meter reading.

This "no connection" measurement capability is handy for other purposes as well. An example is measuring the parasitic elements of a beam antenna. Since the parasitic elements have no feedpoint, you can't measure the resonant frequency the normal way, with an SWR meter. A GDO is also perfect for tuning the traps to resonance on a multi-band Yagi.

A GDO can "sniff out" spurious resonances in the tank circuit of a high-power vacuum-tube RF amplifier. Be sure to turn off the high voltage first!

A GDO has other uses you might not think of. For example, it can measure inductance. Just temporarily connect a capacitor with a known value in parallel with the coil to be tested, measure the resonant frequency and use the formula $L = 1/(2\pi f)^2C$ or use the graph in *The ARRL Handbook*.[2] (L is inductance in µH, C is capacitance in µF and f is frequency in MHz.) It is just as useful for measuring unknown capacitors. Variable capacitors normally are not marked with their value. To identify that "bread slicer" you bought for a song at the local hamfest, just connect it in parallel with a known inductance, measure the frequency, and use the formula $C = 1/(2\pi f)^2L$.

[1]Notes appear on page 58.

Figure 1—The "gate dipper" fits comfortably in the hand.

When you are troubleshooting a receiver, a GDO can help isolate the fault. Tune the GDO to each of the IF frequencies, starting with the last and hold the coil close to that part of the circuitry. If you can hear a signal, then that IF and all the circuitry after it are working. This is especially handy on densely packed, surface-mount boards that are difficult to probe.

If the GDO has an RF output connector, it can be used as a "poor ham's signal generator" in applications where good frequency stability and calibrated level accuracy are not needed. An example is functional "go/no-go" testing of devices such as amplifiers, mixers and wide-band filters.

With the oscillator turned off, the instrument functions as a type of tuned RF detector known as an absorption frequency meter. The obvious use is to check if there is RF energy of the proper frequency in a tuned circuit. It also makes a handy frequency-selective field-strength meter using the capacity probe as an antenna. Another use is to check for feed line radiation. If you run the coil along the coax cable while transmitting, the meter will show the peaks and valleys of the standing waves of the unwanted RF current flowing on the outside of the coax shield. A GDO also makes an excellent "sniffer" to check for RF leakage from a shielded transmitter chassis, both at the fundamental and harmonic frequencies.

Headphone output was indispensable in the "old days" to check the modulation quality of AM transmitters. Hams don't use AM very much any more, but headphones are still useful to listen for key clicks, hum and low-frequency parasitic oscillations. And, if you couple the coil to an antenna, you have a wide-range "crystal" set!

My favorite, literally "off-the-wall," application was mentioned in a comprehensive tutorial on grid-dip oscillators in January 1974 *QST*.[3] A GDO makes a sensitive detector of pipes and other metallic objects inside a wall. If you listen to the signal on a CW or SSB receiver, you can easily hear a change in frequency whenever the coil passes near a metal object.

The Design

I got the idea for this design while reading an article in *Amateur Radio*, the journal of The Wireless Institute of Australia, by Lloyd Butler, VK5BR.[4] The nice feature of his circuit is that it uses two-terminal plug-in coils. One terminal is grounded so you can use a rugged, reliable coax connector for the coil socket. Most GDO designs require three connections to the coil or two connections that must both be insulated from ground.[5] Many of the latter also require a two-section tuning capacitor, which can be hard to find.

The old Heathkit "Tunnel Dipper" had two-terminal coils using a tunnel diode in a negative-resistance oscillator. Tunnel diodes are very hard to find nowadays, so VK5BR made a negative resistance element by connecting N-channel and P-channel JFETs back-to-back (gate to drain). I tried it and it oscillates beautifully. In fact, that is just the problem; it oscillates so strongly that it is difficult to get a good dip. VK5BR's solution was to connect a selected resistor in parallel with each coil to reduce the oscillation amplitude.

I decided to go a different route. The resistor kills the coil Q, which reduces the sensitivity and widens the bandwidth in wavemeter mode. Also, P-channel JFETs are becoming hard to find. Finally, I wanted to eliminate the internal calibration potentiometer that sets the operating point of the oscillator. Figure 1 shows the completed dipper, Figure 2 is a view inside the case and Figure 3 pictures the complete coil set. The schematic and parts list are shown in Figure 4. A pair of source-coupled N-channel JFETs (Q1 and Q2) form the oscillator portion of the circuit. Unlike some GDO designs, no RF chokes are required. Because of self-resonances, chokes don't maintain a high impedance over the wide range of frequencies required for a GDO.[6] This unit has no false dips anywhere in the frequency range.

Q4, a bipolar 2N3904 transistor, serves a dual purpose. Its base-emitter junction acts as the RF detector. Further, it amplifies the rectified current flowing in the base and sends it to emitter-follower Q5, a 2N2907 transistor. I used a 200 µA meter because that was what I found in my junk box. If you use another value, change the value of R5 using the formula $R5 = (1.5 / I_m) - R_m$, where I_m is the full-scale meter current and R_m is the meter resistance. Be careful when measuring meter internal resistance. Measure the test current of your ohmmeter (on the scale you will use) with another meter. A sensitive meter can be damaged by excessive measurement current, although most newer digital meters use test currents in the range of 50-200 µA for their ohmmeter scales. Transistor Q3 is a JFET source-follower amplifier for the RF output connector. The RF output may be used as a signal source or to drive a frequency counter for more accurate frequency readout.

In detector mode, the power to the oscillator and RF buffer is turned off. Q4 detects and amplifies any signals picked up by the coil. The meter sensitivity control works in both oscillator and wavemeter mode and also controls the volume to the headphones. Battery current is approximately 3 mA with the oscillator on and zero in wavemeter mode, when no signal is being received.

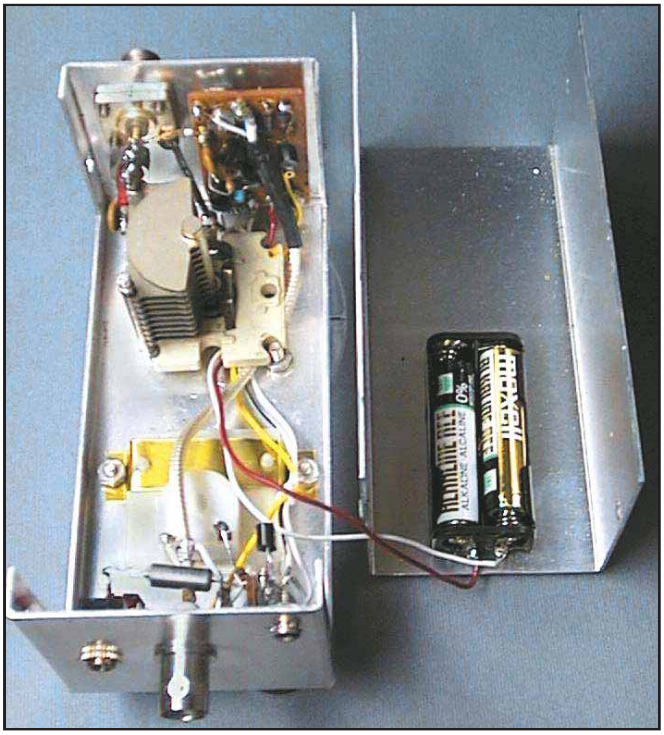

Figure 2—Photograph of the GDO with the cover off. The tuning capacitor was oriented for the shortest possible connection to the coil connector.

Figure 3—This is how the coils looked before the heat-shrink tubing was applied. Small pieces of electrical tape hold the turns in place during construction.

Construction

This project was built almost entirely from junkbox parts. The parts list in Figure 4 consists of parts selected to be similar to those used in the prototype. Feel free to substitute what you have on hand. The exceptions are transistors Q1, Q2 and Q4, which should be the types specified or their equivalents.

The 2¼ × 2¼ × 5 inch chassis is a compromise; it's large enough to allow all parts to fit easily and small enough to fit comfortably in the hand. The coil was mounted off-center, both to allow the shortest connection to the tuning capacitor and to afford easier coil coupling to an external circuit.

The prototype used a perforated test board for the RF portion of the circuitry and a solder tie strip for the meter circuitry. A printed circuit board pattern and parts layout are available at **www.arrl.org/files/qst-binaries/gdo.zip**, should you choose this construction route (the GDO can be hand-wired). Note that the battery is connected with the positive terminal to ground, backwards from the normal arrangement.

The coil forms were made from "3/8 inch" water tubing purchased at the local hardware store. The inside diameter is actually slightly less than 3/8 inch, which makes a nice force-fit onto the 3/8 inch mounting threads of a male chassis-mount BNC connector. The lowest-frequency coil is wound on a large pill bottle with two 1-inch diameter aluminum washers at the connector mount for added strength.

First run the wire through the center of each form and solder it to the BNC connector's center conductor. Then press the form onto the connector threads and cut a small notch in

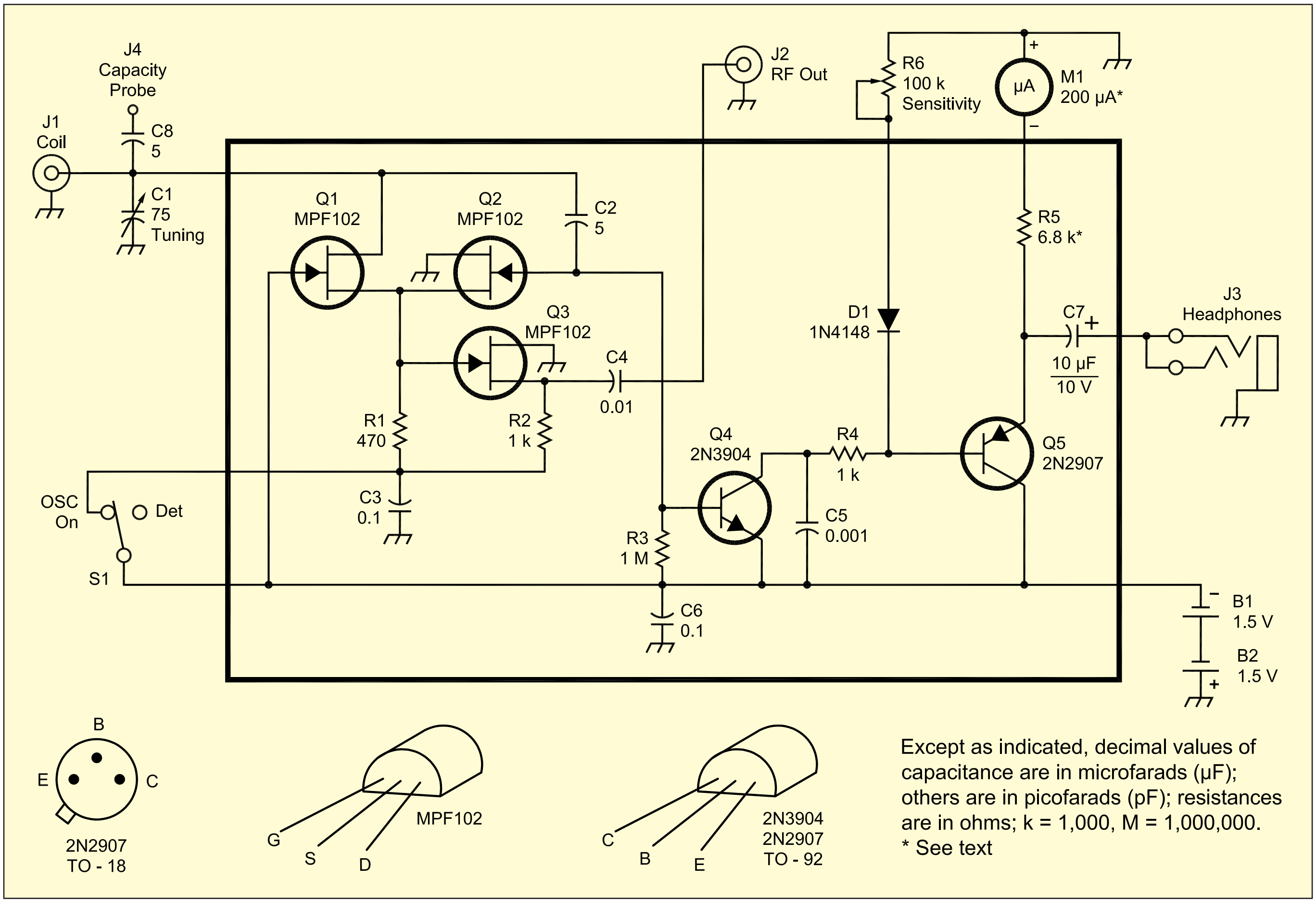

Figure 4—Schematic diagram of the GDO. Part numbers listed are from Ocean State Electronics (OSE) (800-866-6626, www.oselectronics.com), Alltronics (408-847-0033, www.alltronics.com), Digi-Key (800-344-4539, www.digikey.com) and Mouser Electronics (800-346-6873, www.mouser.com). Resistors are available from all of the above sources.

B1, B2—1.5 V AA or AAA cell.
C1—75 pF variable, OSE AVC75 or 365 pF variable BC14400.
C2, C8—5 pF disc capacitor, Digi-Key P11408CT-NF, Mouser 75-10TCCV50, OSE CD5-5.
C3, C6—0.1 μF capacitor, Digi-Key BC1084CT-ND, Mouser 21RX310.
C4—0.01 μF capacitor, Digi-Key BC1078CT-ND, Mouser 21RX410.
C5—0.001 μF capacitor, Digi-Key BC1072CT-ND, Mouser 21RX510.
C7—10 μF, 10 V capacitor, Digi-Key P5134-ND, Mouser 140-XRL10V10, OSE CER10-25.
D1—1N4148 diode, Digi-Key 1N4148DICT-ND, Mouser 512-1N4148, OSE 1N4148.
J1, J2—BNC female chassis-mount connector, Alltronics CB122, Digi-Key ARFX1062-ND.
J3—3.5 mm stereo phone jack, Digi-Key SC1094-ND, Mouser 161-3402.
J4—Phone tip jack, Mouser 530-105-0802-1; phone tip plug, Mouser 530-105-0302-2.
M1—0-1 mA, 1 5/8 inch square panel meter, OSE 60-158 or 0-200 μA, 1 1/2 × 7/8 inch edge-mount panel meter MS200 (see text).
Q1, Q2, Q3—MPF102 transistor, JFET, Digi-Key MPF102-ND, Mouser 512-MPF102.
Q4—2N3904 transistor, Digi-Key 2N3904-ND, Mouser 610-2N3904.
Q5—2N2907A transistor, Digi-Key PN2N2907-ND, Mouser 610-2N2907A.
R1—470 Ω, ¼ W resistor.
R2, R4—1 kΩ, ¼ W resistor.
R3—1 MΩ, ¼ W resistor.
R5—See text.
R6—100 kΩ potentiometer, linear taper, Mouser 313-1000-100K.
S1—SPST toggle switch, Digi-Key EG2350-ND, Mouser 1055-TA1120.

Misc

#18, #22 and #26 gauge enameled wire, Mouser 501-MW18H-1LB, 501-MW22H-1LB, 501-MW26H-1LB, respectively.
10 BNC male chassis-mount connector (for coils), Alltronics CB111.
Dual AA or AAA battery holder, Digi-Key BC2AAAW-ND, BC2AAW-ND, Mouser 122-0421.
2¼″ × 2¼″ × 5″ chassis, Digi-Key HM611-ND, Mouser 563-CU-3004A, OSE 1411KU.
3 ft 3/8″ PVC water tubing for coils.

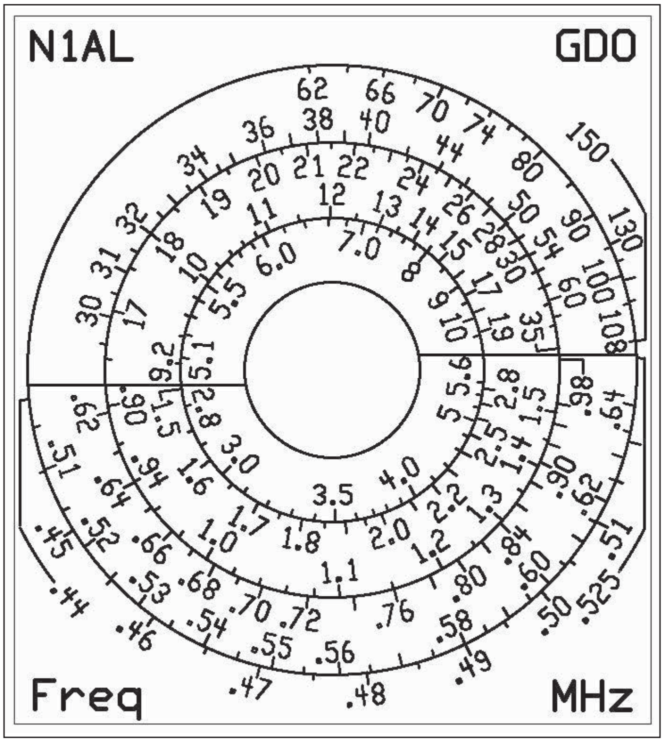

Figure 5—The dial scale for the prototype GDO. If you make your own GDO you will almost certainly need to lay out your own scale.

the other end for the wire to go through. After winding the coil, cut and tin the wire end and solder it to the ground lug mounted on the connector. I covered each coil with a layer of heat-shrink tubing or electrical tape to hold the turns in place and to protect the wire. Figure 3 shows the coils before the heat-shrink tubing was added.

Winding data is listed in Table 1. Unless you happen to duplicate my unit exactly, the frequency range of each coil is likely to be different. However, this data can be used as a starting point for figuring out your own coil designs.

The wire for the two highest-frequency coils is bare copper, salvaged from scraps of Romex house wiring. The other coils are wound with enamel-insulated magnet wire. The exact wire gauge is not critical (although it may affect the number of turns required). A good source for fine-gauge wire for the low-frequency coils is a deflection yoke removed from the cathode-ray tube of a defunct television set.

The three smallest coils (29.5-150 MHz) were space-wound to the lengths listed. The middle 4 coils (2.8-35 MHz) and the largest were close-wound. On the 0.9-1.5 and 1.5-2.8 MHz coils, there were too many turns to fit in a single layer so I "scramble" wound them by overlapping turns, a few at a time, as I wound the coil. It would be neater to lay the wire in two overlapping close-wound layers, but that increases the inter-winding capacitance which can cause spurious resonances and reduced tuning range.

I extended the range of the lowest-frequency coil by connecting it to the GDO through a BNC "T" connector with a pair of 53 pF capacitors attached with clip leads. (Of course it also would have been possible to wind another coil, but I only had one large pill bottle.) Even for the other coils, adding extra capacitance is a useful trick because it slows down the tuning rate, handy for measuring narrow-band devices like crystals.[7]

With the smallest coil, the GDO oscillates over only a small portion of the capacitor tuning range. Fortunately, it happens to cover the two-meter ham band. With the second-smallest coil, the oscillation amplitude drops off at the low end, but it is usable down to about 62 MHz. The circuit would probably work better at VHF if it were constructed with a lower-inductance tuning capacitor.

The small 75 pF tuning capacitor gives only about a 2:1 tuning range. The advantage is that tuning is not so critical and the frequency dial is easier to read. The disadvantage is that it takes more coils to cover the desired frequency range. If you substitute a 365 pF AM broadcast radio tuning capacitor, you should get better than 3:1 tuning range from each coil.

The tuning dial was made from a circular piece of ¼ inch clear plastic glued to a knob. Making the diameter slightly larger than the chassis width allows one-handed operation using your thumb to adjust the tuning. The scale, cemented to the chassis under the clear plastic dial, was drawn using a computer graphics program. Measuring the calibration data and designing the scale were very time-consuming. A better solution would be to include a built-in frequency counter. A 4 or 5-digit readout would be accurate enough since a GDO's frequency stability is not good enough to make a high-accuracy readout useful. Figure 5 illustrates the homebrew dial.

Operation

To measure the resonant frequency of a tuned circuit, switch to oscillator mode and adjust the meter sensitivity to about ¾ scale. Then orient the GDO coil close to, and approximately parallel to, the coil under test and tune the dial until you get a strong dip on the meter. Tune slowly or you may miss the dip. Overly close coupling to the circuit under test causes such a strong dip that the oscillator is pulled far off frequency. For the most accurate measurement, use close coupling to find the approximate frequency, but then move the GDO coil farther away until the dip is barely visible and retune. Figure 6 shows

Table 1
Coil Winding Data for the GDO

Wire Gauge	*Form Diameter*	*Form Length*	*Coil Length*	*Number of Turns*	*Frequency Range*
#12	0.375"	—	0.125"	2	130-150 MHz
#14	0.5"	1.5"	0.5"	3	62-108 MHz
#18	0.5"	2.0"	0.4"	5	29.5-62 MHz
#18	0.5"	2.5"	0.5"	10½	16.5-35 MHz
#22	0.5"	2.5"	0.6"	21	9.2-19 MHz
#26	0.5"	2.5"	1.0"	46	5.1-10.5 MHz
#30	0.5"	2.5"	1.5"	100	2.8-5.6 MHz
#30	0.5"	2.5"	1.6"	180	1.5-2.8 MHz
#30	0.5"	3.9"	3.3"	390	0.9-1.5 MHz
#30	1.25"	3.9"	3.4"	230	620-980 kHz
				(+53 pF)	505-640 kHz
				(+106 pF)	440-525 kHz

the dip meter in use, measuring the frequency of an amplifier tank circuit.

Coupling to toroids or shielded coils can be difficult. One solution is to connect a wire from the capacitance probe to the "hot" end of the circuit to be tested. For looser coupling, just place the wire close to the circuit under test. When measuring the inductance of a toroid with a test capacitor, the capacitor leads often form enough of a loop to allow coupling to the GDO coil. Some authors recommend coupling the GDO to a one-turn loop through the toroid, but that makes the toroid act like a transformer with a shorted secondary and that changes its inductance.

Antenna measurements are best made at the high-current point of the antenna conductor. For a half-wave dipole, this is near the center. Orient the coil perpendicular to the conductor for maximum coupling. Be sure to short the feed point of the antenna before making the measurement. If you can't find the dip, make the shorting wire into a 1-turn loop for better coupling to the GDO coil. You should also see resonance at the odd harmonic frequencies as well as the fundamental.

To measure the electrical length of a transmission line, couple the GDO to a small wire loop; connect it to one end of the line and leave the other end disconnected. (For best accuracy use the smallest loop that gives sufficient coupling.) The line is ¼ wavelength long at the lowest resonant frequency, so the electrical length in meters is 75/f, where f is the resonant frequency in MHz. Again, you will also see resonance at the odd harmonics.

The voltage level at the RF output connector varies from coil to coil but typically runs about 250 mV RMS into an open circuit and 50 mV RMS into a 50 Ω load. That is sufficient to drive a typical frequency counter or serve as a test signal when troubleshooting.

A GDO is like a TV remote control—you don't know you need it until you have it, and then you wonder how you ever got along without it. One simple instrument can do many of the measurements of a bench full of expensive RF test equipment. I've only touched on a few of the many and varied applications for this versatile instrument.[3,7,8]

Figure 6—N3SU grid-dipping her linear amplifier's tank coil. Note that the high-voltage power supply is not only off but is disconnected from the amplifier.

Notes

[1]C. F. (Bud) Bane, W6WB, "...About Grid-Dip Oscillators," *CQ*, Mar 1947, p 13. This seems to be the first grid dip oscillator design in the amateur literature. It was a portable battery-operated unit using a type 3A5 vacuum tube.

[2]*The 2003 ARRL Handbook,* Fig 6.46—Inductive and capacitive reactance vs frequency, p 6.27.

[3]B. Clark, WB4OBZ, "The Art of Dipping," *QST*, Jan 1974, p 16.

[4]L. Butler, VK5BR, "A Dip Meter using the Lambda Negative Resistance Circuit," *Amateur Radio*, Jan 1997, p 15. *Amateur Radio* is the journal of The Wireless Institute of Australia. For North American readers who may not have ready access to this magazine, the article is posted at **users.tpg.com.au/users/ldbutler/NegResDipMeter.htm**.

[5]H. Olson, W6GXN, "A New Look at Dip Meters," *Ham Radio*, Aug 1981, pp 25-28. This is a good survey of different dip meter circuit designs.

[6]The difficulty of designing a wide-band choke is discussed in F. Lewis, W1LKV, "Anatomy of a Solid-State Dipper," *QST*, Dec 1972, p 23.

[7]This trick is one of several described in R. Johns, W3JIP, "Add-Ons For Greater Dipper Versatility," *QST*, Feb 1981, p 37.

[8]M. Bradley, K6TAF, "What Can You Do with a Dip Meter?" *QST*, May 2002, p 65. A good overview on how to use a dip meter.

Al Bloom, N1AL, was first licensed while in high school, in 1968. He received a Bachelor's degree in physics, then a Master's degree in electrical engineering, the latter while working as a W1AW operator. While at the ARRL he co-authored both the License Manual *and the* Operating Manual. *He designed amateur and commercial equipment for the R. L. Drake Company and has spent the last 23 years at Hewlett-Packard, designing RF and microwave test equipment. Al has written several articles for* QST, *including two cover plaque award winners. Mainly a CW operator, Al is on nearly all of the amateur frequencies from 1.8 to 2450 MHz, including satellite operation. He is a life member of the ARRL and an ARRL Technical Advisor. You can contact the author at* **n1al@arrl.net**.

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