Measure High-Frequency AC Volts

Probe/voltmeter measures rms volts from 10 Hz to beyond 10 MHz and also functions as an amplitude-modulation detector

By Duane M. Perkins

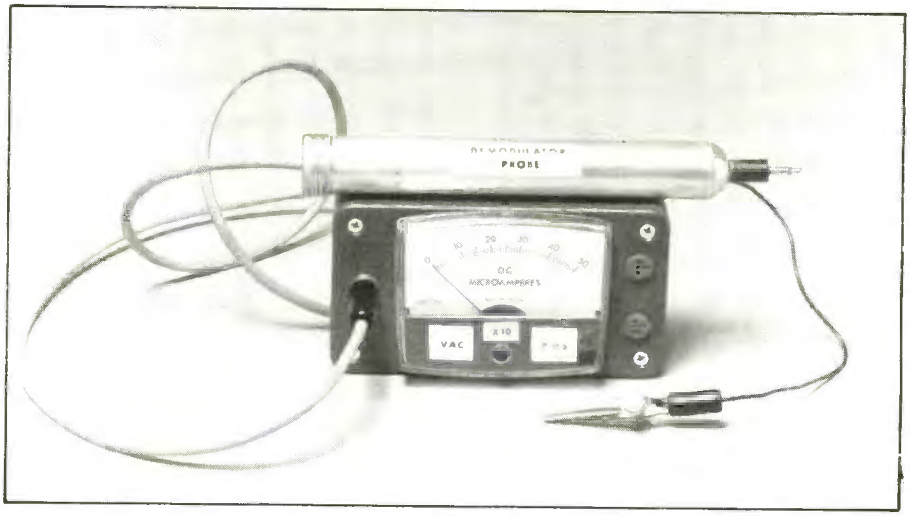
New test instruments are as simple in design and easy to use as the AM demodulator probe. Consisting of a half-wave rectifier and low-pass filter, it processes an r-f input signal to deliver a dc output voltage that varies with the r-f signal amplitude. The average dc output voltage from this setup is proportional to the average ac input voltage.

A demodulator probe is very useful when experimenting with low-level r-f. It's a practical necessity for signal tracing in TV, AM and FM receivers. The output from the probe can be fed to an oscilloscope, audio amplifier or ac voltmeter to let you see, hear or measure the signal being demodulated.

Being a very simple test instrument, you can build the demodulator probe and companion ac rms voltmeter described in this article in just a few hours. It contains only inexpensive and readily available parts that won't break the bank.

About the Circuit

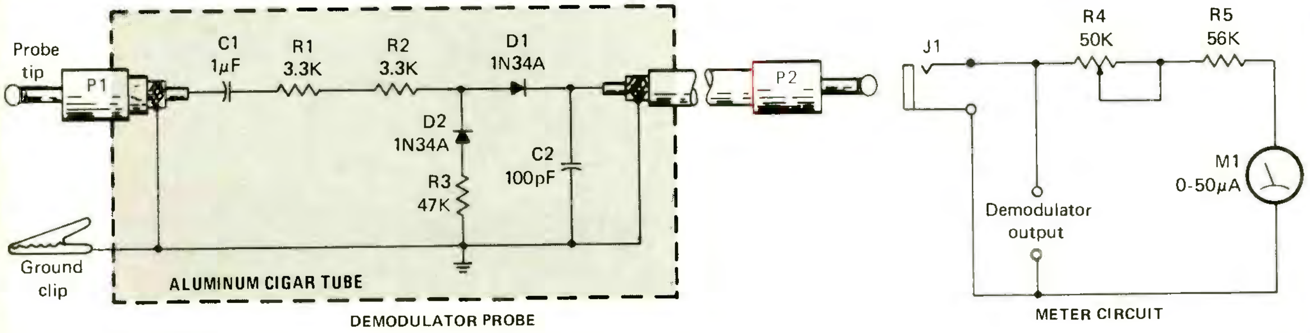
Referring to Fig. 1, you will note that the probe and companion meter circuits are totally passive. Therefore, no internal power source is required for the project. The demodulator circuit shown at the left is a half-wave voltage doubler. Its high series resistances assures high input impedance for minimal loading on a circuit being tested. When the probe is plugged into the meter circuit shown at the right, the resistors provide scaling to give rms voltage readings.



This probe circuit has two principal advantages. Capacitor *C1* blocks any dc between the probe and the signal source. Since the signal source may have a significant dc component of either polarity, *C1* should be a nonpolarized capacitor. The output of the probe increases as the load is reduced and approaches the peak-to-peak ac input voltage when the load is on the order of 10 megohms, making it about 3.5 times as sensitive as when used with the meter circuit in Fig. 1.

With the probe plugged into the meter, a significant voltage is dropped across *R1* and *R2* as a result of the current required to recharge *C2*. The voltage across *C2* will peak at about 80 percent of the rms input voltage. Trimmer potentiometer *R4* is adjusted to calibrate the meter for rms volts (one-tenth of scale). This requires that *R4* + *R5* provide a series resistance of about 80,000 ohms, which puts *R4* at about center of rotation.

Filter capacitor *C2* in parallel with the capacitance of the shielded cable results in negligible ripple at radio frequencies (200 kilohertz and higher) but ripple increases and average dc output voltage drops at lower frequencies. However, the probe can be used to measure very low-frequency ac voltages simply by connecting a larger filter capacitor across the DEMODULATOR OUTPUT terminals in



PARTS LIST

C1—1-μF nonpolarized capacitor
C2—100-pF disc capacitor
D1,D2—1N34A signal diode
J1—Subminiature phone jack
M1—1-to-50-μA meter movement (Radio Shack No. 270-1715 or similar)
PL1,PL2—Subminiature phone plug
R1,R2—3300-ohm, ¼-watt resistor
R3—47,000-ohm, ¼-watt resistor
R4—50,000-ohm trimmer potentiometer
R5—56,000-ohm, ½-watt resistor
Misc.—Aluminum cigar tube; transistor socket; pin jacks or 5-way binding posts; miniature alligator clip, preferably with insulating hood; shielded cable; utility box for meter movement Radio Shack No. 270-222 or similar); terminal strips; epoxy cement; hookup wire; solder; etc.

Fig. 1. Overall schematic diagram of both basic probe and metering circuits. Both are completely passive, eliminating need for internal source of power. Probe's high input impedance minimized loading of circuit under test.

the meter circuit. With a 10-μF capacitor, calibration remains correct down to 10 Hz, but below 10 Hz, the reactance of *C1* becomes the limiting factor. Since the polarity of the output is always positive, *C2* can be an electrolytic capacitor.

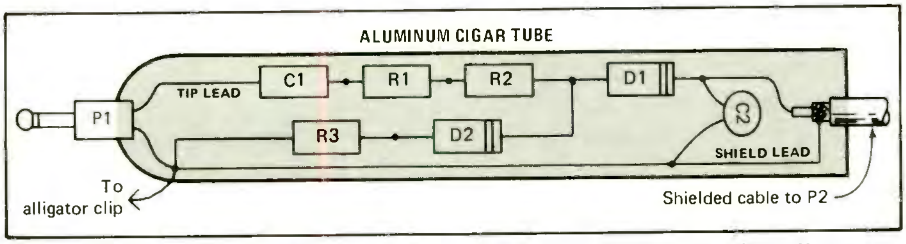


Fig. 2. Construction details for probe portion of project. Note that all components are self-supporting and require no other mechanical elements during wiring. When installing circuit inside tube, do not remove paper or wood liner.

Construction

An aluminum cigar tube makes a good housing for the probe. The components can be soldered together to make an assembly that will slip neatly inside the tube, as shown in Fig. 2. A 3/32″ subminiature phone plug cemented into the tip of the tube can be used to directly contact the signal source or be plugged into a matching jack connected to the signal source.

Drill the hole for the plug just large enough for a tight fit around the plastic part of the phone jack and apply a small amount of epoxy cement around the hole inside the tube. Drill a hole in the end cap for the shielded cable. There is usually a plastic disk inside the end cap and a paper liner inside the tube. Leave these in to provide insulation and drill a hole in the plastic disk that will fit tightly around the shielded cable. Keep the ground wire with the alligator clip as short as practical to minimize impedance.

You can mount the meter in any type of enclosure into which it will comfortably fit, though the Radio Shack No. 270-222 plastic case specified in the Parts List is almost ideal for the specified meter movement with a ⅛″ mini phone jack on one side and a socket on the other side for access to the output signal. In the author's prototype two transistor sockets were used for output signal access, though you can use pin jacks or 5-way building posts if you prefer. An external filter capacitor can be plugged directly into the socket or jacks. You can mount a terminal strip on one of the meter mounting screws to mount *R5* and *R6*. Use a ⅛″ miniature phone plug on the end of the shielded cable.

Checkout and Use

The two units can be tested with the output from a low-voltage power

(Continued on page 89)

Measure High-Frequency AC Volts *(from page 55)*

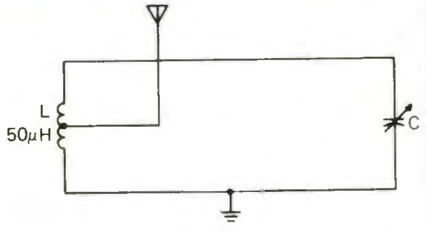
transformer, provided that a voltage divider is used to obtain less than 5 volts rms. For example, two 100-ohm resistors in series across a 6.3-volt secondary would provide about 3.15 volts from the center of the divider to either side. If this results in meter movement, the units are working.

Next, the meter must be calibrated. This requires a known voltage of 2 to 3 volts rms. If you have an ac voltmeter known to be accurate at this voltage, use it to measure the voltage from the divider and select resistors to obtain about 2.5 volts, using values in hundreds of ohms to assure a low-resistance source. If you have only a dc voltmeter, use a 1N34A diode to rectify the ac and a 10,000-ohm resistor load to ground. Measure the dc across this resistor and multiply the reading by 2.22 to correct for rms volts. With a known voltage applied to the input of the probe, adjust *R4* so the meter reads the known voltage.

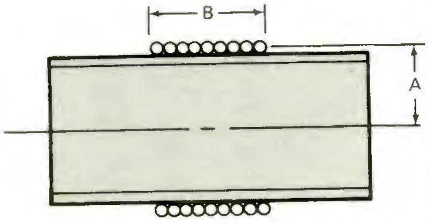
It should be recognized that the meter reading will be correct only if the ac input is a sine wave (although a constant dc offset will have no effect). This is true for most ac voltmeters. It must also be remembered that the meter puts a load on the source and will reduce the voltage if the source impedance is high. The load is about 40,000 ohms.

One interesting application for this project is to receive local AM broadcasting in the manner of the old crystal sets. This requires only a coil and a 250-to-365-pF tuning capacitor attached to a long-wire antenna. The inductance of the coil should be as required to permit tuning the AM band with the capacitor to be used and should be tapped at about 50 microhenries for connection to the antenna and demodulator probe. Connect an earth ground to the bottom end of the coil, and use any handy insulating cylinder for the coil form. Coil winding formulas are shown in the box. **ME**

How To Wind a Coil For AM Broadcast Reception



(A) STEP 1



(B) STEP 2

If you wish to use the probe described in the main text of this article for receiving AM broadcasts, you must add an antenna/tuner circuit to it, as shown in circuit A. Your first step here is to calculate the inductance required, using the formula: $L = 1/[C(2\pi F_O)^2]$. Here, *L* is inductance in microhenries (µH); *C* is capacitance in picofarads; F_O is resonant frequency in kilohertz (kHz); and 2π is 6.28, an approximate constant.

An example of how to use this equation is as follows. Assume that $C = 365$ pF and $F_O = 550$ kHz. Using these figures, we obtain $L = 1/[365(6.28 \times 550)^2] = 230$ µH (approximately). Using the result calculated from this formula, you can wind the coil needed.

Your next step is to calculate the number of turns needed for the coil, based on its calculated value. You obtain this from the formula: $N = [L(9A + 10B)]/A$. Here, *N* is the number of turns; *L* is the inductance in µH; *A* is the radius of the coil in inches; and *B* is coil length in inches.

Assume now the $L = 230$ µH, $A = 0.5''$ and $B = 1.8''$. Using this information, we obtain: $N = \{230[(9 \times 0.5) + (10 \times 1.8)]\}/0.5 = 144$. To determine where to tap the coil at the 50-µH point, use the same formula: $N = \{50[(9 \times 0.5) + (10 \times 0.5625)]\}/0.5 = 45$. This tells you that the coil must be tapped approximately 45 turns from one end.

For a close-wound coil, $B = N/T$, where *T* is the number of turns per inch for the wire gauge. Our example assumes 80 turns per inch, which is attainable with AWG #30 wire without being too careful.

You can use any handy insulating cylinder with the appropriate diameter on which to wind the coil.

PRODUCT EVALUATIONS . . . *(from page 17)*

in the order in which they are called for in the assembly instructions. This eliminates much of the time that would normally be wasted in sorting through a bunch of like-size components for the one called for in each step. Another timesaver is the separate Illustration Booklet that accompanies the assembly manual.

As is usual for Heath, and a foundation on which the company has built its fine reputation, the assembly manual is excellently written and illustrated. Not only does it give clear and concise step-by-step assembly instructions, it contains introductory material on assembly notes, parts identification and soldering instructions. It also contains helpful In Case Of Difficulty and Circuit Description sections for the technically minded builder.

Working at a leisurely pace, we were able to assemble the Security Sentinel in just five hours, including initial testing to make sure it operated as described in the manual. The only tools needed were a soldering pencil (Heath supplies the solder), a Phillips screwdriver, diagonal cutters, longnose pliers, and slip-joint pliers.

Assembly proceeded without a hitch. We encountered no difficulties, either with part identification or mechanical elements that wouldn't line up.

Conclusions

This product is well worth investigating, given the high incidence of burglary today. It does what Heath claims it does and does it admirably. The vocalization is very realistic, with excellent pronunciation and inflection.—*Al Burawa* **ME**