CIRCUIT CIRCUS

By Charles D. Rakes

Detector Circuits

Fellow experimenters, it's time to dig out your junkbox and join me at the Circus for a little circuit wizardry. I find that trying new circuit ideas is a good way to escape the troubles of the world and, at the same time, gain some knowledge in the process. And who knows, one of the circuits that we cover just might be what your next project needs.

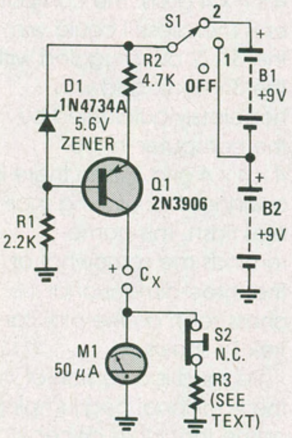

Fig. 1. The leak detector circuit is a simple circuit built around a 2N3906 general-purpose PNP transistor that's configured as a constant-current source, through which a 1-mA charging current is applied to the test capacitor.

This time around, we're going to look at a couple of detector circuits; the first of which is a simple electrolytic-capacitor leakage-test circuit. If you have ever put together an R/C timer circuit that, for some unknown reason, didn't perform as expected, it's very possible that the culprit was a leaky electrolytic timing capacitor.

Some leaky capacitors develop an internal resistance that varies with temperature and/or voltage changes. That internal leakage is like having a variable resistor in parallel with a timing capacitor. In extremely short timing periods, the effect of the leaky capacitor may be minimal, but as the timing period is extended, the leakage current can cause the timer circuit to vary greatly or even fail altogether. In any case, an unstable timing capacitor will turn a perfectly sound timer circuit into an erratic piece of junk.

LEAK DETECTOR.

Figure 1 is a schematic diagram of our electrolytic leak detector. In that circuit, a 2N3906 general-purpose PNP transistor (Q1) is connected in a constant-current circuit configuration through which a 1-mA charging current is applied to the test capacitor. A dual-range metering circuit is used to monitor the capacitor's charge and leakage current. Two 9-volt transistor batteries provide power for the circuit. A 5-volt Zener diode (D1) sets Q1's base at a constant 5-volt level, guaranteeing a constant voltage drop across R2 (Q1's emitter resistor) and a constant current to the capacitor under test (which we'll refer to as C_X).

With S1 in position 1, the voltage applied to C_X is limited to about 4 volts; with S1 in position 2, the voltage across the capacitor rises to about 12 volts. Another battery can be added in series with B1 and B2 to increase the charging voltage to about 20 volts. With S2 in its normally closed position (as shown), the meter is connect in parallel with R3 (the meter's shunt resistor), giving the circuit a full-scale reading of 1 mA. When S2 is depressed (open), the metering range of the circuit is reduced to 50-µA full scale.

MODIFYING THE CIRCUIT.

The circuits in Figs. 2 and 3 illustrate two methods of selecting a shunt resistor (R3 in Fig. 1) to extend M1's range from its basic 50-µA range to 1 mA.

If you have an accurate voltmeter that can read 1 volt, use the circuit in Fig. 2

PARTS LIST FOR THE LEAK DETECTOR

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1—2200-ohm
R2—4700-ohm
R3—See text

ADDITIONAL PARTS AND MATERIALS

Q1—2N3906 general-purpose NPN silicon transistor
D1—1N4734A 5.6-volt Zener diode
M1—50-µA meter
B1, B2—9-volt transistor-radio battery
S1—SP3T switch
S2—Normally-closed pushbutton switch
Perfboard materials, enclosure, AC molded power plug with line cord, battery(s), battery holder and connector, wire, solder, hardware, etc.

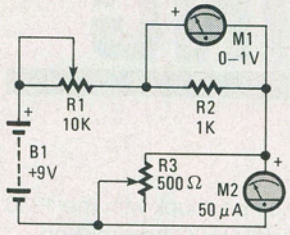

Fig. 2. Use this circuit to determine the value of R3 (in Fig. 1), if you are using a voltmeter.

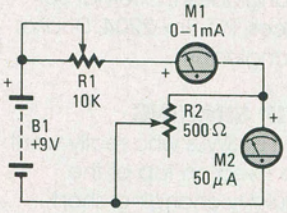

Fig. 3. If your most-accurate measuring instrument is a current meter that can monitor 1-mA, use this circuit to determine R3's value.

to select the value of R3. To use the Fig. 2 circuit, set R1 (the 10k potentiometer) to its maximum resistance and R3 (the 500-ohm potentiometer) to its minimum value. Connect a battery as shown and adjust R1 for a 1-volt reading on M1. Slowly increase the resistance of R3 until M2 (the current meter) reads full scale. Readjust R1 as you adjust R3 to keep a 1-volt reading on M1. When M1 reads 1 volt and M2 reads full scale, the potentiometer is set at the resistance value needed for R3. You can either use the potentiometer for the shunt resistor or select one of equal value from your resistor supply.

On the other hand, if your most-accurate measuring instrument is a current meter that can monitor 1 mA, use the circuit in Fig. 3. Follow the same procedure for the circuit in Fig. 3 as in Fig. 2 and adjust the R1 for a 1-milliampere reading.

To use leakage test circuit, start with S1 in the off position. Connect the capacitor under test to the C_X terminals, with the proper polarization. Switch S1 to position 1 and the meter should (depending on the value of the capacitor) read full scale for a brief time and then drop back to a zero current reading. If the capacitor is shorted or extremely leaky, the meter will read up scale continuously.

If the meter does drop to zero, press S2 and the meter shouldn't move up scale on a good capacitor. If the capacitor's voltage rating is above 6 volts, switch S1 to position 2 and the results will be the same for a good capacitor. If the meter reading rises, the capacitor is not a good candidate for use in a timer circuit.

It's possible that a capacitor will fail the test and still be a good unit. If an electrolytic capacitor is idle for long periods without being charged, the leakage current can be high when a voltage is first applied; but if the voltage remains across the capacitor for an extended time, it can often be rejuvenated. The test circuit can be used to regenerate a sleeping capacitor and the results monitored on M1.

METAL DETECTOR.

A while ago we discussed a simple metal-detector circuit and, judging from the response, it was obvious that a number of you were very enthusiastic about the subject. So the next circuit that we'll discuss is one that is designed to do the same job, but in a different way.

One of the most sensitive and inexpensive metal detectors that you can build is a variation of the VLF TX/RX (very-low frequency, transmitter/receiver) detector, which is a two part apparatus. Such double-box detectors—which would not respond to anything smaller than a pound coffee can—were generally designed to detect large metal objects buried deep, beneath the ground.

Our's is a mini-version that can detect coin-sized objects from a few inches away, or larger objects at a distance of over two feet. The sensing loops (coils) on both the transmitter and receiver portions of our detector are slightly over 4 inches in diameter and are separated by about 12 inches. The operation of the TX/RX metal detector is based on the directional properties of the magnetic field produced by the transmitter loop and the reception properties of the receiver loop.

In such circuits, the majority of the magnetic energy flows from the transmitter loop in an edgewise direction with almost no

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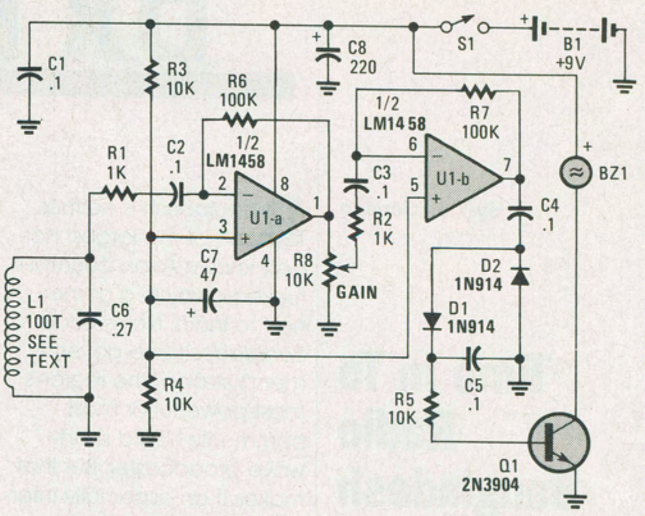

Fig. 4. The receiver portion of the metal detector is built around an LM1458 dual op-amp, a single 2N3904 general-purpose silicon transistor, and a 100-turn homebrew coil that's tuned to about 7 kHz via C6.

PARTS LIST FOR THE VLF RECEIVER

SEMICONDUCTORS

U1—LM1458 dual op-amp, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor
D1, D2—1N914 general-purpose small-signal silicon diode

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1, R2—1000-ohm
R3–R5—10,000-ohm
R6, R7—100,000-ohm
R8—10,000-ohm potentiometer

CAPACITORS

C1–C5—0.1-μF, ceramic-disc
C6—0.27-μF, Mylar or similar
C7—47-μF, 16-WVDC, electrolytic
C8—220-μF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

B1—9-volt transistor-radio battery
BZ1—Piezo buzzer
S1—SPST switch
L1—Receiver loop, see text
Perfboard materials, enclosure, battery holder and connector, wire, solder, hardware, etc.

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radiation perpendicular to the loop. The receiver loop offers the same directional properties as the transmitter's loop, but since it is positioned perpendicular to the transmitter loop, almost no energy is detected. When a metal object is placed within the field of either loop, the loop's magnetic field is slightly distorted, allowing the receiver to detect a small part of the redirected energy.

The VLF receiver, see Fig. 4, is built around an LM1458 dual op-amp and a single 2N3904 general-purpose NPN silicon transistor. Coil L1, the pick-up device, is a homebrew inductor (100-turn loop) that is tuned to approximately 7 kHz by C6. Any 7-kHz signal picked up by the loop is fed to U1-a, which provides a gain of 100. The second op-amp is also configured for a gain of 100. The two op-amps produce a combined gain of 10,000, depending of the setting of R8. The output of U1-b at pin 7 is fed to a rectifier circuit that converts the 7-kHz signal into a positive DC voltage.

That DC voltage is then fed to the base of Q1 through R5, causing Q1 to turn on. With Q1 turned on, BZ1 sounds to indicate that metal has been detected. Power for the receiver is supplied by a single 9-volt transistor radio battery.

The transmitter portion of the circuit (see Fig. 5) is built around a single transistor that's configured as a Colpitts oscillator. The transmitter's sensing coil, L1 (another 100-turn loop), is tuned to about 7 kHz by capacitors C2–C4. Transmitter power is supplied by a 9-volt battery.

Assembling the circuit is a snap. The loops are wound on plastic end caps (that are made to fit on 4-inch plastic pipe) with an outside diameter of 4½ inches. The coil is made by jumble-winding 100 turns of number-26 enamel-covered copper wire around the center of each end cap. The ends of the coil are then taped in place. The loops are then mounted to opposite ends of a wood dowel (about 12 inches), and oriented perpendicular to each other.

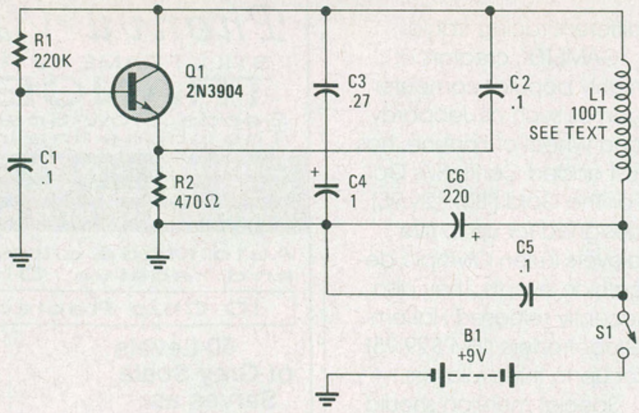

Fig. 5. The transmitter portion of the detector is built around a single transistor that's configured as a Colpitts oscillator, and another 100-turn coil (the transmitter's sensing loop), which is tuned to about 7 kHz by capacitors C2–C4.

PARTS LIST FOR THE VLF TRANSMITTER

CAPACITORS

C1, C2, C5—0.1-μF, ceramic-disc or mylar
C3—0.27-μF, Mylar or similar
C4—1.0-μF, Mylar or similar
C6—220-μF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

B1—9-volt transistor-radio battery
Q1—2N3904 general-purpose NPN silicon transistor
R1—220,000-ohm ¼-watt, 5% resistor
R2—470-ohm, ¼-watt, 5% resistor
L1—Transmitter loop, see text
S1—SPST switch
Perfboard materials, enclosure, battery holder and connector, wire, solder, hardware, etc.

The receiver and transmitter circuitry can be built on perfboard and mounted inside the end caps on which the loops are formed, or placed in separate plastic enclosures and positioned away from the dowel mounted loops.

Tuning up and checking out the detector is easy. Turn both units on; the buzzer (BZ1) should sound. Turn the receiver's gain down until the sound just about ceases, and then slowly rock the transmitter's loop back and forth until a perfect null is obtained. Keep increasing the receiver's gain and re-positioning the transmitter for the deepest null. If everything is working correctly, the null (at full receiver gain) will be sharp. If not, the receiver and transmitter may not be tuned to the same frequency.

To tune the receiver to the transmitter's frequency, connect a DC voltmeter to the cathode of D1 and vary C6 for the maximum output voltage at the diode; 4 to 5 volts is normal.

The detector is most sensitive when the circuit is operating at maximum gain and off null just enough to produce a low-level output from BZ1. ■