

Here are some metal detector circuits from three separate Circuit Circus columns.

## METAL DETECTOR (March 1991)

The next entry is one of my favorite gadgets - a simple two-transistor metal detector - which you can put together in an evening or two and enjoy using for hours on end. The circuit (see Fig. 3) probably won't lead you to a pot of gold, or any other treasure for that matter. But it can help locate wiring in the walls or pipes in the floor, and will cost you next to nothing to build. And if you happen to have a youngster under foot with nothing to do, this circuit just might be the one gadget that will get junior outdoors and into a fun hobby.

In Fig. 3, transistor Q1 (a 2N3904 NPN device) is connected in a simple LC oscillator circuit with the values of L1, C3, C4, and C9 determining the circuit's operating frequency. The oscillator's output is fed through C1 and R4 to a 455-kHz ceramic filter. When the oscillator is tuned to the filter's center frequency, the filter acts like a parallel tuned circuit and produces a high level 455-kHz signal at the junction of R3 and R4. The 455-kHz signal is fed to the base of Q2, which is configured as an emitter follower. The

output of Q2 (taken from its emitter) is then converted to DC by D1, and from there, is applied to M1 (a 50- to 100- $\mu$ A meter).

With The oscillator operating at, or very near the filter's center frequency, the meter will read somewhere in the vicinity of mid-scale. But when any metal object larger than a BB is brought near the loop, the meter's reading will either increase or decrease, depending on The type of metal. The circuit will detect a penny two inches away or a "D"-cell battery at about five inches in open air.

The search loop is wound on a small diameter form that's best suited for locating smaller objects at close range, but a larger loop may be built to detect larger objects located at greater distances. A plastic end cap for a 4-inch PVC sewer pipe (which can be purchased at just about any plumbing-supply shop) can be used as the coil form for The search loop. The search loop should be ten close-wound turns of number-26 enamel-coated copper wire wound around the bottom of the end cap and taped firmly in place. The electron-

ics can be built on perfboard and should be housed in a metal cabinet.

Capacitor C1 can be any variable capacitor that you happen to find in your junkbox or one removed from an old broadcast-radio receiver. The 50- $\mu$ A meter movement can come from an older volt-ohm meter or from some other piece of retired gear. Several different 455-kHz ceramic filters were tried in the circuit and all seemed to work just fine. If you can't locate a ceramic filter, just send an SASE. (self-addressed, stamped envelope) to me at "Circuit Circus," Popular Electronics Magazine, 500-B Bi-County Blvd., Farmingdale, NY 11735 and I'll send you one. [Note: Popular Electronics is no longer in business. For ceramic filters, try Digi-key Corp.]

The loop should be located at least one foot away from the locator's cabinet, separated by a non-metal support. A wood dowel rod is a good choice. Run a twisted pair of unshielded wires between The loop and the circuit board.

If for some reason you don't get a meter reading when turning C9 through its rotation, it could be that the oscilla-

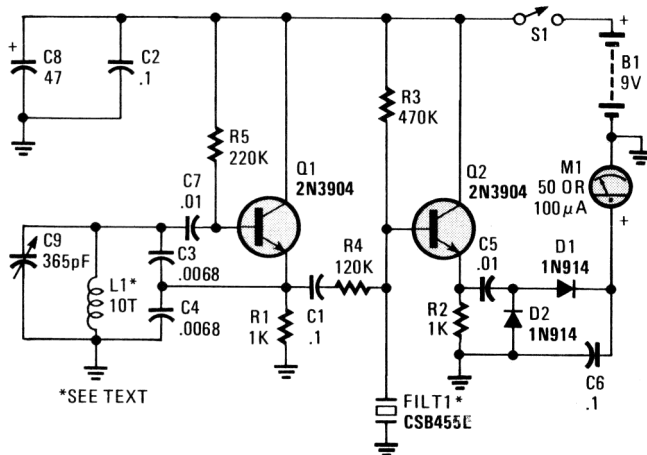


Fig. 3. The metal detector is little more than a simple oscillator circuit (built around Q1), whose output is fed to a meter (M1), causing it to deflect to about mid-scale. When the sense coil (L1) is brought near metal, the oscillator frequency changes, and that change causes the meter needle to move either up or down the scale depending on the type of metal detected.

## PARTS LIST FOR THE METAL DETECTOR

### RESISTORS

(All resistors are 1/4-watt, 5% units.)

- R1, R2—1000-ohm
- R3—470,000-ohm
- R4—120,000-ohm
- R5—220,000-ohm

### CAPACITORS

- C1, C2, C6—0.1- $\mu$ F, ceramic-disc
- C3, C4—0.0068- $\mu$ F, 50-WVDC polystyrene
- C5, C7—0.01- $\mu$ F, ceramic-disc
- C8—47- $\mu$ F, 16-WVDC, electrolytic
- C9—365-pF variable (see text)

### ADDITIONAL PARTS AND MATERIALS

- Q1, Q2—2N3904 general-purpose, NPN silicon transistor
- D1, D2—1N914 general-purpose, small-signal silicon diode
- L1—Search loop (see text)
- FI—455-kHz crystal-filter (Murata CSB455E or similar)
- B1—9-volt transistor-radio battery
- M1—50- to 100- $\mu$ A meter (see text)
- Perfboard materials, enclosure, wire, solder, hardware, etc.

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tor just isn't tuning to the filter's frequency. A frequency counter can be connected to the emitter of Q1 to see what signal (if any) is present. Or, if a counter isn't available, use a standard BC receiver and tune to the oscillator's second harmonic. If the oscillator is operating at 500 kHz, tune your radio to 1 MHz and you should hear the carrier.

If the oscillator's frequency is too high, add capacitance across C9. If the frequency is too low decrease C3 and C4. Also if the meter won't quite make it to full scale, R4 can be reduced in value; if the needle bangs full scale, R4 can be increased.

Through a little experimenting, you'll soon determine the best method to use

in tuning the locator for detecting the size and type of desired metal objects. The circuit is more sensitive when the tuning is adjusted so that the meter is at about half scale when no metals are present; at that setting, the circuit will indicate ferrous and non-ferrous metals by causing the meter to increase with one and decrease with the other.

## METAL DETECTOR (June 1991)

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.

Ours 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 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

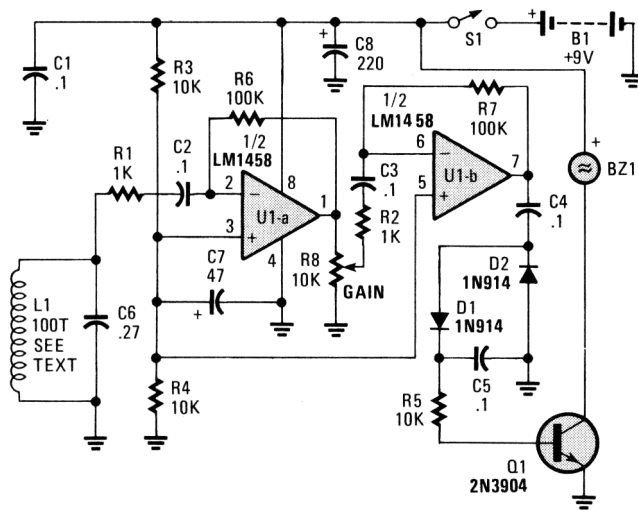


Fig. 4. The receiver portion of the metal detector is built around an LM1458 dual op-amp, a single 2N3904 general-purpose silicon transistor, and a 100-turn homebrew coil that's tuned to about 7 kHz via C6.

## 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 1/4-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.

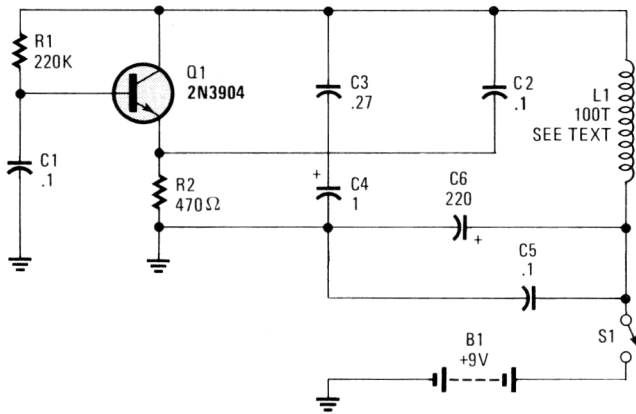


Fig. 5. The transmitter portion of the detector is built around a single transistor that's configured as a Colpitts oscillator, and another 100-turn coil (the transmitter's sensing loop), which is tuned to about 7 kHz by capacitors C2-C4.

### PARTS LIST FOR THE VLF TRANSMITTER

#### CAPACITORS

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

#### ADDITIONAL PARTS AND MATERIALS

- B1—9-volt transistor-radio battery
- Q1—2N3904 general-purpose NPN silicon transistor
- R1—220,000-ohm  $\frac{1}{4}$ -watt, 5% resistor
- R2—470-ohm,  $\frac{1}{4}$ -watt, 5% resistor
- L1—Transmitter loop, see text
- S1—SPST switch
- Perfboard materials, enclosure, battery holder and connector, wire, solder, hardware, etc.

(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 4-1/2 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.

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 repositioning 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.

### METAL DETECTOR (August 1991)

Our next entry see Fig 2, places the NE602 at the center of a simple yet sensitive metal detector. Transistor Q1, a 2N3904 general-purpose NPN transistor, is connected as a Colpitts oscillator, operating at a frequency of about 250 kHz. The oscillator's inductor, L1, serves as the metal sensor. When the loop is brought near a metal object, the loop's inductance changes, causing a shift in oscillator frequency which is transmitted to pin 1 of U1.

Integrated circuit U1's internal oscillator is also operating at a frequency of about 250 kHz. When the two oscillators are operating at, or about the same frequency U1's mixer output at pin 4, is an audio tone that equals the difference frequency of the two oscillators. If the loop oscillator is operating at 250 kHz

and the local oscillator is operating at 250.5 kHz, the audio tone would be the difference of the two, or 500 Hz.

The audio tone passes through a low-pass filter, made up of L3 and C8, and then travels to the headphone jack (J1) through coupling capacitor C12. When the sense loop is passed over a metal object, the Colpitts oscillator's frequency is shifted, causing the audio tone to change, thereby indicating that metal has been detected.

Inductor L1 is a homemade coil, made from 5 turns of #20 enamel-coated copper wire wound on a 9-inch diameter wood or plastic form. After winding the coil, tape the windings in place and attach a non-metallic handle to the search loop. The coil should be connected to the circuit via shielded mike or mini-coaxial cable. To obtain

the best operating stability, the metal detector circuit should be neatly assembled (keeping the component leads as short as possible) and housed in a metal cabinet. Transistor Q1 and its associated components should be located away from U1 and its support components, so that the two oscillators won't lock together when the circuit is tuned for a very low-frequency, audio-output tone. A standard 9-volt transistor radio battery will do for the power source.

To use the circuit, position the search loop away from any metal object and adjust C9 for a low-frequency audio tone. It is much easier to detect metal objects at greater distances from the search loop if the output-tone's frequency is very low. That's because it is much easier to detect a two- or three-hertz change at 15 Hz than at 150 Hz.

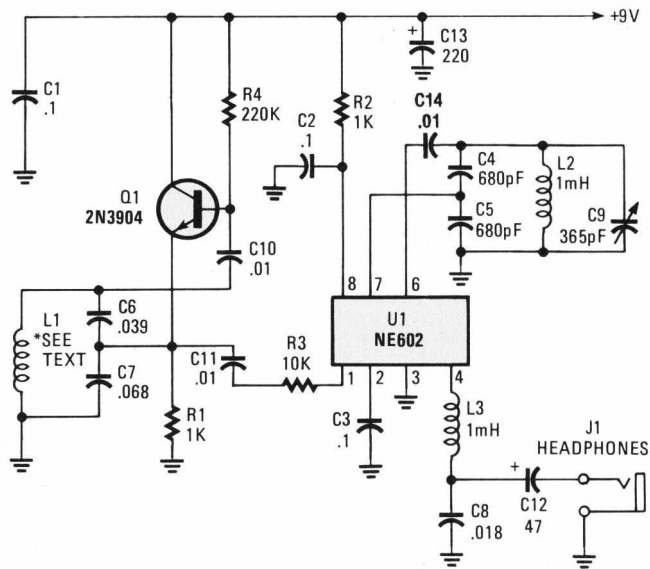


Fig. 2. In this metal-detector circuit, transistor Q1 (a 2N3904 general-purpose transistor) is configured as a Colpitts oscillator. When sense-loop L1 is brought near metal, the loop's inductance changes, shifting the oscillator's operating frequency.

Therefore, it is wise to set C9 for the lowest possible output frequency for maximum sensitivity. When searching for buried objects, position the search loop parallel to the ground and about one inch above its surface. Then simply sweep over the desired area.

### PARTS LIST FOR THE METAL DETECTOR

#### RESISTORS

All resistors are 1/4-watt, 5% units.)

R1, R2—1000-ohm

R3—10,000-ohm

R4—220,000-ohm

#### CAPACITORS

C1-C3—0.1- $\mu$ F, ceramic-disc

C4, C5—680-pF, ceramic-disc

C6—.039- $\mu$ F, mylar

C7—.068- $\mu$ F, mylar

C8—.018- $\mu$ F, mylar

C9—365-pF, broadcast variable (see text)

C10, C11, C14—.01- $\mu$ F, ceramic disc

C12—47- $\mu$ F, 16-WVDC, electrolytic

C13—220- $\mu$ F, 16-WVDC, electrolytic

#### ADDITIONAL PARTS AND MATERIALS

U1—NE602 double-balanced mixer, integrated circuit

Q1—2N3904 general-purpose NPN silicon transistor

L1—See text

L2, L3—1-mH choke (Mouser Electronics Part 43LH210)

J1—Headphone jack

Perfboard materials, enclosure, 9-volt power source, #20 enamel-coated copper wire, IC socket, wire, solder, hardware, etc.