BASIC CIRCUITRY

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METAL-DETECTING CIRCUITS II

Hello, Circuiteers, are you ready for some more metal detector circuitry fun? If so, stick around. We ended our last visit with a simple two-transistor Beat-Frequency Oscillator (BFO) detector circuit, and we're starting out this time with an even simpler single-transistor BFO detector circuit. How do we do that? Read on and find out.

Single Transistor Circuit

Before getting into the circuitry, we had better take a quick look at how the single-transistor detector system operates. I'm sure that at some time you've heard a whistle or tone while tuning your AM broadcast receiver or, even more likely, when listening to an AM short-wave broadcast station. In radio circles, this is referred to as a heterodyne signal. An AM receiver detecting two RF signals, which are very close in frequency, usually causes this condition. If the two RF frequencies are less than a few kHz apart, an audio tone (difference frequency) will be heard. This is basically how our single-transistor detector circuit operates.

In our single-transistor circuit, see Fig. 1, only one RF oscillator circuit is used. The other RF signal is supplied by one of many AM broadcast radio stations. A portable transistor AM radio receives the two RF signals and outputs an audible tone. The mixing and audio amplification is handled by the transistor radio. If either RF signal shifts in frequency, the audio tone will increase or decrease by the same amount. Since the frequency stability of all licensed AM broadcast stations is rock solid, only our search oscillator will produce a shift in frequency. The end result is a detector that operates like our two-transistor circuit, but requires less parts and time to construct.

The oscillator circuit in Fig. 1 is very similar to the oscillators used in our previous circuit. Transistor Q1 is connected in a Colpitts oscillator cir-

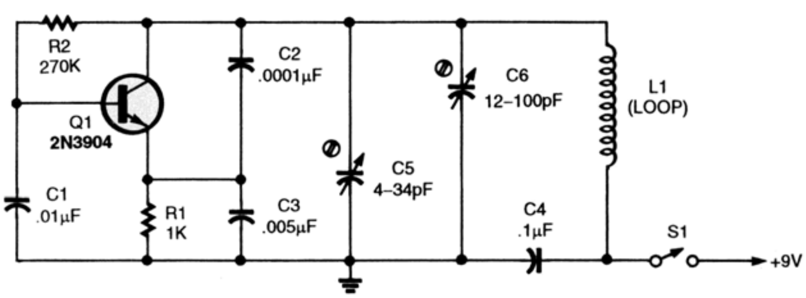

Fig. 1. Here is the schematic for the single-transistor circuit. Transistor Q1 is a general-purpose, NPN transistor; and it serves as the heart of a Colpitts oscillator circuit.

PARTS LIST FOR THE SINGLE-TRANSISTOR CIRCUIT (FIG. 1)

SEMICONDUCTORS
Q1—2N3904, or similar general-purpose NPN transistor

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2—270,000-ohm

CAPACITORS
C1—.01-µF, ceramic disc
C2—.0001-µF, ceramic disc
C3—.005-µF, ceramic disc
C4—.1-µF, ceramic disc
C5—4–34-pF, 7-mm, ultra-miniature trimmer, Mouser part #24AA113
C6—12–100-pF, Mouser part #242-3410-70

ADDITIONAL PARTS AND MATERIALS
S1—SPST switch
L1—Loop, see text

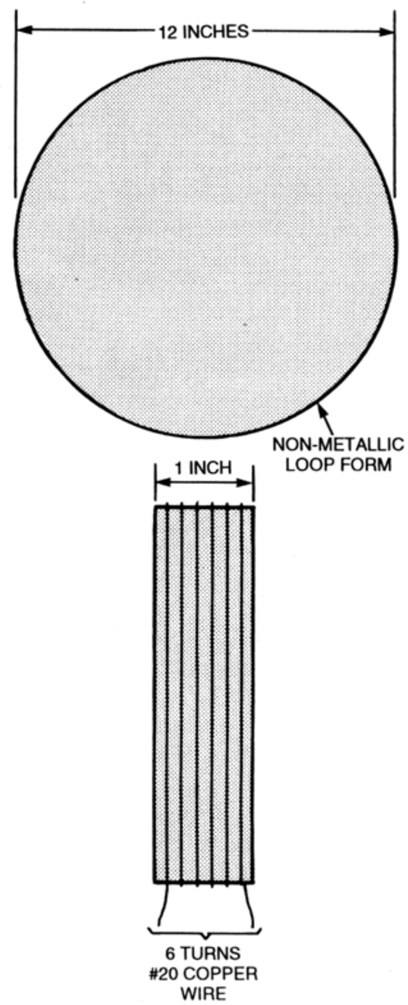

Fig. 2. The loop dimensions are shown above. The form can be constructed of a rigid material, such as wood or plastic.

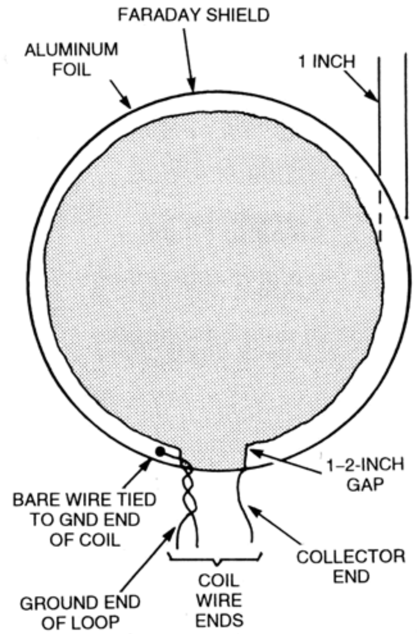

Fig. 3. This detailed diagram of the loop shows the leads extending from the copper wire, as well as the makeshift Faraday shield.

cuit with components C2, C3, C5, C6, and L1 making up the oscillator's tuned circuit. Changing any one or any combination of these components will vary the oscillator's operating frequency.

Increasing the value of any capacitor will lower the oscillator's frequency and decreasing the value will increase the frequency. Increasing L1's inductance will also cause a decrease in frequency and vice versa.

Building The Loop

The search loop may be constructed in several different ways; however, the

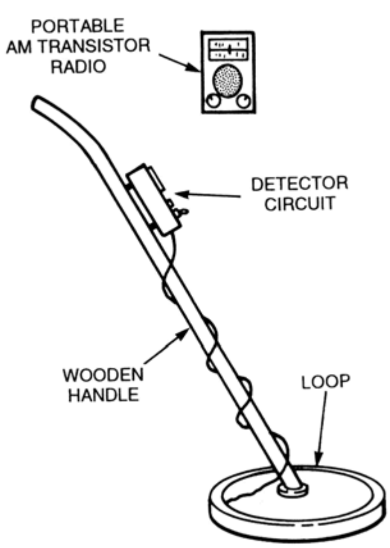

Fig. 4. Here is an artist's rendition of the completed metal-detector unit. Any inexpensive AM transistor radio can be used in conjunction with the detector.

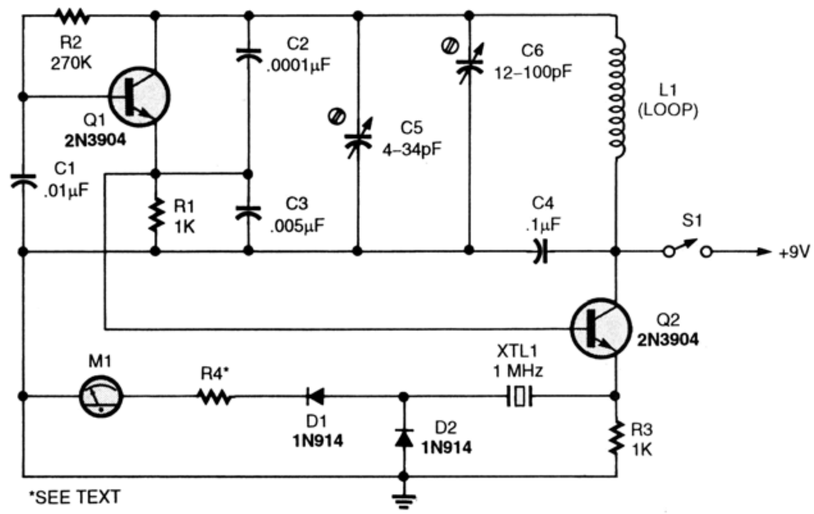

Fig. 5. The crystal-filter metal-detector circuit is shown above. The narrow band-pass of the crystal allows for a high sensitivity to minute frequency changes.

method offered here should get you headed in the right direction. Refer to Fig. 2 as a guide for constructing the loop. The loop form should be constructed from non-metallic and non-moisture-absorbent material. A sealed wood form will do, and it can be either solid or hoop-like. The form should be ¼ to 1 inch wide to allow room for the coil windings. Close wind six turns of #20 enameled or insulated wire on the form. Wrap the windings with at least two layers of good quality plastic electrical tape. Put the loop aside and construct the oscillator circuit on a piece of multipurpose PC board with pre-drilled holes. Stability is one of the most important considerations in building any stable oscillator circuit, so keep all component leads short and solidly mounted.

The two variable capacitors should be mounted in a manner that allows tuning from outside the enclosure. In order to achieve the best results, the circuit should be housed in a metal cabinet to which the circuit ground is connected. Temporarily connect the loop to the circuitry with about 30 inches of shielded microphone cable or 2-conductor intercom wire. Any wire gauge from #18 to #24 will do. Actually two insulated wires may be twisted together by hand and used.

Place the loop away from any metal object and apply power to the circuit. Locate a transistor radio near by and tune in a station somewhere near the middle of the dial. Adjust both C5 and C6 to a frequency that will heterodyne with the broadcast station. If nothing happens, it is most likely that the oscillator is not operating near the desired frequency. Now, how do we determine if the oscillator's frequency is too low or too high? Naturally, a frequency counter would be the easiest way to determine the oscillator's frequency. If one is not available, what then? A shortwave receiver that runes both below and above the standard AM broadcast band can be used to ferret out the oscillator's frequency.

Once the oscillator's frequency is determined, adjustments can be made to

PARTS LIST FOR THE CRYSTAL-FILTER DETECTOR (FIG. 5)

SEMICONDUCTORS

D1, D2—IN914 silicon signal diode
Q1, Q2—2N3904, or similar general-purpose NPN transistor

RESISTORS

(All resistors are ¼ watt, 5% units.)
R1, R3—1000-ohm
R2—270,000-ohm
R4—See text.

CAPACITORS

C1—.01-µF, ceramic disc
C2—.0001-µF, ceramic disc
C3—.005-µF, ceramic disc
C4—.1-µF, ceramic disc
C5—See Parts List for Fig. 1
C6—See Parts List for Fig. 1

ADDITIONAL PARTS AND MATERIALS

XTL1—1-MHz crystal
M1—50-µA to 1-mA meter
Metal cabinet, PC board material, etc.

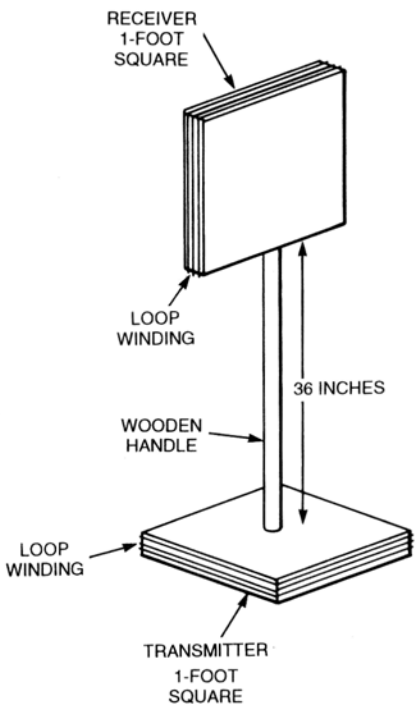

Fig. 6. The detector shown in the above diagram is excellent for deep level searches. The "90-degree out-of-phase" relationship of the two square loops helps limit cross-interference between the transmitter and receiver, thus eliminating feedback during operation.

move the frequency into the broadcast band. Reducing the total capacitance of the oscillator's tuned circuit or lowering the inductance of the loop will raise the frequency. Lowering the frequency is accomplished by increasing the capacitance of the tuned circuit or by increasing the inductance of the loop. Removing or adding a turn to the loop is a good method to use if the oscillator is way off frequency.

Adding A Faraday Shield

The search loop normally scans the ground in a parallel manner in search of metal objects. The loop's parallel position to the ground forms a capacitance to ground, which shifts the oscillator's frequency. As the loop moves up and down above the ground, the oscillator's frequency shifts in a like manner. Adding a Faraday shield to the loop will help in reducing the ground-effect frequency-shift problem.

The Faraday shield is a metal shroud that is formed around the loop with an insulating gap in the middle. A shield can be formed out of aluminum foil by cutting a length that's 3 inches wide and long enough to go almost completely around the edge of the loop while leaving a gap of 1 to 2 inches in the middle, see Fig. 3. Once the aluminum foil is formed, add a 4-inch length bare wire under the foil at one end and glue the shield in place. Place the loop on a flat surface and place a solid object on top to secure the foil to the loop form. After the glue dries, connect the other end of the bare wire to the loop's ground-end connection.

An old broom handle or dowel rod is attached to the middle of the loop and serves as the handle and support for the loop and detector circuit. See Fig. 4. The AM radio may be attached to the handle as well or carried separately.

Position the loop over the area to be searched and tune the oscillator to produce an audible beat frequency tone. Maximum sensitivity is achieved when the oscillator is within a few cycles of the broadcast station. This detector will detect all types of metal, so be ready to dig, and then dig some more.

Crystal-Filter Detector

Our next entry is a version of one of my favorite metal-detector circuits. A loop and an oscillator circuit similar to the one in our previous detector are the basic ingredients used in the crystal-filter detector. The addition of an emitter follower gives isolation to the oscillator and supplies a low-impedance source for the crystal. The output is rectified by Dl and D2 and fed to the meter. Take a look at Fig. 5, as you continue to read the circuit description.

Here's a brief description of how the crystal-filter metal-detector circuit operates. The oscillator is tuned to the series resonance frequency of the crystal, which can be any frequency from 100 kHz to over 1 MHz. However, in our circuit, a 1-MHz crystal is used. When the oscillator is operating at the crystal's frequency, the output at the meter is at maximum.

Any shift in the oscillator's frequency will cause a reduction in the meter reading. The circuit is very sensitive to small frequency shifts due to the crystal's narrow band-pass characteristics in the series mode. The basic loop construction used in the previous detector circuit may be used here as well.

This detector's circuitry should be constructed in the same manner as our previous circuit. If any component moves or vibrates during use, the meter will falsely indicate a detected object. Build it solid. The choice of the meter used for M1 can vary from a sensitive 50-µA to a 1-mA movement. The value of R4 is selected for a full-scale meter reading when the oscillator is operating at the series-resonance frequency of the crystal.

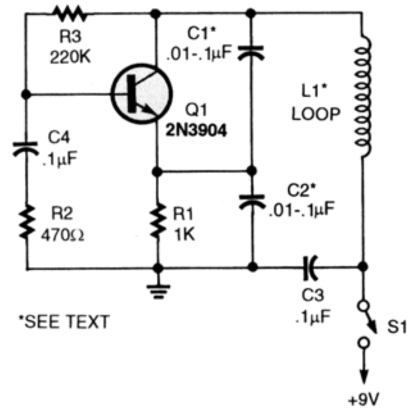

Fig. 7. The transmitter circuit in the above schematic operates in a range of 35 to 50 kHz. The oscillator circuit is similar to the previous two mentioned.

PARTS LIST FOR THE TRANSMITTER (FIG. 7)

SEMICONDUCTORS

Q1—2N3904, or similar general-purpose NPN transistor

CAPACITORS

C1, C2—.01 to .1-µF, ceramic disc (see text)

C3, C4—.1-µF, ceramic disc

RESISTORS

(All resistors are ¼-watt, 5% resistor units.)

R1—1000-ohm

R2—470-ohm

R3—220,000-ohm

ADDITIONAL PARTS AND MATERIALS

S1—SPST switch

L1—Loop, see text

Transmitter/Receiver Detector

Our last detector circuit is suitable for locating large metal objects at greater depths—feet instead of inches. This two-box detector has been around for about 75 years and is still one of the most popular deep-searching detectors. The basic system is shown in Fig. 6.

Two non-metallic boxes serve as the 2 housing for the electronics and the forms for the loops. The transmitter and receiver boxes are mounted on a 3-foot-long wood handle, with the receiver placed in a horizontal position and the transmitter in a vertical position. This 90-degree relationship between the transmitter and receiver allows for mini-

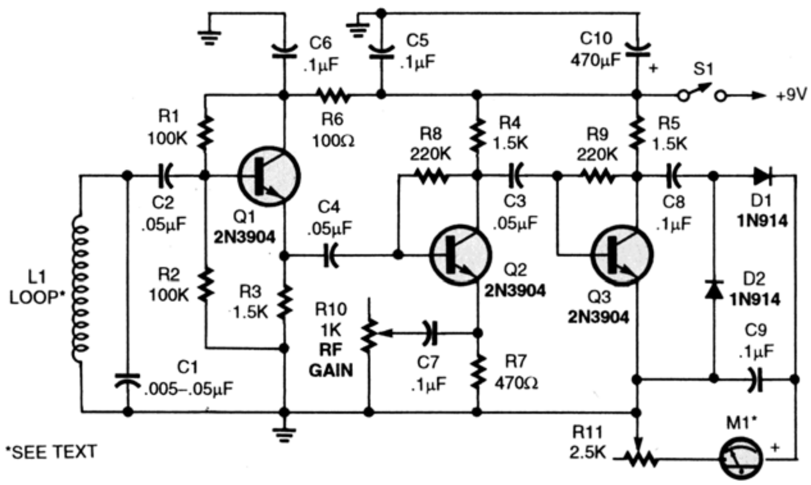

Fig. 8. The receiver circuit shown above can fit on a 2- × 3-inch piece of PC board. Two transistors are used to perform RF amplification.

PARTS LIST FOR THE RECEIVER (FIG. 8)

SEMICONDUCTORS

Q1–Q3—2N3904, or similar general-purpose NPN transistor
D1, D2—1N914 silicon signal diode

CAPACITORS

C1—.005 to .05-µF, ceramic disc (see text)
C2–C4—.05-µF, ceramic disc
C5–C9—.1-µF, ceramic disc
C10—470-µF, 25WVDC electrolytic

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1, R2—100,000-ohm
R3–R5—1500-ohm
R6—100-ohm
R7—470-ohm
R8, R9—220,000-ohm
R10—1000-ohm potentiometer
R11—2500-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS

S1—SPST switch
M1—50-µA to 1-mA DC meter
L1—Loop, see text

mum transfer of signal between the two loops. Placing a large metal object between the two loops causes the transmitter's field to distort, allowing some of the signal to reach the receiver's loop. The signal is amplified by the receiver and indicated on the meter as metal detected.

Building The Transmitter

We'll start with the transmitter circuit first, (see Fig. 7) because it is the simpler of the two units. The transmitter circuit is very similar to our previous two oscillator circuits, with a slight variation in the base bypass circuit. The values of frequency-determined capacitors, C1 and C2, are the same. Depending on the size of the loop, they can vary from .01 to .1-µF.

The receiver loop normally requires a capacitor equal to ½ the value of C1 or C2 in the transmitter circuit. The transmitter loop is tuned with C1 and C2, which are always the same value. The actual value of capacitance across the transmitter loop is ½ the value of either C1 or C2. It is most important that both loops are tuned to the same frequency.

About any loop size from 8 to 12 square inches will do, but we'll stick to the 12-inch box and offer values for that size. The loops are formed by close winding 20 turns of #24 to #26 wire around each housing. Run about 8 inches of wire from each end of the loop to the inside of the housing for circuit connections. Tape the winding in place with plastic electrical tape.

The operating frequency will be somewhere between 35 kHz and 50 kHz. The capacitor values for C1 and C2 are .1-µF for the transmitter and .05-µF for C1 in the receiver circuit. Less turns or smaller loops may be used for higher frequency operation. Try and keep the operating frequency below 200 kHz, as this type of metal locator works best at low frequencies.

Building The Receiver

The receiver (see Fig. 8) is a simple two-transistor RF amplifier circuit with an isolated emitter follower input. The RF signal is picked up by the loop and coupled through Q1 to the input of the first RF amplifier stage, Q2. Transistor Q2's RF gain is set by R10. The signal from Q2's collector is fed to the base of Q3, and Q3's output is coupled to a two-diode detector circuit. The DC output is indicated by M1.

The receiver circuitry will fit on a 2- X 3-inch piece of multipurpose PC board material. Mount the components close to the board with short leads and keep the input components away from the output circuitry. The meter can be any DC type with sensitivity of 50-µA to 1-mA. If a 50-µA meter is used, R11 may need to be increased to a 10K potentiometer. Mount the circuit in the receiver box and connect the loop.

Mount the transmitter box on one end of the wood handle and the receiver on the other. The receiver will need to be mounted so that it can be tilted up and down to obtain a balance between the two loops. This can be accomplished by using a small hinge attached to the end of the handle and the receiver housing. Once the balance point is found, the receiver can be mounted in that position.

Hopefully, you will find some use for at least one of our metal-detector circuits. Until next time, may all of your circuits work!