

# CIRCUIT CIRCUS

By Charles D. Rakes

## Oscillator Round-Up

With spring just around the corner, it's a great time for *Circuit Circus* to run an electronic marathon to see how many "user friendly" circuits we can cram into our allotted space. So here we go.

### TTL CRYSTAL OSCILLATOR

Our first circuit came about when a project we were working on required a low-cost crystal oscillator that would produce both a

and its surplus availability. If the required frequency happens to be one of the popular computer or industrial standards, the price is likely to be very low, but if a special non-standard frequency is required, be prepared to pay a much higher price. In any case, it would be difficult to build a circuit that performs as well as this one for less money.

Two gates of a 7400 quad two-input NAND gate make up the actual oscillator circuit, with a crystal

generated at the junction of C1 and XTAL1. The impedance at that point is extremely high and can not supply a direct output signal. Transistor Q1, configured as an emitter-follower amplifier, offers a high input impedance to the sine-wave signal and a low output impedance to an external load.

The circuit will kick start even the most stubborn crystals and can operate with crystal frequencies of less than 1 MHz to over 10

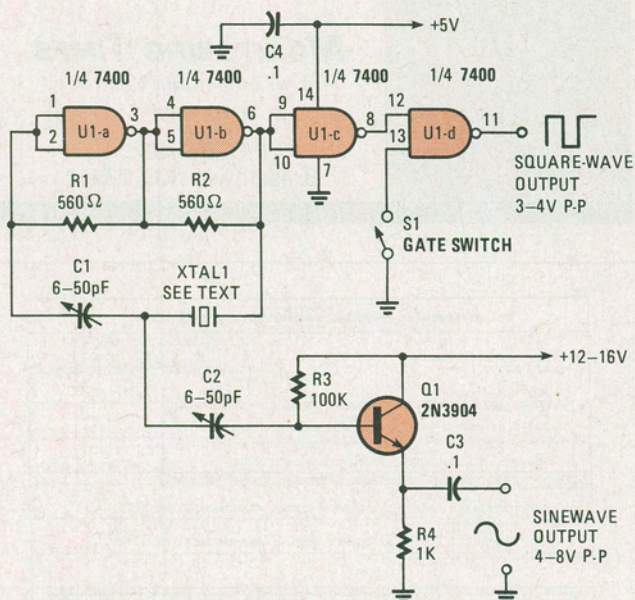


Fig. 1. Two gates (U1-a and U1-b) of a 7400 quad 2-input NAND comprise the actual oscillator circuit, with feedback controlled by a crystal (XTAL1) and a variable capacitor (C1). Gate U1-c is used to buffer the output of the oscillator, while U1-d is used to turn the output on and off.

square- and a sine-wave outputs. Frequency stability, low cost and a small parts count were the three major design criteria to be considered. The TTL crystal oscillator circuit shown in Fig. 1 fills the bill.

With TTL IC's and 2N3904 transistors going for pennies, the cost of the oscillator primarily depends on the crystal's frequency

### PARTS LIST FOR THE TTL CRYSTAL OSCILLATOR

#### RESISTORS

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

- R1, R2—560-ohm
- R3—100,000-ohm
- R4—1000-ohm

#### ADDITIONAL PARTS AND MATERIALS

- U1—7400 quad two-input NAND gate, integrated circuit
- Q1—2N3904 general-purpose NPN silicon transistor
- C1, C2—6-50-pF, trimmer capacitor
- C3, C4—0.1-μF, ceramic-disc capacitor
- S1—SPST toggle switch
- XTAL1—Crystal (see text)
- Perfboard materials, enclosure, 5-volt power source, wire, solder, hardware, etc.

and a variable capacitor functioning as the feedback network between the input of gate U1-a and the output of gate U1-b. Gate U1-c operates as a buffer between the oscillator and output stage, U1-d. Switch S1 serves as a manual gate control to turn the square-wave output of U1-d at pin 11 on and off. With S1 open, as shown, the square-wave appears at the output, and when closed it is turned off. The switch may be replaced with a logic gate to electronically control the output.

A near perfect 6- to 8-volt peak-to-peak sine wave is

generated at the junction of C1 and XTAL1. The impedance at that point is extremely high and can not supply a direct output signal. Transistor Q1, configured as an emitter-follower amplifier, offers a high input impedance to the sine-wave signal and a low output impedance to an external load. The circuit will kick start even the most stubborn crystals and can operate with crystal frequencies of less than 1 MHz to over 10

MHz. Setting up the oscillator circuit is easy. If you have an oscilloscope available, connect it to the square-wave output of U1-d at pin 11 and set C1 in the middle of the range that produces the best output waveform. Now monitor the sine-wave output and set C2 for the best looking waveform. Go back to C1 and tweak adjust it back and forth slightly for the best sine-wave output.

### TWO-TRANSISTOR CRYSTAL OSCILLATOR

Our next item, see Fig. 2, is a two-transistor, crystal-oscillator circuit that works

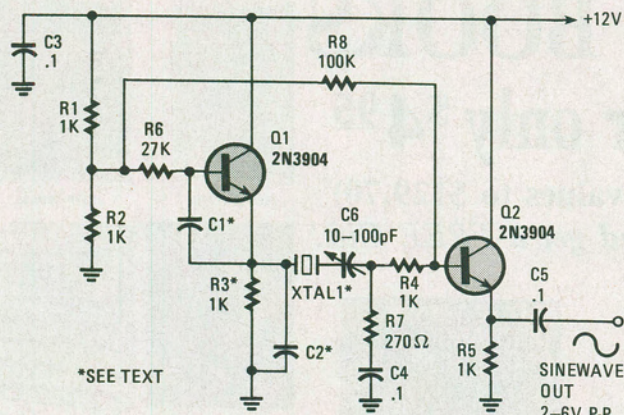


Fig. 2. Built around two general-purpose transistors, this oscillator produces a sine-wave output of from 2 to 6 volts peak-to-peak.

### PARTS LIST FOR THE TWO-TRANSISTOR CRYSTAL OSCILLATOR

#### RESISTORS

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

- R1-R5—1000-ohm
- R6—27,000-ohm
- R7—270-ohm
- R8—100,000-ohm

#### CAPACITORS

- C1, C2—See text
- C3, C5—0.1- $\mu$ F, ceramic disc
- C6—10- to 100-pF, trimmer

#### ADDITIONAL PARTS AND MATERIALS

- Q1, Q2—2N3904 general-purpose NPN silicon transistor
- XTAL1—See text
- Perfboard materials, enclosure, 12-volt power source, wire, solder, hardware, etc.

great, costs little, and uses no coils or chokes. Here again, the cost depends mainly on the crystal used, as the total cost of the other components (provided that you have a full junkbox to raid) should be no more than a couple of dollars.

Transistor Q1 and the few surrounding components make up the oscillator circuit. The ground return for the crystal is routed through C6, R7, and C4. At the junction of C6 and R7, which is a fairly low impedance point, the RF is fed to an emitter-follower amplifier, Q2. The shape of the waveform at the C6/R7 junction happens to be a near perfect sine wave. The output, at the emitter of Q2

varies in amplitude from about 2- to 6-volts peak-to-peak, depending on the crystal's Q and the values used for capacitors C1 and C2.

The values of C1 and C2 determine the frequency range that the circuit will cover. For crystal frequencies below 1 MHz, C1 and C2 should be 2700 pF (.0027  $\mu$ F). For frequencies of 1 MHz to about 5 MHz, use 680-pF capacitors; and for 5 MHz up to about 20 MHz, use 200-pF capacitors. You might try experimenting with values of those capacitors to obtain the best looking output waveform. Also, the setting of capacitor C6 will influence both the output level and waveform shape.

## METAL DETECTOR

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 frequen-

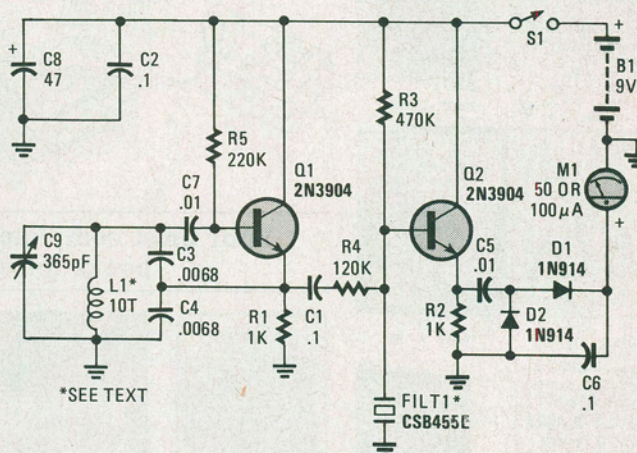


Fig. 3. The metal detector is little more than a simple oscillator circuit (built around Q1), whose output is fed to a meter (M1), causing it to deflect to about mid-scale. When the sense coil (L1) is brought near metal, the oscillator frequency changes, and that change causes the meter needle to move 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)
- F1—455-kHz crystal-filter (Murata CSB455E or similar)
- B1—9-volt transistor-radio battery
- M1—50- to 100-mA meter (see text)
- Perfboard materials, enclosure, wire, solder, hardware, etc.

cy, 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 electronics 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 S.A.S.E. (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.

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 oscillator 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. ■