Metal Detector

Build this low-cost project and locate those hidden pipes and wires.

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This detector is intended for locating pipes, cables, nails and screws in walls rather than buried treasure. Although it is extremely simple and can be constructed at very low cost, its level of performance is quite good. It can detect quite small screws at a distance of 25 to 50 millimetres. This may not seem to be particularly good, but it requires quite complex circuits to detect small objects at ranges substantially larger than this.

The maximum range of the unit with much larger pieces of metal is not much greater than the range with small target objects. However, as a unit of this type is normally only used for detecting small pieces of metal at relatively small depths, this lack of range on large objects is not of major importance.

The unit uses standard off-the-shelf components, including the search coil. Some metal detectors are difficult to use because the presence of metal is indicated by a small change in pitch from an audio tone. This method of indication can be difficult even for someone with a good sense of pitch. In this case the method of indication is very clear, with a panel LED switching on when metal is detected.

Operating Principle

The block diagram of Fig. 1 shows that basic setup used in the metal detector. Like most metal locators, it is based on an LC oscillator which has the search coil as the inductor in the parallel LC tuned circuit.

In this circuit a feedback control is used to adjust the oscillator so that there is only just sufficient feedback to sustain oscillation. While it might appear that placing metal near the search coil will have no significant effect on the circuit, it does in fact have a very strong influence on the performance of the oscillator. One effect is to change the value of the inductance by a small amount, but this often exploited effect is not utilized in this circuit. Instead it is the slight change in the Q of the coil that is of importance.

Q Value

The Q value of an inductor is effectively a measure of its efficiency, and the result of metal close to the search coil is to give a reduction of its Q. This slightly dampens the oscillator, and the strength of the output signal decreases. In fact the Q will be reduced to the point where oscillation ceases altogether if even a small piece of metal is brought very close to the coil.

This reduction in the amplitude of the oscillations must be converted into a switching signal to operate the LED indicator. This is achieved using two simple signal processing stages, the first of which is a rectifier and smoothing circuit. This provides a DC output signal that is roughly proportional to the strength of the AC output signal from the oscillator.

The next stage is a voltage comparator. This compares the output from the smoothing circuit with a reference voltage. If the voltage from the smoothing circuit is lower than the reference voltage, the output of the comparator goes high and switches on the LED If the output from the smoothing circuit is the higher of the two voltages, the output of the comparator goes low and the LED is switched off.

In practice the feedback control is adjusted so that under standby conditions the output voltage from the smoothing circuit is just high enough to hold the LED in the off state. Metal close to the search coil then gives a lower output voltage and switches on the LED

Circuit Description
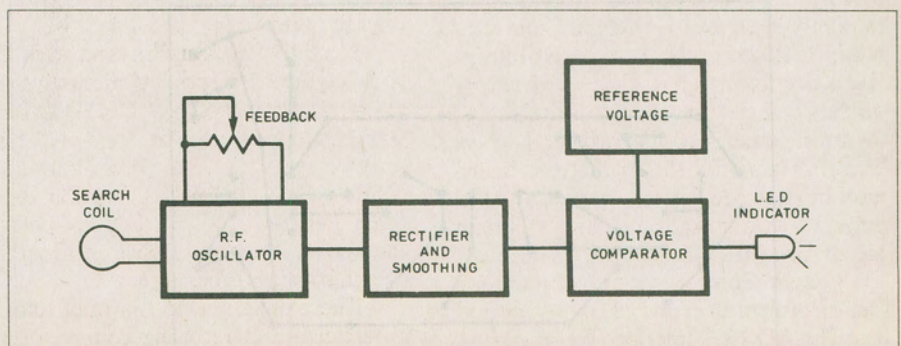
The full Metal Detector circuit diagram

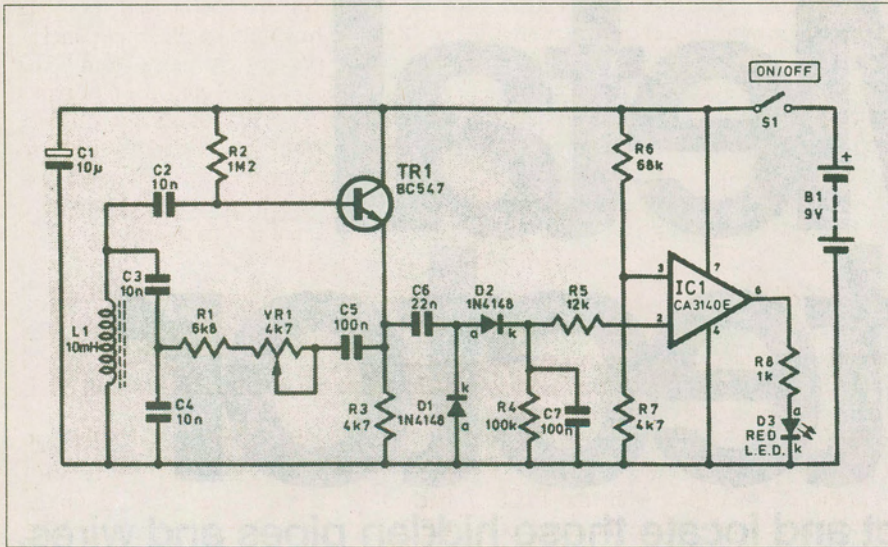Fig. 1. Block diagram of the basic setup for the Metal Detector.

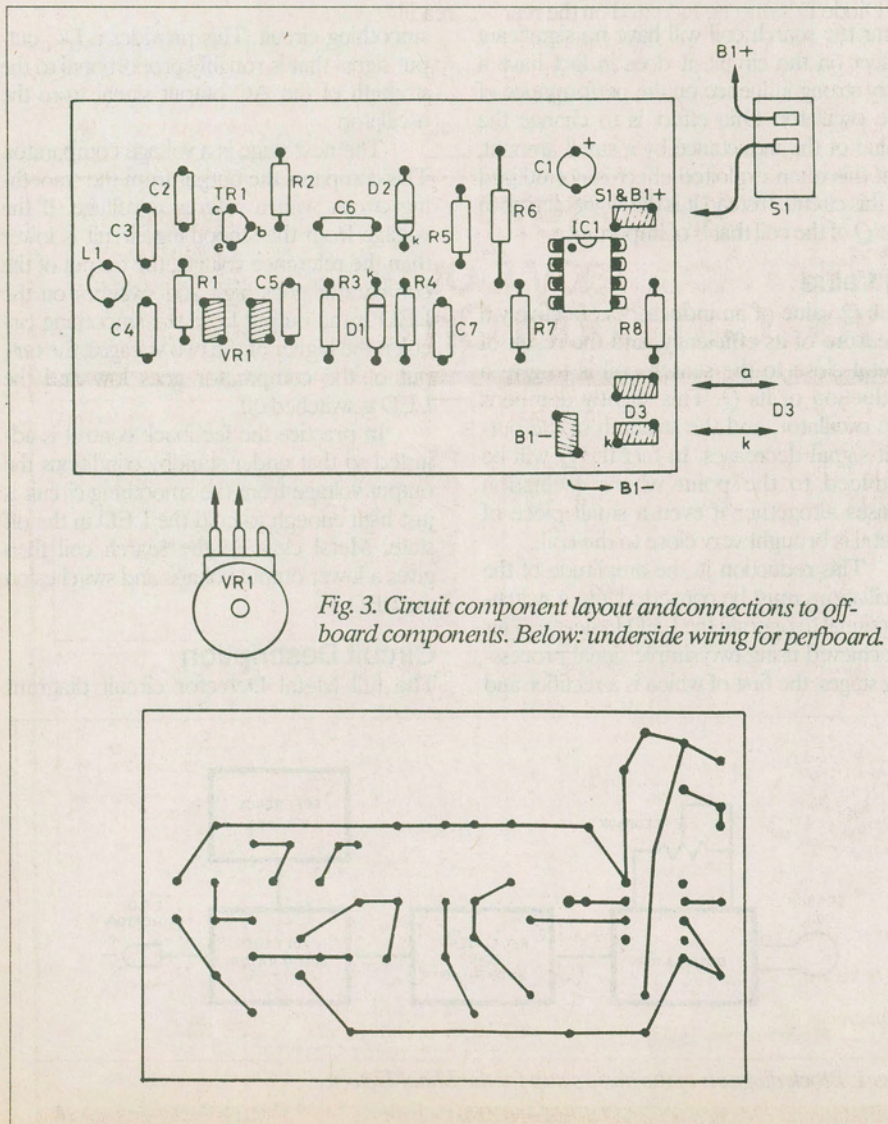*Fig. 2. Full circuit diagram for the Metal Detector.*

Fig. 3. Circuit component layout and connections to off-board components. Below: underside wiring for perfboard.

appears in Fig. 2. The oscillator is based on transistor TR1 which operates in the emitter follower mode. This provides slightly less than unity voltage gain, but here is a voltage step-up through the tuned circuit which enables oscillation to be sustained.

The tuned circuit is formed by coil L1, capacitors C3 and C4, with the two capacitors providing a capacitive centre tap. Potentiometer VR1 is the feedback level control. With the specified values the circuit oscillates at about 20kHz.

Capacitor C6 couples the output of the oscillator to the rectifier and smoothing circuit. The voltage comparator is an operational amplifier (IC1) used open loop. Due to their very high DC gain operational amplifiers work very well in this role.

Reference Voltage

The reference voltage is provided by resistors R6 and R7. These produce an output voltage of well under 1V, and there seems

PARTS LIST

Resistors
R1	6k8
R2	1M2
R3,R7	4k7
R4	100k
R5	12k
R6	68k
R8	1k

All 0.25W 5%

Potentiometer
VR1	4k7 lin.

Capacitors
C1	10u elec. 25V
C2,C3,C4	10n
C5,C7	100n
C6	22n

Semiconductors
D1,D2	1N4148 diode
D3	Red LED
TR1	BC547, 2N3904 npn
IC1	CA3140E op amp

Miscellaneous
L1 10mH choke such as Miller 70F102AL
S1 ....SPDT min. toggle
B1.............................. 9 volt battery

Case; battery connector; matrix board (perfboard) or Veroboard; control knob; 8-pin DIP socket; wire, etc.

to be an advantage in a low reference level. This is because a low reference level permits VR1 to be adjusted for a very low level of oscillation without the LED being activated, and a low level of oscillation seems to offer optimum sensitivity. In fact, making resistor R7 even lower in value might give improved sensitivity. Diode D3 is the LED indicator and it is driven from the output of IC1 by way of current limiting resistor R8.

The current consumption of the circuit under standby conditions is about 2.5 milliamps, but this increases to approximately 9 milliamps when the LED switches on. A small 9V battery is an adequate power source for many hours of operation.

Construction

The circuit can be built on Veroboard, or on plain matrix board. Details of the component layout and underside wiring of the board for matrix board are given in Fig. 3. As IC1 is a MOS input device, the use of an IC socket is recommended. Leave the IC in its anti-static package until the unit is in all other respects finished, and try to handle this component as little as possible when fitting it into its holder.

Any 10mH choke should be suitable for L1, such as the Miller series of RF chokes.

Once all the components have been fitted, check that there are no errors and then trim off the leadout wires so that only about four millimetres of each one protrudes on the underside of the board. The wiring is then added from point to point.

Case

The case for this project must be plastic (or some other non-metallic substance) as a metal case would shield the search coil and prevent the unit from functioning. The board must be mounted on long mounting bolts with spacers used to bring coil L1 right up against the front panel.

Having L1 well back from the front panel would effectively reduce the range of the unit. You could even drill a hole for it in the front panel so that its top surface could be brought flush with the front panel.

Diode D3 must be mounted on the rear panel so that it is visible with the front panel placed against a wall. The cathode terminal of a LED is normally indicated by a shorter leadout wire.

Switch S1 and potentiometer VR1 must not be mounted on the front panel as they would prevent the panel from being placed close to walls. Again, the rear panel is probably the best position for these. There is no need to go to great lengths to keep all metal well away from coil L1 as VR1 can be adjusted to compensate for a certain amount of metal close to L1.

In Use

After a final check of the wiring, switch on and try adjusting potentiometer VR1. The LED should switch on with the control fully advanced, but should switch off if it is backed off somewhat.

Optimum sensitivity is obtained with the feedback or sensitivity control VR1 backed off just far enough to extinguish the LED, and for really good sensitivity VR1 must be adjusted very carefully. If you try placing a small piece of metal near L1, such as the blade of a screwdriver, it should be readily detected.

The prototype readily detected screws, pipes, and cables in the walls of my house, as well as some unexpected pieces of metal such as reinforcing over some doors. ∎