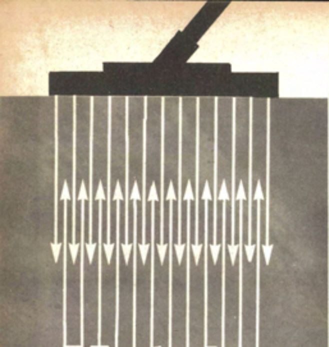


Metal Detector

By F.G.RAYER

THE device described in this article can help to locate concealed metal, under paving or the earth, under floors, or behind walls. The search coil and detector are attached to a wooden handle, so can be moved about over the ground. The maximum distance to which a metal object can be located depends on the adjustment of the circuit, and also circumstances, such as the presence of other metal objects, size of the metal to be located, and to some extent on materials which may lie between the metal and search coil.

RANGE

The range at which detection could be secured was up to about 6in from a small metal item such as a coin, extending to about 1ft 6in for a metal object having an area of about ½ sq ft or larger. Long items of small width, such as small pipes or wires, can only be detected at short range. The kind of metal, and the ability of the user to note a small change in tone, also influences the maximum possible range.

Moving the search coil near a large mass of wet earth changes the tone, but a manual control allows adjustment for this. In such circumstances the search coil should be moved at a uniform distance from the ground, or regularly in contact with it.

DETECTOR CIRCUIT

Two r.f. transistors are used in a heterodyne circuit (Fig. 1) with a further transistor as an audio amplifier. L1 is the search coil, with collector and base tappings, and tuned by the fixed capacitor C4.

The second oscillator is built around a cored coil L2. The frequency is initially set by adjusting the core and trimmer VC1. The circuit can then be tuned over a narrow band by the manual control VC2.

The r.f. output from TR1 and TR2 is coupled to the detector D1 by small capacitances C2 and C7. TR3 provides audio amplification, with base bias secured by the rectified signal through D1.

The coils L1 and L2 are each tuned to about 550kHz. When L1 and L2 are operating at the same frequency, no beat note is produced or heard in the phones. The presence of metal near the large search coil L1 detunes its frequency, producing a heterodyne beat heard in the phones. The change of frequency increases as the metal object is approaching the coil, and falls as the distance between coil and object grows larger again.

SENSITIVITY

For most sensitive results, VC2 is tuned so that a low audio tone is heard with no metal near L1. The tone then changes when metal is approached. If both tuned circuits are set to exactly the same frequency to begin with, "pulling" of one circuit by the other reduces sensitivity. This effect can be made less serious by reducing the values of C2 and C7, but volume then becomes rather low. It is thus better to work with a constant tone.

The gain of the audio amplifier has no bearing on the range of detection, but boosts detector output to a suitable level. The single audio stage was found sufficient, using 4,000 ohm headphones.

ASSEMBLY

The detector is wired on an s.r.b.p. panel which should fit in a plastics box (Fig. 2), 7in × 4½in × 1½in deep.

Top left—the search coil; top right—the headphones; bottom—the electronic detector

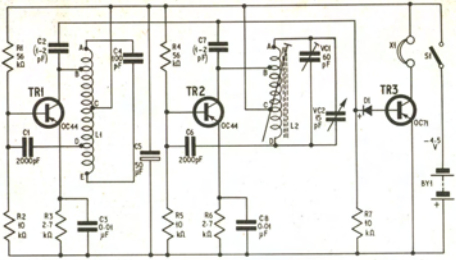


Fig. 1. The complete circuit diagram of the metal detector

COMPONENTS...

Resistors
- R1 56kΩ
- R2 10kΩ
- R3 2·7kΩ
- R4 56kΩ
- R5 10kΩ
- R6 2·7kΩ
- R7 10kΩ
- All ±10%, ¼W carbon

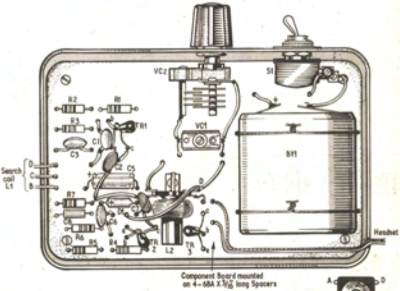
Capacitors
- C1 2,000pF
- C2 2pF ceramic
- C3 0·01μF
- C4 100pF mica
- C5 50μF elect. 12V
- C6 2,000pF
- C7 2pF ceramic
- C8 0·01μF

Variable capacitors
- VC1 60pF compression trimmer
- VC2 15pF air space variable control

Inductors
- L1 uses p.v.c. covered single core bell wire, about 20 yards (see text)
- L2 uses 32 s.w.g. enam. copper wire, about 10 yards and a ⅜in or 10mm coil former with dust iron core (see text)

Transistors and Diode
- TR1, 2 OC44 or NKT152 (2 off)
- TR3 OC71 or NKT251
- D1 OA79, OA81, or similar

Miscellaneous
- S1 Single-pole, on-off toggle switch
- X1 Headphones, 4,000Ω type
- BY1 Battery 4·5V type 1289
- Plastics box, perforated s.r.b.p. 6½ × 4½
- Tinned copper wire and p.v.c. covered flexible wire
- Wood for detector sensor and handle (see text)



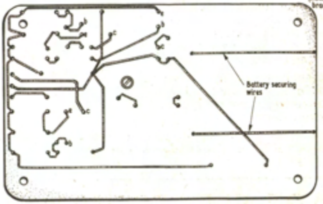


Fig. 2. The electronic unit is mounted in a plastics box. The component side and underside wiring of the board are shown above

The wire ends of the components pass through small holes, and are soldered underneath to 24 s.w.g. wire connections. Insulation is placed on leads where necessary.

The 4·5V battery is secured with cord or wire passed through holes in the component board. Leads are soldered on. Polarity must be correct.

The switch and VC2 are fitted after placing the wired panel in the box. Long leads for the search coil pass through a hole in the box end and are taped to the handle down to the search coil at the bottom.

The capacitors C2 and C7 can be 2pF fixed ceramic types, or be made from thin insulated wire about 1½in long and twisted together.

COIL WINDING

The oscillator coil L2 is wound from 32 s.w.g. enamelled wire on a ⅜in or 10mm diameter former with an adjustable core. The winding begins at A, Fig. 2. This end will go to VC1 and VC2, Fig. 2, after the coil is wound and mounted. For the first section, A to B, wind on 125 turns, in a compact pile. Make a loop of the wire about 3in long at B. Continue winding in a pile in the same direction for a further 45 turns, and make another loop at C (battery negative). A further 15 turns in the same direction finishes the coil; this end (point D) goes to VC1, VC2 and C6.

Do not let the loops cause the coil windings to come loose. Turns are held with a little adhesive or wax. When firmly set the loops at A, B, C, and D are bared for about ½in and soldered to the appropriate junctions on the component board, or via the tags on the former if fitted.

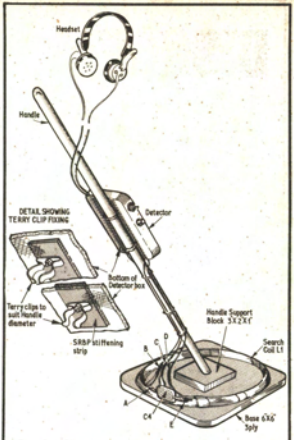


Fig. 3. Construction details of the search coil. Make sure that the Terry clip fixings do not touch the wiring

SEARCH COIL

The search coil L1 is wound with thin single core bell wire and is 5in in diameter. A temporary former of near this diameter is used to wind the coil, winding 10 turns from A to B. A loop is made at B and winding continues for another 12 turns to loop C. Wind four turns more, make loop D, then wind 15 turns more, and end at E. The ends and loops should be identified by coloured sleeving or other means. The insulation is removed for about ½in for connection to the long leads from the box.

The coil is removed from its temporary former, and bound with adhesive tape. It is attached by adhesive to a piece of 3-ply wood about 6in × 6in, Fig. 3. C4 is soldered to the ends of the coil at points A and E.

ASSEMBLY OF SEARCH COIL

A block of 1in thick wood about 2in × 3in is drilled at an angle to take a thick dowel or broom handle, Fig. 3. This is glued in place, and the block is glued to the centre of the plywood plate.

The detector can be fitted to the handle about 1ft up the handle by means of two Terry clips bolted to the box. The search coil leads B, C and D (Fig. 2) are arranged to run down to the tappings, and are secured with tape or thread to the handle.

The complete detector unit ready for mounting on the handle and connecting to search coil

If it is required to dismantle the instrument for portability, the handle could be made a tight push fit into the block with a screw to secure it. Leads from the coil could terminate in a small 3-pin plug to insert in a socket on the detector box. A jack could be used for headphones.

ADJUSTMENTS FOR CORRECT OPERATION

No results can be obtained until the two tuned circuits are operating on a near frequency. Adjusting VC1, VC2 and the core of L2 throughout their full range should produce a heterodyne whistle in the phones. If so, adjust VC1 so that zero beat arises with VC2 about half closed. Rotating VC2 from this position, in either direction, should cause the tone to rise in pitch.

If no tone can be heard switch off and temporarily disconnect TR3, and use a meter to check battery current. This should change if C4 is shorted, or if VC2 is shorted. If there is no change in current when either of these tests is made, the appropriate oscillator is not working, and connections should be checked. When all is satisfactory reconnect TR3.

If both TR1 and TR2 are oscillating, but no tone is obtained, their frequencies are probably too far apart. One way of checking this is to take a 300pF variable capacitor, and temporarily connect it across L1 (A to E). If closing this capacitor enables a heterodyne to be produced, then the frequency of L1 is too high for L2 to match. This is corrected by increasing C4, or by reducing VC1, or having fewer turns on L2, or withdrawing the core, until VC1 and VC2 can be adjusted as described.

Should a heterodyne only be possible with extra capacitance across L2, then L2 is at too high a frequency. This can be overcome by reducing C4, or increasing the value of VC1, or screwing the core of L2 further in.

VC2 is best adjusted to give a low frequency tone in the headphones, and so that the frequency rises when L1 approaches the metal sought. If the tone falls, passes through zero, then begins to rise, VC2 can be retuned to the other side of zero beat when no metal is near L1. ★