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EPE BOUNTY TREASURE HUNTER

THOMAS SCARBOROUGH



An inexpensive, easy-to-build, induction balance design that will find a 25mm (1 inch) diameter coin at up to 240mm (9 1/2 in.) depth

METAL detecting is a popular pastime. The author himself, with his son, located a wreck with an old *EE* design – uncovering, among other things, small items of gold and pinfire ammunition.

There are two significant barriers, however, to owning and operating one's own metal detector. The first is cost. A good metal detector may easily cost a hundred pounds plus, and this may not represent an offhand investment, particularly for young people.

The second is complexity. A typical metal detector may comprise fifty or a hundred components even without the hardware, and this would represent a serious challenge to many constructors, not to mention the time involved.

Alternatively, one can settle for a simpler and cheaper design. However, while such designs may initially provide good fun, they typically have poor depth of penetration, a predilection for rusty iron, and poor stability.

The author's aim with this design was to create a minimalist induction balance (I.B.) metal detector, while also achieving good performance. This method of metal detection has a good depth of penetration, and distinguishes well between ferrous and non-ferrous metals.

It is also capable to a large extent of rejecting iron, and also tin foil. This is a boon for anyone who is searching in the first instance for coins or noble metals.

GOING DIGITAL

The reason for the simplicity of the design is that it largely dispenses with analogue circuitry, and uses a digital transmitter and digital peak detector instead. The full block diagram for the *EPE Bounty* Treasure Hunter is shown in Fig.1.

As the search coils pass over metal, only digital signals of a certain amplitude break through. Since these are in the audio range, they are immediately transferred to

a piezo sounder (WD1) or headphones. (This has the added bonus, in some countries, of eliminating the need for an operating licence.)

GOOD DETECTION

The resulting circuit, as simple as it is, bears comparison with some of the best. For example, the *EE Buccaneer* (not now available) was described at the time as "outperforming almost any other design of its type" – the *EPE Bounty*, by comparison, exceeds its performance by around 40 per cent.

The following is the Bounty's response to a 25mm (one inch) diameter brass coin at varying distances, with good tuning:

160mm	A "singing" tone
200mm	A clear tone
240mm	A barely discernible signal

The *EPE Bounty* will detect a pin at 35mm, and large non-ferrous objects at half a metre's distance and more. Note, however, that these measurements apply *in air*; and not *in the ground*, where depth of penetration will depend largely on the mineralisation present.

Contrasted with this, it is far more reluctant to pick up tin-foil. A tin-foil disc of the same size as the brass coin is detected at only half the distance in air. This rejection of tin-foil is due in part to the metal detector's low frequency, which avoids what is called "skin effect". Besides this, if the two coils are positioned as described, ferrous metals are to a very large extent rejected – to such an extent, in fact, that a 25mm diameter brass coin looks the same to the detector as a lump of iron weighing *twenty times* as much.

Bounty's power consumption is conveniently low – it draws around 10mA, which means that it may potentially be powered off a small PP3 9V battery. As it is, it is powered off eight AA batteries in



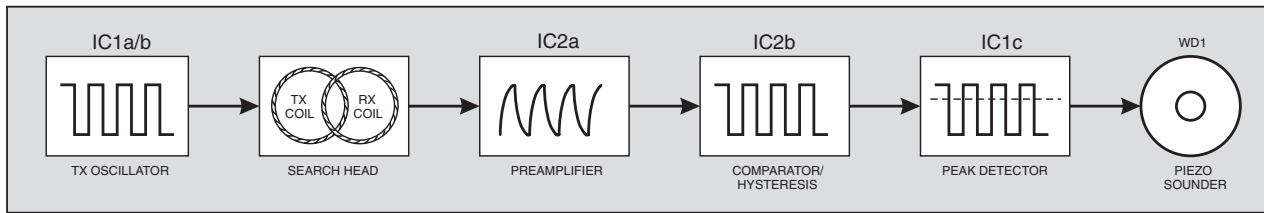


Fig. 1. Block diagram of the EPE Bounty Treasure Hunter.

series (12V), which should provide about 100 hours of continuous use when using cheap batteries.

CIRCUIT DESCRIPTION

The complete circuit diagram for the EPE Bounty Treasure Hunter is shown in Fig.2. The search head of a typical I.B. metal detector comprises two coils – a transmitter coil (Tx), and receiver coil (Rx). In this case, the Tx coil is driven by a square wave oscillator, which sets up an alternating magnetic field in the coil.

The receiver coil is positioned in such a way that it partly overlaps the transmitter coil – see Fig.3. By adjusting the amount of overlap, a point can be found where the voltages in the Rx coil “null”, or cancel out, so that little or no electrical output is produced. A metal object which enters the field then causes an imbalance, resulting in a signal being generated.

The transmitter oscillator, built around IC1a, is a simple clock generator, based on a single gate of a 40106 hex Schmitt inverter i.c. While such oscillators tend to be unstable in operation, this is unimportant for our purposes here – we merely need to set up the alternating magnetic field in the coil Tx.

So that IC1a is not unduly loaded, IC1b is used as a buffer. IC1a oscillates at an audio frequency determined by resistor R1 and capacitor C1, while resistor R2 limits

the peak current passing through the transmitter coil to 12mA.

ON THE LEVEL

The front end of the receiver section is a simple yet sensitive preamplifier, based on IC2a, which boosts the signal from the coil Rx. Its gain (about 165) is set to a level where signal amplitude shows good variation at the presence of metal. It also provides sufficient gain for the following stages.

Wired as a comparator or rather, a level detector, IC2b detects the peaks of the amplified receiver waveform. These peaks, however, are sharp and small, like the proverbial tip of the iceberg, and this could severely stunt the sensitivity of the circuit. It is at this point that a simple yet vital enhancement is introduced. Resistor R9 is added to provide hysteresis, through positive feedback, thereby returning the signal to a square wave, and effectively tripling the sensitivity of the detector.

The output of IC2b at pin 7 is fed, via capacitor C5, to peak detector IC1c. Since IC1c is a Schmitt inverter, only pulses of a certain amplitude break through to output pin 6. With correct adjustment of the Tune and Fine Tune controls, VR2 and VR3, there is a point at which the signal just breaks through in the form of a random crackling sound. No further amplification is required, and since capacitor C6 blocks

d.c., virtually any kind of earpiece, sounder, or loudspeaker may be used to make the signal heard.

SEARCH COILS

The winding of the two search coils is relatively easy, and is not critical – a little give and take is permissible. Both the coils are identical. The full coil winding and construction details are shown in Fig.3.

Use 33s.w.g. (about 0.26mm) enamelled copper wire, winding 100 turns on a 150mm dia. former (see Fig.3). You may create the former with a sheet of stiff cardboard with twelve pins stuck through it at a suitable angle (the heads facing slightly outwards). The coil should be wound clockwise around the pins, then temporarily held together with stubs of insulating tape passed underneath and pressed together over the top. The coil may be jumble-wound.

Once this has been done, the pins are removed, and a second coil is wound in exactly the same way. In each case, mark the beginning and end wires. Label one coil Tx (transmitter), the other Rx (receiver). Each coil is then tightly bound by winding insulating tape around its entire circumference.

FARADAY SHIELD

Next, each coil needs a Faraday shield. This minimises “ground and capacitive

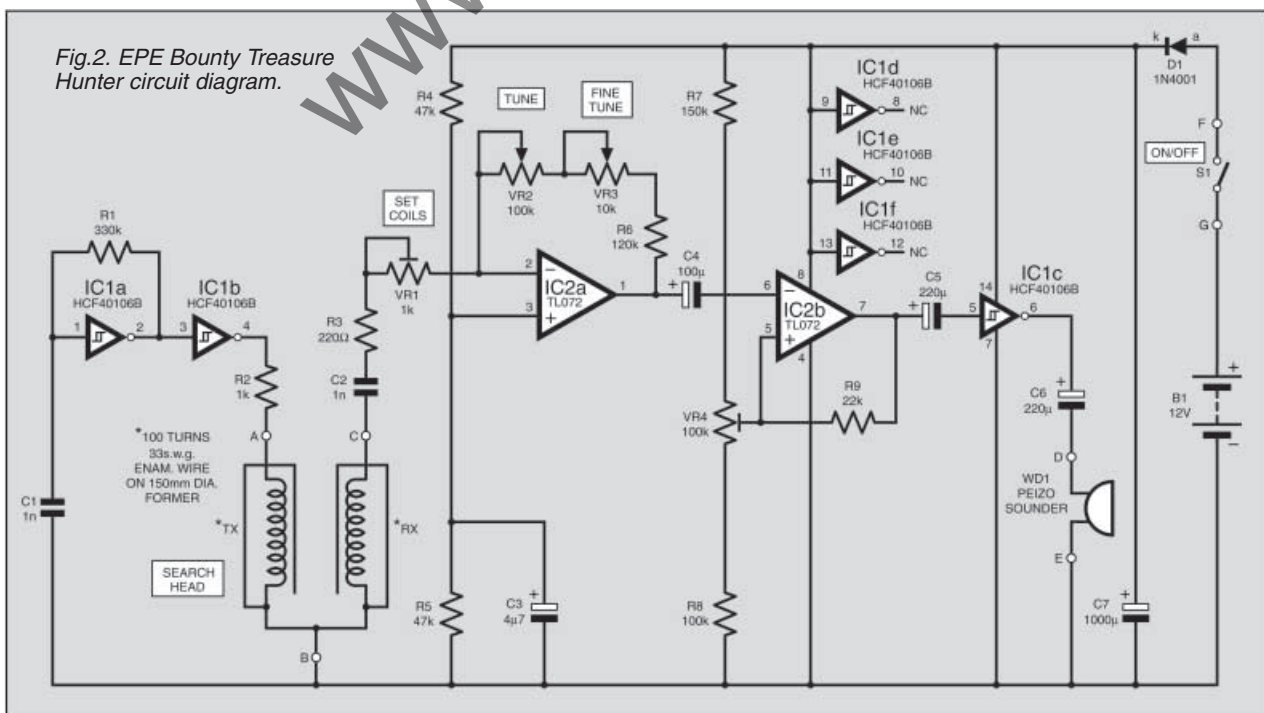


Fig.2. EPE Bounty Treasure Hunter circuit diagram.

effects (electrostatic coupling)” in the search head. The shield is made with some long, 20mm wide strips of aluminium or tin-foil.

Scrape the enamel off the base of the Tx coil’s “end” and Rx coil’s “beginning” wires. Now solder a 100mm length of stiff, bared wire to each scraped area, and twist this around the coil, over the insulating tape. This provides an electrical contact for the Faraday shield.

Beginning at the base of this wire, the foil is wound around the circumference of the coil, so that no insulating tape is still visible underneath it – but the foil *does not* complete a full 360 degrees. Leave a small gap – say 10mm – so that the foil does not meet after having done most of the round. Do this with both coils. Each coil is now again tightly bound with insulating tape around its entire circumference.

Attach each of the coils to quality single-core screened audio cable (microphone cable), with the Faraday shields being soldered to the screen. *Do not* use stereo or twin-core audio cable, as this may cause interference between the coils.

Gently bend the completed coils until each one is reasonably flat and circular, with the wires facing away from you. Both coils’ beginning wires should be to the left of their end wires. The Faraday shield connections should be side by side.

Now bend the coils further (see Fig.3), until they form lopsided ovals – like capital Ds. The backs of these Ds overlap each other slightly on the search head – this is the critical part of the operation, which we shall complete after having constructed the circuit.

Last of all, wind long, 20mm wide strips of absorbent cloth around each coil (thin dishwashing cloth would suit), using a little all-purpose glue to keep them in place. Later, when resin is poured over the coils, the cloth meshes the coils into the resin.

CONSTRUCTION

EPE Bounty’s printed circuit board (p.c.b.) measures just 76mm × 46mm. The

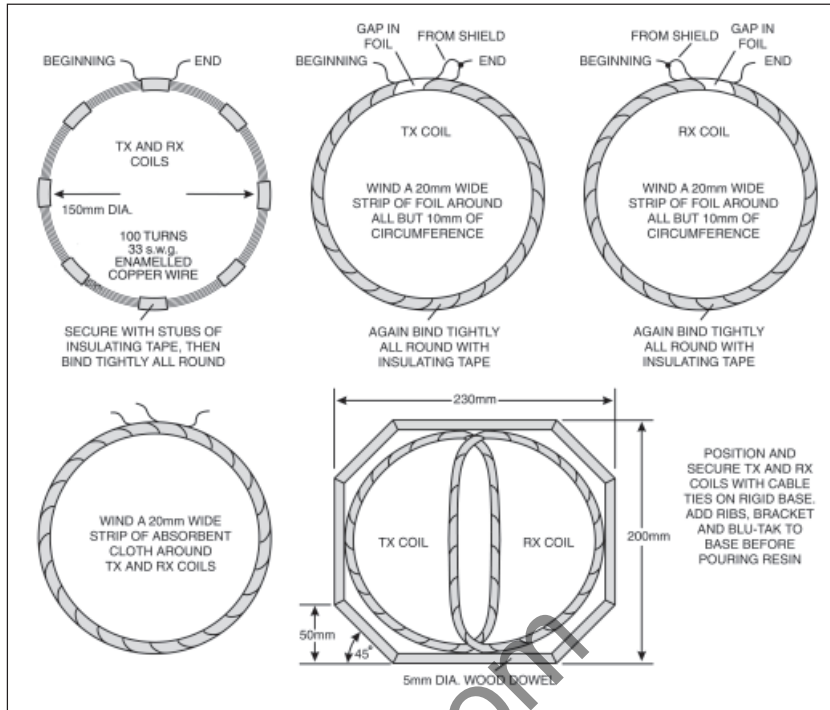


Fig.3. Search head construction for the EPE Bounty.

topside component layout, off-board interwiring and full-size underside copper foil master pattern details are shown in Fig.4. This board is available from the EPE PCB Service, code 370.

Component values and types are not critical, although high grade components will improve performance. The author’s preferred choice for IC1 was the SGS-Thomson HCF40106BEY, although any 40106 i.c. should work adequately.

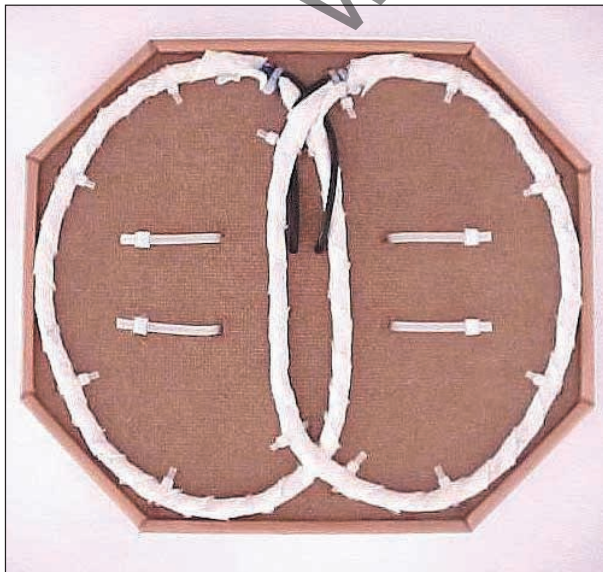
Begin construction by soldering the 8 solder pins, the 14-pin and 8-pin d.i.l. sockets and resistors in position. Finish up with diode D1 (note the cathode (k) is marked by a band and points away from the edge of the p.c.b.), and the capacitors.

Once soldering is complete, carefully check the p.c.b. for any solder bridges and wiring errors.

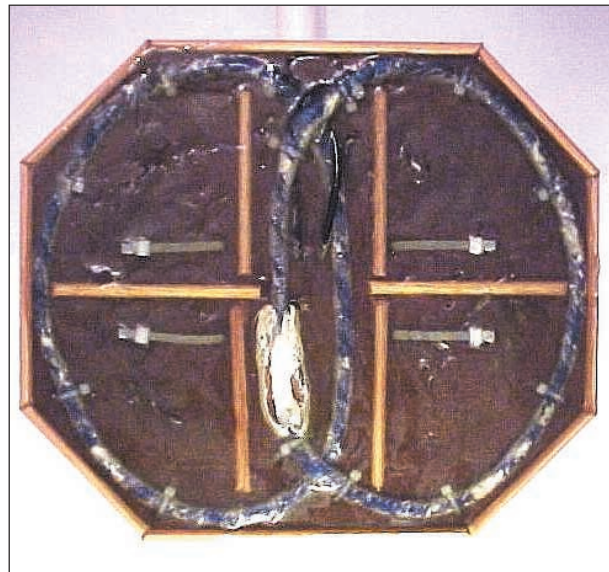
CASING-UP

Prepare the case for the audio cable, switch S1, potentiometers VR2 and VR3, and piezo sounder WD1. Drill four holes for the steel nuts and bolts, which will hold the two lengths (one long, one short) of p.v.c. conduit (see Fig.5).

Mount VR2 and VR3 where quick and easy adjustment is possible. Wire up piezo sounder WD1, tuning controls VR2 and VR3, switch S1, and the battery clip to the p.c.b. Keep all wires short. Choose potentiometers with metal cans (bodies) and



The search coils positioned with cable ties prior to potting.



The potted coils with a small section left for final adjustment.

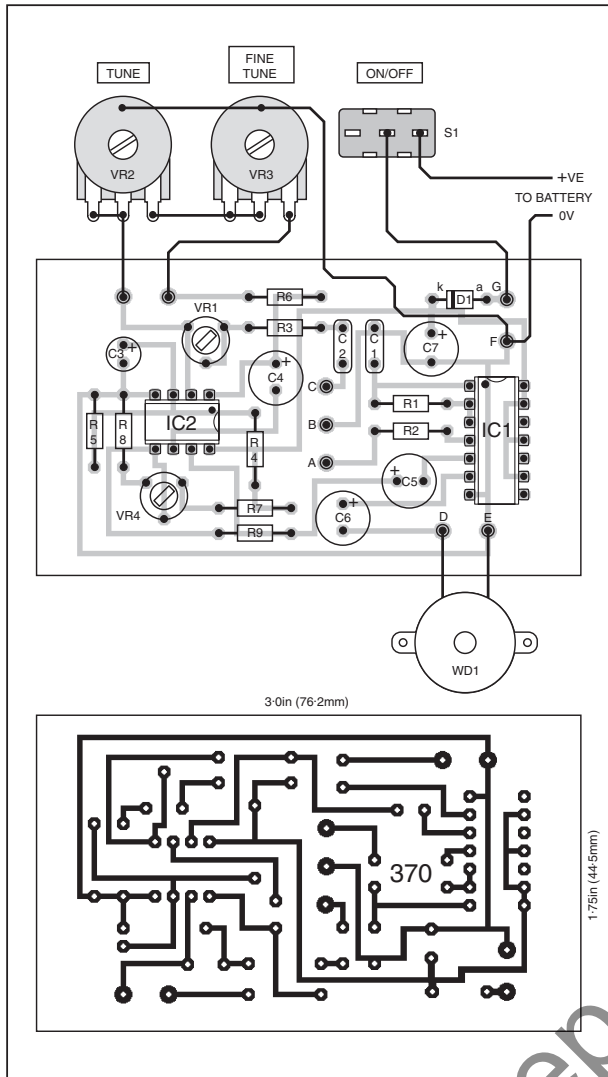
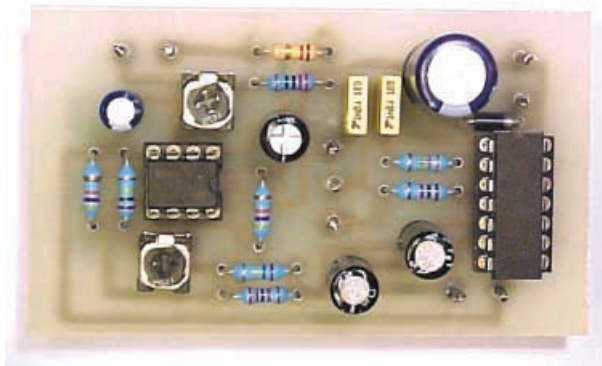


Fig.4. P.C.B. layout and wiring and full size master foil pattern.

plastic shafts for VR2 and VR3, and connect the cans to 0V on the p.c.b. (perhaps via the potentiometers' washers) – this is important for circuit stability.

A slider switch, S1, prevents accidental switching as the unit is transported. If you wish, add a socket for headphones in parallel with, or in place of, the piezo sounder WD1. Make sure that the battery is secure, and will not move about in the case.

In the case of extremely noisy environments, an i.e.d. may be used besides the piezo sounder. This is wired from IC1c pin 6, via a 1k series resistor, to 0V.



The finished prototype p.c.b. D1 has been moved in the final version.

COMPONENTS

Resistors

R1	330k
R2	1k
R3	220Ω
R4, R5	47k (2 off)
R6	120k
R7	150k
R8	100k
R9	22k

All carbon film 0.25W 5%

Potentiometers

VR1	1k cermet preset
VR2	100k carbon track (metal can, plastic shaft)
VR3	10k carbon track (metal can, plastic shaft)
VR4	100k cermet preset

Capacitors

C1, C2	1n metallised polyester film (2 off)
C3	4μ7 16V radial electrolytic
C4	100μ 16V radial electrolytic
C5, C6	220μ 16V radial electrolytic (2 off)
C7	1000μ 16V electrolytic

Semiconductors

IC1	HCF40106BEY hex Schmitt inverter (see text)
IC2	TL072 dual j.f.e.t. op.amp

Miscellaneous

WD1	piezo sounder
S1	on-off slider switch
SK1	3.5mm mono jack socket (optional – see text)
B1	12V battery (8 x AA)

Battery holder (8 x AA); PP3 battery clip (for battery holder); 100m 33s.w.g. (approx. 0.26mm) enamelled copper wire; printed circuit board, available from the *EPE PCB Service*, order code 370; ABS case with external dimensions 150 x 80 x 50mm; 14-pin d.i.l. socket; 8-pin d.i.l. socket; link wire; solder pins; solder, etc. 3m quality single-core screened audio cable; 2m 20mm wide strips of aluminium-foil; 100mm stripped single-core wire (2 off); control knobs (2 off); quality insulating tape; all-purpose glue

Hardware

White masonite 230mm x 200mm (search head baseplate); 1m x 5mm dia. wooden dowel (baseplate surround to contain resin); 1.5m 20mm outer diameter p.v.c. conduit (shaft and upper handle); 90° angle bend to suit 20mm p.v.c. conduit (hand-grip); square rainwater downpipe socket (swivel bracket on search head); plastic w.c. seat hinge nut and bolt set (swivel bracket); 500ml polyester resin and hardener/catalyst; 2.5mm nylon cable-ties (12 off); 4mm nylon cable-ties (4 off); 5mm x 30mm nuts and bolts (4 off); 5mm washers (16 off); 200g Bluetack/Pres-stik; epoxy glue.

Approx. Cost
Guidance Only

£20

excluding headset & batts

HARDWARE

Suggested hardware construction using p.v.c. piping and joints is shown in Fig.5. The author again chose a minimalist approach. Attach the base of the detector's shaft (the longest piece of p.v.c. conduit) to the search head by means of a swivel-joint. Use 4mm nylon cable-ties to secure the brackets to the search head. The author made the brackets from a square rainwater downpipe socket sawn in two. The large plastic nut and bolt of the swivel-joint were taken from a w.c. seat hinge set. *Do not use any metal fittings or fastenings on the search head.*

Before bolting the shaft to the control box, feed the audio cable through it – then bolt it to the side of the control box. Bolt the shorter length of p.v.c. conduit to the other side of the control box, and push the 90 degree angle bend onto its bottom end.

Attach the audio cables from the search coils to the p.c.b. as shown (see Fig.3), with the screen of both audio cables again going to 0V. Finally, insert IC1 and IC2 in the d.i.l. sockets. IC1 is static sensitive – discharge your body to earth before handling.



Mounting of the p.c.b., controls and sounder in the case.



Case mounted between the conduit handle and search head shaft.

SETTING THE COILS

The one downside to any I.B. metal detector design is its need for two coils, which must be very carefully and rigidly positioned in relation to one another. The present design does make some room for error, though not much. Nonetheless, the method of setting the two search coils is simple enough, if one works patiently and carefully. A completed p.c.b. is required before we can "pot" the coils.

The coils should be potted with clear polyester resin on a hard, non-metallic base (do not buy polyester resin *filler*). Any base will do, on condition that it is *rigid*. The author used a piece of white masonite (see Fig.3), and glued a border of 5mm wood dowelling around the perimeter to hold the resin. The potted coil was left "raw" beneath the masonite, protected by the resin.

Begin by placing the coils directly on top of one another, ensuring that they are correctly orientated (their Faraday shield connections being side by side – see the

Search Coils cross-head earlier). Adjust VR2, VR3, and VR4 to their mid-points. Adjust VR1 to 780 ohms. Attach a 12V battery pack, and switch on. The circuit should be "singing" – that is, beeping loudly and continuously.

Now slowly move the coils apart. When they are somewhere past the halfway mark, the piezo sounder will fall silent. This is where the voltages in the receiver (Rx) coil "null". Note that there may be a few peaks and troughs in the volume as you move the coils apart – you need to find a place of virtually complete silence.

Continue to move the coils apart. At a precise point, in a very narrow "slice" between silence and singing, the piezo sounder will crackle – or it might hum and then crackle.

Now edge the coils closer together again, ever so slightly, adjusting preset VR4 as you go, so as to maintain a loud singing in the piezo sounder (not just a hum), until the coils cannot be edged any closer while still maintaining the loud

singing. It is at this precise point – not a fraction of a millimetre this way or that – that the coils need to be set.

The main purpose of preset VR4 is to find the precise point at which there is a crisp transition from silence to singing. With the correct setting, any intermediate hum should be eliminated. (While the hum does not affect performance, it may be a distraction.)

MAKE YOUR MARK

Take a marker pen, and mark a series of holes in the baseplate around both sides of the coils. These holes are used to pass 2.5mm cable-ties through, to hold the coils tightly to the baseplate. Use five or six cable-ties for each coil, to ensure that they are firmly and flatly secured before pouring the resin.

Also, use cable-ties to secure the audio cables as well. Further, glue some lightweight wooden ribs across the bottom of the search head (to the baseplate), across the centre of the coils. Their purpose is to

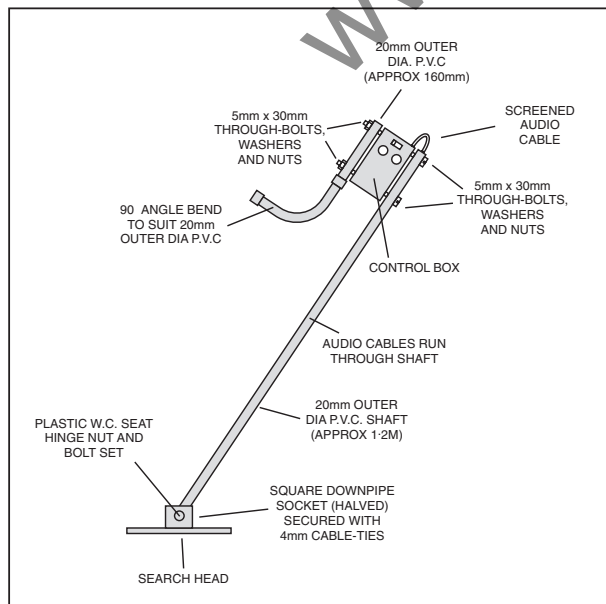
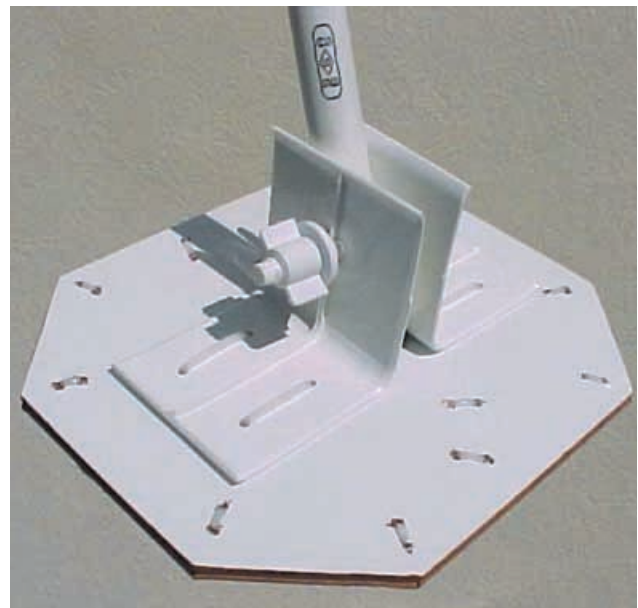


Fig.5. General construction of the hardware items.



The finished search head.

limit shrinkage in the resin, since this could seriously unbalance the circuit.

Use some Blu-tack (or Pres-stik) to tightly seal the holes underneath the baseplate before pouring the resin – polyester resin is very “runny”, and sticks faster than many glues. Make sure the baseplate’s dowel surround is “resin-tight”. Carefully bend the coils at the centre of the baseplate until you reach the exact balance at which there is neither silence nor singing from the piezo sounder, but a crackle.



Finished control box mounted to the handle and search head shaft.

Also – *this is important* – cover a small section (about 40mm) of one of the coils, at its centre, with Blu-tack (Pres-stik), giving the Blu-tack vertical walls. This will be removed after the resin has set, and allows for final bending of this small section of coil.

Now you are ready to mix and pour the resin. Use about 80 per cent of the recommended amount of catalyst, so that there is not too much heat and shrinkage in the resin. Pour the resin over the cloth which surrounds the coils, so as to soak it, and keep on pouring until the entire baseplate is well covered with resin.

The circuit may no longer function correctly at this point until the resin has hardened, so make no more adjustments, but switch off. Wait at least 24 hours until removing the Blu-tack from the small section of coil, which will leave the section exposed.

Set tuning controls VR2 and VR3 to their mid-points, and bend the exposed section of coil (likely inwards) until a crackle is heard, between silence and singing. Now pour resin over this patch also, to fill it.

Finally, preset VR1 serves as an emergency measure to alter the gain at the inverting input of preamplifier IC2a, without destabilising the rest of the carefully balanced circuit around IC2a/IC2b. Use VR1 in case the setting of the coils did not go well, and the bending of the small section of coil proves fruitless.

IN USE

Keep the search head away from all metal, and away from computer equipment, which may cause serious interference with the circuit – and switch on. Adjust VR2 until the *EPE Bounty* is at a point where a crackle is heard, between silence and singing – use VR3 for fine-tuning. Carefully experiment with board-mounted preset VR4 in case a low-level hum has been interjected between the silence and singing.

For best results, keep front panel controls VR2 and VR3 tuned for a fast crackle. While a slow crackle is more pleasing to the ear, this will reduce sensitivity. Move a coin over the search head, and piezo sounder WD1 should “sing”.

In actual use, the adjustment of the *EPE Bounty Treasure Hunter* will be affected by the mineralisation of the ground you are searching, as well as temperature and voltage variations. While the design has good stability, some readjustments to tuning controls VR2 and VR3 are inevitable.

An investment in a metal case for the electronics, while costing a few pounds more, would maximise stability, but this is not essential. A higher value for resistor R6 will give the detector a sharper edge (that is, a sharper transition between silence and singing), while a lower value will provide a gentler transition.

For best results, the search head is moved slowly to and fro over the ground, just skimming its surface.

May you be rewarded with much bounty!

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