JOIN THE GOLD RUSH WITH OUR 'PROSPECTOR' METAL LOCATOR

Australia is caught in the grip of gold fever and now you can join the rush with our new "Prospector" metal locator. With a price which is a mere fraction of some of the more pretentious commercial designs, the "Prospector" is easy to build and has a performance which is sure to upset those who have paid the big money for the expensive import. In a word, its a bargain.

by RON DE JONG

Over the past few months we have had an unbelieveable number of enquiries and requests for a metal locator. With gold fever at an all time high and new reports of gold finds almost daily, people are itching to join the search and are willing to pay outrageous prices for metal locators.

In fact, we have been bemused by all the fuss. On the one hand, we have been amazed by the prices of some of these metal locators and the vast array of knobs they have and on the other hand, we have been struck by the apparent success of these locators in helping people find nuggets.

Is it all a hoax? Is there a firm in the phone directory with a "rent a nugget" service for metal locator distributors? Is there gold to be found in the suburbs of Melbourne and Sydney? Who really knows? And for that matter, who cares? We have stopped wondering and have produced a cheap and very effective metal locator instead. We called it the "Prospector".

Metal locator designs can be classified into three broad groups, viz the IB or TR type (induction balance or transmit/receive), the BFO type (beat frequency oscillator) and the PI type (pulse induction). Compared with the better IB or PI designs, the older BFO circuits are not really in the race. But our Prospector circuit is a new BFO design which uses a nifty digital mixing circuit which greatly increases the sensitivity.

In fact, the sensitivity of the Prospector BFO design compares quite favourably with some commercial induction balance designs which have the "ground-exclusion balance" feature although we admit that the GEB feature may give a performance advantage when searching for objects in heavily mineralised ground.

Apart from resulting in a simpler circuit, the BFO principle used in the Prospector also results in a unit which is easier to construct, in that it has only one search coil. By contrast, induction-balance metal locators usually require at least two search coils which often have a complex shape and which have to be accurately aligned with respect to each other.

Ease of operation is a feature of the "Prospector". It has just two controls, pitch and volume. The user listens to the audio output via a pair of stereo headphones. Besides being more comfortable than the cheap earpiece provided with some metal locators, stereo headphones have the advantage of reducing the effects of ambient noise.

Now have a look at the circuit of our new metal locator. While the Prospector is a good deal more sensitive than the average run-of-the-mill metal locator, the circuit is not at all complicated. Only three CMOS IC's are involved, two 4011 quad NAND gates and a 4013 dual-D flipflop.

The 4011 quad NAND gates are wired to provide two LC oscillators. One is the search coil oscillator while the others is the reference oscillator. These oscillator circuits are based on a design featured in the July 1978 issue of "Wireless World". With the advantage of low cost and the ability to interface directly with digital circuitry, the oscillator circuits enable a high Q to be realised because of the negligible loading of the CMOS inputs.

Identical circuits are used for the search coil oscillator and the reference oscillator so that any changes in ambient temperature or battery voltage cause both oscillators to drift by the same percentage, with the result that

We estimate that the cost of the "Prospector" metal locator is about

$20

This price includes tax but does not include the cost of handle and coil former.

the beat frequency remains fairly constant. This stability is desirable in any metal locator, but especially so in this design because of the high sensitivity involved.

Operation of each oscillator is quite straightforward. Looking at the search coil oscillator first, IC1a and IC1b act as a simple non-inverting amplifier, providing high gain with negligible input loading and low output resistance. The 220k resistor doesn't effect normal operation of the circuit but it does ensure that the oscillator starts properly when power is first applied. Feedback is applied from the output of gate IC1b via a 680pF capacitor to the parallel tuned LC circuit comprised of the search coil inductance and the .001uF and two 330pF capacitors.

The reference oscillator works in the same fashion but a 455kHz IF transformer is used instead of the search coil. The reference oscillator runs at about 6 six times the frequency of the search coil oscillator, and is set by tuning the slug in the transformer — the actual tuning procedure is discussed later.

The operating frequency of the search coil oscillator is dependent on the inductance of the search coil, according to the usual formula:

$$f = 1/2\pi(LC)^{1/2}$$

In our case the operating frequency is about 100kHz though the exact frequency is unimportant and need only be in the range of 80kHz to 140kHz.

When metal is brought near to the search coil the frequency of the search coil oscillator will change slightly. Theoretically, ferrous metals such as iron and steel will increase the frequency of the search coil oscillator while metals such as gold, silver, brass and aluminium will decrease the frequency of the oscillator. In practice though most pieces of iron and steel will be indistinguishable from gold, etc because their ferromagnetic properties are completely swamped out by "eddy current" losses.

Each of the two oscillators is buffered by two of the remaining NAND gates, to reduce coupling and loading effects in the digital "mixing" circuit which consists of one section of the dual-D flipflop. The other half is not used.

To understand the operation of the mixer it is important to know how a D-type flipflop works, or rather, what it does: The logic level at the D (data) input is transferred to the Q output during the positive transition of the clock pulse.

In our circuit, the reference oscillator output is applied to the D-input of the

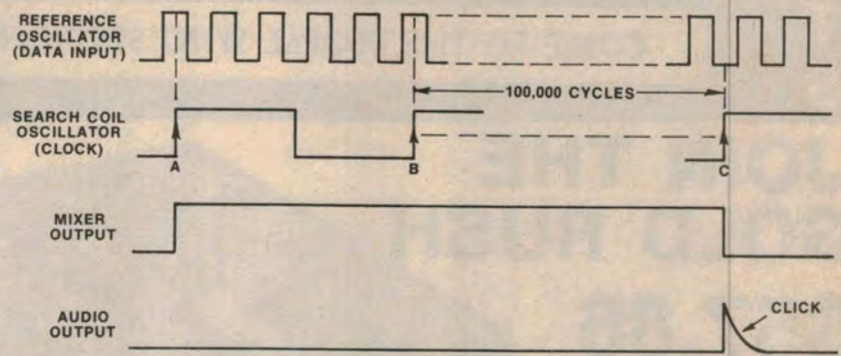
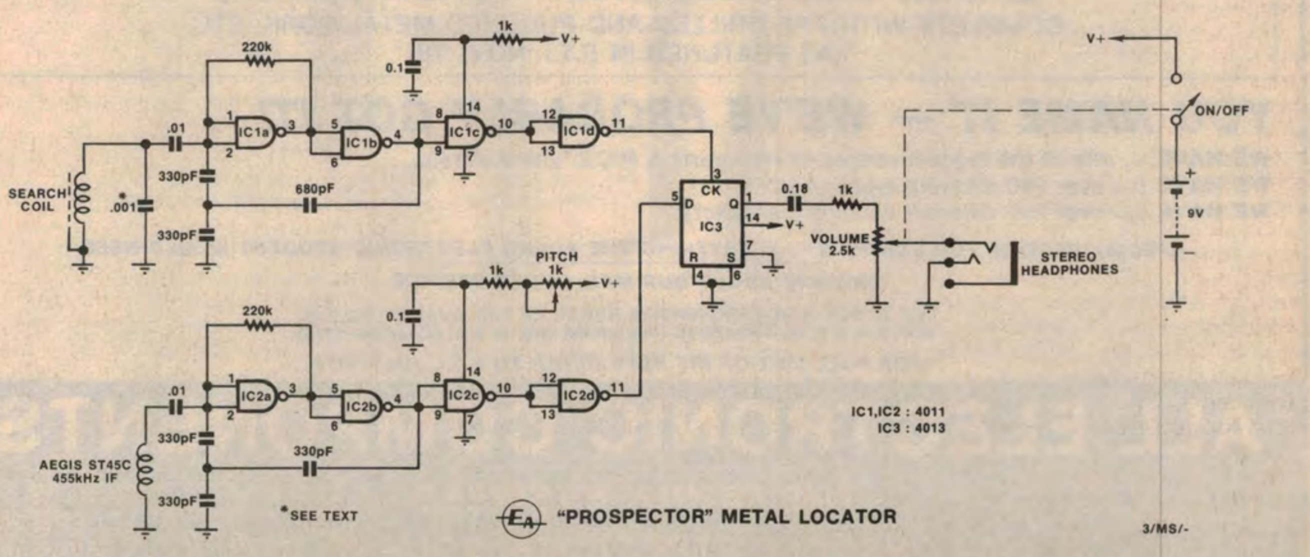


FIG. 1



The circuit of the metal locator uses only three CMOS ICs.

flipflop while the search coil oscillator output is fed to the clock input. Both oscillator outputs are square waves and the reference oscillator is running at about six times the search coil oscillator frequency. The timing diagram of Fig. 1 helps illustrate the operation.

Starting from the leading edge of the first clock cycle, we see that at point A the data input of the flipflop is high and will be transferred to the output of the flipflop. The next clock cycle at point B also coincides with a high at the data input so the output of the flipflop remains high. In fact, while ever the reference oscillator frequency is an exact even multiple of the search coil frequency this state of affairs will continue indefinitely and the output of the flipflop will remain unchanged.

If, however, the search coil frequency differs by as little as 1/12th of a hertz then about 100,000 cycles after point A (ie, after one second) the clock signal will not coincide with the data input and a low logic level will be transferred to the output of the flipflop. This produces a click in the headphones which are connected to the output of the flipflop.

When the beat frequency is set to say 10Hz, ie 10 clicks per second, then a change of one click or one hertz in the beat frequency still corresponds to a change of 1/12th of a hertz in the search coil frequency.

Note that for proper operation of the mixer the reference oscillator must be set for the sixth harmonic, or the fourth or eighth — as long as it is an even harmonic because otherwise a low and a high would be alternately clocked by the flipflop. This would give a beat frequency of 100kHz which is inaudible.

Output from the mixer circuit is used to drive a pair of stereo headphones via a 0.18uF capacitor and an amplitude control consisting of a 1k resistor and 2.5k potentiometer. We have used a capacitor to differentiate the output from the flipflop so that whenever the output changes, either from a high to a low or low to high a brief click is produced in the headphones.

A 1k potentiometer in series with the supply to the reference oscillator functions as the pitch control. Its operation relies on the fact that the frequency of the reference oscillator is dependent on the supply voltage. Using the 1k potentiometer provides a modest change in supply voltage and results in a change in frequency. The resulting difference in frequency between the two oscillators is then multipled by the mixer circuit.

There are several advantages in this pitch control circuit. It eliminates the need for a trimmer capacitor and simplifies layout because there are no signal voltages on the leads to the potentiometer.

Current consumption of the "Prospector" is typically about 2.5mA

PARTS LIST

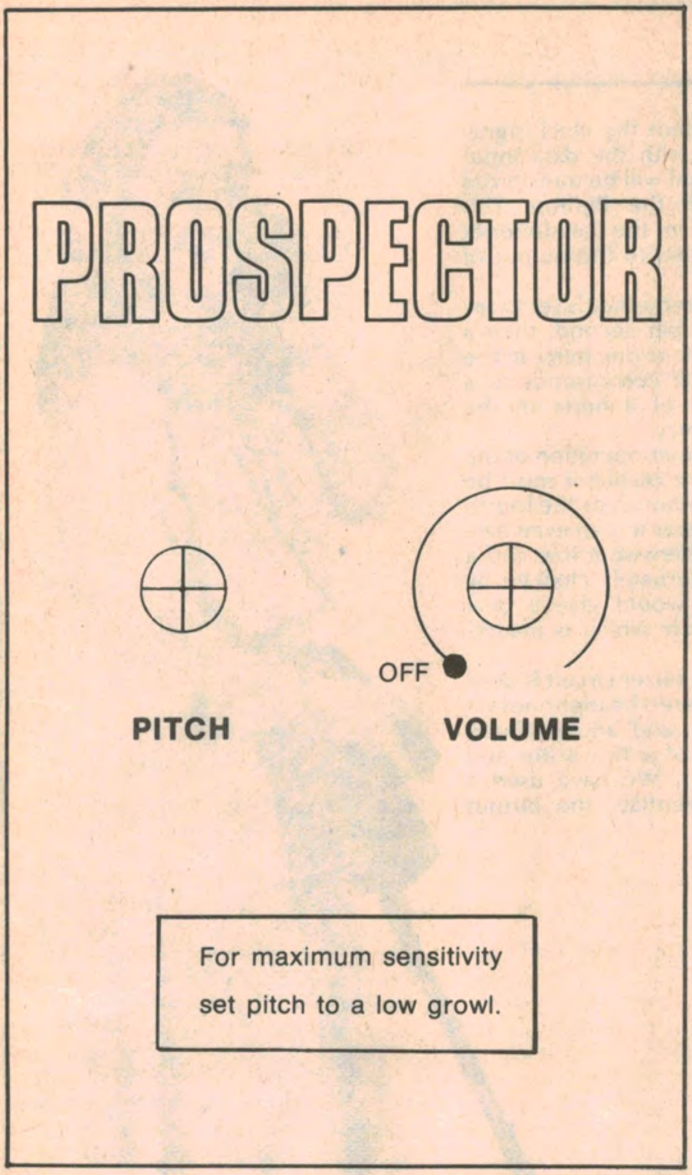
1 Plastic zippy box, 158 x 96 x 50mm
1 PC board coded 79md9, 74 x 58mm
1 2.5k linear rotary switch potentiometer
1 1k linear rotary potentiometer
1 Stereo headphone jack
1 Nine volt transistor battery, Eveready 216 or similar
1 Aegis ST45C 455kHz transistor IF transformer or similar
25 metres of 26 SWG enameled copper wire
1.5 Metres of shielded audio cable
1 Battery clip to suit Eveready 216
1 Stereo headphone set

INTEGRATED CIRCUITS
2 4011 CMOS
1 4013 CMOS

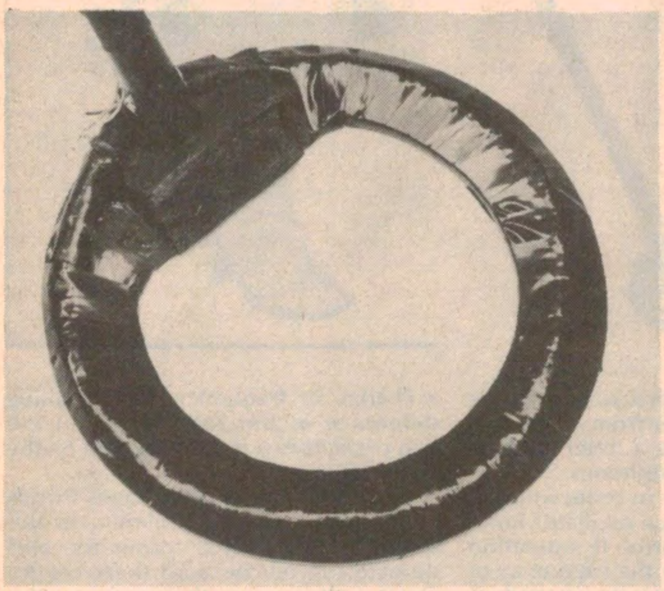
CAPACITORS
1 0.18uF metallised polyester (greencap)
2 0.1uF metallised polyester
2 .01uF metallised polyester
1 .001uF metallised polyester (see text)
1 680pF polystyrene or ceramic
5 330pF polystyrene or ceramic

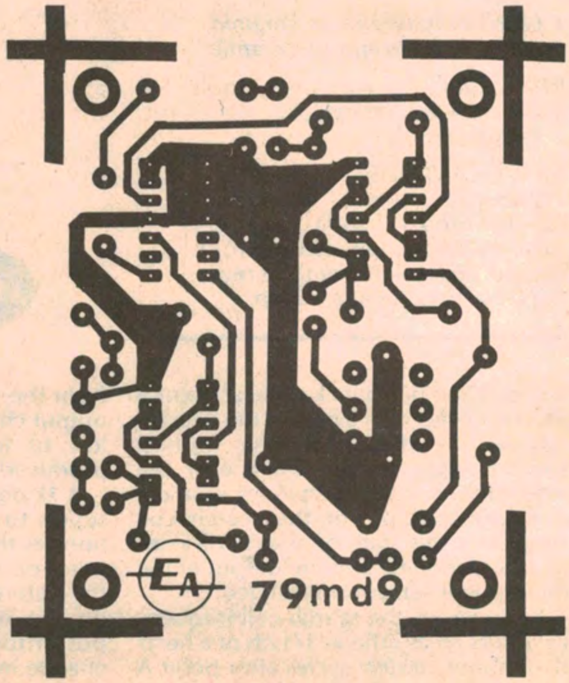
RESISTORS
(¼W, 10% tolerance)
2 x 220k, 3 x 1k.

MISCELLANEOUS
Plywood, dowel, aluminium tubing, rubber handle grip, insulation tape, hook-up wire, four tapped spacers (12mm), screws, nuts, washers, saddle clamp.

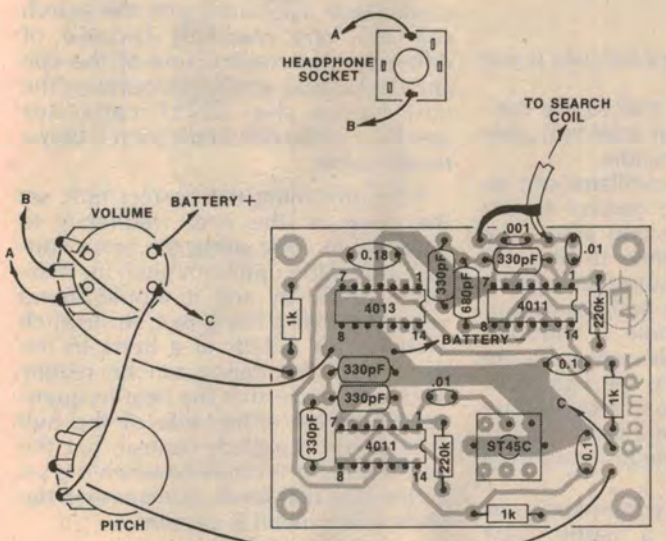


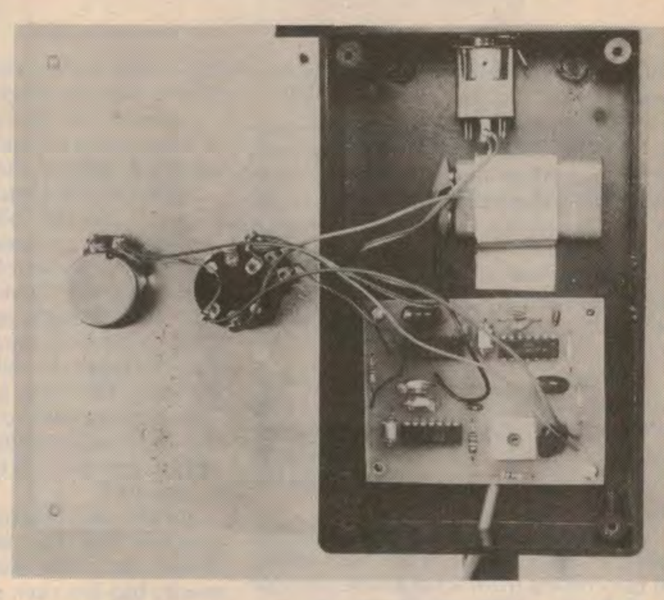
LEFT: Here is an actual size reproduction of the front panel artwork. RIGHT: an actual size copy of the artwork for the side panels.





ABOVE: Close-up of the coil carrier. Note how the coil has been attached to the top of the carrier and wrapped with insulation tape. RIGHT: An actual size copy of the PC pattern.





Use this wiring diagram and inside shot of the prototype to guide construction.

rising upto 3.5mA with the amplitude control set to maximum. The low current drain is due to the CMOS circuitry used and it leads to an expected life of about 150 hours for the specified battery — that's a lot of prospecting time.

Well that covers the circuit description: construction of the "Prospector" should present no difficulty. The circuitry is housed in a small an inexpensive plastic zippy box with most of the components mounted on a small PC board coded 79md9 and measuring 74mm x 58mm. Mount the resistors and capacitors on the PC board first then the three CMOS ICs taking the usual precautions — handle the ICs without touching the pins and solder the two power supply pins first.

Next drill all the mounting holes for the PC board, headphone socket, amplitude and pitch controls and the battery clamp. Use the basic layout shown in the accompanying wiring diagram and use the front panel artwork also included in this article to position the holes for the amplitude and pitch controls. If you so desire you can make an attractive front panel for the metal locator using the artwork already mentioned and some Scotchcal photosensitive aluminium. On the other hand, we anticipate that kitset suppliers will make suitable panels available.

With the main controls and the headphone socket mounted you can now complete the wiring to the PC board. The only remaining steps are to construct the search coil and make a simple alignment to the reference oscillator.

The coil should be made from 50 turns of 26SWG enamelled copper wire. Wind the turns close to each other around a 180mm circular former. Just about anything will do for this purpose such as an empty plastic ice cream container or you can wrap it around a square former such as cardboard box and then bend the coil to a roughly circular shape.

After completing the coil winding, wrap the coil in at least three layers of insulation tape bringing the two output leads out close to each other. Then wrap the coil in a tight layer of aluminium foil. The foil acts as a "Faraday screen" and reduces the effects of ground capacitance on the search coil frequency — but it won't effect the sensitivity of the metal locator. Cut the foil into 20mm wide strips and wind it around the coil making sure that the two ends don't connect. This is very important because otherwise the shield would form a shorted turn and markedly reduce sensitivity.

Wind a couple of turns of 18 gauge (or similar) tinned copper wire around that part of the shield which is closest to the coil leadouts. Twist the ends of tinned copper wire several times to form a robust connection which can be soldered to later.

Then wrap the coil again in another two layers of tape which should preferably match the colour of the handle and control box. Now you should be ready to proceed with the timber coil carrier.

We made our coil carrier from thin plywood cut into a circle with an inside diameter of 150mm and an outside diameter of 220mm. Alternatively, tempered hardboard or some other non-metallic material such as plastic would be suitable. You could even consider using a Frisbee for the purpose.

METAL LOCATOR

Commercial metal locators use a waterproof plastic housing for the coil(s).

Attaching the coil carrier to the handle is a little tricky. We made the handle from a 90cm length of 18mm dowel attached to the coil carrier by means of an angled gluing block made from a scrap of timber. The handle is angled to the coil carrier at 135 degrees. Don't use screws or nails to do this job as they will reduce the effective sensitivity of the coil.

The coil is fixed to the carrier assembly using a couple of layers of insulation tape. We suggest you attach the coil to the topside of the carrier as this will help protect it from damage or abrasion.

Mount the control box on the handle using a saddle clamp which can either be purchased from a hardware store or made from a scrap of aluminium.

Rather than simply fix a rubber handgrip to the handle rod we made a curved extension piece from aluminium tubing which slips over the end of the dowel. The rubber handgrip is then fitted over the end of the aluminium tubing. The resulting handle assembly makes the Prospector easier to use since the centre of gravity is just below the handgrip.

Connect the search coil to the control box via a length of shielded cable spiralled around the handle.

Now the reference oscillator can be aligned. Set the pitch control to the middle of its rotation and adjust the slug in the IF transformer to obtain a null frequency. Make sure that it isn't a false null though, ie a null corresponding to an odd harmonic — wind the slug through its whole range before deciding that you have the right null. This is quite easy to do in fact because the right null results in a much louder output and sounds quite different from a false null.

To set the reference frequency we suggest that you use a plastic screw driver or other non metallic instrument, but be sure not to damage the slug and don't wind the slug more than a millimetre or so above the top of the can. After making a course adjustment of the pitch of the beat frequency it can then be fine-tuned by using the pitch control.

If you can not obtain the correct null then the search coil frequency is not in the right range, ie. between 80 and 140kHz. The frequency can be corrected by either increasing or reducing the value of the .001uF capacitor which is shown across the search coil. The capacitance associated with the search coil can vary markedly because of differences in construction of the coil and the Faraday screen surrounding the coil hence the .001uF capacitor specified in the circuit diagram is only a rough value.

After obtaining the correct null, set the pitch of the beat frequency to about 10 to 20Hz using the pitch control. This is the optimum pitch for maximum sensitivity and it should sound very much like a low growl. At this pitch a change of 1/12th of a hertz in the search coil frequency can be readily discerned. Note that the beat frequency can be set either side of the null position on the pitch control, but the best sensitivity is obtained when it is set on the side that gives an increase in the pitch when metal is present.

Well, you should now be at the stage to actually try your metal locator with some real "paydirt". Just a few suggestions for possible locations: — try public beaches, parks, old ghost towns and the old gold mining districts such as the areas around Bathurst and Bendigo, but don't forget your own backyard because gold has been recently found in some Melbourne suburbs!