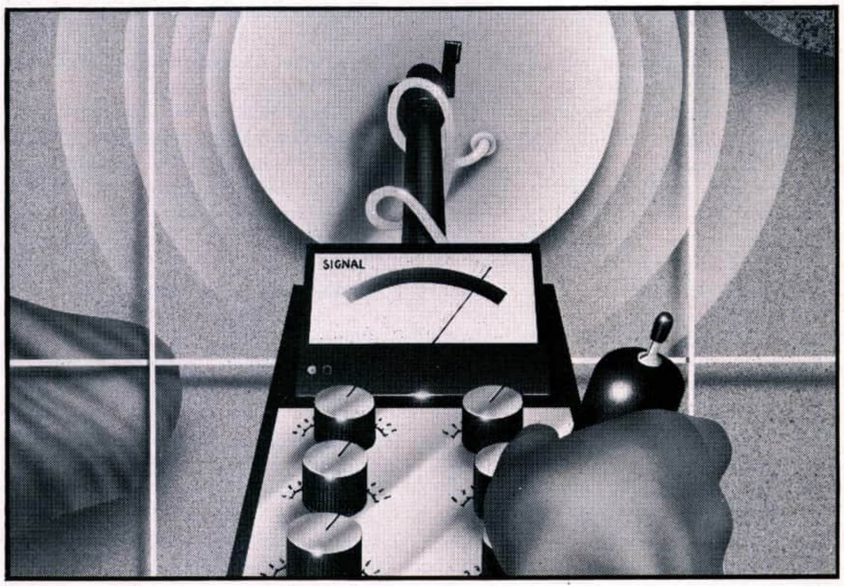
# METAL DETECTION

**BY THE PROF**

## PROSPECTING WITH A HOOVER

*Metal objects "call out" to metal detectors as they sweep the ground by interfering with the detector's circuitry. Different detectors measure different aspects of the effect and convert them to audible or visual signals.*

Although the "treasure" hunting craze of the seventies seems to have waned considerably during the eighties, metal detection still remains a popular aspect of electronics. It is also one that, perhaps after some over-kill in the past, has received very little attention in the technical press over the last few years. Even if you are not interested in going out into the wilds in search of buried treasure, the technology of metal detection still represents an interesting aspect of electronics. It is also potentially a very interesting line of pursuit for the electronics experimenter.




Most metal detector designs for the home constructor seem to be of either the bfo (beat frequency oscillator) or ib (induction balance) varieties, but there are actually many other types in existence. Although the term "metal detector" brings to mind images of treasure hunter style equipment, this type of equipment is actually used in a wide range of applications. These include things as diverse as pipe and cable location, airport and other security applications, medicine, and electronic ignition systems.

In this article we will consider a number of different methods of metal detection, including both the common and some of the more obscure systems. In most cases practical circuits with detailed descriptions are not provided, but a metal locator project will be provided in a future issue.

### BEGINNINGS

Electronic metal detection has its origins further back in time than most people would imagine. In fact the first electronic metal detector was designed over one hundred years ago (in 1879 by Professor D.E. Hughes apparently). What is perhaps even more surprising is that the original design was of the induction balance variety. I own a sophisticated metal detector produced by a well known manufacturer of this type of equipment, and this is of the induction balance type. In fact many of today's more complex detectors seem to be of this type. This is not to say that modern detectors are simply refined versions of the original, and that no new techniques have evolved over the past hundred years or so. As we shall see, there are numerous types of detector currently in use.

Many of today's metal detectors are quite complex pieces of equipment, but the principles on which they operate are relatively straightforward. Much of the complexity of most detectors is in the "bells and whistles" rather than in the main detector part of the circuit. Virtually all methods of detection rely on a pick up coil or coils, and the effect on the electrical characteristics of the coil that a piece of metal in reasonably close proximity is likely to have. However, some detectors have coils which detect changes in a radiated signal, rather than directly detecting the metal. As far as I can ascertain, all normal forms of metal detector use a search coil of some sort or other.

In this article I will provide basic details of all the types of metal detector that I have been able to locate. Most of these methods I have seen in operation, but with some of the less common types I am not reporting from first hand experience. An important factor to keep in mind is that there is usually more than one way to exploit each basic method of detection. Consequently, the block diagrams provided here to illustrate the way in which each type of detector operates are only intended as examples. Not all metal detectors of each type will operate precisely as described here, but they will be based on the same fundamental principle.

### BFO

The bfo (beat frequency oscillator) method of detection is one of the most simple, and has been much used at the low cost end of the detector market. Most of the early home constructor units were also of this type, and I would guess that many readers of PE have built one of these. The block diagram of Fig.1 shows the general make-up for a unit of this type.

The search coil forms part of an L – C tuned circuit which acts as the frequency selective circuit in an oscillator. The detected metal could be regarded as being analogous to the adjustable core in an i.f. transformer, and it causes a shift in the frequency of the oscillator. The oscillator could operate at an audio frequency so that

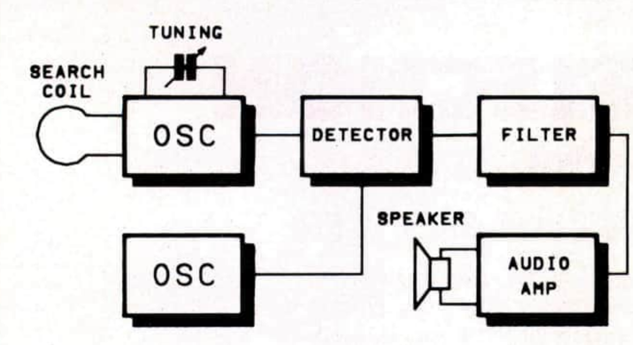



**Fig.1.** *The set up used in a BFO detector*

the shift in frequency would be audible, but this would give totally inadequate sensitivity in practice. The problem is simply that the shift in frequency is not very great, and with direct audio operation not even a well trained ear would be able to detect it.

A high operating frequency and the heterodyne principle are used to give improved sensitivity. The output from the search oscillator and a second oscillator are fed to a detector and rf filter. The output from the filter is the "beat" note, which is merely the difference between the frequencies of the two oscillators. These are tuned so that the beat note is a low audio frequency. If, for example, the search oscillator operates at 199kHz and a metal object produces a 0.01% reduction in frequency in absolute terms this represents a shift of 10Hz. This is not very much, but if the beat note was set at 50Hz, this would give a 20% reduction in output frequency, with an actual output frequency of 40Hz. This would be clearly detectable by the human hearing mechanism. By contrast, direct operation at 50Hz and a 0.01% shift in frequency would given an inaudible shift of just 0.005Hz!

## SENSITIVITY

For optimum sensitivity a high search oscillator frequency and low beat note are required. In practice a high operating frequency is not possible due to legal requirements, but drift in oscillators would probably preclude the use of operating frequencies of many megahertz anyway. With this type of detector the output is normally in the form of an audio tone from headphones or a loudspeaker, but the change in output frequency can be used to give some other form of indication with the aid of some additional circuits. Most bfo detectors only seem to give the standard audio output though. Unfortunately, some people are literally tone deaf, and the straight audio output is not something that everyone finds usable.

I suppose the main attraction of this type of detector is that it is cheap, rather than being highly sensitive or easy to use. In the hands of an experienced operator quite good results can be obtained, and this method of detection provides discrimination between ferrous and non-ferrous metals. One category gives an increase in the output tone while the other produces a reduction (which type metal has which effect depends on how the unit is set up).

A drawback of bfo detectors is that they suffer from ground effect problems. This is where placing the search coil close to the ground gives an indication from the unit even with no metal present. In theory this does not matter provided the coil is kept a constant distance above the ground, but in use this is virtually impossible even with relatively flat terrain. Fortunately, the ground effect problems can be practically eliminated with the aid of a Faraday shield. This is a metal sheath placed over the coil, but broken at some point so that it does not quite form a complete ring. In my experience this dramatically improves results with this type of detector, and for a home constructor unit something as basic as a sheath of aluminium foil will work wonders for the user-friendliness of the unit. Multi-layer search coils are sometimes used with bfo detectors in an attempt to improve sensitivity at larger depths.

## DROP-OUT DETECTOR

There are types of detector which are even more simple than the bfo variety, and which offer a similar level of performance. They seem to be relatively unknown and little used in practice though. A very simple method that I have found to be quite effective is to have an oscillator which includes the search coil in its L-C tuned circuit, and to also have an accurate voltage monitoring circuit of some type included in the unit. When metal is brought near to the coil it produces a change in the operating frequency, but probably of greater importance in this case, it alters the Q value of the coil. The voltages in an oscillator are not exclusively under the control of the bias network, and in many cases the bias circuit exerts very little control. The change in Q and operating frequency will give small voltage shifts with many oscillator designs, and these can be detected by the voltage monitoring circuit.

Vast numbers of metal locators must have been manufactured over the last ten to fifteen years, and one might reasonably expect that there would be several special integrated circuits for this purpose. This does not seem to be the case though, and the commercial detectors I have seen have had circuits based on 741Cs and the like. The only chip designed for this application that I have been able to locate is the intriguingly named CS209 "stud detector" from Cherry Semiconductors. This device is primarily intended for detecting studs and nails in walls, but it is suitable for other metal location applications. Fig.2 shows in somewhat simplified form the general arrangement used in the CS209.

Once again, we have an oscillator with the search coil acting as the inductor in its L-C tuned circuit. The feedback level must be carefully adjusted to the point where the oscillator only just manages to sustain oscillation. The oscillator is sensitive to changes in the Q value of the coil, and the effect of a metal object close to the search coil is to produce a drop in the amplitude of the output signal. The output is demodulated and fed to a level detector circuit. The latter detects the drop in signal level and activates two output stages. The two outputs are both current sinks which can handle currents of up to 150 milliamps, but one is normally switched off while the other is active under stand-by conditions.

Simple arrangements of this type are capable of quite good results, but can also be disappointing in practice due to stability problems. The CS209 seems to offer good performance in this respect

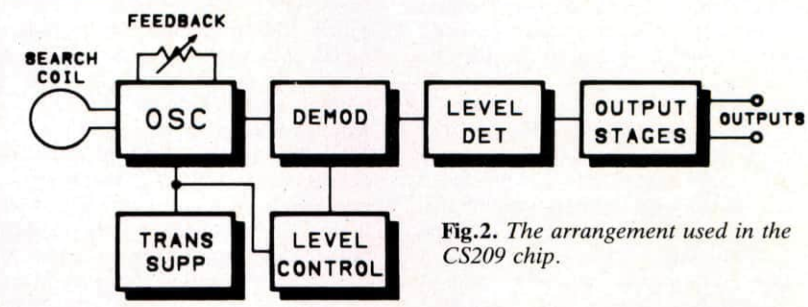



**Fig.2.** *The arrangement used in the CS209 chip.*

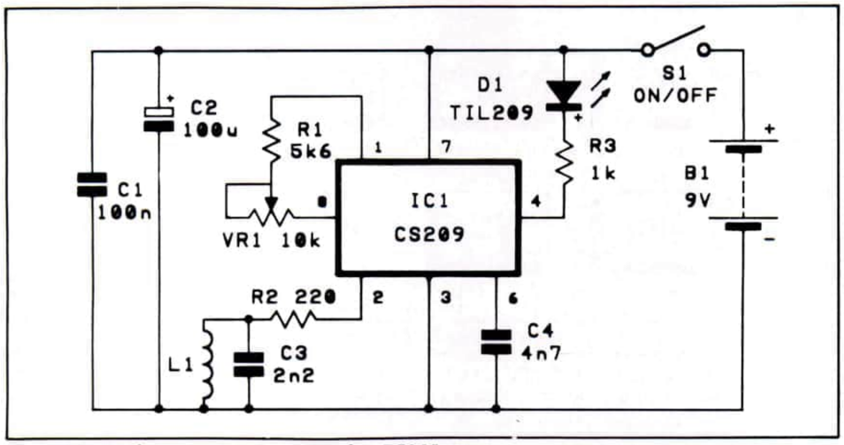



**Fig.3.** *Basic detector circuit using the CS209*

as it has a high quality built-in voltage regulator and a transient suppressor circuit. Another potential flaw in circuits of this type is the strong innate hysteresis. In this case it occurs due to the reluctance of the oscillator to restart once oscillation has been allowed to drop-out completely. In the CS209 this problem is minimised by a level control circuit which ensures that the oscillator can not cease oscillating even if a very large piece of metal is placed close to the search coil.

For those who would like to experiment with the CS209 the basic metal detector circuit of Fig.3 is provided. The data sheet for this device recommends a value of about 100ΩH for L1, but its exact value does not seem to be critical. VR1 must be carefully adjusted for the highest resistance that does not result in D1 switching on. In fact it might have to be backed-off slightly from this setting, since D1 might otherwise tend to hold in the on state when the unit is activated. The automatic level control circuit minimises the amount of hysteresis, but it does not totally eliminate it. Although in this basic circuit only led D1 is switched on when metal is detected, obviously an audio alarm or other form of indicator could be controlled by the circuit. The normally on output, incidentally, is at pin 5 of IC1.

## IN THE BALANCE

The induction balance system requires two coils, or what in practice may be three coils with some tappings. For the moment we will only consider the basic twin untapped coil arrangement as depicted in the block diagram of Fig.4.

We have the familiar oscillator and search coil, but this time with a second coil feeding into an amplifier. Although a strong coupling from the coil driven by oscillator to the second coil would be expected, careful positioning of the two coils provides what is a very inefficient coupling with no significant output from the pickup coil. This sounds difficult, but is achieved merely by partially overlapping the two coils. A piece of metal close to the coils produces an imbalance and gives a strong output from the amplifier stage.

There must be endless ways of converting this rise in signal level into some form of indication to the operator of the equipment, but the general method shown here seems to be a popular one. It provides an audio output tone that rises in volume when metal is detected. This form of indication is generally much clearer than the varying tone produced by a bfo detector.

The output from the amplifier is fed to a detector circuit that gives a dc output level which is proportional to the output level from the amplifier. If meter indication is required, the meter can be driven from the detector stage via a buffer amplifier. For an audio output the next stage is a dc amplifier which incorporates a shift control that can be used to raise the quiescent output voltage above its normal level of close to zero. In practice this control sets the volume of the output tone under stand-by conditions, and results are generally better with a quiet tone rather than having zero output under quiescent conditions. This control is sometimes (rather confusingly) referred to as a "tuning" control incidentally.

The next stage is a "chopper", which is merely an electronic switch that gates the output of the dc amplifier on and off. This generates a squarewave signal having a peak to peak amplitude equal to the output voltage from the dc amplifier. Accordingly, the volume of this audio signal rises and falls in sympathy with the signal level received by the pickup coil. Most people find a change in volume easier to work with than the change in pitch provided by bfo type detectors, but by using a voltage controlled oscillator (vco) a change in pitch could be obtained if preferred. The chopper could be driven from an audio oscillator, but it is often controlled by the main oscillator via a divider stage. Unlike bfo designs, ib circuits often work at quite low frequencies (typically about 15 to 20kHz).

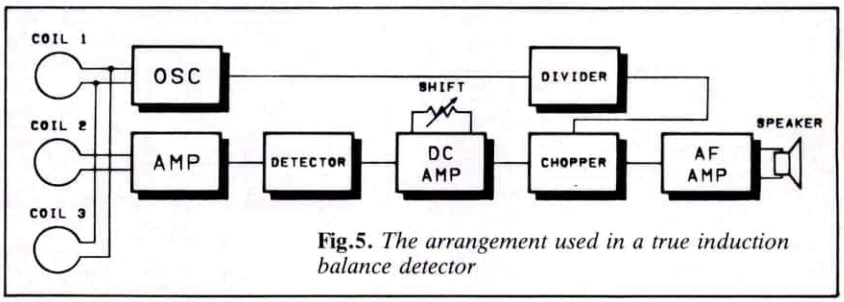



**Fig.5.** *The arrangement used in a true induction balance detector*

A three coil induction balance circuit uses the arrangement shown in Fig.5, which is what some metal detector experts consider to be the only true ib setup. It is virtually identical to the slightly simplified type described previously, and it differs only in that two coils are driven from the oscillator. In practice these two coils are carefully positioned and phased so that there is zero output from the third coil, with the pick-up from coil 1 coil being cancelled out by the pick-up from coil 3. The standard search head arrangement is to have coil 2 sandwiched between coils 1 and 3, with coils 1 and 3 having the same number of turns but being wound in opposite directions.

This type of detector operates in what is essentially the same manner as the two coil ib type, with metal in the vicinity of the search coil upsetting the balance of the system, and producing a stronger output from the amplifier. With both types it seems to be normal to have the system adjusted so that under quiescent conditions there is considerably less than

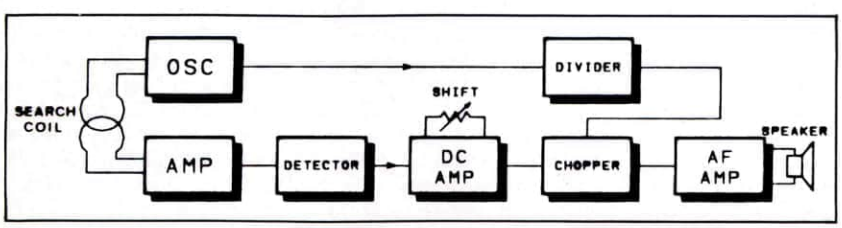



**Fig.4.** *An induction balance detector arrangement*

perfect balancing. This enables the unit to discriminate between ferrous and non-ferrous metals. The latter give a decrease in coupling whereas the former produce increased coupling.

Many of the more up-market ib designs have quite sophisticated discrimination capabilities. This generally takes the form of a control that enables the unit to be nulled on a piece of metal, and it will then fail to respond (or at least be very insensitive to) any pieces of that particular metal in the search area. A typical use of the discrimination facility is to render the detector insensitive to aluminium foil, which is found in large quantities in many popular types of hunting ground. Note that discrimination means the ability of a detector to ignore certain metals: it does not mean the ability to ignore everything but (say) gold or silver. In my experience the discrimination facilities of metal detectors are less worthwhile than much of the advertising literature would have you believe. There is often a penalty to pay in the form of reduced sensitivity, and setting up a machine which has adjustable discrimination and other advanced features can make setting up a video recorder to automatically record a programme look like child's play.

Induction balance metal detectors suffer from ground effect problems. Some ib detectors now have a facility to "tune" out the ground, but variations in soil moisture etc can make frequent re-adjustment necessary. A very useful facility is an automatic nulling circuit, which, over a period of a second or two always adjusts the circuit for zero output. On the face of it this cures the ground effect problem, but renders the detector insensitive to everything else as well! However, in use the detector is swept quite rapidly over the earth, and if the search head passes over any metal the unit will produce a clear indication before the nulling circuit has a chance to rebalance the circuit. Having used this method to roughly locate an object, the unit is switched to the ordinary mode so that it can be pin-pointed.

### IB OR NOT IB

There seems to be some lack of agreement as to which detectors are ib types, and which are t/r (transmit/receive) units. The general consensus seems to be that the types described above are forms of ib detector, while the system depicted in the block diagram of Fig.6 is the t/r type.

This system is very similar to the ib type, and it has one coil driven from an oscillator and a second one feeding into an amplifier. The amplified signal and some of the output from the oscillator are fed to a mixer. The signal from the amplifier is coupled to the mixer via an inverter, or perhaps some other form of phase shifter circuit. The idea is to have the signals at the mixer out of phase so that they cancel each other out. The signal from the oscillator is fed to the mixer by way of a potentiometer so that the signal level can be adjusted for precise cancelling. As for the ib type, metal close to the search head alters the strength of the signal from the pick-up coil, giving an imbalance in the signal levels fed to the mixer and producing an output from the mixer. This signal is fed to a detector stage, and the resultant dc signal is amplified before being applied to a meter. Of course, the dc signal can be fed to a chopper and audio amplifier if an audio indication is required as well.

As the t/r type of detector operates on what is really the same principle as the ib type, it has very much the same advantages and drawbacks.

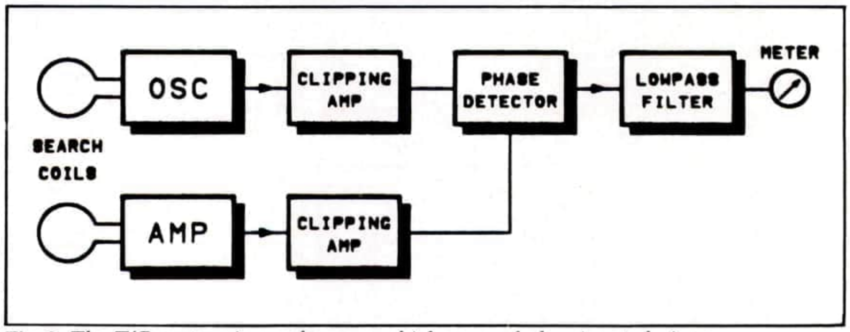



**Fig.6.** *The T/R system is another one which uses a balancing technique*

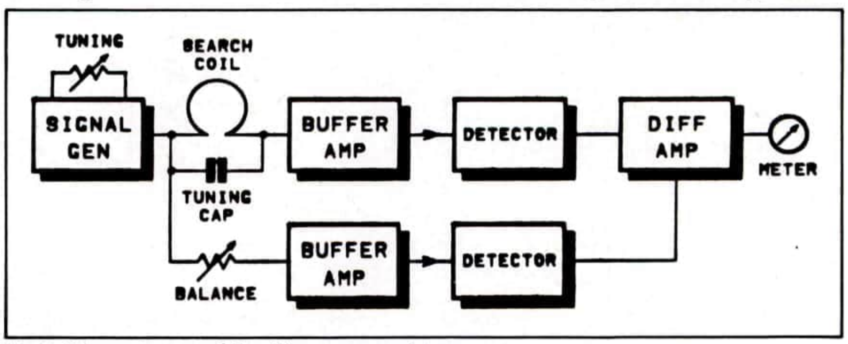



**Fig.7.** *The system used in off-resonance detectors*

### OFF-RESONANCE

This seems to be a little used type of detector, and it utilises the setup shown in Fig.7. It is another type of detector that relies on a balancing process, but the operating principle is not the same as the ib and t/r types. In fact it is much more like the bfo type of detector in this respect.

A signal generator feeds a signal to a buffer amplifier and detector circuit by way of an L-C tuned circuit that incorporates the search coil. Some of the direct output of the search coil is fed via a balance control to another buffer amplifier and detector circuit. The output signals from the detectors are fed to a differential amplifier, and under quiescent conditions the balance control is adjusted for zero output from this amplifier. As with a bfo locator, metal near to the search coil causes a shift in the resonant frequency of the tuned circuit. In this case the tuned circuit is used as a filter, and the signal generator is tuned just off-resonance where the filter has a rapid roll-off rate. The shift in resonant frequency therefore gives a change in signal level that gives an imbalance at the differential amplifier, and a consequent meter deflection.

Compared to a bfo type detector this system has the advantage of providing meter indication, or an audio signal of varying volume if suitable output circuitry is included. In other respects it should perform as well (or as badly as) an equivalent bfo design.

### PULSE TYPE

Pulse induction detectors operate on a principle that is completely different to ib and bfo style detectors. Fig.8 shows a somewhat simplified block diagram for a pulse induction detector.

The principle of operation may be different, but a search coil is still central to the operation of the system. A pulse generator supplies brief pulses to the coil, and this generates a magnetic field around the coil. On the trailing edge of each pulse the magnetic field collapses and generates a reverse voltage across the coil. The coil must be damped (electrically that is!) so that the reverse voltage spike decays quite rapidly. If there is a piece of metal in the vicinity of the coil it will either produce an eddy current or become magnetised by the field of the coil, depending on whether the metal is non-ferrous or ferrous. As far as the effect on the reverse pulse from the coil is concerned, in either case the pulse becomes stretched.

Turning the elongated pulse into a

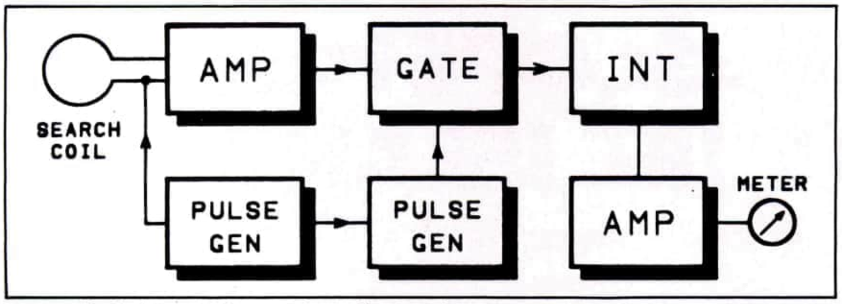



**Fig.8.** *Block diagram for a pulse induction detector*

clear visual or audible indication is usually done with the aid of a gate and an integrator. The gate is opened by pulses from a second pulse generator, but this circuit is triggered from the main pulse generator. Remember that it is the reverse pulse generated across the coil that must be allowed to pass through the gate circuit, and not the signal from the main pulse generator. The second pulse generator is therefore triggered on the trailing edge of the signal from the main pulse generator. In fact it is the part of the reverse pulse where it nears 0 volts that is really of interest, and the gate pulse can usefully be delayed slightly so that the initial part of the waveform is cut out. The integrator generates an output voltage that is a product of time and input voltage, and the stretched pulses give a higher output voltage. This signal is amplified and fed to a meter, and the output from the amplifier can be used to drive some form of audio indicator circuit if desired.

This system has definite advantages over the other types described so far, including its immunity to ground effect problems, and what is generally much better stability than other types of detector. It is not without drawbacks though, such as an inability to differentiate between ferrous and non-ferrous metals, and what is often a relatively high level of power consumption (although some other types of detector tend to be so packed with circuitry that they also consume large amounts of power). A point that has to be borne in mind with this type of detector is that it gives absolute rather than relative detection. In other words, whereas it is possible to adjust other types of detector to nullify the effects of any metal which forms part of the detector itself, this is not possible with a pulse induction type. It is therefore important to have metal-free construction in the search head and at least the lower part of the detector's "stem".

## VLF PHASE ANGLE

This is an interesting type of detector, but I can not say that I have ever encountered a unit which utilises this technique. It is reminiscent of a simple ib or t/r detector in that one coil is driven from an oscillator, while a second coil is used as a pick-up that drives an amplifier. Note that the coils are not arranged in such a way as to give zero output from the pick-up coil. Operation of this system relies on a reasonably strong output signal being obtained from the pick-up coil. The output signal of the oscillator and the output of the amplifier are fed to squaring circuits, as shown in the block diagram of Fig.9.

The effect of metal close to the search head is to produce a phase shift in the output from the pick-up coil. Linear or digital circuits could be used to detect this phase change and convert it to some form of visual or audible output indication, and the digital approach is probably the more simple but effective method. In fact an ordinary logic gate can operate as an effective phase detector. Things would normally be arranged so that the two signals are normally in phase, and move out of phase when metal is detected. This gives zero output or very brief pulses from the phase detector under stand-by conditions, but longer pulses as metal is brought close to the search head. A lowpass filter is all that is needed to convert the pulses into a dc output signal, or perhaps some form of digital pulse duration measuring circuit could be used to provide a visual indication on a digital display.

A unit of this type could be designed to operate at virtually any frequency, but it is advantageous to use a very low frequency as this apparently avoids problems with the dreaded ground effect.

## CONCLUSION

There are several different types of metal detection circuit currently in use, with each type having its advantages and disadvantages. Clearly the perfect metal detector has yet to be invented. People who have never used a metal detecor tend to have an exaggerated idea of the sort of performance that can be obtained. It takes a good unit to detect a 2p coin at a depth of 150 millimetres or so, and few units can detect even quite large pieces of metal at much more than two or three times this figure. Super high sensitivity is not necessarily an asset anyway, and it can simply provide confusing results with every speck of metal being detected. When using my detector at full sensitivity it often detects what turns out to be a small patch of rust!

Ready made metal detectors of fair performance seem to be quite expensive, and this is one aspect of electronics where it is certainly possible to build a unit that will cost considerably less than buying a "real one". There is plenty of scope for anyone wishing to try their hand at designing this type of equipment. One last point is that an operating license is no longer needed in order to operate a metal locator in the UK, but it is only legal to use detectors that fall within certain (not especially stringent) specifications. PE

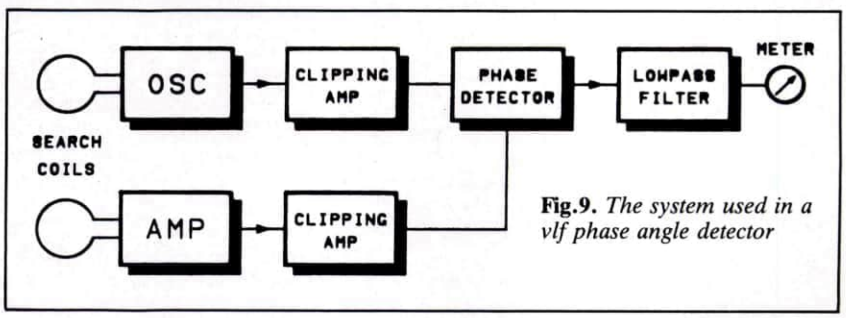



**Fig.9.** *The system used in a vlf phase angle detector*

## BAEC PUZZLE SOLVED

*The British Amateur Electronics Club has had periodic publicity through PE's news pages. The address previously quoted was that of the Hon Sec to whom several readers wrote asking for membership details. Receiving no reply they contacted your Ed who, loving a challenge, made more enquiries. It seems that Hon Sec moved but Hon Printers didn't update BAEC's Hon Mag.*

*Hon Ed chatted with Hon Chairman who says that membership enquiries eventually come to him anyway so suggests readers should contact him directly: Mr C. Bogod, 'Dickens', 26 Forrest Road, Penarth, South Glamorgan, tel. 0222 707813.*

*It's a club worth joining if you're looking for electronic companionship and an interesting quarterly magazine-newsletter full of ideas, circuits, information and sources of discount electronic goods. But please be good to Mr Bogod and send a stamped addressed envelope with any letter to him.* **Ed.**

# SEEING SCOPE FOR TREASURE ISLAND

**BY LONG JOHN BECKER**

## THE PROOF OF THE PROBING IS IN THE KITTING

*What your editor is trying to tell you is that he has been given a make-it-yourself metal detector to play with! Wooden leg optional...*

*An ideal educational or hobby project*

While reading through Robert Penfold's article on metal detection, completely by coincidence, a press release from C-Scope about one of their several metal detectors arrived on my desk.

My curiosity being what it is I rang them to see how their designs related to RP's observations. Kate d'Lima, to whom I spoke, was extremely helpful with information and also suggested that I might care to examine one of their detector kits, the K5000. Never having used any sort of metal detector before, I jumped at the opportunity.

### PRESENTABLE

A few days later a large well packed box arrived. Opening the wrapping I was immediately impressed by an attractively illustrated box and by the way in which everything inside has been packed and presented.

The interior was lined in specially sculptured polystyrene foam with various parts and packages neatly inserted into it. All the hardware parts were protected by polythene wrappings, and all the electronic components had been put into a selection of sealed polythene bags. Obviously this kit has been designed with the presents market in mind – and anyone receiving it as a gift would certainly be delighted by the appearance.

Accompanying the parts is an illustrated 34 page A4 size assembly and operation manual. Following a brief preface about C-Scope and the kit, a page is devoted to an itemised contents list, split into nine sections pointing me to an introduction, parts list checking, soldering, pcb assembly, mechanical assembly, wiring assembly, setting up procedure, trouble shooting and operation.

### FORWARDS

The introduction describes the K5000 kit as having been designed to offer a challenge to an electronics enthusiast while being detailed enough for a novice to understand and complete successfully. It goes on to say that the kit requires no prior knowledge of electronic components or assembly techniques, and that it can be completed with a minimum number of tools. While assembling the kit I had these statements in mind and I certainly conclude that they are true.

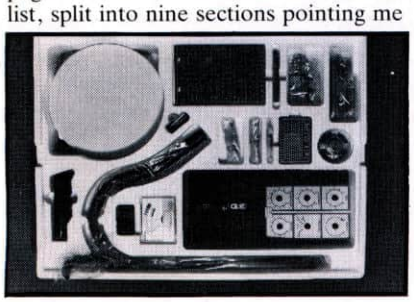
The tools suggested are a 1.5 Allen key screwdriver, a Phillips quarter inch blade screwdriver, wire cutters, long nose pliars, junior hacksaw, soldering iron, ruler, 5.5mm and 14mm box spanners. In fact I did not use an Allen key or the box spanners, but instead used a modelmaker's screwdriver and a pair of heavy duty pliars.

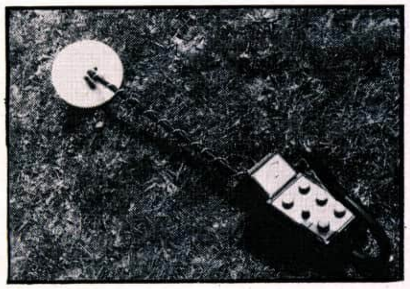
### EASY AS PCB

The parts list checking section is thorough. It leads you through details of what resistors, capacitors and ics look like, even colour codes and component outlines are shown. There is a complete list of all the parts and in which bag to find them. Apart from tools, the only items not supplied are batteries, of which you will need to buy 12 of the HP7 type, or similar.

For the complete novice, half an illustrated page is devoted to instruction on soldering. Then comes the first of the exciting parts – the pcb assembly.

As far as was possible for an addicted assembler, I followed the instructions in detail and I feel sure that novices will find it very straightforward. A step-by-step approach is taken, using words and





pictures to tell you precisely what each component looks like and where it goes. It is almost impossible to put a component in the wrong place.

At this point I would make a few suggestions to C-Scope. First, it would be useful if in the pcb assembly section they explained the best way to remove any soldered component if it had been put in the wrong place.

### PLUGGING SOCKETS

Secondly, from many years experience connected with kits I recommend that the ics should not be soldered in but instead should be used with sockets, so allowing easy removal if necessary. If someone was careless and soldered in an ic the wrong way round it would be difficult for an inexperienced constructor to remove it. The use of ic sockets is definitely preferable.

Another suggestion is that the insertion of ics should be left until after all the electronic and mechanical assembly has been done. Although the mos ics are less prone to static electricity problems once they are physically within a circuit, I still feel it is best if the risk of handling them is minimised by leaving their insertion till last.

### LENGTHENED

A further comment is that although the manual appears to give all the necessary information to identify electronic components, I noticed that some capacitors only had their manufacturer's coded identities on them. Experienced constructors probably won't be confused by this, though a novice might, even though the identities can be intelligently deduced. As C-Scope already go to such lengths to make things easy, I suggest that additional code clarification here would make it even easier.

Although the pcb is solder protected in non-connection areas and the risk of solder shorts is minimal, I would suggest that the advice about checking soldering is put immediately following the pcb assembly section instead of, or as well as, in the trouble shooting section.

Incidentally, I could have done with a bit more solder supplied – the connecting tags really like to drink it. Another metre would probably do. Of the connecting ribbon cable there was no shortage and I only used about two thirds.

It was interesting for me to assemble another designer's pcb kit, and in the two hours it took me I enjoyed doing it. I was impressed by the overall thoroughness of the explanation.

### TEXTURED HARDWARE

Mechanics are not as familiar to me as electronics, and on the hardware assembly I can truly say that I approached it as a novice. In retrospect, I am surprised at myself for finding one or two parts initally perplexing and I can admit now that in some instances I was guilty of not reading the words or studying the pictures properly.

Somehow, though, I got the feeling the authors of the electronics and mechanical stages were different people and that some of the explanation about the hardware was not so detailed as that for the pcb assembly. I am sure that everyone will find the answers, like I did, but a little extra detail would be even more helpful.

I felt, too, that the attachment of the detector head and the full length of handle would have been best left until after the wiring had been completed – my overcrowed workbenches didn't leave much clear space for satisfactorily balancing the head, handle and control box.

It would have been preferable for the control spindles to have had flattened sides and that the knobs had either been push-ons or used grub screws that would accept a small electrical screwdriver. Most people will have the latter, but Allen keys to suit the knobs supplied are not part of everyone's tool kit.

### CHECKING PROCEDURE

After spending two and half hours doing the mechanical and wiring assembly I proceeded straight on to the setting up – you know how keen one can be to try out something new.

There are only three minor adjustments to be carried out to preset controls on the pcb. Adjusting the first two produced the required changes as stated in the text and I found that the detector recognised when coins were passed close to it. The third preset, the ground-exclude trimming capacitor C3, can simply be set midway and adjusted more precisely in the light of experience. I'm pleased the unit has been designed so that the controls can be set without the need for a meter or other test gear.

The trouble shooting section I didn't need to use, but it appears to be comprehensive, covering each stage of the circuit in turn. The complete circuit diagram shown will be of interest to anyone with technical knowledge.

### CONTROLLED OPERATION

An eight page section is devoted to operating the metal detector. It covers the theory of detection, how the detector can discriminate between various objects, accepting or ignoring them depending on the control settings. There are six controls on the panel allowing for adjustment of sound volume, tuning, sensitivity, ground exclusion, discrimination level, and switched seventh control in the handle is in effect a type of memory recall and discrimination function selector.

Care and maintenance of the detector are covered, and then a lengthy guide to techniques for treasure hunting is given. A few detailed examples of searching would perhaps be useful here – like how to get the detector to recognise a specific item knowingly presented to it, using different items so that one can learn from controlled experiments.

### EBULLIONT

Within five hours of starting to assemble the kit, I was succesfully 'finding' various things that I was deliberately 'losing'. My interest has been aroused to try searching for 'treasure' more earnestly now that summer is supposed to be with us. Following successful field trials I might just see if Brink's Mat or Fort Knox need any help...

I am very impressed by assembling and briefly using this detector. As I have not used one before I cannot compare it with others, but one thing is certain, the K5000 is a very well thought out metal detector kit.

The few suggestions I have made here should not be taken as serious criticisms; they are intended as helpful observations for minor improvements to an excellent kit. Congratulations to C-Scope.

### PIECES OF EIGHT

The price of the K5000 metal detector kit at the time of going to press is £124.50 including vat. There is a full after-sales repair, maintenance and spare parts service. The detector can also be bought ready built direct from C-Scope for an extra £40. The kit is available from good hobby and electronics shops, or from C-Scope International Ltd, Dept PE, Wotton Road, Ashford, Kent, TN23 2LN. Tel: 0233 29181.

C-Scope are also running a competition with K5000 kits as prizes – see page 5. PE