

# the PW Sandbanks

P. J. Wales

Pulse Induction metal detectors have been available on the commercial market for some years and essentially their circuits remain unchanged from the original design. They have developed their own unique reputation because they have inherent features that other metal detectors do not have. They have always been very powerful machines capable of detecting a 2p coin up to 230mm underground. Because of the very low frequencies used they are insensitive to ground effects, coke, salt water, wet grass or small pieces of aluminium foil. Their sensitivity is a function of their current consumption and thus their battery life is generally poor, but their main disadvantage is their inability to discriminate between ferrous and non-ferrous materials.

The author has spent two years developing a circuit which combines good sensitivity, low current consumption and ease of use; a circuit which the enthusiast can build himself without the need for elaborate and complex test gear. The circuits have been particularly tuned to gold and silver, and they can be set up perfectly with only a meter. The unit illustrated is assembled into a case available as a kit from Ambit International Ltd.

## Theory

The basic principles of the PI metal detector are best understood by reference to the block diagram, Fig. 1(a).

As with most metal detectors, the heart of the machine is the coil. When power is applied to the coil it generates a magnetic field proportional to the number of turns of wire and the current passing through them. When the power is removed the voltage across the coil first drops to zero and then, as the magnetic field decays, builds up in the reverse direction as a back e.m.f. is induced into the coil. If the coil is correctly damped the back e.m.f. dies away as shown in Fig. 1(b). Should there be a piece of metal near the coil, it is affected by the magnetic field either to produce eddy currents or to be magnetised, depending upon whether the metal is non-ferrous or ferrous. In either case the result is the same in that the back e.m.f. takes longer to die away. This effect is most apparent in the time it takes to reach 0V.

Thus the detector circuits are arranged to process the area of signal where the back e.m.f. nears 0V. This is done by amplifying the coil waveform and then taking a sample of the voltage just as it gets to 0V. This sample is fed to an integrator which produces an output voltage proportional to the back

e.m.f. decay time. This voltage is used to control the frequency of a voltage controlled oscillator (v.c.o.) which drives the speaker.

## Circuit Description

The short negative-going pulses which are applied to the coil are generated by means of a 555 timer (IC1) operating in the astable mode. The repetition frequency is about 66 pulses per second and the duty cycle (ratio of pulse length to pulse interval) about one percent. The output at pin 3 is amplified and inverted by Tr1 and applied to the power transistor Tr2. This transistor is run in a linear mode to increase switching speed and also reduce current consumption. The waveform on its collector follows the dotted line in Fig. 1(b) which shows that up to point A, Tr2 is saturated whilst the current builds up in the coil. After point A, the transistor goes into its linear mode, conducting approximately 0.5 amp.

Before describing the signal processing it is convenient to deal with the power supply arrangements. A 10.5V battery (seven cells) is used in the design illustrated, though any supply between 9V and 12V is satisfactory. The quiescent current consumption is about 50mA, rising to about 100mA on full detect. The positive line from the battery has been designated 0V. The other line is therefore -10.5V. Decoupling of the battery supply is provided by C1. Two other supply lines are derived from the basic battery supply.

The first of these, +12V, is generated by an oscillator-rectifier arrangement. A c.m.o.s. ring oscillator based on IC3 runs at about 30kHz. The output is applied to the buffer

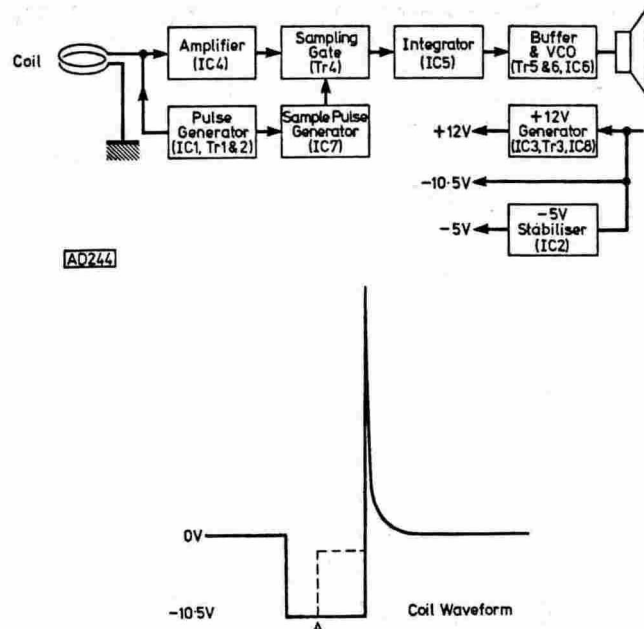
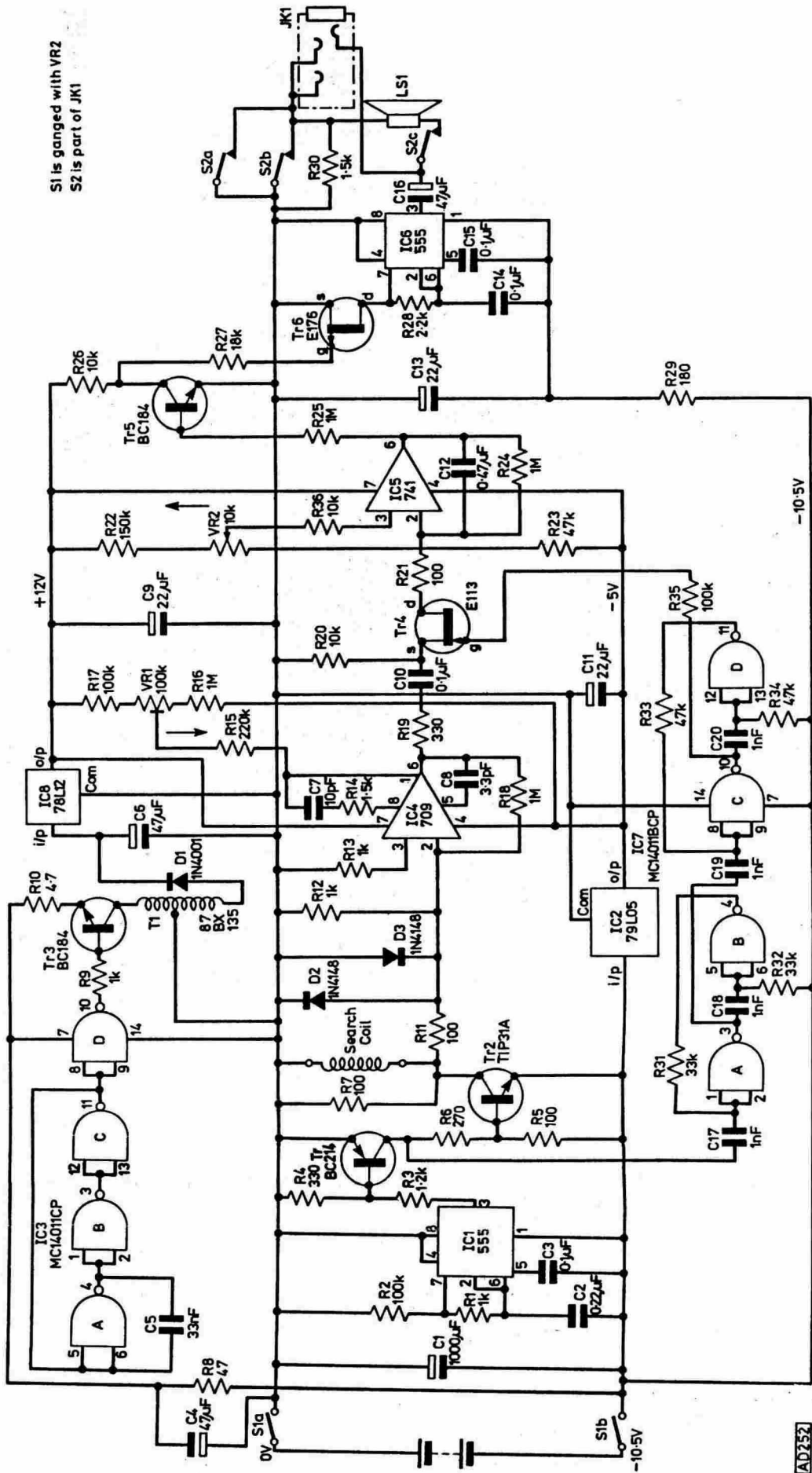


Fig. 1: (a) Block diagram of the PW Sandbanks P.I. metal detector. Except for the power supply arrangements and component references, this is typical of any P.I. machine. (b) Coil waveform



transistor Tr3 which has an autotransformer T1 as its collector load. The 50V peak pulses produced are rectified by D1 and smoothed by C6. Regulator IC8 maintains the output at 12V.

It is essential that IC3 is an unbuffered "A" type, since the buffered "B" type will not work in this circuit. No attempt is made to tune T1, as tuning tends to upset the ring oscillator, making it unstable. The circuit is decoupled by R8 and C4, to prevent 30kHz ripple being fed into the amplifiers.

The second derived supply line is a stabilised -5V for the amplifiers. This is provided by regulator IC2.

The signal across the search coil is fed via a clipping network R11, D2 and D3, which limits the voltage swing at the input to amplifier IC4 to  $\pm 0.7V$  to prevent overloading. The gain of IC4 is set to 10,000 by means of R18, and frequency compensation is designed to provide the fastest response with maximum reliability. The output offset is set by means of VR1.

In order to be able to sample the waveform across the search coil as it reaches 0V, it is necessary to generate a delayed gating pulse. This is done by IC7, which is arranged to form two monostables. The first, IC7a and b, produces a pulse 50 $\mu$ s wide, starting on the trailing edge of the pulse at Tr1 collector. The second monostable, IC7c and d, is triggered by the first, and generates a pulse 75 $\mu$ s wide, which is the sample pulse. This is applied to the gate of Tr4, turning the latter on for 75 $\mu$ s, 50 $\mu$ s after the transmit pulse ends. See Fig. 3.

When the sample pulse is on the gate of Tr4, the source-drain impedance is very low, and the voltage at the output of IC4 is transferred to the input of IC5. For the rest of the period the impedance of Tr4 is very high, and IC4 output is isolated from IC5. The small negative-going pulses are amplified and integrated by IC5/C12 to form a low-rise sawtooth waveform whose d.c. level is proportional to the width of the back-e.m.f. pulse. The output offset of IC5 is adjusted by means of VR2.

The output of IC5 is connected to Tr5 which is a low-gain inverter. When IC5 output is low, the collector of Tr5 is at +12V and Tr6 source-drain impedance is too high for capacitor C14 to charge. When the output of IC5 is high, Tr5 is switched on and the source-drain impedance of Tr6 is low. This allows C14 to charge and IC6 then functions as an audio-frequency oscillator whose frequency is proportional to the amount by which the width of the back-e.m.f. pulse exceeds 50 $\mu$ s.

The oscillator output is applied to the internal loudspeaker, or to headphones when these are plugged into JK1.

## Construction

The battery holder should first be assembled sufficiently to provide power for testing. It will be finished when the circuits are built and tested. The top adaptor should be gently tapped into the aluminium tube using a piece of wood as a buffer to protect the pvc from damage. The spade terminal which forms the negative battery connection should then be riveted to the tube with the special rivet provided. Remove the epoxy coating from the first 15mm of the tube with a Surform tool or file and glue the battery cap holder to the tube with an isocyanocrylate

### Resistors

|                   |                 |
|-------------------|-----------------|
| $\frac{1}{4}W$ 5% |                 |
| 4.7 $\Omega$ 1    | R10             |
| 47 $\Omega$ 1     | R8              |
| 100 $\Omega$ 4    | R5, 7, 11, 21   |
| 180 $\Omega$ 1    | R29             |
| 270 $\Omega$ 1    | R6              |
| 330 $\Omega$ 2    | R4, 19          |
| 1k $\Omega$ 4     | R1, 9, 12, 13   |
| 1.2k $\Omega$ 1   | R3              |
| 1.5k $\Omega$ 2   | R14, 30         |
| 2.2k $\Omega$ 1   | R28             |
| 10k $\Omega$ 3    | R20, 26, 36     |
| 18k $\Omega$ 1    | R27             |
| 33k $\Omega$ 2    | R31, 32         |
| 47k $\Omega$ 3    | R23, 33, 34     |
| 100k $\Omega$ 3   | R2, 17, 35      |
| 150k $\Omega$ 1   | R22             |
| 220k $\Omega$ 1   | R15             |
| 1M $\Omega$ 4     | R16, 18, 24, 25 |

### Potentiometers

|   |         |
|---|---------|
| 100k $\Omega$ min. horiz. preset        | 1VR1    |
| 4.7 $\Omega$ lin. pot. with d.p. switch | 1VR2/S1 |

### Capacitors

|  |                 |
|--|-----------------|
| <i>Polystyrene</i>                     |                 |
| 10pF1                                  | C7              |
| 1nF4                                   | C17, 18, 19, 20 |
| <i>Sub-min plate ceramic</i>           |                 |
| 3.3pF1                                 | C8              |
| <i>Polycarbonate, 100V</i>             |                 |
| 33nF1                                  | C5              |
| 0.1 $\mu$ F4                           | C3, 10, 14, 15  |
| 0.22 $\mu$ F1                          | C2              |
| 0.47 $\mu$ F1                          | C12             |
| <i>Tantalum Bead, 16V</i>              |                 |
| 22 $\mu$ F3                            | C9, 11, 13      |
| <i>Electrolytic, 16V p.c. mounting</i> |                 |
| 47 $\mu$ F3                            | C4, 6, 16       |
| 1000 $\mu$ F1                          | C1              |

### Semiconductors

|                    |        |
|--------------------|--------|
| <i>Diodes</i>      |        |
| 1N40011            | D1     |
| 1N41482            | D2, 3  |
| <i>Transistors</i> |        |
| BC1842             | Tr3, 5 |
| BC2141             | Tr1    |
| E113 (or BF256B)   | 1Tr4   |
| E1761              | Tr6    |
| TIP31A (or BD535)  | 1Tr2   |

|                            |                |
|----------------------------|----------------|
| <i>Integrated Circuits</i> |                |
| MC14011CP1                 | IC3 (see text) |
| MC14011BCP1                | IC7            |
| 78L121                     | IC8            |
| 79L051                     | IC2            |
| 5552                       | IC1, 6         |
| 7091                       | IC4            |
| 7411                       | IC5            |

### Miscellaneous

T1 Toko 87BX135. JK1 Switched stereo jack. PL1/SK1 3-pole connector, Bulgin P632. LS1 8 $\Omega$  2 or 2½ in. Materials for case, battery holder, shaft, search coil, etc. (see text).

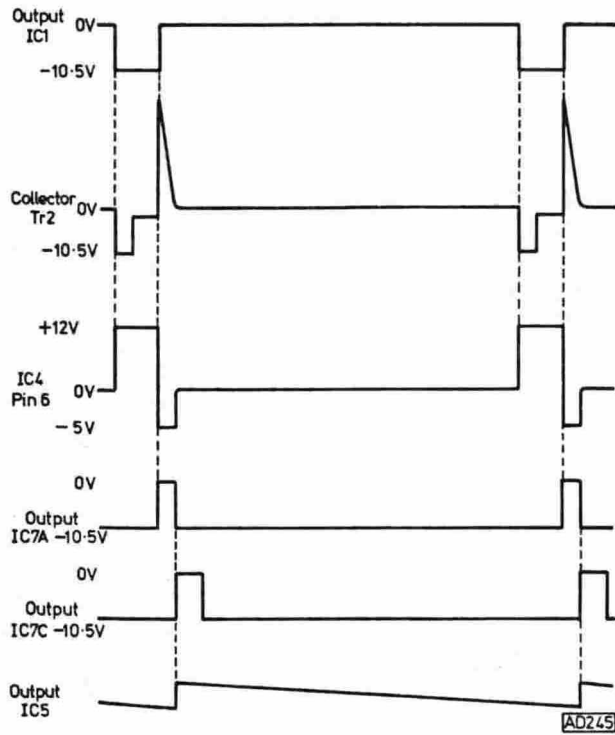


Fig. 3: Timing diagram

adhesive such as Cyanolit or Super Glue 3. Stretch the spring so that it is about 50 percent longer than its original length. It should now slide easily down the tube. Bend the contact plate extensions down at right angles and clip it over one end of the spring. Fold the extensions over the spring to clamp it firmly. Bend out the last 10mm of the spring to cause it to scrape the side of the tube and push it down the tube with the batteries.

The coil is wound from 20 turns of 26 s.w.g. enamelled copper wire in a 200mm diameter circle. The coils should be secured with twists of copper wire, ensuring that they do not form a short circuit around the coil. Do not use adhesive tape

for this as the epoxy resin tends to lift it away and then the coils move whilst they are setting. Feed a 2m length of 3-core miniature mains cable into the hole in the side of the bottom tube and out of the machined end. Strip it and solder the blue and the brown to the ends of the coil. Glue the bottom adaptor into the coil with Cyanolit and leave it to set hard.

Place the coil in the moulding and shape it to lie as flat along the bottom as possible, ensuring the minimum resin used and the lightest coil. Seal the wire into the adaptor with Seccomastic to prevent the resin from leaking past the wire. Chock up the moulding until the top surface is horizontal and ensure that it is firmly supported. The epoxy resin in the kit has resin and hardener in one plastic bag, separated by a plastic clip. Remove the clip and mix thoroughly for at least five minutes. Snip off the corner of the bag and carefully pour it over the coil using only enough to cover it. If any resin is spilled, do not wipe it off the moulding as it comes off easily when it is set. Leave to harden for 24 hours minimum. An alternative printed circuit coil is available from Ambit International.

### PCB Assembly

Very few of the components are critical but to avoid problems it is advisable to use only new, best quality parts. The circuit has been designed so that a working unit can be set up perfectly using only an Avometer. Due to the complexity of the circuit, it is recommended that each stage is built and tested before progressing to the next. Accordingly a loading sequence is given for each part of the circuit followed by a testing and fault finding guide. Each part of the circuit must be working correctly before progressing to the next stage. It is inadvisable to try to build this circuit on Veroboard as the layout is fairly critical, and at least a double-beam 'scope will be necessary for fault finding if problems occur.

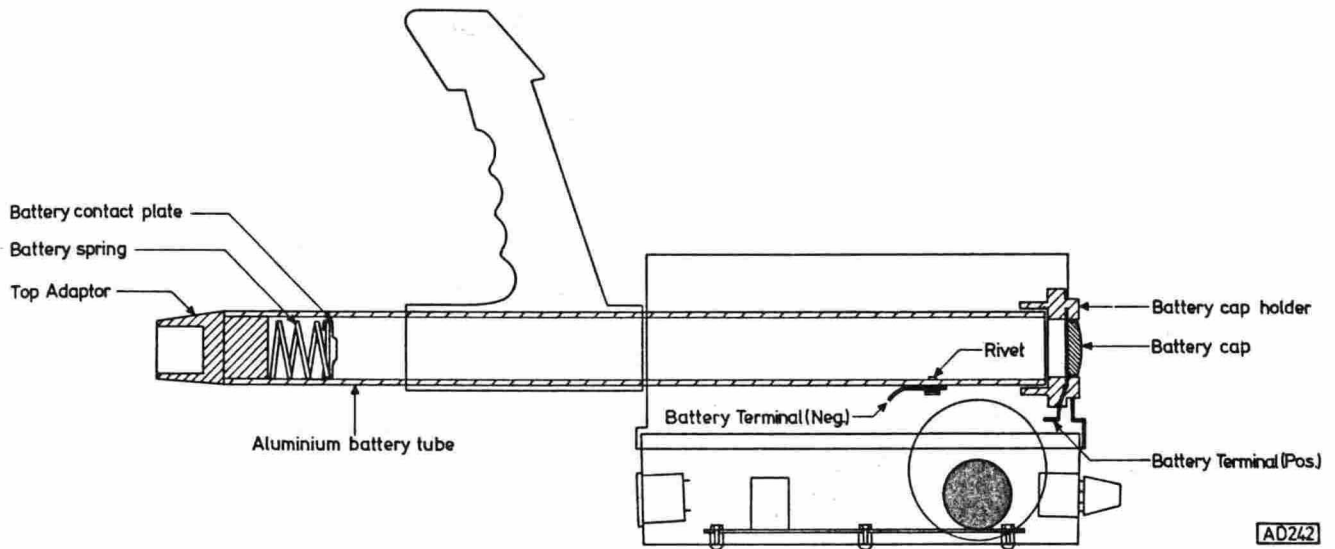


Fig. 4: Details of the case assembly

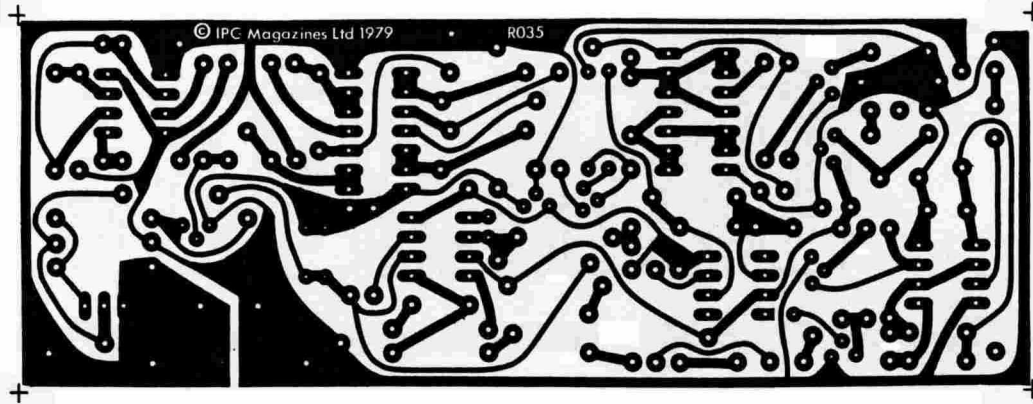


Fig. 5: Foil pattern of the p.c.b., shown full-size

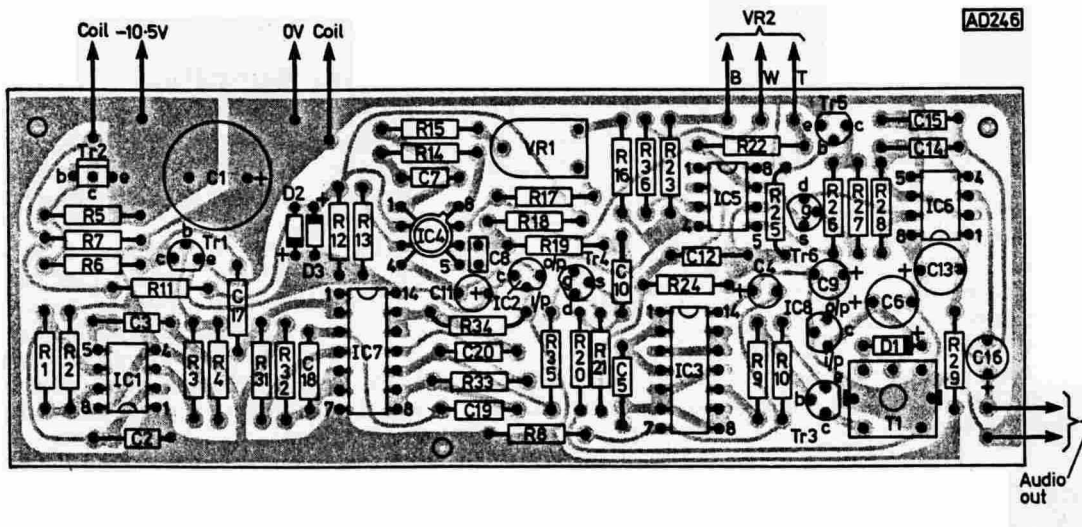


Fig. 6: Component layout on the p.c.b.

**Pulse Generator:** Load IC1, C1, C2, C3, R1 and R2. Check, crop and solder. Wire the p.c.b. to the battery spade sockets via S1 (part of VR2). Connect the spade sockets to the battery holder terminals. Switch on and measure the output at pin 3 IC1. It should be one per cent of  $10^2.5V$ , i.e. 105mV. Switch off.

**Power Stage:** Load R3, R4, R5, R6, R7, Tr1 and Tr2. Check, crop and solder. Switch on and measure the voltage between Tr1 collector and the negative rail. It should be the same as IC1 output, i.e. 105mV. Switch off and solder the coil temporarily into the p.c.b. Make up an improvised peak-reading probe for the meter by wiring a 1N4001 diode between the positive test clip and its lead (positive or white end of the diode towards the lead) and a 0.1 $\mu$ F capacitor across the leads. Switch on again and measure the voltage between the collector of Tr2 and 0V (meter negative to 0V). This can be anything between 12V and 50V, this being the peak back e.m.f. voltage. Switch off.

**Minus 12V Supply:** Load R8, C4, C5, IC3, R9, R10, Tr3, D1, C6, IC8, C9 and T1. The usual precautions must be taken while handling the c.m.o.s. IC3. Damage may result if a static charge is applied to its pins. Check, crop and solder. Switch on. The output of IC8 should be +12V. If it is not, check that R8 has at

least -7V on it and that pin 10 of IC3 has half of the voltage at R8. If not, then the i.c. is suspect. If so, then check the positive end of D1 which should have more than +15V on it. If not, suspect Tr3. Switch off.

**Minus 5V supply:** Load IC2 and C11. Switch on and measure the output of IC2, it should be -5V. Switch off.

**Amplifier:** Load R11, D2, D3, R12 to R19 inclusive, C7, C8, IC4 and VR1. Check, crop and solder. Move the coil away from any metal and turn on. Adjust VR1 to give an output voltage of +0.5V on pin 6 of IC4. Move the coil to a large piece of iron and the voltage should go up to 0.7V or so.

If the output cannot be set to 0.5V then check the voltages on pins 2 and 3. They should be nearly the same at 0V. If not, fit a new 709. If they are correct solder a 100k $\Omega$  resistor across R15 and check that the 709 output can be adjusted. If not, fit a new 709 but if so, replace R15 with the largest resistor that will allow the output to be adjusted from rail to rail. Set the output to +0.5V and switch off.

**Sample Pulse generator:** Load C17 to C20 and R31 to R35 inclusive. Ensure that IC7 is a buffered type and insert it carefully. Check, crop and solder. Switch on and try to measure the output of IC7 at pin 10. As the waveform is a square wave of duty cycle 0.1 percent the voltage should be very close to -10.5V. Switch off.

**Sample Circuit and Integrator:** Load C10, Tr4, R20 to R24 inclusive, R36, C12, IC5 and wire up VR2. Check, crop and solder. Switch on with the meter between pin 6, IC5 and 0V. Move the coil away from metal and set VR2 so that the output is about 0V. Move the coil near metal and the voltage should rise to almost +12V. If the output cannot be set to 0V measure the input voltages on pins 2 and 3. Pin 2 should be slightly negative and pin 3 should be adjustable to either side of it. If the voltages are wildly out suspect IC7. If they are very near,

alter the value of R22 or R23 to bring the range of VR2 to the correct point. Switch off.

**Buffer and VCO:** Load R25, Tr6, Tr5, R26 to R29 inclusive, C13 to C16 inclusive, IC6 and wire temporarily to the speaker. Check, crop and solder. Switch on with the coil away from any metal. Ensure that with VR2 right down the speaker is silent, and with VR2 right up and the coil near metal, the tone is at its highest pitch. This can be adjusted slightly by altering VR1, keeping the output of IC4 within the limits of 0V to +0.5V.

## Final Assembly

When the circuit is working correctly, fix the coil plug PL1, jack JK1 and potentiometer VR2 into the bottom tray, and leave flying leads from the p.c.b. Mount the p.c.b. from 3 screws through the case with suitable spacers, and solder the leads to PL1 and JK1 as shown in Fig. 7. Solder R30 across the jack and glue the speaker into the case with Evostik. Slide the battery tube through the top half of the case and glue the battery cap to the case with Cyanolit. Cement the tube to the inside of the case and the battery cap to the case with ABS cement. Fit the bottom, half of the case into position and drill 4 holes for self-tapping screws, avoiding the speaker.

Assemble the complete detector and wind the lead from the search coil around the shaft as shown in the photographs to keep it tidy. Cut the lead to a suitable length, then strip it and connect it to the free socket SK1.

## Alternative cases

As mentioned previously, this circuit can run from a supply between 9V and 12V without modification, so the battery used is up to the builder. A PP9 will last up to 15 hours, HP2s up to 80 hours and MN1300s up to 200 hours. Should the constructor decide to build his own case then a visit to the local builders' merchant will secure most of the necessary items for the shaft and handle.

The coil should be wound as detailed but it could be glued to a piece of glass fibre p.c.b. material with all of the copper etched away. The coil must be rigid and waterproof so it is best to cover it with Araldite. The shaft and handle can be made from 3/4in water pipe but the best material is 3/4T which has a thick wall suitable for threading. There are a number of

proprietary brands of case available to house the electronics. The part of the shaft nearest the coil must be non-metallic.

## In use

Whether you use a kit or make your own, the way to use the machine is exactly the same. Best results will be obtained when the user has experience with his machine.

Switch on and turn up the control until the speaker is at its highest pitch. Back the control off until the speaker has just stopped clicking. If the control is set too close to the quiet point then as the coil changes direction through the magnetic field of the earth, it will give an output, so set it back just a fraction more. The best point will be found with lots of practice.

If you are sure there is something to detect and know roughly where it is then the machine can be set with the speaker just clicking at about 1Hz. Search very slowly and listen for a change in the rate of clicking. The machine is at its most sensitive at this point. When you are very familiar with your machine you may wish to alter the value of C14 to 47nF which increases the sensitivity to small objects but makes the control more critical.

## Follow-up #1 to Sandbanks Metal Detector

P.J.Wales

Practical Wireless April 1979

The more experienced constructor, having built his "Sandbanks", may wish to increase its performance, and these notes are a guide as to how that may be achieved.

The locator works by transmitting a heavy magnetic field over the find (which we shall call the subject) and comparing the decay of that field in the subject, to the decay in the coil. Hence, if the rate of decay in the subject is faster than that in the coil, the subject will not be detected. Thus the first item to evaluate is the coil.

## Energy Storage

To detect small and fast-conducting objects such as gold, silver or copper, the energy stored in the coil must be as low as possible. The energy is stored in three ways. First the magnetism, which we want as large as possible, secondly the inductance, which is very low in an air-cored inductor, and thirdly and most importantly, the capacitance, which has no effect other than to slow down the rate of decay of the magnetic field. The capacitance is produced by the proximity of the conductors in the coil, and they are only separated by the thickness of the insulating varnish, so a significant improvement can be obtained by insulating the wire used for the coil with a pvc sleeve. Greater gains can be obtained by winding the coil, with the extra insulation, in a neat manner so that the inside turns are as far away from the outside turns as possible. This leads us on to a flat coil which has about two-thirds of the capacitance of the wire bundle coil. However, it is

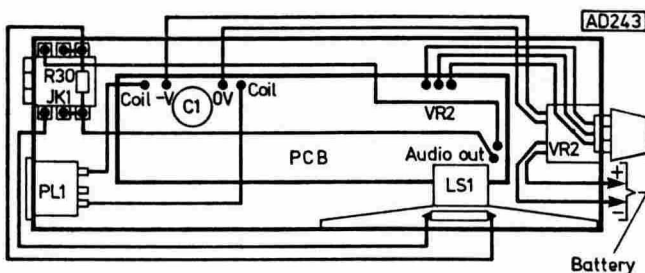


Fig. 7: Wiring details for the case assembly

very difficult to wind, but if you succeed, then Araldite the coil before potting it or the turns may move in the potting compound. By far the best solution is to use a printed circuit coil, as designed by the author and available from Plessis Electronics, Castle house, Old Road, Leighton Buzzard, Beds, which has a capacitance of about half that of a wire bundle.

## Coil Shape and Size

The next stage in the coil design is to alter the size of the coil. Generally speaking, to maintain the same parameters within the machine, it is necessary to increase the number of turns when reducing the diameter of the coil. A small coil will locate objects very accurately, but its range is reduced. For greater range, the coil can be increased in diameter, and as a rough guide, doubling the coil size will double the range, within limits.

Square coils also have a lot to offer, because the range on a square coil is greater than that on a round coil of a similar size. Even greater range can be obtained by using a rectangular coil, and the optimum ratio of the sides is 4:1. One manufacturer of machines using the Pulse Induction principle offers a coil 1.83 x 0.48m (72 x 18in) as a standard with one of his detectors.

## Modifications

Experimenting with coils for enormous range is very easy, but finding nails 3m under hard ground is not very rewarding, so stay within reason. In order to take maximum advantage of any reduction in coil capacitance achieved, it is necessary to reduce the time between the transmit pulse and the sample pulse, called the delay time. The shorter the delay time, the more sensitive the detector is to gold. The delay time in the PW "Sandbanks" is altered by changing the value of R31 and R32. It is easiest to replace these two with 47kΩ presets during tests, putting in suitable resistors when a satisfactory performance has been reached. It is best to check the delay time using a double-beam oscilloscope, but lacking one of these, the control VR2 should be set to its midpoint and VRI adjusted to ensure that the output of the 709 is at 0V. Then reducing the added presets until the speaker just starts clicking ensures the optimum delay time.

## Internal Delays

It may be argued that the internal circuits produce their own delays and this is certainly true, but the circuit has a fall time of 3 microseconds and this is quite fast enough. No improvement was obtained with a £4.50 r.f. power transistor and low-capacitance diodes. The capacitance at the coil connections was measured as 231pF and an ordinary coil as 681pF. Reducing the 100Ω resistor R7 will reduce the decay time but it will also reduce the current in the coil and its damping effect will alter, so leave it alone.

When you have wound the coil that meets with your requirements, do not forget to waterproof it and make it rigid. If it is left loose, the machine will drift all over the places as the coil capacitance changes when the coil moves.

# Follow-up #2 to Sandbanks Metal Detector

P.J.Wales

Practical Wireless August 1979

Response from readers to the PW "Sandbanks" article of January 1979 has taken two forms, faults which cannot be located, and requests for variations on the theme. The most common fault reported has been that of the output of IC4 going negative when a large piece of metal is brought near the search coil. A few letters were selected at random and the writers were asked to send the offending p.c.b. in for examination. In only one case was the 709 faulty. This particular device is running in its fastest possible mode, and so all stray capacitance and inductance around it should be at a minimum. This means that the i.c. must not be a socket, and it should preferably be a TO5 version. All of the associated components should have short leads and be mounted as close to the board as possible. If these precautions are observed, it is very unlikely that IC4 will go unstable.

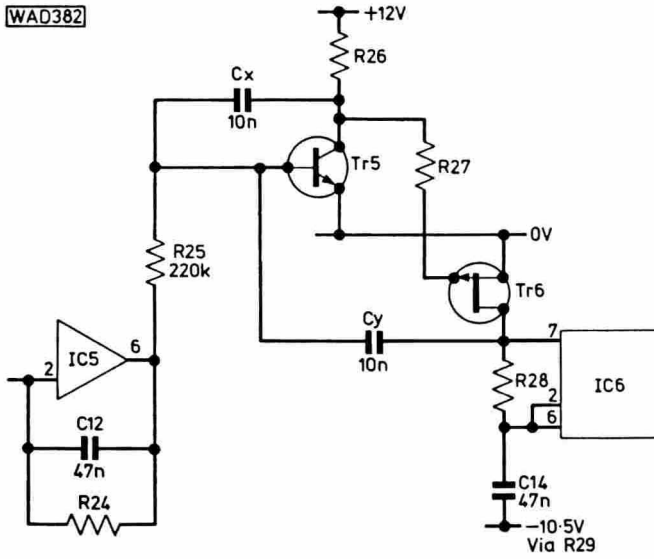
## Power Supply Problems

The second phenomenon which can cause the output to go negative is poor power supply regulation. If your "Sandbanks" has this problem, then check the -5V rail and the +12V rail. If they are more than one volt out then that is the fault. If they are correct, then try adjusting VR1 whilst monitoring the 12V rail. If it varies or if it is low anyway then that is the fault. The cure is not so easy to find, but is frequently due to either the 709 or the 741 taking too much current, so disconnect pin 7 on each i.c. and measure the current. The 709 should take 2.6mA and the 741, 1.7mA. If either or both is taking more then change them, but the figures are only manufacturers' typical figures, the devices are not faulty.

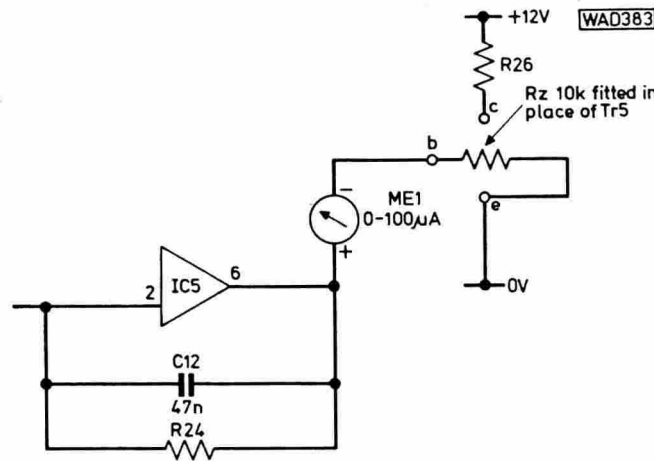
A very large number of these circuits have been tested, and less than one per cent of them have had to have any changes made to the circuit values as published in PW. The only fault that it has not been possible to cure was that of drift. The circuit should remain absolutely stable once set, and if any reader has had this problem and cured it. the author will be very pleased to hear from him or her.

## Response Speed

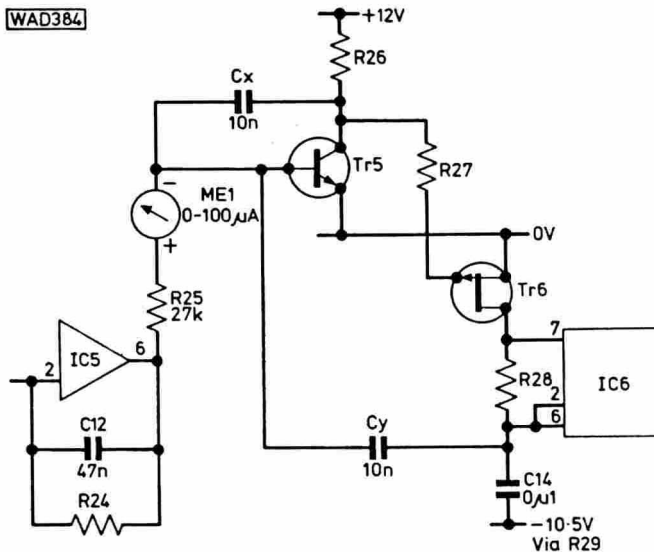
To get the very best from your "Sandbanks" several things can be optimised, but the first step is to fit a printed circuit coil, as described in the April 1979 issue. This really does increase the sensitivity to gold and silver tremendously. Having fitted this and made the appropriate changes to the sampling circuit, the next improvement is in the response speed. This is defined by two things, the pulse rate of IC1, and the integration time of IC5. The pulse rate can be increased to 500Hz by changing C2 to 33nF. This change allows the integration capacitor C12 to be reduced from 0.47μF to 47nF. The circuit now is 10 times as



**Fig. 1: Improving the audio quality. Only those components with values indicated are subject to change**



**Fig. 2: Providing a meter readout instead of the audio indication**



**Fig. 3: Providing a meter readout but retaining the audio indication**

fast as it was and will detect a coin being thrown through the coil.

## Audio Changes

Checking the machine's performance now, will prove that the next step of improving the quality of the audio is a good one to take. The first problem with the audio is that it is too low in frequency, and when a coin is detected at maximum range, the change in audio frequency is so slow that it is very easy to have passed the coin and miss it. To remedy this, change R25 to 220kΩ and C14 to 47nF. This now gives a much higher pitch but the tone comes on too fast and it is very difficult to tell how deep the find is by the tone. It is also very unstable due to the short integration time of IC5. The instability can be cured by wiring C<sub>x</sub> (10nF) from base to collector of Tr5 on the back of the p.c.b. The speed of the audio can be corrected by wiring another 10nF, C<sub>y</sub> on the back of the board, this time between pin 7 of IC6 and the base of Tr5. This has a great feedback effect and now the audio is super-smooth from a fast clicking to a very high pitch indeed (Fig. 1).

Having got the audio working correctly, the next step is to balance all of the tolerances in the circuit. This should be effective for 95 per cent of all "Sandbanks" but if it does not work on yours, then do not worry, your machine is still very powerful.

To peak the sensitivity, connect a meter between the output of IC4 and the 0V rail. Set the audio, with no metal near the coil, to about half-pitch. Adjust VR1 so that the audio is at its lowest frequency with the meter reading between 0V and 8V. If the meter reads outside these limits when at the lowest pitch, then re-adjust VR1 for 0.5V and leave it there; it is very near the optimum setting at this point. If you can get a minimum between 0 and 8V then expect to see about 5V typically.

## Meter Option

Some readers have requested a meter option for the "Sandbanks", but adding one which will improve the sensitivity is not easy. Ambit International do make a suitable meter, scaled "1" to "5" and legended "Tuning", and with a bit of fiddling it should be possible to fit this into the end of the handle. There are two different ways to wire this into the circuit; the easiest way is if you intend to discard the audio stage completely. This makes the machine more sensitive, but you do have to watch the meter all of the time. If this is the way you want to do it, then remove Tr5 and R25. Solder a 10kΩ resistor R<sub>Z</sub> between the base and emitter connections in the p.c.b. and connect the meter into the holes for R25 (Fig. 2).

To retain the audio stage, it is necessary to build the audio modifications as previously detailed, but leave out R25, and leave C14 as 0.1µF. R25 now becomes a 27kΩ but the meter is connected in series with it, and measures the base current of Tr5. It will be found when adjusting VR2, that the meter will just leave the "1" mark before the audio starts. This is the correct position for VR2 and so it is easy to verify that the setting has not changed when the machine is in use (Fig. 3).



## Component Problems

The demand for the “Sandbanks” kit was much greater than was anticipated and so Ambit have had some problems in supplying some of the less common parts of the kit, such as IC2, which has been modified in some kits. The biggest problem has been the supply of the cases, but I am assured that these are available now, and so if you were disappointed before, it is worth contacting Ambit again.