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HOW TO BUILD YOUR OWN

METAL AND TREASURE LOCATORS

BY

F.G. RAYER, T.Eng.(CEI), Assoc. IERE

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INTRODUCTION

The use of electronic metal detectors or treasure locators has become quite an extensive hobby. During out-door seasons of the year, searches are made on the seashore, or over waste ground or the suspected sites of ancient hoards. Electronic devices of this kind detect the presence of buried metal objects, but do not of course respond to objects which are not metallic in character, such as pottery.

Finds made by metal locators over the past few years are so numerous that it is impracticable to try to list or mention them. It is for this reason that there is quite an extensive trade in ready-made locators. These are often expensive items, and it is often not easy to see why they are so costly. In fact, the heterodyne locator is a comparatively simple piece of equipment, and no one should experience any real difficulty in following either its method of working, or in constructing such a device. A side by side comparison between a ready-made locator and a comparable home-built detector will normally show that they give exactly the same results.

There are also of course more mundane uses for such instruments, such as finding buried pipes or manhole covers. Methods of using such locators are fully explained here, as well as principles of operation, and actual construction.

PART I
PRINCIPLES AND CONSTRUCTION

A heterodyne metal detector must produce an emission which is present beyond the confines of the device. This may be likened to the transmission of a low-powered radio signal, and it is clear that in certain circumstances this signal could cause interference to the reception of broadcast programmes. For this reason, certain requirements need to be met, if the chances of causing interference are to be kept to a minimum.

NON-INTERFERENCE

If high power oscillator or radiating circuits were used in the detector, this would obviously increase the chances of causing interference. Where the metal detector would be used in locations far removed from houses, the chances of actually causing interference to radio reception would be small. But where searches are made at no great distance from dwellings, interference would be more probable. This would take the form of whistles or audio tones, heard in conjunction with wanted radio programmes, and spoiling their reception.

Fortunately there is no disadvantage in the use of low-power oscillators, as the range of detection of an object does not depend on the power of the oscillator. The regulations for such equipment specify that the radiated field strength of any signal produced should not be stronger than 100uV/m (100 microvolts per meter) at a distance of 100 yards from the loop. It is easy to fulfil this requirement by using equipment which is quite unable to produce a field anything like this figure.

Even very low powered equipment can produce interference if used very near to radio receivers, and when the actual working frequency, or a harmonic of it, falls on or near a broadcast frequency. So there are also limitations on the frequencies which may be used.

If a detector operated at the same frequency as a broadcasting station, and its radiations were picked up at sufficient strength, this would cause interference. Whistles would in fact be expected if the interfering signal were within 10kHz or so of the transmission frequency of the broadcasting station.

A similar effect may arise where harmonics of the metal detector frequency fall near the frequency of a broadcasting station. The actual working frequency of a detector oscillator is its fundamental frequency, and harmonics are multiples of this frequency. Harmonics are thus 2x, 3x, 4x, 5x and higher multiples of the metal detector oscillator frequency. For example, if the detector oscillator operated at 100kHz, its harmonics would be 200kHz, 300kHz, 400kHz, 500kHz, and so on.

As long wave broadcasting takes place in this country on 200kHz, second harmonic interference could be caused.

Fortunately, the harmonics grow progressively weaker, and are thus less likely to cause interference. But working frequencies should nevertheless be selected so that trouble from this cause is not likely.

STABILITY

If the elements that determine the working frequency of an oscillator vary in character with changes in temperature, vibration, alterations in battery voltage, or from other causes, this may move the frequency away from that required. Clearly this is undesirable from the point of view of reliable working of the detector. The change in frequency might also move the frequency to one causing interference. So a sufficiently high degree of frequency stability is needed, and is obtained by suitable design of the equipment.

It is also necessary to arrange the equipment so that random or careless adjustment, which would place the detector on an unsuitable frequency, is unlikely. It is in fact convenient to have a minimum of external controls, as this also helps easy operation when actually using the equipment for searching. Other adjustments, which may be necessary when first setting up the metal detector for operation, can best be with internal, pre-set controls, which will afterwards be left alone.

With a suitable circuit and components, random shifts in working frequency are only likely to arise if poor constructional work is present. Loose turns on reference or search coil oscillator windings, or careless, insecure assembly generally, can quite easily be avoided.

REGULATORY DEPARTMENT

Heterodyne metal detectors fall within the scope of equipment the use of which is controlled by the Radio Regulatory Department of the Home Office. This also deals with amateur transmitting licences for home or mobile use, model control, ship and aircraft licences, and those for other classes of apparatus.

The Department address to which application should be made for a licence is Waterloo Bridge House, Waterloo Road, London, SE1.

SENSIBLE USE

Though treasure and metal detectors are clearly most generally used for finding buried objects, they are sometimes pressed into useful service to find buried water pipes, metal conduit concealed in plaster or walls, and for similar purposes. This may bring a detector very near a neighbour's radio receiver, or aerial lead, and possibilities of radio interference are then increased. If interference arises, it is only sensible to make such tests for metal as brief as possible, or at times when no nuisance is caused. It is, in fact, illegal to interfere with anyone's normal enjoyment of reception free of interference.

Similarly, the possession of a metal detector clearly does not give anyone the right to trespass on other people's property, or to make themselves a nuisance on the seashore, or to conduct random excavation on sites where genuine and carefully controlled searches for objects of historical value may be taking place. In short, any usage should be of a reasonable and sensible nature.

MINE DETECTORS

Present metal detectors are largely descended from the earlier military mine detector. Clearly a device which could locate a concealed metal object was of enormous importance.

An early mine or metal detector of this kind was a large and relatively heavy object, employing valves, with their associated low tension and high tension batteries. Some were supplied with an additional audio amplifier, and even this could need half a dozen dry cells for the valve filaments, and a 60 volt or 90 volt HT battery.

Fortunately the use of transistors has made these cumbersome devices unnecessary. A modern detector can be light, compact, and run on a small dry battery at virtually negligible cost. Compact metal detectors, now popular, would have been completely impossible before semi-conductor techniques replaced the old thermionic valve circuits.

PRODUCTION OF HETERODYNE

If two different frequencies are mixed together, one resultant frequency obtainable after doing this is the difference between the two frequencies. Thus, in a superhet or superheterodyne receiver, mixing an incoming signal of 1500kHz with a local oscillator frequency of 1970kHz would make available a 470kHz signal for the intermediate frequency amplifier.

A similar method can be used to produce a heterodyne which is of audible frequency. In Fig. 1 assume that the first oscillator is operating at 90kHz, and the second oscillator at either 91kHz or 89kHz. Both signals pass to some type of detector or non-linear device, and the output from this is the difference in frequency of the two oscillators. That is, 91 - 90kHz, or 90 - 89kHz, which is 1kHz or 1,000 hertz. The original frequencies, which are 90kHz and 91kHz (or 89kHz) are inaudible, but the heterodyne of one thousand cycles per second is an audio tone, and could be heard with headphones, or could be raised in level by means of an audio amplifier, to operate a loudspeaker.

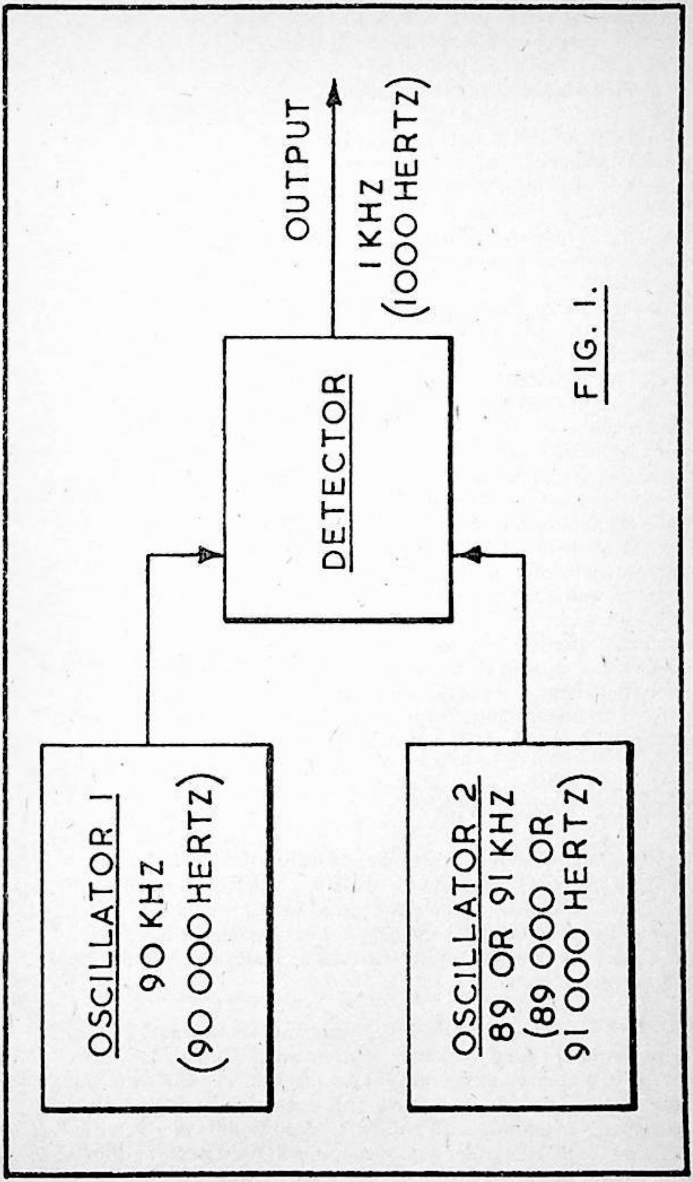

OSCILLATOR 1
90 KHZ
(90 000 HERTZ)
OSCILLATOR 2
89 OR 91 KHZ
(89 000 OR
91 000 HERTZ)
DETECTOR
OUTPUT
1 KHZ
(1000 HERTZ)

FIG. 1.

This principle is the basis of the heterodyne metal detector. The second oscillator may be higher or lower in frequency that the first oscillator, as explained. But to simplify matters it may be assumed that the second oscillator operates on the lower frequency, 89kHz, but is also variable.

With the first oscillator (1) permanently operating at 90kHz and the second oscillator (2) operating at 89kHz, the difference is 1,000 hertz, as already explained. Suppose, however, that the frequency of (2) changes to 89·1kHz. The difference between (1) and (2) is now 90 - 89·1 = 900 hertz. So the output frequency has changed from 1,000 to 900 hertz, which would easily be apparent to the ear.

Should (1) be on 90kHz as before, and (2) be set to 90kHz also, there is no difference, and no audio frequency is produced. But as soon as (2) is altered, the *difference* becomes audible. The actual change in frequency of (2) may be exceedingly small, in terms of a percentage of the frequency of (2), and yet still be in the audible range. This is more easily seen if the frequencies are written in hertz, or cycles per second. Thus if (1) is operating at 90,000 hertz, and (2) at 90,020 hertz, the difference or audio output will be at 20 hertz.

When the heterodyne or audio output is of high frequency, a small change is not so easily heard. As example, a change from 5,000 hertz to 5,010 hertz is far less obvious than a change from 50 hertz to 60 hertz. The extent to which the human ear can distinguish very small changes in frequency varies with different persons, and also depends somewhat on practice. Extremely low frequencies, of only a few cycles per second, will be heard more as a plop-plop or ticking sound, than as a tone. Somewhat higher frequencies are heard as a buzz or hum, such as "mains hum" at 50 hertz. Higher frequencies move up the musical scale, and will eventually become so high that they are no longer audible.

HETERODYNE LOCATOR

With the heterodyne treasure or metal locator, the first oscillator can be the fixed frequency, or reference oscillator. The frequency of oscillation of the second oscillator is then controlled by the presence of metal objects. The outputs of (1) and (2) are combined in the manner described, and the resultant output provides an indication of the presence or otherwise of metal.

The effect may be used in more than one way. As example, if (1) and (2) are set to the same frequency, with no metal present, the heterodyne will rise in frequency as the metal is approached. The closest position is thus shown by the highest pitch. This method is often used. Its main disadvantage arises only with poorly-designed circuits in which one oscillator "pulls" the other due to coupling in the detector ciruit. As a result, small changes in frequency in (2) are followed by corresponding small changes in frequency in (1) and no audio output, or indication, is obtained.

An alternative method is to have (1) and (2) working on somewhat different frequencies. The presence of metal will then move (2) to either a higher or a lower frequency, causing a rise or fall in pitch in the audio tone.

It is probably better to use an actual locator to observe these effects. Fortunately adjustments, or the manner of use, only become critical when the locator is operated at the extreme limit of its detection range. At shorter ranges, strong, easily-apparent indications will be obtained, even with some incorrect adjustment.

The matter of the range which is obtainable with a locator is very important. It will be found that various high-priced locators, though possibly of sounder construction, and perhaps with weatherproofing, or other advantages, may not offer any improvement at all on a much simpler, cheaper circuit. In fact, claims which are made about the range of detection possible should always be investigated. This may depend on all sorts of other factors. It is much easier to detect something of the dimensions of a dustbin lid, as example, at a given range, than a small coin.

Other features may be more a matter of convenience or choice – such as the use of a loudspeaker instead of headphones, or the presence of an indicating meter.

METAL FINDING

The frequency of the second oscillator is controlled by a search coil, or flat coil which can be moved along on or near the ground, or wherever metal may lie. This coil is so designed that it has an extensive field surrounding it, as in Fig. 2. When metal comes within the field of the coil, the effective coil inductance is changed, and this alters the oscillator frequency.

The change in oscillator frequency depends on the size of the metal object and its distance from the search coil, as well as on other factors. By moving the coil about over the area concerned, it is possible to decide whether the object is small and near, or larger but at a greater distance. The position of the metal can also be decided fairly accurately.

The frequency of the search coil circuit, and that of the internal reference oscillator in the locator, will be combined in the way explained, so that the heterodyne can be checked with headphones, or other means. In this way the presence and position of the metal is found.

There is some advantage in having alternative search coils of different type, if maximum possible utility is wanted. However, many treasure locators have a single coil, suitable for general purpose work.

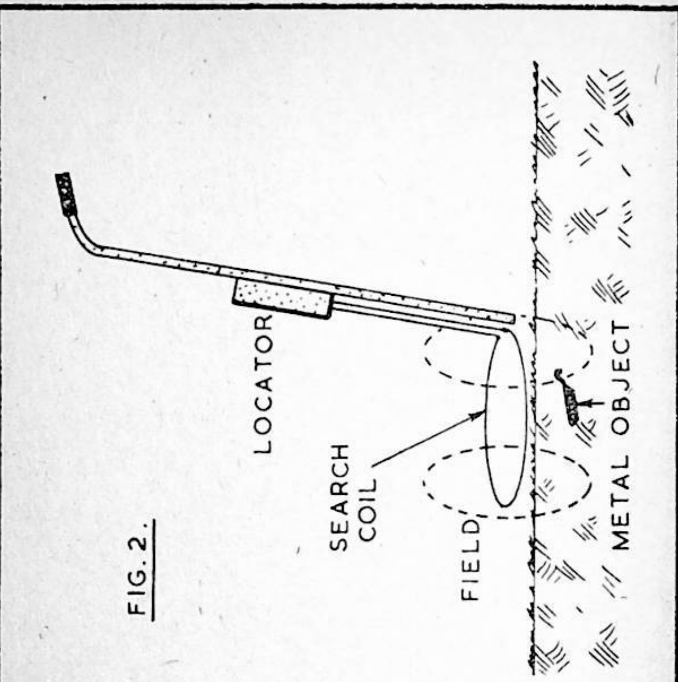


FIG. 2.

The ability to detect a piece of metal depends also on some other factors, over which there is generally little control. These include the presence of other, perhaps larger, metal items, and also the existence of poor conductors such as saturated or wet sand or earth.

Some cheap and moderately-priced ready-made detectors have a coil situated in an insulated casing, and changes in frequency can arise with this, due to capacitance with the ground. This means that there are shifts in the heterodyne tone with movements which bring the coil nearer the ground, or move it away. An instrument of this kind is feasible for use, but this effect can be avoided by a form of screening which prevents unwanted capacity effects to the coil turns, while not interfering with the ability of the coil to detect metal objects.

It will be seen that although a heterodyne metal locator will always operate in a general manner to that explained, there are various improvements or modifications which can be introduced.

PRACTICAL CIRCUITS

Practical locators can be extremely simple, or may employ quite a large number of components in more complex circuits. The very simple locators may, in favourable circumstances, give a performance almost equal to the more complicated devices. But usually there will be some loss of operating convenience, as with single transistor locators which have to be used in conjunction with a portable radio receiver.

The circuits which are included here should not present any particular difficulty, either in construction or adjustment. Details of "trouble shooting" are also given where appropriate. Generally little more than a multi-range test-meter will be wanted to find out which section of a non-working locator is at fault. By dividing the circuit up into sections – such as reference oscillator, coil oscillator, and detector – it is possible to simplify the location of any fault, so that it can be easily traced. This means that the constructor need never be faced with a whole, non-working device, with no indication of where the fault lies.

Transistors and similar items are of easily-obtained types, but this does not mean that alternative or similar items could not be used. Naturally any substitutions of this kind ought to be made only when it is known that satisfactory working is still possible.

PRACTICAL CONSTRUCTION

Probably the simplest way to assemble the circuits shown is to use perforated board, placing resistors and other small components on one side of the board, and having wiring on the reverse side. Plain perforated board with a matrix of 0.1 in and 0.15 in between hole centres is readily available, and is easily cut to the wanted size.

A saw with small teeth is recommended for cutting, and the board should be supported on a flat surface near to the cutting line. Larger holes, such as may be needed to fix coils or other items, or which are necessary to mount the board, should be drilled before mounting any components.

As it is not usually necessary to reduce dimensions to the absolute minimum, the 0.15 in matrix board is preferred, as allowing a little more free space between leads and joints.

Resistors and tubular capacitors may be fitted flat on the board, or vertically, as necessary, by shaping the wire ends to pass through the correct holes. In many places the wire ends of such components will be long enough to reach to other connecting points. Excess wire is snipped off. Elsewhere, it may be necessary to use connecting wire. The gauge is not important, but about 24 swg is convenient to handle.

In many places leads can run from point to point under the board by routes which will avoid any unwanted contact with other leads or joints. Elsewhere, or where wires cross, insulating sleeving should be slipped over the bare wire as necessary. Small diameter sleeving, such as 1mm, is most suitable. It can be very helpful to have two or three colours as these will allow positive and negative circuits to be identified, as well as transistor or other leads, when required.

Thin flex should be provided for battery connections. Use red for positive, and black for negative, and fit the proper type of battery clips. A battery must never be connected in the wrong polarity.

Other items required, such as nuts and bolts, tags, jack socket and plugs, will be readily available from stockists of radio components. This also applies to the larger items, such as headphones, loudspeakers, volume controls, and other parts.

A case will be required for the circuit board, battery and associated items, and it is not easy to improve on the ready-made plastic boxes which can be purchased from various shops and stores. In general, these seem to be available in two types. One is of a flexible material which is easily cut or drilled with no chance of cracking. The other is a rigid type of box, quite strong, but brittle. This type is preferred, but some care is necessary to avoid cracking the material, when drilling it. The drill should be sharp, and should be applied with only light pressure, the box being supported on a piece of scrap wood. Small holes can be enlarged with a reamer, file tang, or by filing, but again care is needed as too much pressure will snap the material.

Clear plastic boxes can be painted, if wished. If so, the best finish is obtained by painting the box inside, before any assembly work. This will give a perfectly uniform and protected finish. Use one of the quick-drying paints as available for painting models, and be quite sure it is hard before replacing the box lid.

SOLDERING

The construction of devices of this kind is not really practicable without soldering. Anyone except an absolute beginner will be able to solder. The beginner will also find that he can do so, if he uses a radio or electronic wiring cored solder, an iron which has been allowed to reach its proper temperature, and all joints are clean and bright.

Place the solder on the joint, and the iron on the solder and joint, so that the flux core of the solder can take effect where it is needed. The solder should melt in two or three seconds and flow over and around the joint. Remove the iron at once, especially when soldering transistors, as lengthy heating is unnecessary and may damage some components.

Do not try to solder to dirty or oxidized tags or leads – even if solder is built up round the joint it will probably be defective electrically. New, bright leads and tags will solder at once, but otherwise they need to be scraped bright first.

TRANSISTOR LEADS

Difficulty sometimes arises in identifying the leads of transistors, when they are mounted on a circuit board. They may be concealed by other components, and often a top or side view will remain, whereas lead-outs are coded when viewing the device from below.

Any difficulty from this can be avoided by placing short pieces of coloured sleeving on the leads in advance. These need only be ¼ in to 3/8 in or so long. With NPN transistors, it is convenient to use black for emitters (which goes to negative), red for collectors (which go to positive circuits) and some other colour for the base.

REFERENCE OSCILLATOR

The audio tone indicating the presence of metal is obtained by beating together the outputs of two high frequency oscillators, in the way explained. The frequency of one oscillator is controlled by the metal-sensing search coil. The second, or reference oscillator, has a fixed frequency, or may have a small "trimming" adjustment so that it is easily set to the most suitable frequency.

It is convenient to base the design on a centre frequency of 100kHz. If adjustments allow trimming to about 10kHz each side this frequency, the available coverage will be about 90-110kHz. In use, 100kHz will not be employed, because of possible 2nd harmonic interference to 200kHz radio reception. With this coverage, the actual frequency can be off-set from 100kHz, so that, as example, the oscillator is operating on 95kHz, or 105kHz. It should be sufficiently stable to maintain its frequency without any need for repeated adjustment.

Fig. 3 is the circuit of an oscillator which may be used either at a pre-set frequency, or with a trimming control. It uses a ready-made inductor, though home-wound coils can be fitted as shown later.

R1 supplies base current for the transistor, and C1 provides feedback from the oscillatory circuit to the base in the correct phase to maintain oscillation.

L1 is the primary of the coil, which is a Denco IFT13. This is a 465kHz type intermediate frequency transformer, and the additional capacitor C2 across the winding shifts this to approximately 100kHz.

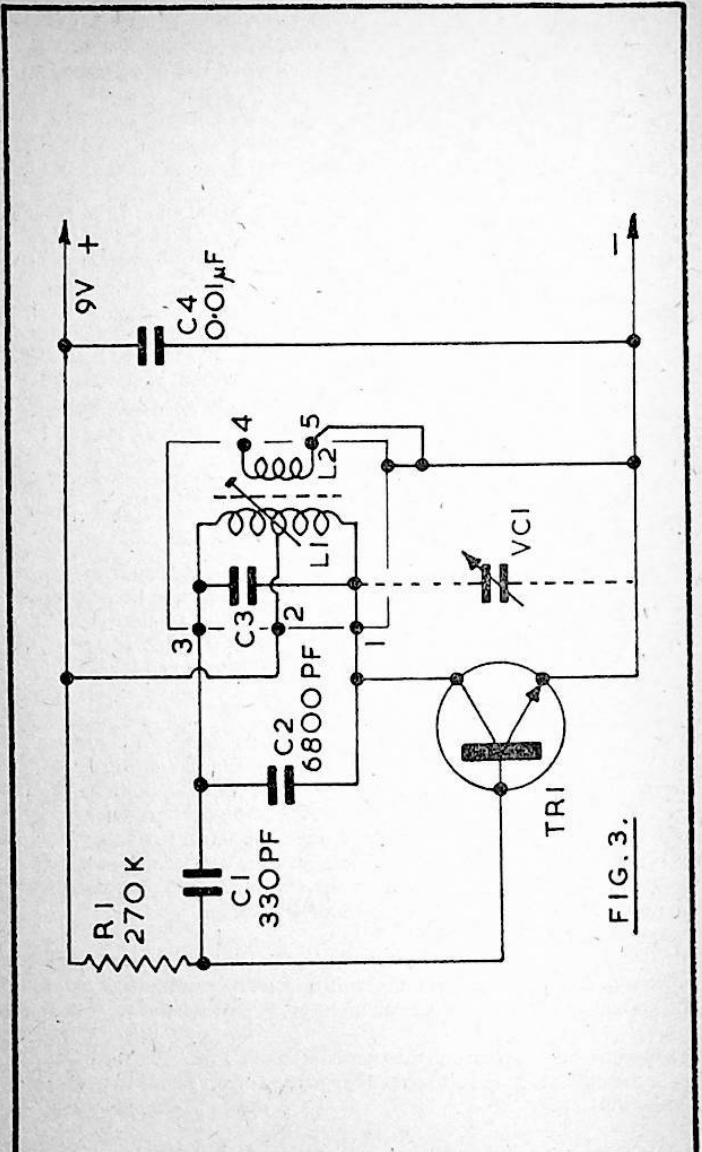


FIG. 3.

C3 is the capacitor fitted internally across L1. With an IF transformer of this kind, the normal working frequency depends on both the value of C3, and the inductance of L1. This means that transformers of other manufacture might have a winding of different inductance, even though intended for 465kHz. As a result, the value shown for C2 would not necessarily be correct if a component other than the IFT13 were fitted. Should such a change be made, and it is found that no possible adjustment of the IFT core gives the wanted frequency, then C2 would have to be changed in value to suit.

The variable capacitor VC1 is optional. Without it, the circuit can be set to frequency by adjusting the core of L1. When it is used, a small band of frequencies can be covered, without needing to adjust L1 core. The purpose of this will become clear in later circuits.

The secondary winding L2 allows coupling the oscillator to a later circuit, where the heterodyne will be produced. A coupling winding is not essential for this purpose, but it is already present on the IFT13 and helps isolate the oscillators so that changes in frequency of one will not pull the frequency of the other, thus causing the difficulty described earlier.

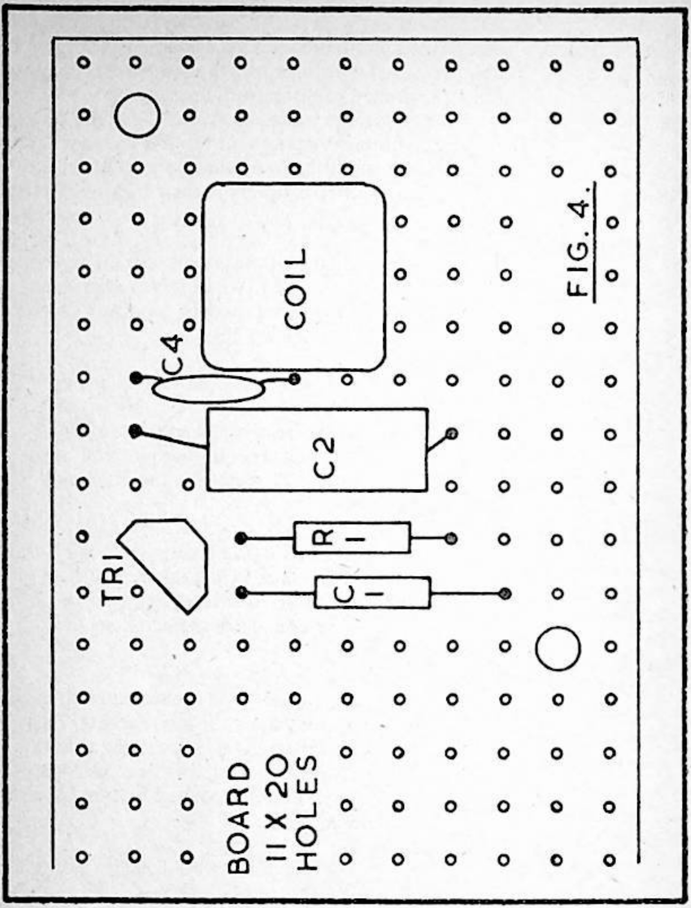
With circuits of this and similar type, oscillation is not produced if the transistor has insufficient gain for the feedback provided, or if feedback is too low with the correct transistor, or if feedback is of the wrong phase. This means that primary connections and values should be as shown.

Another set of unsatisfactory working conditions is encountered where the level of feedback, transistor gain, or values allow squegging. This arises from cutting off of the collector current in such a way that the oscillator frequency spreads over a wide band, producing a hissing, or audio whistles which are not the result of a heterodyne beat between reference and search coil frequencies.

ASSEMBLY

This circuit may be wired either as a separate unit; or on part of a board which will carry the other stages required. A suitable layout for components and wiring is shown in Figs. 4 and 5. The board is large enough to accommodate the other stages also.

First drill the board to take the coil pins and two tags which are in contact with the metal can. The finished board is most easily mounted by two 6ba bolts. These can be about ½ in long, so that washers or extra nuts will raise the board sufficiently for its underside wiring to be clear of the case.



Wiring is very straightforward. Remember not to "cook" the transistor joints, when soldering them. There is little point in compressing or crowding items to achieve the smallest possible piece of equipment, and this is only likely to make assembly and wiring difficult.

Where external leads are required, wires or pins are provided. Flying wire leads are best colour coded – as example, red for battery positive, and black for negative, with some other colour for other wires which may be necessary. If pins are used instead, obtain those intended for 0.15 in matrix board. They are best put in with a proper pin-insertion tool, while supporting the board adequately below as near to the hole as possible. Leads of suitable length can then be soldered to the pins later. Similar means of soldering on external leads can be devised by leaving about ¼ in of stout wire projecting above the board, or by twisting a loop of wire through two adjacent holes.

A beginner will often find it helpful to mark each component outline with coloured pencil or ink, as it is fitted, and to mark each connection as it is put on and soldered. There is then no chance of omitting anything. Also check to see that there are no short-circuits from bare wires or joints, and that all joints are properly soldered.

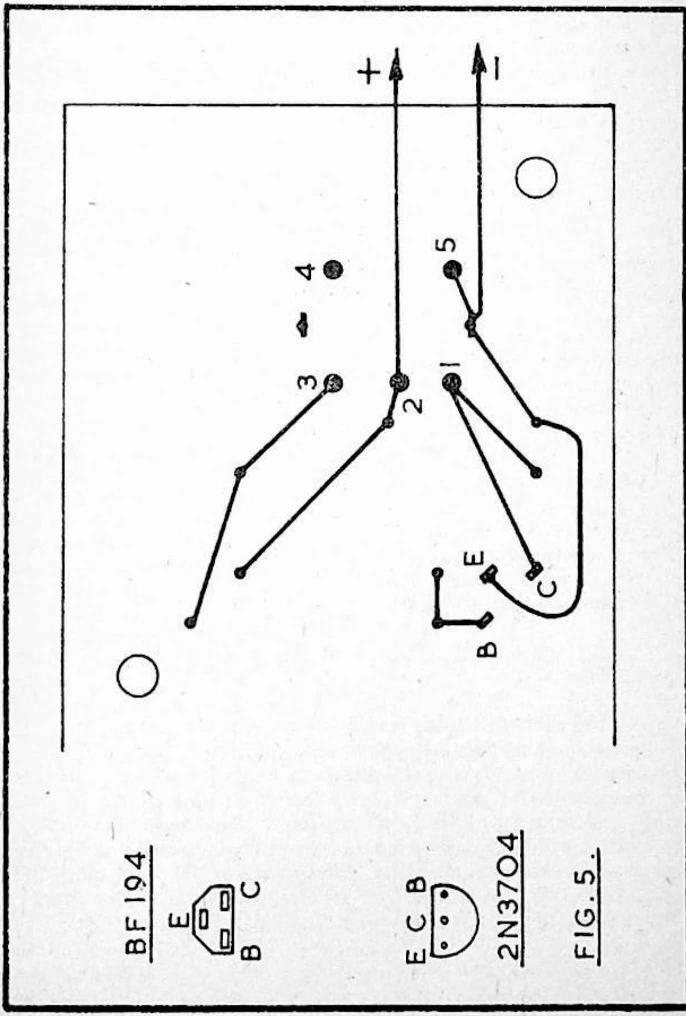


FIG. 5.

TESTING

If each part of a circuit is tested when finished, this avoids the situation where a complete locator has been made, but does not operate, and its builder has no idea of where the fault may lie. It is assumed that a multi-range test meter is to hand, as this is a quite inexpensive item, and will be of great service.

Oscillation can be checked by placing the meter in series with one battery lead. A range is selected which will indicate about 2½mA. This will probably be the 0-5mA or 0-10mA meter range. Take meter positive to positive on the 9v battery. Oscillator negative goes to battery negative, and oscillator positive to meter *negative*.

Current should be around 1mA or so, and should rise to about 2mA or so if pins 1 and 3 of L1 are temporarily shorted with a piece of wire or metal tool. If there is no change in current in this way, the stage is not oscillating, and it is necessary to look for omitted or defective connections.

It is then necessary to check the oscillator frequency. This is readily done with any portable or other radio which has a long wave band, or which has a switch position giving reception of the 200kHz programme. Tune in this programme (it *must* be on long waves) and place the oscillator near the receiver. Rotate the core of L1 until an audible whistle begins, accompanying the programme. A point will be found for the core where this whistle ceases (or falls to a very low frequency). Turning the core a little either way from this point will cause a whistle which rises in pitch.

The oscillator is off-set from 100kHz in a low frequency direction by screwing the core into L1, or by closing VC1, when present. It is off-set in a high-frequency direction by moving the core a little out of L1, or by opening VC1. When it is off-set to an amount which has caused the tone to rise very high in pitch and cease to be heard, its harmonic no longer interferes with 200kHz reception.

FAULT TRACING

Faults which cause failure are very unlikely, but a few points which may be checked are worth noting, as they will apply also to later stages. Checking R1 with the meter will make sure no error was made in reading the colour code. Capacitors such as C1 and C2 can only be tested for short circuit with the meter. So if there is any reason to suspect them, the solution will be to replace them with new components. The winding L1 can be checked with the meter. This leaves only the transistor. If the meter shows that 9v is present from emitter to collector, but no collector current flows, then a new transistor is required, if R1 is connected.

In general, trouble from defective components is only likely when using surplus items. It is very unusual indeed to encounter a defective item among those purchased new from a reliable supplier.

An alternative transistor which may be used in the reference oscillator stage is the 2N3704. Note that its leads are not in the same relative positions as the BF194. No circuit changes are required. When testing with a meter in the battery circuit, expect a current of around 2mA with the 2N3704, rising to about 7mA when the stage is not oscillating.

SEARCH COILS

The search coil is generally of quite large diameter, and it is this item which is moved about near the ground, to detect metal objects. There are several methods of constructing efficient coils of this type. That adopted may depend to some extent on the choice of the constructor, or on what materials are to hand, or whether a screened coil is required or not.

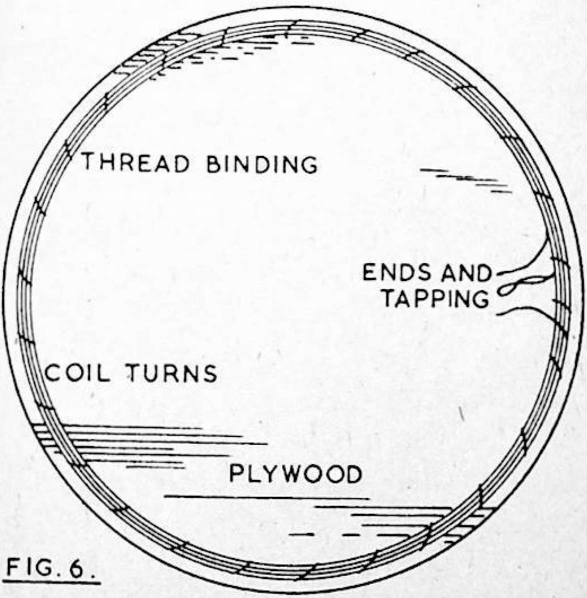


FIG. 6.

Mechanical or weather protection for the coil is not important if it is used with care, and only in dry conditions. But otherwise protection is necessary to keep rain or spray off the turns. This is generally easy to arrange. Coils suitable for under-water searching can also be made.

The self-supporting winding shown in Fig. 6 is among the easier coils to make. The turns are wound in a pile on an object of a suitable diameter, and are then removed and bound with thread, to keep them together. The object used as a temporary former must be slightly tapering (as example, a plant pot), or a strip of card must be put round, and the turns wound on this. Without these precautions it may be impossible to get the coil off its former, when wound. It is afterwards cemented to a disc of thin wood or other insulating material, of slightly larger diameter. This supports and strengthens it, and affords protection when moving the coil about at ground level.

Another method is shown in Fig. 7. This provides a square or rectangular coil. The base is a piece of plywood or similar material. Four projections near the corners take the coil turns. The projections may be pieces of dowel or wood set in holes, or glued and screwed in place, or 6ba or 4ba bolts can be used, with insulated sleeving to avoid contact with the turns. The wire itself will of course be insulated, but enamel insulation in particular is easily scratched away so that a short-circuit to unprotected bolts is likely. An advantage of this type of winding is that the number of turns can be readily changed.

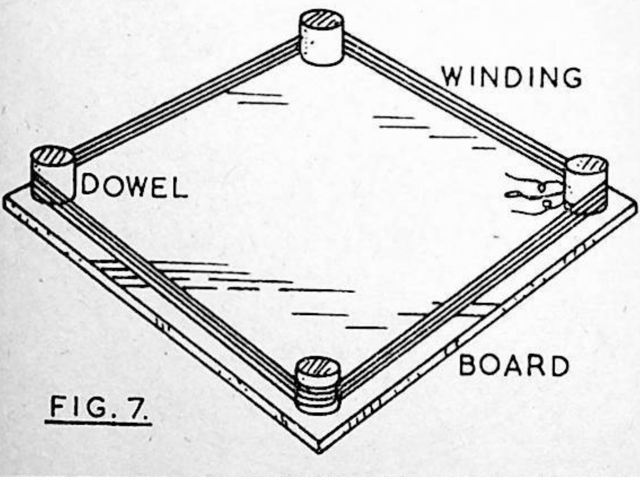


FIG. 7.

Fig. 8 is another type of coil, of robust construction. The turns of wire are wound in a shallow channel provided in the perimiter of the wooden disc. This former can be made from three discs of plywood, cemented together. The middle piece is of smaller diameter, so that a channel is available to accommodate the turns. The discs are marked out with a compass, or pencil and string pivoted to a small nail, or by drawing round a suitable object. The important dimensions will be the diameter and thickness of the middle board, as this will determine the diameter of the coil, and the extent to which turns pile up on each other. The outer discs are merely to keep the turns in place, and can be thin wood or paxolin. (This type of former is rapidly and easily made from a single piece of wood if a lathe is available.)

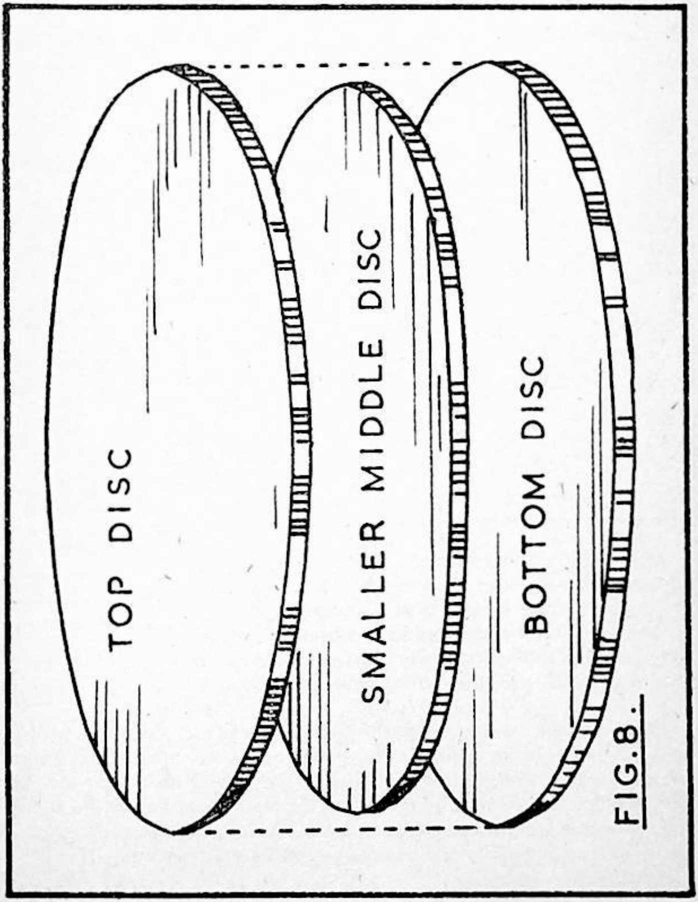


FIG.8.

The coil shown in Fig. 9 requires only a single piece of thin insulating material, such as 1/16th in thick paxolin. An odd number of slots is cut in this, to an equal depth. As winding progresses, pass the wire down through one slot, and up through the next. This forms a kind of basket coil, with half the turns on top of the disc, and half below it.

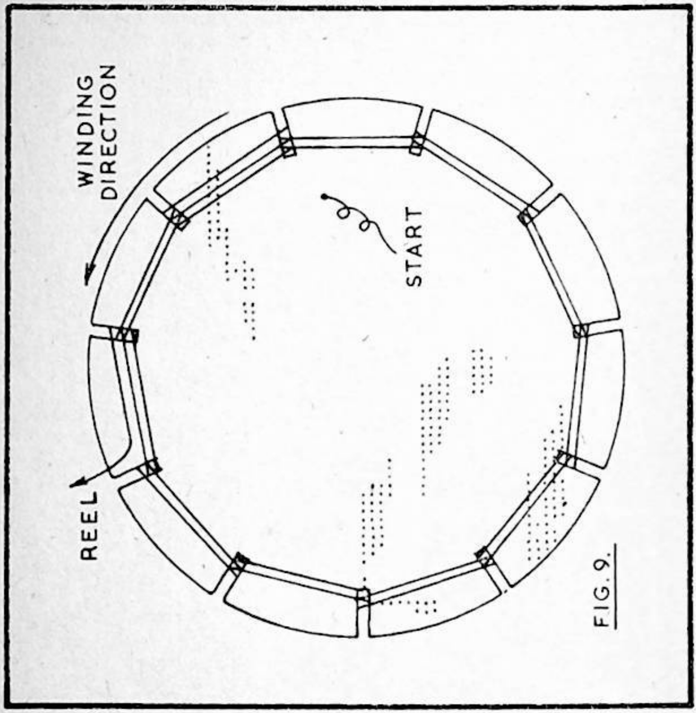


FIG. 9.

It will be realised that with any kind of home-wound coil, the tension of turns, or their exact diameter, may be expected to vary a little. To compensate for changes in inductance which arise from this, trimming to frequency can be provided in the locator. By this means any reasonably variation in the actual winding can be allowed for, even to the extent of having a slightly wrong number of turns.

It may be noted that increasing the coil diameter, or having more turns, or having turns in closer proximity to each other, will move the coil frequency in a low-frequency direction, by increasing its inductance. A similar effect is produced by increasing the capacitance across the winding. Opposite circumstances (fewer turns, smaller diameter, more space between turns, or lower capacitance) cause the coil frequency to be higher than planned.

SEARCH COIL OSCILLATOR

The circuit in Fig. 10 is very similar to that used for the reference oscillator. L3 is the search coil, and will often be at a little distance from the other components. The tapping and component values are chosen to give suitable feedback to maintain oscillation, and leads run from the component board to C, Tap, and B, which are collector, tapping, and base circuit connections.

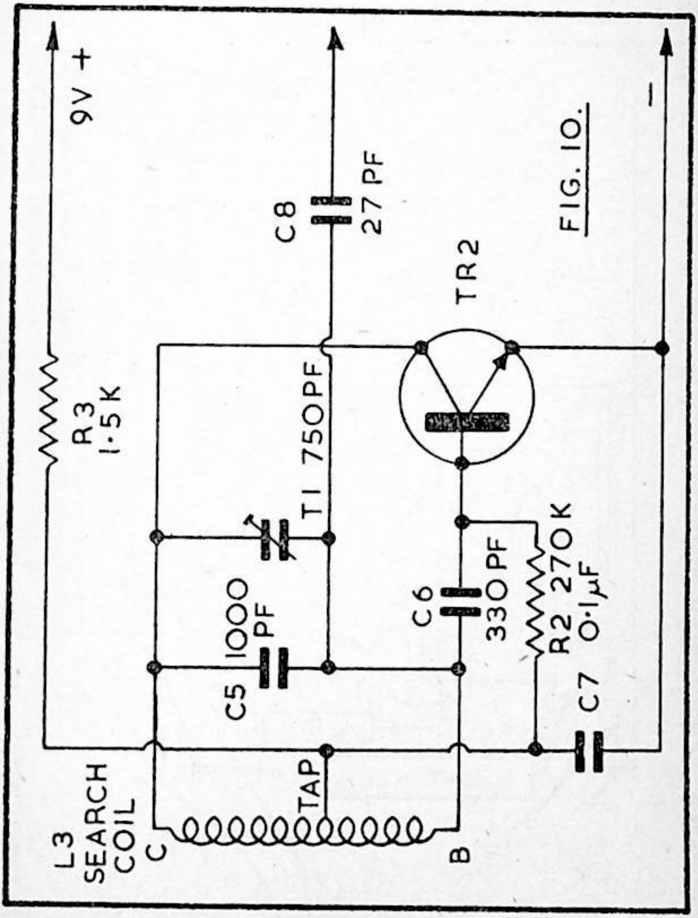


FIG. 10.

C5 is the main capacitance across L3, but the trimmer T1 is provided, so that the working frequency can be adjusted. T1 is a compression type trimmer, and its minimum capacitance is about 150pF. Its correct position should be about half screwed down, so there is latitude for adjustment in either direction.

The components (excluding the search coil) are assembled on the perforated board in a similar manner to that already described. It is also in order to use unperforated board, drilling small holes to pass the leads from components.

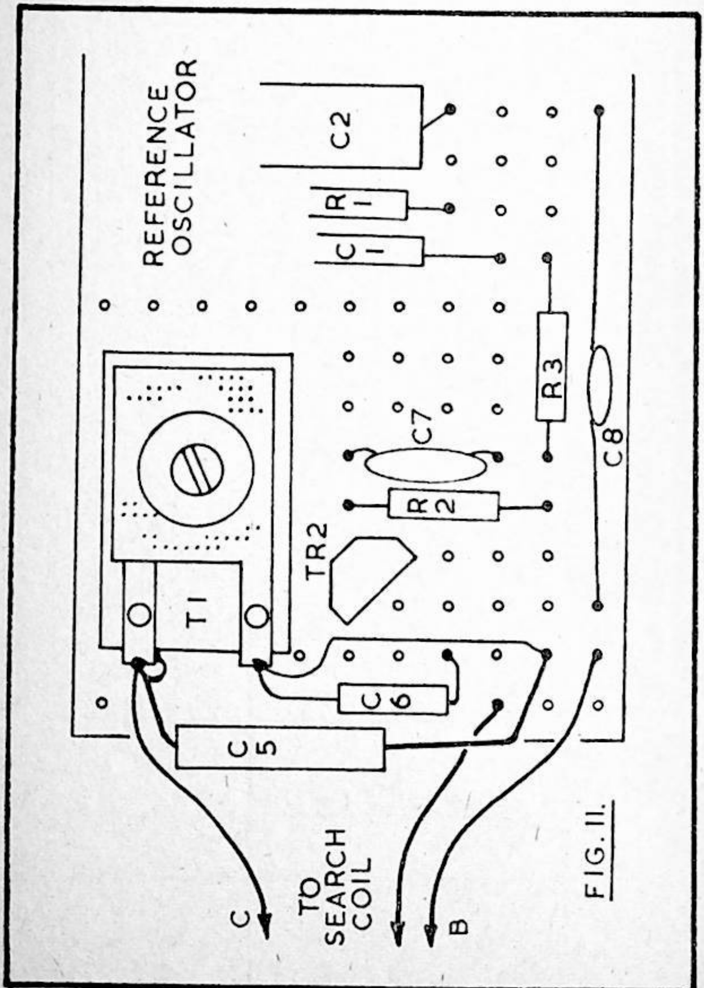


FIG. 11.

Actual wiring for this part of the locator can be seen from Figs. 11 and 12. The leads from C, Tap and B can be soldered on and cut to suitable length later. The connection from C8 will run to the heterodyne detector.

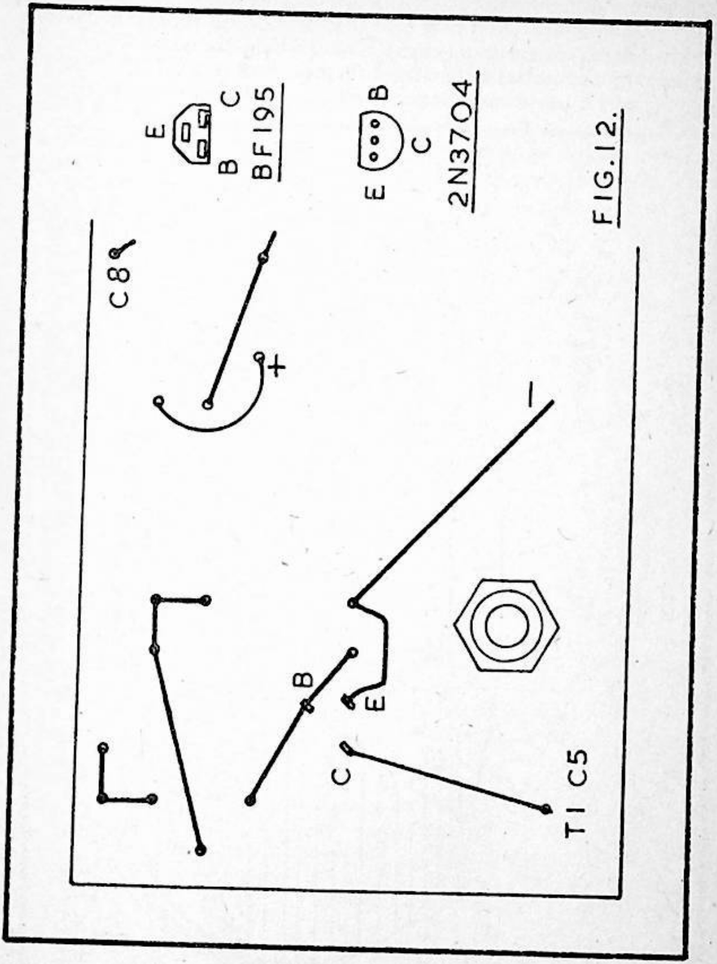


FIG. 12.

COIL

The search coil has fifty-four turns of 32 swg enamelled wire, 7½ in in diameter and ¼ in winding width. To prepare the former, cut a disc of ¼ in plywood 7½ in in diameter. This can be done with a keyhole or pad saw. Smooth the sawn edge with glasspaper, if this appears necessary. Cut two slightly larger discs – these may be 8 in in diameter. Apply adhesive to the meeting surfaces, and fix these each side the 7½ in disc Figs. 8 and 13. Leave under pressure until the adhesive is hard.

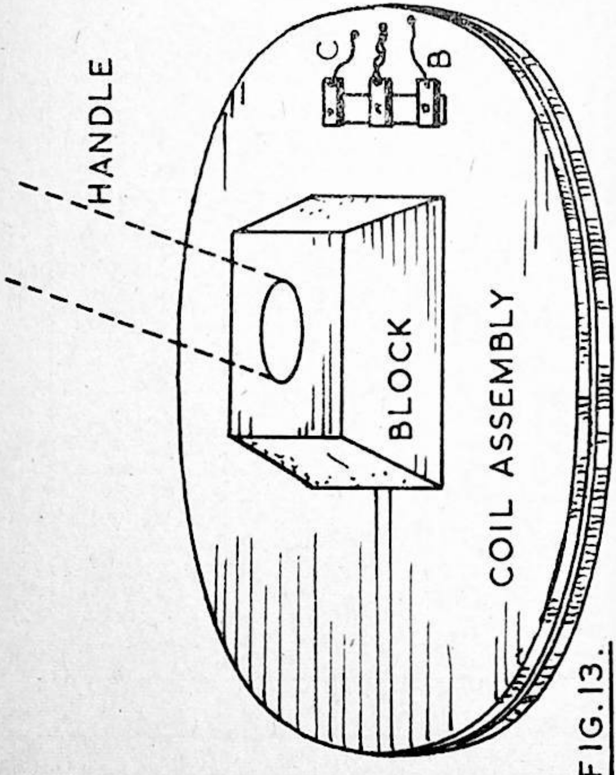


FIG. 13.

As this locator is a straightforward design, which can give good results but avoids needless complication, the search coil is not screened. Drill three small holes ¼ in from the edge of the top disc, and pass the end of the 32 swg wire up through one hole. This is point C. Wind on thirty-four turns, and take the wire up through the next hole, forming a loop for the tapping. Continue to wind in the same direction for a further twenty turns, and cut off the wire, taking the end up through the last hole, for point B.

Scrape insulation from the ends and tapping, for soldering. They may be taken to a 3-way tagstrip, to which other leads can be soldered. Alternatively, solder on wires for this purpose, and cover the joints with sleeving or tape.

When the coil has been tested, wind a few turns of thin tape in the slot to cover the wire, and varnish or paint the wood. The paint can be taken over the edges of the discs and on to the tape, to help exclude moisture, but the turns of the winding must not be saturated with varnish or paint.

TESTING

If wished, this stage can be tested by itself, in a similar way to that used with the reference oscillator. Temporarily connect the coil to its three points on the circuit board. Note the current drawn by means of a meter in series with the battery. This should be around 0.5mA with the stage oscillating, rising to over 1mA if B and C on the coil are shorted with a piece of wire. It is not necessary that currents be very close to these figures, as they depend on the individual transistor and setting of trimmer T1. Any rise in current, with B and C shorted, proves that the oscillator is working. Should there be no change in current, then it is necessary to look for omitted connections, or other defects, as already explained. These are not very probable, but as only a few moments are needed it is worth proving that the stage oscillates, by noting current in this way.

The 2N3704 may be used in this stage, and the current will be approximately 0.5mA, rising to 3ma or so when the stage is not oscillating. No changes need be made to component values, but take care to use the correct transistor connections, as these are not in the same relative positions as those of the BF195.

Tuning to frequency can be carried out as already described. Alternatively, wait until the other stages of the locator are wired, and adjust T1 until a heterodyne is produced.

The reference oscillator and search coil oscillator must be tuned to within a few thousand cycles or kilohertz of each other, as already explained, so that an *audible* heterodyne is produced. This is easier to accomplish if the frequency of each has been checked. However, the locator will work whatever the frequencies actually obtained are, provided they are sufficiently near each other. The most important reason for checking the frequencies, and off-setting them similarly from 100kHz, is to avoid interference to broadcast reception. That is, the choice of frequency is not bound up with getting the locator to work, but is chosen so that its use can be able to conform to the need to avoid interference to radio reception.

HANDLE

Nearly all locators have a handle allowing the search coil to be moved over the ground while walking. A block of wood about 2 x 3 in in size and 1½ in thick has a hole to receive the handle, and is cemented to the top disc. It is convenient to have the handle slope slightly. For this locator, a piece of broomhandle about 2ft 6in long will do very well.

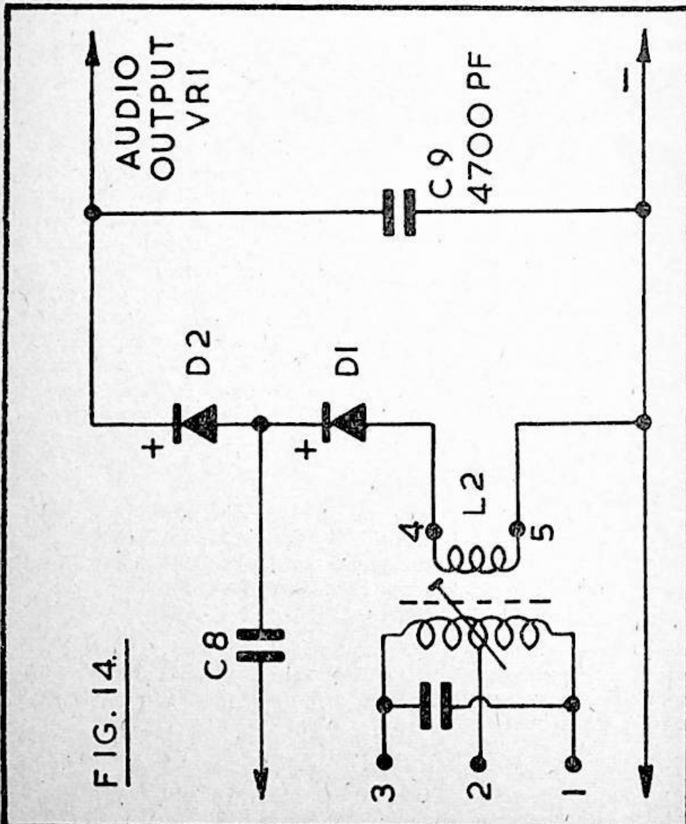


FIG. 14.

HETERODYNE DETECTOR

Various circuits can be used for this part of a locator, which is a type of mixer in which an audio tone is produced corresponding to the difference in frequency of the two radio-frequency inputs to the stage. The circuit in Fig. 14 requires few components. Input from the reference oscillator is by the secondary of the oscillator coil, L2. The search coil oscillator input is from the small isolating capacitor C8. Output from this stage is at audio frequency.

Any general purpose, AM detector, or similar diodes will be suitable for this circuit. Examples are the OA81, OA91, and 1N67A.

Space is available near the screened coil for the few components, and wiring for these is shown in Fig. 15. This places both oscillators and the detector on the same board, forming a unit which gives an audio output to take to an audio amplifier.

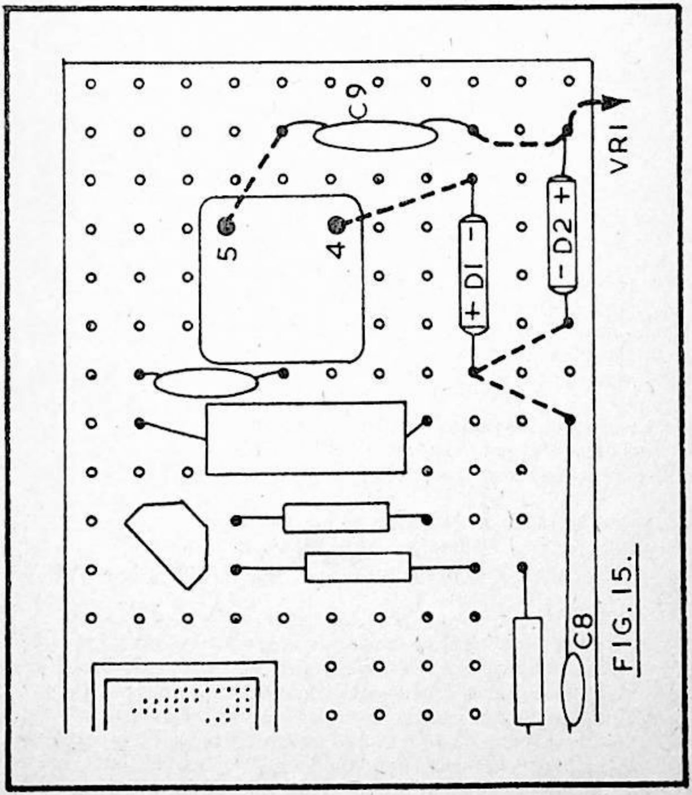


FIG. 15.

This board may be checked by using medium or high impedance headphones, which are temporarily connected from the AF output point VR1 to the negative line. The volume obtained will not be very great, and is not sufficient for use out-of-doors. It will, however, allow the functioning of the circuit to be checked. To do this, rotate either the search coil trimmer or reference oscillator core carefully, to produce an audio tone in the phones. This is most easily heard with sensitive, high-resistance phones, but as the purpose is merely to check working, the audio level obtained is not important.

When the audio tone has been obtained, it should be found that this changes in pitch if a metal object such as a tobacco tin is moved near the search coil. Final adjustments for best sensitivity are made later.

AUDIO AMPLIFIER

When a locator is in actual use out-of-doors, there will often be wind and other external noises, and the audio tone has to be raised to a sufficient level for easy listening in all conditions. For use with a headset, a simple one or two stage transistor amplifier will easily be adequate. This requires few components, and the total battery current allows long periods of use, even with a small battery. Headphones are often used, for this reason, and because the tone may be a nuisance to other persons, if audible from a loudspeaker.

Despite this, there are occasions when a loudspeaker is much more suitable. Friends can then hear what is happening, while some people find a headset tiresome, especially as it may hinder conversation. It is thus quite a good idea to make provision for operating a small loudspeaker, while also having a phone jack. A headset can then be plugged in here, silencing the speaker. A gain or volume control is also of advantage, though it is not essential. It will allow the volume level to be adjusted to suit the user, or external noise conditions.

By having the audio section on a separate board, alternative amplifiers are easily made, to suit the purpose in view, and without disturbing any wiring on the oscillator board.

The gain of the audio amplifier has no bearing on the maximum distance at which objects can be detected, provided the audio tone is at a high enough level to be heard easily. A relatively simple amplifier can thus be used.

A 2-stage amplifier using the circuit in Fig. 16 will have enough gain and power output for most purposes. VR1 is the volume control. It may be omitted if a loudspeaker is permanently in use, but is necessary when phones are also to be plugged in. Base bias for TR3 is by means of R4, and R5 is the collector load for this stage. A suitable choice of transistors and values allows direct-coupling to the output stage, which is an emitter follower. Audio signals are developed across R6, and go to speaker or phones via C11.

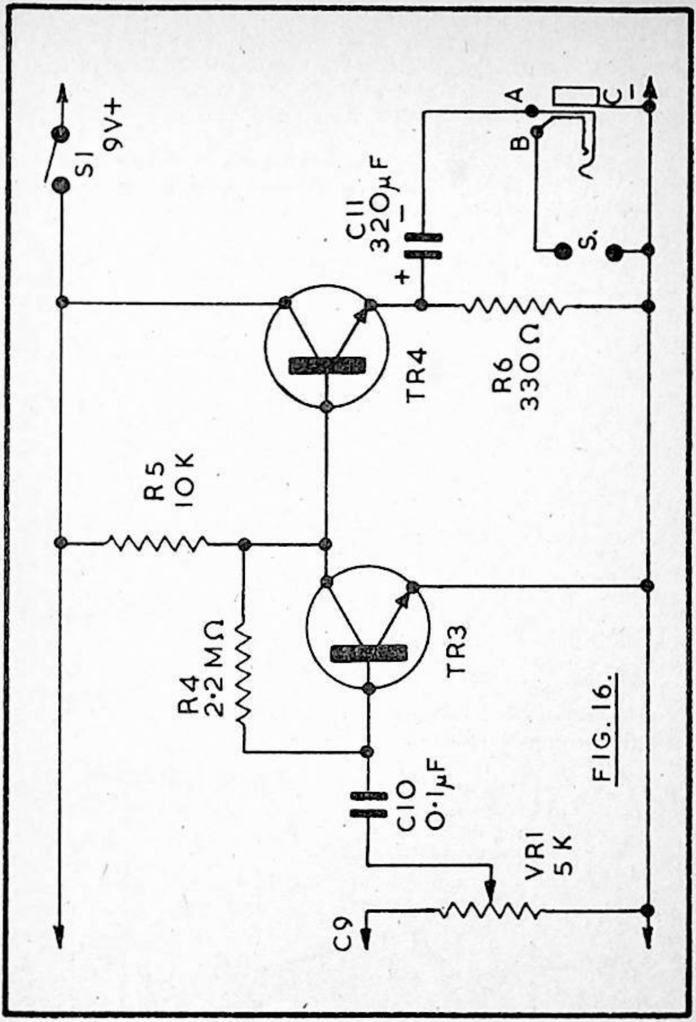


FIG. 16.

This circuit needs very few components. It also has the advantage that the speaker or phones will be coupled by C11, so that the DC resistance of the speaker unit or headset does not upset working conditions. The speaker can be of about 8 ohm to 75 ohm impedance, volume being slightly increased with the higher impedance units (say 16 ohm and over). Current drain is around 15mA.

BOARD

There is no reason why the whole locator should not be wired on a single perforated board, as this need only be a little longer to leave space for the audio section. Alternatively, if a separate board is used, this allows a larger amplifier to be substituted later without disturbing the oscillators and detector.

Fig. 17 shows the location of components, and Fig. 18 connections to them. The BC108 transistors can be replaced by 2N3704 devices, with no change in component values.

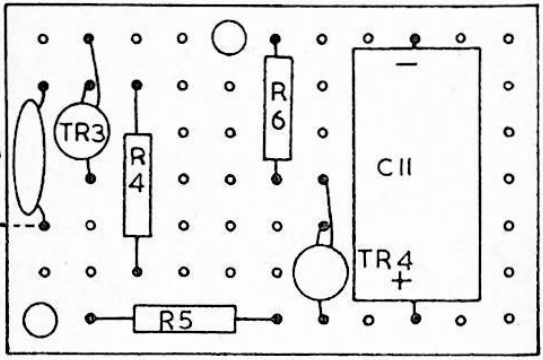


FIG.17.

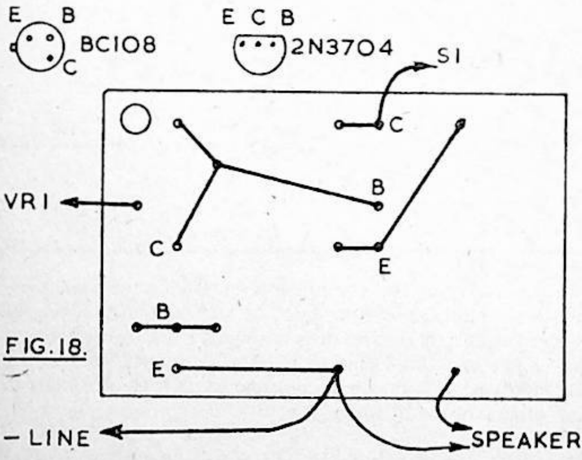


FIG.18.

It will be convenient to leave a flying lead from C10, to go to VR1. Also a black lead for negative, a red lead for positive, and a wire from C11 negative, to take to the speaker or jack socket. On-off switch S1 is integral with the volume control VR1.

A 3.5mm jack socket is suggested, but it may be any size to suit the headphone plug. The positions of contacts may not be as shown. When no plug is inserted, the circuit is from tag A to tag B, and thus to the speaker, which is returned to negative. When a plug is inserted, A breaks contact with B, silencing the speaker, and A then provides the circuit to the plug tip, the plug sleeve being returned via C. Wire the socket so that this is correct.

Other transistors than those mentioned can be satisfactory in this circuit, but it might be necessary to modify some of the resistor values. Because of the direct coupling, the DC operating conditions of the two stages are linked.

Any fault or need for tests in this section is unlikely. It would only be necessary to check connections etc. here if the heterodyne is heard with the phones connected across VR1, but not when they are plugged into the output jack socket.

COMPLETED LOCATOR

The operational circuit boards are fitted in a small case which will also carry the battery, a speaker unit, and the controls. These are placed as in Fig. 19 so that the control knobs are on the right, when using the locator. A box about 4½ x 6½ in in size and 1½ in deep will readily take the circuit boards, battery, and a small speaker unit. It should have a properly fitting lid or top, and may be metal or plastic – the latter is cheaper.

Drill holes for the volume and pitch controls, phone jack, and for leads to pass out to the search coil. An opening for the speaker can be made by drilling a ring of small holes, or using an adjustable tank cutter. Alternatively, circles or rows of ¼ in holes will form a grille. The speaker can be bolted in place or fixed with adhesive, according to its type.

Two wood screws through the case hold it to the wooden handle. The circuit boards are held with screws, with extra nuts or other means of spacing underneath, to clear wiring. If the box is metal, take care no unwanted contact or short-circuit is made to it. With a plastic case, use sharp tools and light pressure, to avoid breakage.

The speaker is reasonably protected by a piece of fabric over its aperture. When the lid is fitted, the box should be weatherproof.

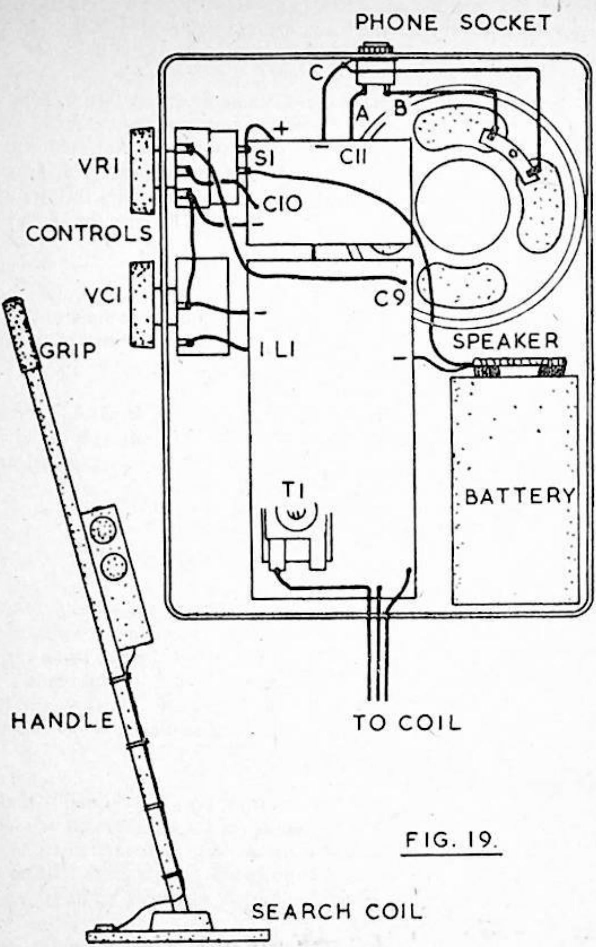


FIG. 19.

PITCH CONTROL

This is VC1, Figs. 3 and 19. Its purpose is to allow easy manual trimming of the oscillator frequency. When first putting the equipment into operation, set VC1 half closed. Rotate the coil core so that this is the central, or zero beat position. The control knob will then allow exact re-setting to this, or off-setting slightly to produce a continuous tone.

HANDLE

The search coil and locator are positioned as in Fig. 19. A wooden handle is most easily prepared, and it can have a top grip fashioned from a piece of rubber tubing or hose, or a cycle handlebar replacement. The main need is to have everything reasonably strong and rigid, with an easily held handle, and to avoid unnecessary weight.

Connections are taped to the handle, where they run down to the search coil. Parts should be painted, so that they do not absorb moisture from wet grass, or become saturated.

LOCATOR USE

A few minutes spent with the locator and metal objects which are to hand will show the methods of operation. Begin with larger items, which will produce a great change in pitch. From this, proceed to smaller items, which have less influence on the tone.

With VC1 adjusted to zero beat with no metal near, a tone will commence and rise in pitch as the search coil is brought near the metal object.

If VC1 is slightly off-set from this position, so that a very low audio tone is produced, this tone will either rise in pitch as metal is approached, or fall to zero, then rise. If the latter is the case, off-set VC1 the other side the zero beat position.

Indications depend on the kind of metal, its area, shape, and its distance from the coil. After getting accustomed to using the locator with test objects which can be seen, it can be taken out to search for buried items.

COMPONENTS

R1	270k	
R2	270k	
R3	1.5k	
R4	2.2 megohm	
R5	10k	
R6	330 ohm	(All resistors 5% ¼ watt)
VR1	5k log pot with switch S1.	

C1	330pF
C2	6800pF
C3	Present in IFT can
C4	0.01uF
C5	1000pF
C6	330pF
C7	0.1uF

C8	27pF
C9	4700pF
C10	0.1uF
C11	320uF 10v
VC1	300pF or 500pF small solid dielectric variable capacitor
T1	750pF compression trimmer
TR1	BF194 or 2N3704
TR2	BF195 or 2N3704
TR3	BC108 or 2N3704
TR4	BC108 or 2N3704
D1	OA91 or 1N67A
D2	OA91 or 1N67A
L1/L2	Denco (Clacton) Ltd. IFT13, or home-wound (see later)
L3	Made as directed.

Box, battery and clips, 2½ in or smaller speaker, jack socket, knobs, wood for handle etc., 0.15 in matrix perforated board.

PART II
ALTERNATIVE COILS, DETECTORS, AMPLIFIERS

With the reference oscillator circuit shown earlier, a ready-manufactured inductor was fitted. This is convenient to simplify construction, as it avoids any need to wind a coil for this position. However, a home-wound coil may be preferred in some cases; or it may be wished to press into service coils of other inductance value. It is also possible to use coils which do not need a tapping or feed-back winding, and to make other modifications to the coil itself, or the circuit with which it is employed.

It is convenient to base the oscillatory circuit on a middle frequency of 100kHz, for the reasons explained earlier. This means that some adjustment each side this frequency will be necessary, and a relatively large change in frequency is obtainable by having a coil with an adjustable core. The relative position of this core modifies the inductance of the winding, which will be at a maximum when the core is fully in the winding. Inductance falls as the core is withdrawn from within the turns of the coil, being at a minimum with the core entirely removed.

The inductance of the winding will depend on the number of turns, their diameter, the type of core, and other factors.

The second factor which will modify the frequency of the circuit is the parallel capacitance. With a given inductance, frequency falls as capacitance is increased. Alternatively, with a given parallel capacitance, frequency falls as the inductance is increased.

The relationship between inductance and capacitance, for a frequency of 100kHz, is shown in Fig. 20. From this, it will be seen that high values of capacitance are required, when the inductance is relatively small. The chart could be continued for even higher values of capacitance and lower values of inductance, but the capacitors rapidly become very large. Should the inductance/capacitance ratio become too unfavourable, the circuit will cease to oscillate. High gain circuits can operate with high values of capacitance, but there is a limit in this direction in practical terms.

At the other end of the graph, very high values of inductance become necessary, as the capacitance is reduced. Again, the graph could be continued in this direction (preferably on a different scale) but windings with very many turns become necessary. The resonant frequency is also considerably changed by very small alternations to capacitance, such as may arise in circuit wiring, or in the transistors and other components themselves.

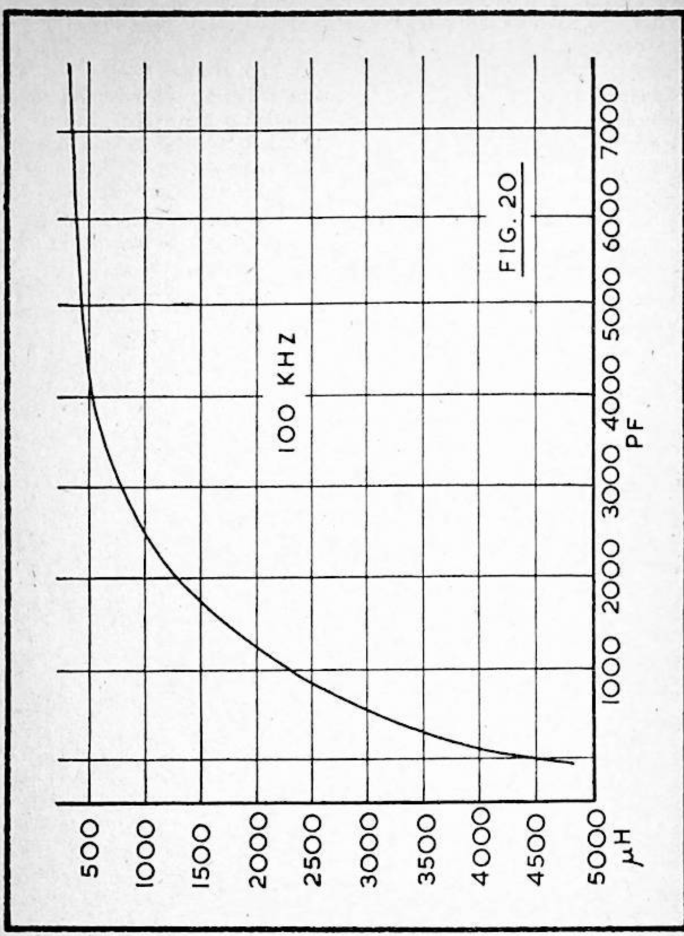


FIG. 20

It will thus often be better to adopt values which fall on the graph, and other circuit considerations may further limit the choice of values. One of these is the shift in frequency which can be obtained by means of a trimmer or variable capacitor of particular value. This shift is very great for high value inductors, but small for low value inductors with higher fixed parallel capacitance. At worst, adjustment of the trimmer or variable capacitor may be so critical that it is troublesome; or it may give so small a change in frequency that its full rotation may not be sufficient to compensate for small errors in setting the coil core.

These points need to be kept in view when pressing into service broadcast receiver or other ready-made coils, or when winding coils.

FREQUENCY STABILITY

Random, unwanted movement of the core, or turns, will change the inductance of the winding, and thus the oscillator frequency. Where a large number of turns will be used in a home-wound coil, it can be helpful to place these between two insulated discs, previously cemented on the former. This provides a small bobbin, to take the winding.

Discs for this purpose can be cut from 1/16th in thick paxolin or other insulating material, the central holes being enlarged a little at a time until they can fit tightly on the coil former. " Bostik 1" and similar adhesives are suitable for fixing. If the turns are wound regularly between these discs, with moderate tension, no other precautions will be needed except a touch of adhesive at the wire ends.

The regular winding of a coil in several layers by machine cannot be duplicated by hand. If turns are taken off such a coil to bring down its inductance, secure the outer turns with adhesive.

Windings having a fairly large number of turns can be wound in a compact pile by hand. This is sometimes called "jumbled winding". When the coil is finished, some adhesive will have to be applied to keep the turns in place. Generally, such a winding should not be saturated with an ordinary varnish or paint which penetrates between turns. Some modification to the exact inductance values obtained can also be expected, and arises from the placement of turns, and width of the winding.

When the coil has an adjustable core, it is often possible to make some modification to the gauge or type of wire, or coil diameter without upsetting results, as the position of the core will be able to compensate. A means of finding the oscillator frequency by listening for its harmonics has been described. If the oscillator is working at 100kHz, harmonics can be detected at 200kHz, 300kHz, and so on. It is not always sufficient to check at 200kHz only, if coil data are not closely followed, because if the oscillator were working at around 67kHz, its third harmonic would fall on 200kHz. This would be shown by other harmonics being found at about 134kHz and 268kHz. If such a coil were fitted in a locator needing an oscillator working at about 100kHz, no results at all would be obtained as neither the fundamental frequency of 67kHz nor the harmonic at 134kHz would be near enough to 100kHz. Yet an oscillator harmonic could be detected at 200kHz, and if it were assumed this means the oscillator must be working at 100kHz, a very great deal of time might be spent in looking for faults which did not exist in the detector or other circuits.

Another cause of drift is alteration in the values of capacitors with changes in temperature. Unsuitable capacitors can cause quite large changes in frequency, producing a steady rise or fall of the audio tone, and making re-adjustment of the manual trimmer necessary. Silver mica or other high stability capacitors should be fitted in the tuned circuits.

If necessary, capacitors may be connected in parallel to produce a required value. As example, 1000pF and 1200pF capacitors in parallel would total 2200pF. The most suitable pre-sets are approximately 50-450pF, 100-580pF, 150-750pF, 300-1000pF, 400-1250pF, and 500-2000pF. These offer considerable range for compensation or adjustment of the total capacitance across a coil.

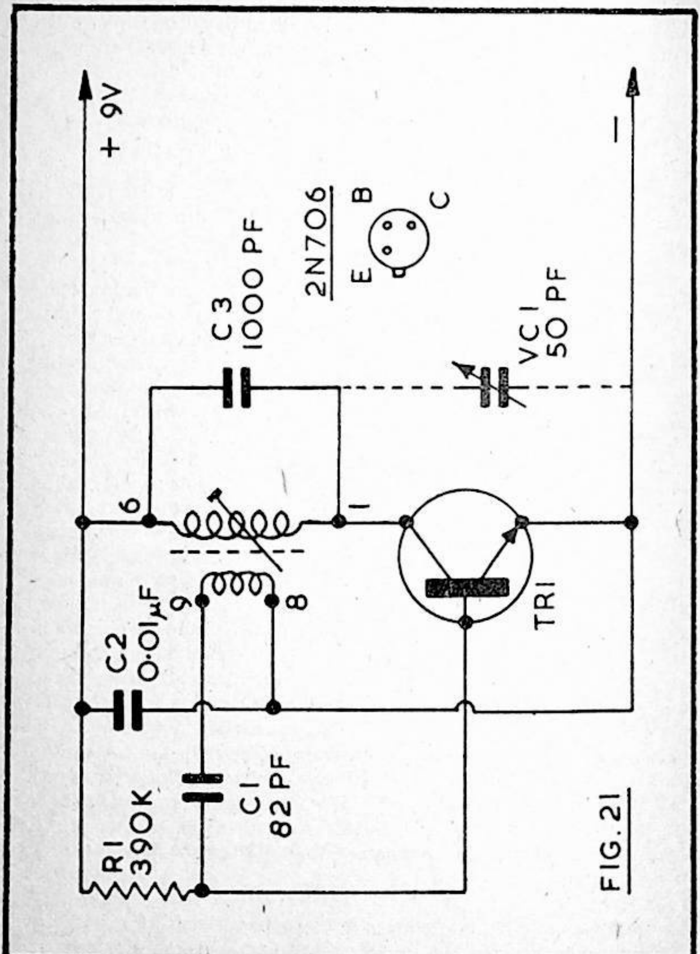


FIG. 21

BROADCAST COILS

An obvious choice when looking for a coil is to choose a long wave radio tuning coil. This would be expected to cover about 150-400kHz or so, with a 350pF or similar capacitor, so may have an inductance of around 2500uH. From Fig. 20, a parallel capacitor of about 1000pF could be expected to tune this to 100kHz. The exact value may depend on the degree of adjustment provided by the coil core. A winding may be present which can be used for feedback for the transistor oscillator. If not, such a winding might be added, as it will need relatively few turns.

Fig. 21 is a circuit for the Denco (Clacton) Ltd., "Blue" *valve type* Range 1 (long wave) coil. This is an aerial tuning coil. Here, the aerial coupling winding, pins 8 and 9, is used for feedback purposes, and the tuned winding, pins 1 and 6, has C3 in parallel.

With this particular coil, 960pF is suitable for C3, as well as 1000pF. A silver mica capacitor is preferred, though not essential here.

R1 provides base current, and RF feedback is by C1. There is not a great deal of latitude in the choice for C1, as small values provide insufficient feedback to maintain oscillation, while large values cause squegging to develop, as described earlier. It is necessary that the winding 8-9 provide feedback in the correct phase, so with other coils these connections might have to be reversed.

Whether or not oscillation is present can be tested with a meter, if wished. This is placed in series with the battery, as explained earlier. Current is expected to be around 0.25mA with the transistor oscillating, and around 1mA when it is not doing so, due to wrong phase of feedback, or temporarily shorting pins 1 and 6. In any case, if shorting 1 and 6 results in no change of current, the stage is not oscillating and this must be corrected before it is incorporated in a locator. In some circumstances it may be found that oscillation depends on the placement of the core, as its position can influence the degree of coupling between the two windings. If oscillation stops for some core positions, this will be shown by the meter test described.

If a variable capacitor is required for trimming purposes, this can be about 50pF. A larger value is not wanted here, for the reason explained in reference to Fig. 20. The stage is readily assembled on an insulated board, in the way shown previously.

WOUND COIL

Fig. 22 is an oscillator using a home-wound coil. The former used for the winding may be ¼ in in diameter and 7/8 in long, or 7mm by 22mm. A slight change in diameter can be compensated for by the core position, while a longer former is of course suitable.

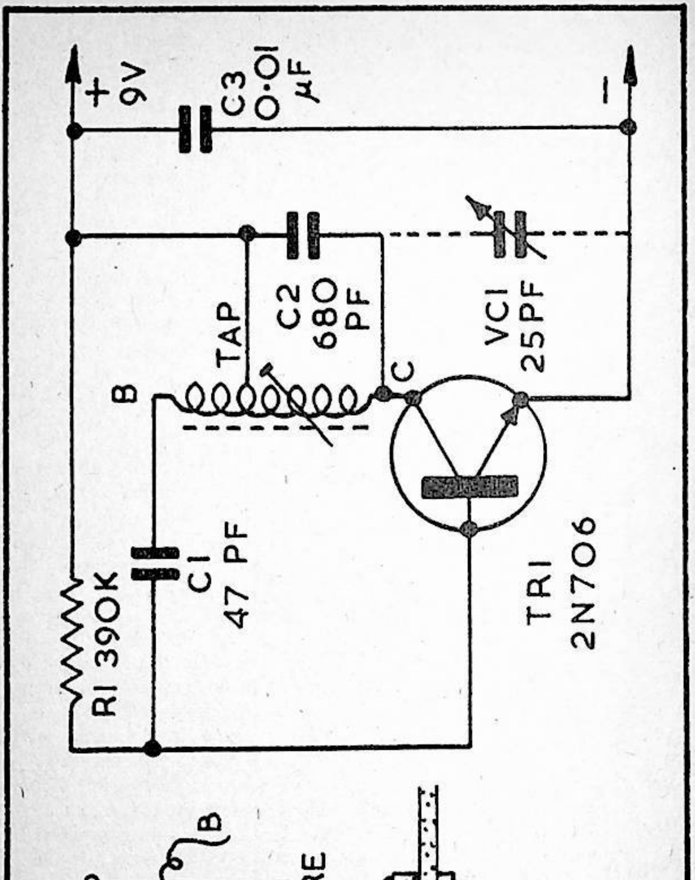

+
9V
C3
0·01
µF
−
TAP
C2
680
PF
VC1
25PF
B
C
R1 390K
C1
47 PF
TR1
2N706
TAP
B
CORE
C

FIG. 22

As a large number of turns is used, they are placed between two insulated discs. These are ¾ in in diameter, and are cemented near the top of the former, as shown, with a space of 3/8 in between them. Small holes are drilled for the wire ends to pass out of the bobbin.

The winding is of 34swg enamelled wire, and has 680 turns in all. Pass end C through a hole at the former, wind on 600 turns, and make a loop for the tapping. Wind on a further 80 turns, in the same direction, finishing at B.

It is not particularly difficult to make such a winding by hand, but some form of mechanical winder will greatly ease work. This may be contrived from a hand-operated geared drill. Clamp it in a vice so that it can be rotated with one hand, while feeding the wire through the fingers of the other hand. Remove the coil former core, so that a screw or threaded rod can pass through it, and be gripped by the drill chuck. Clamp the coil former with a washer and nut. Count how many times the chuck revolves, for one turn of the handle. Division then gives the number of handle turns to count. As example, if the ratio is 5:1, turn the handle 120 times for 600 turns, and 16 times for 80 turns on the coil. If the gear ratio is not exactly a whole number, work out the number of revolutions on paper, remembering that a few turns either way will not be important. The spool of wire should be arranged to turn on a nail or other pivot.

Another form of winder can be made by fitting the former to a horizontal axle, which has a handle and runs in two bearings. This can be done in a few minutes with constructional toy parts, with a step-up gear drive if wanted, and if gears are available.

The wire is fed on reasonably evenly, with light tension. A strip of adhesive tape round the completed coil will keep the outer turns in position.

Component values are shown in Fig. 22, and a check for oscillation and frequency can be made after assembly, to prove that the stage is working correctly. The winding is near the top of the former, as shown, so that it will be removed from metal which may be close by under the insulated board; and also to allow maximum adjustment of inductance. The core can initially be placed approximately as shown. Screwing it upwards lowers frequency. Moving it down and out of the coil raises frequency.

AIR-CORED COIL

If an air-cored coil is used, there is no means of adjusting its inductance, except by adding or removing turns. So it is necessary to fit a parallel trimmer for this purpose. The circuit in Fig. 23 uses such a coil, wound with 32swg enamelled wire, on a tube or former 0.3 in in diameter and 1 in long.

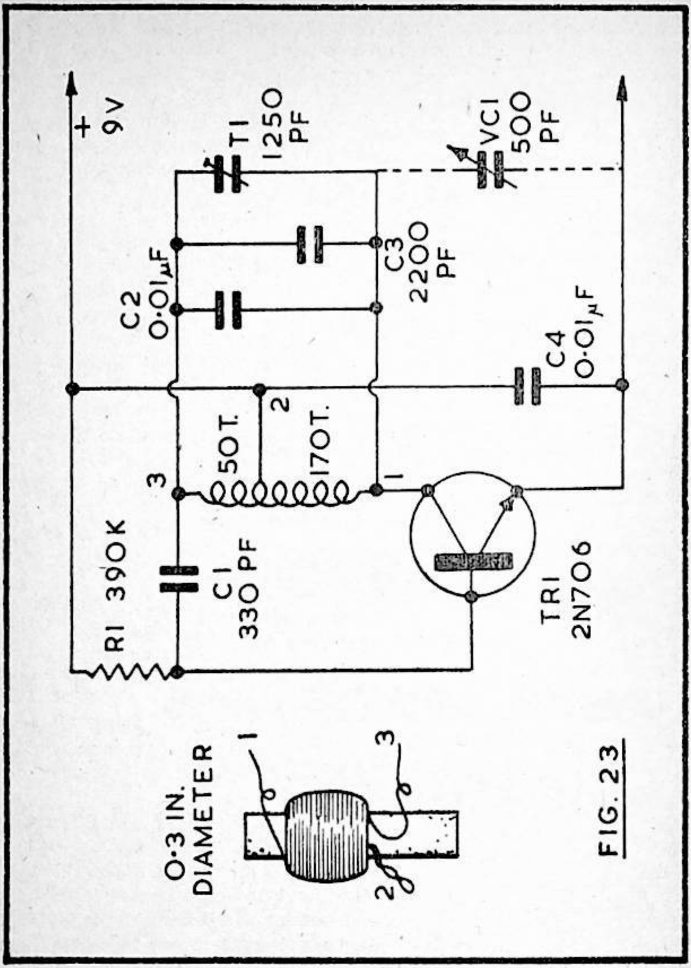
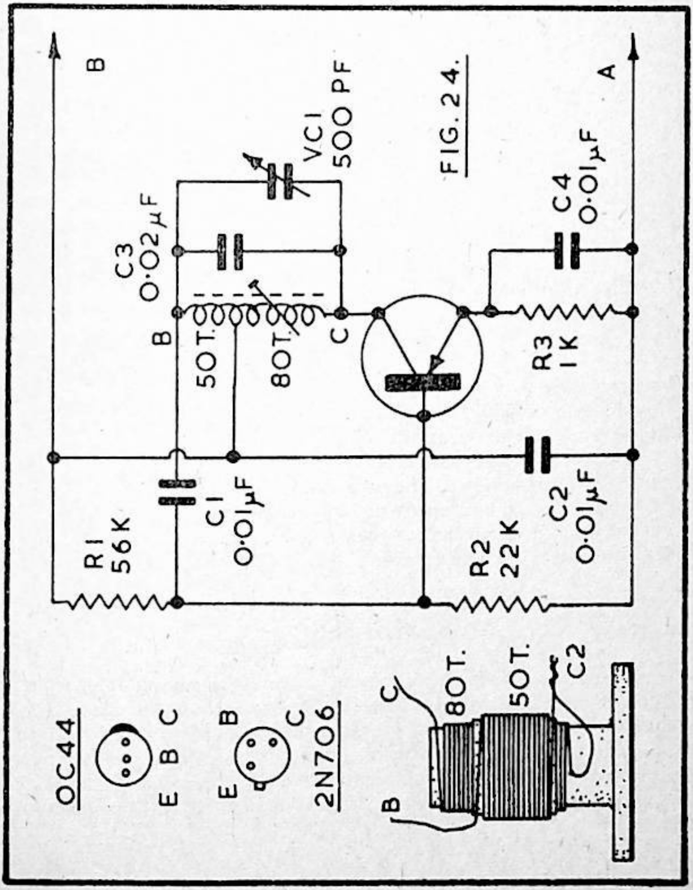


FIG. 23

Commence winding at 1 by securing the wire, either with a touch of adhesive, or by passing the end through a small hole drilled in the tube. Wind on 170 turns, keeping them reasonably even, and in a pile ½ in long. Form a tapping loop 2, then continue winding in the same direction for a further 50 turns, placing these turns on top of the earlier 170 turn section and ending at 3. Secure the wire with a little adhesive. This coil can be mounted by making the tube a push-fit in a hole in the insulated board carrying other components, cementing it in position.

The lack of a core reduces inductance, and a relatively high parallel capacitance is necessary. This is made up from two fixed capacitors, one of 10,000pF and the other of 2200pF, and a 1250pF compression trimmer. Since the placement of turns can influence the coil inductance, and no core is present to correct this, it would be necessary to modify the fixed capacitor values, if the circuit does not tune to the wanted frequency. This limitation is unavoidable with an air-cored, pile wound coil of this type, when made individually by hand.

Coil winding may be simplified by using a high capacitance, so that the coil is of lower inductance and has few turns. Fig. 24 is such a circuit. Emitter bias is also provided, and helps to stabilise operating conditions. The base operating point is set by the relative values of R1 and R2, which form a divider across the supply. The value of R3 is chosen so that with normal operating current the voltage drop in this resistor results in



the base/emitter potential being correct. Should collector and emitter current be low, due to falling battery voltage, the individual transistor, or other reasons, the current through R3 falls. The voltage drop in R3 is lower, and the base/emitter potential is modified, to help maintain current. On the other hand, if emitter current is too high, the opposite effect is obtained.

Fig. 24 shows a PNP OC44 transistor, and A is positive, while B is the negative line. This would be convenient for both oscillators if an audio amplifier with a positive ground line were to hand, and is to be used.

For the NPN transistor (2N706) A is the negative line, and B is positive.

The coil former has an adjustable core, is 7/16th in diameter, and allows a winding length of 1 in. There are 130 turns of 32swg enamelled wire in all. Commence winding at the top of the former, securing the wire with cotton or adhesive. This is point C and a few inches of wire are left for connecting purposes. Wind on 80 turns, closely side by side, and cover the turns with a layer of thin insulated tape. Scrape the wire here, and form a loop for the tapping. Then continue winding, in the same direction, placing fifty turns side by side on the tape, ending at point B.

Feedback through C1 to the base maintains oscillation. C3 is the parallel tuning capacitance, and should be of 5% tolerance for preference. Two 10,000pF silver mica capacitors in parallel will be suitable here.

No particular difficulty should arise in assembling the components on an insulated board, provided the coil is not immediately adjacent to a metal box or panel.

Due to the large parallel capacitance already present, only a small shift in frequency is obtained by VC1, and 500pF is generally the largest readily-available component of small dimensions likely to be obtainable. The oscillator is initially set on the wanted frequency by adjusting the core, with VC1 half closed. The core should subsequently be sealed with wax, or may be held by thin elastic run between core and former as the core is screwed in. A precaution such as this is wise with any cored coil, and is essential if the core is loose.

SEARCH COIL ASSEMBLIES

The size and type of search coil can be chosen to be most suitable for the purpose in view. Coils of large diameter are better to locate objects at a greater distance than are small coils, but there is clearly a practical limit, if only from the need for reasonable portability. In addition, very large coils are not satisfactory for pinpointing the position of small objects. For these reasons, a coil of about 5in to 10in diameter will generally be chosen.

Many popular locators use a coil of about 6in to 8in or so in size. These are reasonably portable, and the diameter is satisfactory for objects with a range of average sizes.

The search coil is most often a fixed part of the equipment, and is permanently connected. This is a satisfactory arrangement for all general purposes. There are, however, some advantages for using coils which can be rapidly changed. It is then feasible to employ a small, medium, or large diameter coil, or one having an extension, and constructed so that it can be immersed in water. For interchangeability, some form of plug and socket connector can be used.

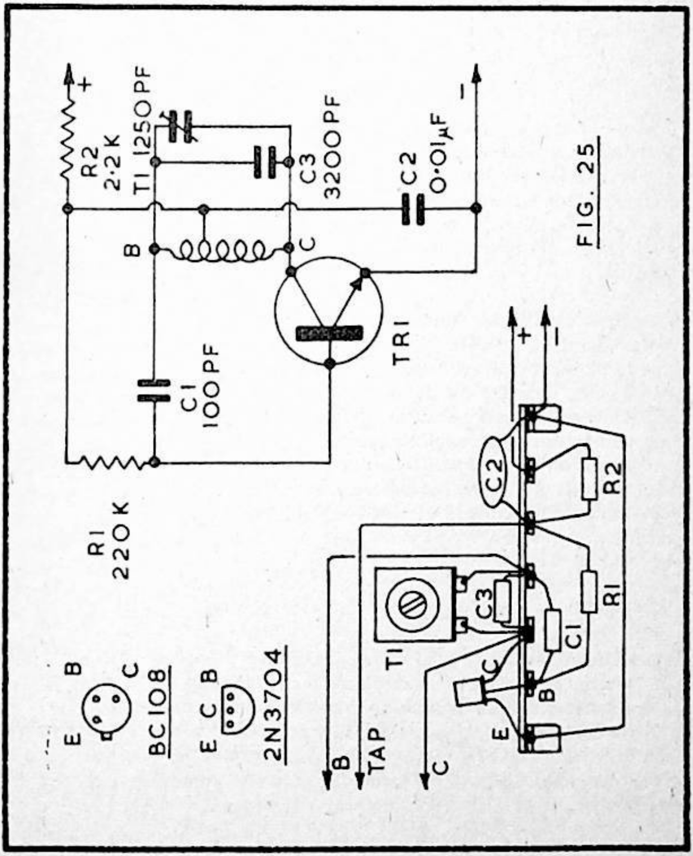


FIG. 25

6in COIL

A locator with a 6in coil can be a compact and easily carried item, and though its range of detection is a little less than when a larger coil is used, it is quite practical for general purposes.

Fig. 25 is a circuit for a 6in coil, and it can be used with either a BC108, or 2N3704, without changes to any component values.

The actual winding is 6in in diameter, and is placed in a channel 1/8in wide. This need only be about 1/8in deep, to accommodate the turns. The former to take the winding can thus be constructed from a disc of 1/8in thick plywood 6in in diameter, faced each side by discs about 6¾in in diameter. One of the adhesives specially made for fitting woodwork together will prove to be most suitable, and a sound, solid joint should be made, so that turns of wire cannot slip down between one disc and the next. The top disc can be ¼in plywood, to give a little extra strength.

If means to do the work are available, the former can instead be a 6¼in disc of wood about 3/8in to ½in thick, in which a channel 1/8in wide and 1/8in deep is cut round the circumference. Whatever form of construction is used, sandpaper if necessary to remove rough edges, and varnish or paint the whole to keep out damp. Here, shellac varnish or knotting will dry in a few minutes, though other varnishes can be used.

Make three small holes, about ½in apart, and sloping from the channel up through the top board. The winding is 34swg enamelled wire, and about 65ft will be adequate, so that 2oz (approx. 100yds.) would make several coils. Thread the wire up through one small hole, leaving several inches projecting, and mark this B. Wind on fifteen turns, and make a loop, taking this up through the next hole. Continue winding in the same direction for a further twenty five turns, cut off the wire and take the end up through the last hole, marked C. Good protection for the winding is by a length of outdoor insulating tape, tightly round the perimiter of the disc.

TAG-STRIP

Fig. 25 shows wiring of this coil oscillator on a 7-way tag-strip. This may be preferred to the use of an insulated board, though the latter is of course satisfactory. No insulation is needed on the wires, except for positive and negative connections. T1 can be located where convenient, and leads run to it; or it can be soldered directly to the tags. It is probably as well to leave the transistor until last, to avoid repeated heating here.

Where the locator will only be used in dry weather, solder leads to a 3-way tag-strip screwed to the search coil, from which stouter insulated wires will extend to the locator oscillator. Otherwise it is necessary to protect leads and joints from moisture. This can be done by forming the junctions inside a small insulated box or block, which can be sealed with "Seelastik" or other means, such as binding with insulating tape. Or solder on either thin flexible leads, or bare 24swg tinned copper wires, of sufficient length to reach the tag-strip, and slip insulating sleeving over the total length of the wires, including the joints. A little sealing compound round the holes where the wires emerge will then keep out moisture.

If rain or dew gets into the coil or connections, working is likely to be upset. Salt water will cause corrosion. The oscillator is adjusted to its working frequency by rotating T1, as already described.

This coil, as with the others described, is intended for use at frequencies near 100kHz. It may thus be employed in conjunction with any of the reference oscillator circuits shown earlier. It will be remembered that the detector can only produce an audio tone when the two oscillators are operating within a few kHz of each other.

SHIELDED COIL

A search coil equipped with a shield is a little more difficult to make than an unshielded coil. The shield is of a special type, intended to reduce capacitative effects to near objects, and it operates in a similar manner to a Faraday screen. It almost totally encloses the search coil, except for a narrow gap which interrupts it electrically. If this gap were omitted, it would act as a single short-circuited turn enclosing the search coil, and the latter could not function.

Details of the coil can be seen from Fig. 26. As the turns are to be enclosed by foil, they cannot be wound on a permanent former (as with Fig. 25). Instead, it is necessary to wind the coil on a temporary former. Eventual removal of the turns is greatly aided if this object tapers slightly, as described earlier. The wire is 26swg enamelled. Temporarily fix the end of the wire to the former with adhesive tape. Wind on twenty-five turns in a compact pile. Form a loop for the tapping, and wind a further twenty-five turns in the same direction. The diameter is approximately 6in.

The whole winding is moved a little towards the smaller end of the former, and a few pieces of tape are put under its turns, and pressed together to hold the turns together. The coil is then removed completely from the former, taking care not to get it out of shape. It is then bound continuously with cotton or thread, the tape loops being removed as they are reached. When this is complete the coil should be compact and fairly rigid.

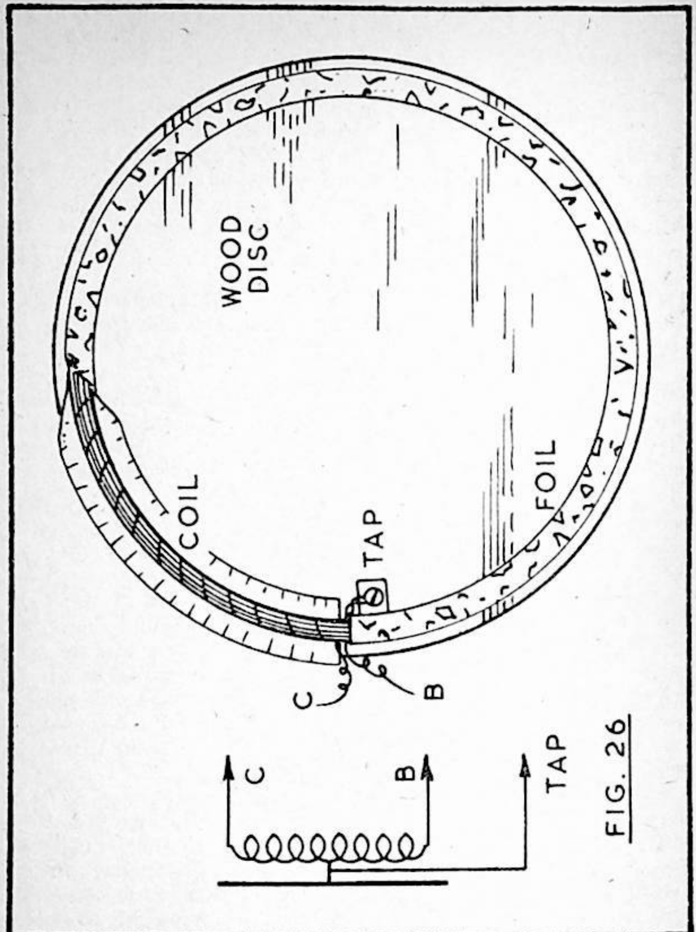


FIG. 26

The screen is cut from kitchen aluminium foil. Mark and cut a disc 7in in diameter, and cut away an unwanted centre piece 5in in diameter. Completely cut away a piece about 1/8in wide so that the foil resembles a C. Snip inwards, all round the foil edges, to a depth of about ¼in to 3/8in.

Put insulated sleeving on the tap and wire ends of the coil, and place the coil centrally on the prepared foil. Fold the foil over the coil, working systematically, so that the winding is completely enclosed, except for the narrow gap where the leads emerge. Here, the foil must *not* touch. Leave a small tag of foil projecting, so that the tapping can be connected to it electrically. This can be done with a small bolt, with two washers and nut, passing through a hole in the foil tag.

The foil can now be bound with thread, to keep all secure, and a little cement can be spread on the insulated leads where they come out of the foil screen, to prevent movement.

Cut a disc of plywood about 6½in in diameter, and varnish it. The screened winding is then cemented to this all round, by spreading adhesive liberally on the foil and wood. When the coil is correctly positioned, place a flat board on top of it, and hold this down with a moderately heavy weight. Adhesive should not spread up on to this board, which is removed when the whole is dry.

The circuit in Fig. 25 is used with this coil. C1 is changed to 33pF, and C3 to 2200pF. A check of frequency should be made as explained.

It will be found that a coil of this type is likely to vary more in actual inductance, than one wound as in Fig. 25. This arises because of the placement of turns, the extent to which turns are compressed together when binding with cotton, and the degree to which the foil closely surrounds the turns, and thus adds extra capacitance to the circuit. All these factors are likely to vary somewhat with a home-wound coil.

Normally, T1 should give enough adjustment to compensate for changes in frequency caused by these effects. However, if it is found that the frequency is still too low, with T1 fully unscrewed, the simplest solution is to reduce the value of C3. Disconnect the 2200pF capacitor, and try 2000pF instead. Similarly, if it is found that the frequency is too high, with T1 fully screwed down, then the value of C3 may be increased. It may be changed to 2700pF, or a capacitor of about 500pF may be added in parallel with the 2200pF component. In this way, the wanted frequency can be made to fall within the range of adjustment available by means of T1.

The coil is used in the same way as an unscreened coil, but it will be found that stray capacitance effects – such as those of wet soil – are eliminated, and do not cause small shifts in the locator tone.

It is not feasible to change the number of turns on a winding of this kind, once it has been constructed, and if the individual coil should prove to be of slightly incorrect inductance. Nor is a check of frequency *before* adding the shield of any aid, because this will differ considerably from that of the shielded winding. For these reasons, constructional details should follow those given as closely as possible.

TWO-TERMINAL COIL

With any form of oscillator, feedback from the output circuit of the transistor to its input circuit has to be in the correct phase. In the circuits shown, output has been from the transistor collector, and input to its base. There is a 180 degree or half-cycle phase change in the transistor used in this way. In order that each impulse shall arrive at the base at the correct instant to maintain oscillation, a further 180 degree change in phase is introduced by the feedback circuit.

With the search coils shown, this is achieved by having a tapped winding, with collector input to one end, and base output derived from the other end. The tapping is effectively earthed. That is, the required positive supply is provided for it, and this is not earthed, but effective earthing at radio frequency is obtained, either from the low impedance of the battery circuit, or by using a by-pass capacitor down to the earth line. The latter is actually the negative battery circuit, not an actual earth, but it can be regarded as a virtual earth, or the ground or return point.

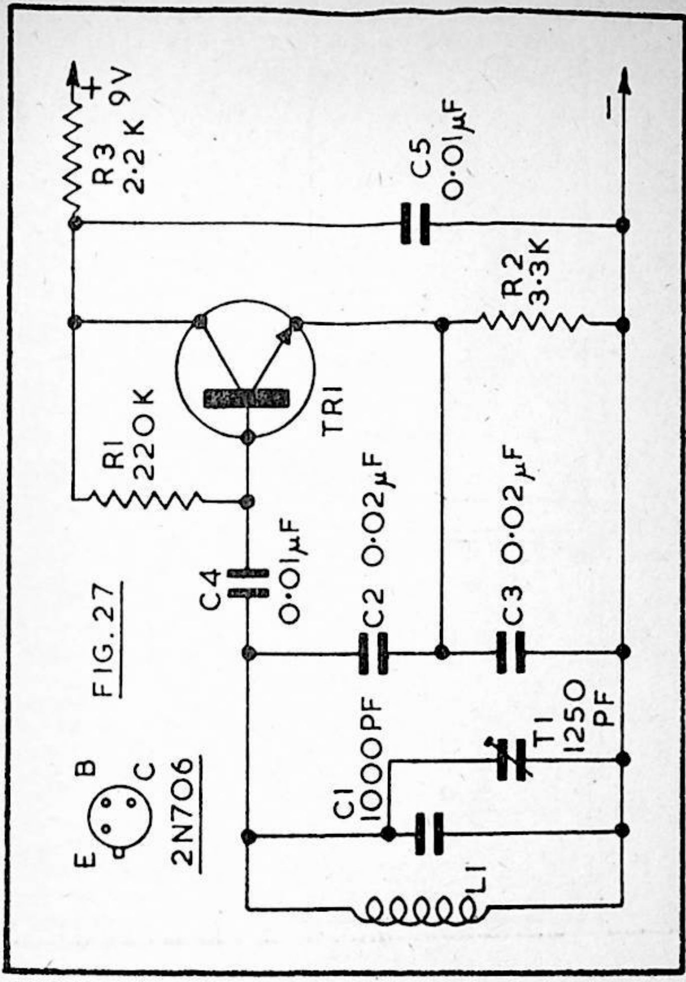
In these circuits, the emitter is also grounded. So the phase of oscillation at base and collector, relative to the emitter, is correct to produce and maintain oscillations. This means that a tapping has to be formed on the coil, and a third lead run up to the locator circuits.

The need for a tapping can be avoided by using the circuit in Fig. 27. The collector is grounded by means of C5. L1 is the search coil, with parallel capacitor C1, and trimmer T1. The emitter is, however, connected to the junction of the capacitors C2 and C3, and an oscillatory frequency voltage, in the correct phase, is developed across R2.

With C2 and C3 in series in this way, the effective capacitance placed across L1 by these components is 0.01uF. The exact values of these capacitors thus help to set the working frequency. It is not essential to use close-tolerance capacitors. T1 is expected to allow trimming the circuit to the wanted frequency. But should this prove not to be the case, frequency is easily raised by removing a turn or so, or by reducing the value of C1 to 820pF. If frequency were too high, however, C1 can be increased to 1200pF or 1500pF, or a turn or so may be added to L1. With this in mind, inexpensive 10 per cent tolerance capacitors can be fitted for C2 and C3.

The search coil L1 consists of twenty turns of 32swg enamelled wire, placed in a slot 3/16th in wide, and has a diameter of 8 in. The construction of this type of winding has been described earlier. For this coil, three discs of 3/16th in thick plywood may be used, the middle disc being 8 in across, and the others a little larger.

Current figures, when making oscillation checks, have been given for many circuits. These are only approximate, as mentioned, as they depend on individual transistors and other features. The most important point is that a change in current should be found when the search coil L1 is temporarily short-circuited. This arises from the difference in operating conditions, between the oscillating and non-oscillating state. If there is no such change, the cause should be located and corrected before proceeding any further, as the stage cannot operate.



SQUARE COIL

Circular coils made in the way shown for earlier circuits are robust, and quite easy to make. However, a square coil with the turns supported on short lengths of wooden dowel at the corners needs the minimum amount of woodworking. Such a coil is shown in Fig. 28.

The base is a piece of wood about 7 x 7 in and preferably at least 3/8 in thick. Mark the drilling points on the corners of a square 6 x 6 in. Drill these holes ¼ in in diameter, to take pieces of ¼ in dowel, which project about ½ in above the board. Fix with adhesive.

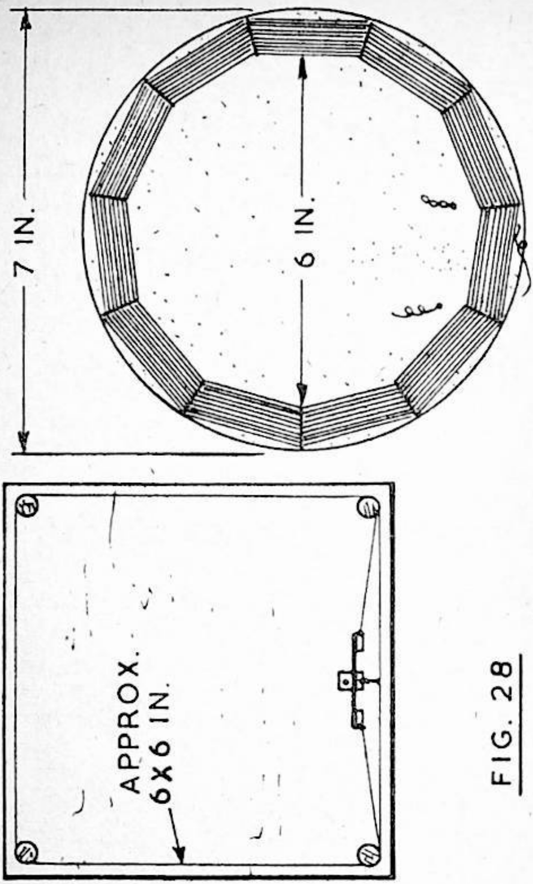


FIG. 28

The winding is of 32swg enamelled wire, and is kept in a compact pile against the board. Use nineteen turns from collector to tapping, and a further eleven turns to the base circuit end of the winding. Keep the wire fairly taut, and add a little adhesive where the turns run round the dowel pegs.

This coil is intended for use with the circuit in Fig. 25. A 2N706 is employed. C1 is changed to 560pF, and C3 to 5200pF. Other values are as shown.

A coil of this kind can be made very readily, but it is not protected against rain or rough usage, so has to be treated with some care. There is also likely to be more range in inductance, due to the extent to which turns pile on each other, and how tight the wire is. This means that it is possible that it may be necessary to modify the value of C3 slightly, or to change the number of turns, if it is found the frequency is incorrect and outside the adjustment provided by T1. Fortunately it is easy to cut a turn or two off; or to solder on the 32swg wire, cover the joint with tape or sleeving, and wind a few more turns on. These can be at the collector end of the winding.

BASKET COIL

A coil wound on cardboard will avoid the need for any woodworking and is very easily made as also shown in Fig. 28. Stout card is required, and will be found satisfactory provided it is kept dry. A stronger coil could be made by using 1/16th in thick paxolin or other insulated material, but this cannot be cut with scissors.

The card should be flat and strong, and is 7 in in diameter. Also draw a 6 in diameter circle on it. Divide the perimiter into eleven approximately equal sections. Cut from the circumference to the 3 in radius line, so as to form eleven slots 1/8 in wide and ½ in deep.

The winding is of 32swg enamelled wire. Pass the end through a small hole, and bring the wire up in the nearest slot. Take the wire backwards and forwards through the slots, as they are reached. Half the turns will be seen one side of the card, and half the other side. Wind on fourteen turns, and form a loop. Continue winding in the same direction for twenty-three more turns, and cut off the wire and pass the end through a hole.

The circuit in Fig. 25 is also used with this coil. C1 is changed to 560pF, and C3 is 4700pF. The transistor is the 2N706.

In view of the liklihood of rubbing the unprotected turns along the ground, some protection is required. This can be given by a further disc of card or plywood, 7 in in diameter. Should this kind of winding be used, and maximum protection be wanted for it, a shallow plant-pot saucer may be placed over it. These are only 1 in or so deep, and are of plastic material, and may be cemented to the bottom, protective disc of the coil, so that it is wholly enclosed.

COIL MOUNTINGS

A simple method is to use a block of wood, drilled for the handle (Fig. 13). In some cases it is convenient to be able to adjust the angle of the coil, as when walking up or down hill. This can be arranged by pivoting the handle between two pieces of wood fixed to the search coil.

The pivot can be a 2ba bolt, with wing-nut. The coil can then be set at once to any wanted angle, to suit the person using the locator.

With this type of fitting, and a tag-strip or terminal block, screws or other small metal items will be permanently fixed in the proximity of the coil. This makes no practical difference to working, but the coil circuit has to be tuned after any such fitting is in place.

UNDERWATER COIL

It is not difficult to make a completely waterproof coil assembly, and with this it is possible to search in shallow water. To ease construction, a plastic container with tightly fitting lid can be chosen, to take the coil. The container should be reasonably strong, and of minimum depth. It may be found most convenient to use it inverted.

The handle can be fitted to a disc of wood, which is well varnished and fixed to the bottom of the inverted container with screws. Put an outdoor type plastic sealer between wood and container. Flexible leads of well insulated wire are taped to the handle, and pass through into the container. Plug and seal these holes.

The search coil is cemented to the inside of the container lid. A little free lead is required, so that connections to the locator wires can be soldered and taped with the lid off. Adhesive is then spread completely round the rim of the lid and container, and the lid is put on. The result should be completely moisture and water proof.

In other than shallow water the top and bottom of the container may be curved inwards by the water pressure. To minimise this it is necessary to use a strong, non-flexible type of box. It will be found relatively easy to make a coil assembly which is protected against spray and a few inches of water, but more difficult to keep out water if the coil is much further immersed. Such a coil is best made as an optional plug-in accessory, as it can then have an extension handle, with a sleeve made from 1 in diameter or similar rigid plastic pipe (as used to replace copper pipes in plumbing). This can then be pushed on the locator handle at the bottom, and the coil leads can be plugged into the locator.

It is necessary to re-trim the coil when immersed, unless it is screened. The effects of water round the coil connections will be reduced if the insulation is thick, as capacitance from conductor to water is thus reduced. A screened lead can be used, but all conductors and electrical items must of course be completely protected against water.

A moisture-proof coil can be constructed wholly of wood, using three discs, or a disc with a slot turned in its rim, with the winding protected by sealing compound and tape. It is not easy to keep water out of all items, however. Again, trimming to frequency (by adjustment of capacitor values in the locator) should be made after all constructional work is finished.

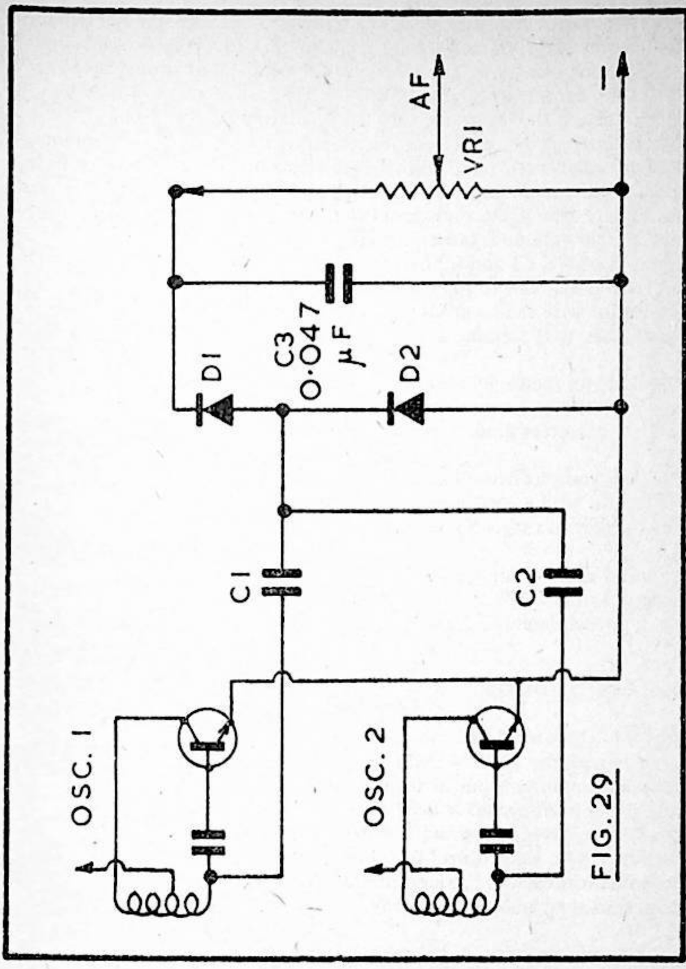


FIG. 29

ALTERNATIVE DETECTORS

Any metal locator using a reference oscillator and search coil oscillator assembled from the circuits and details given earlier will need a heterodyne detector. This receives the two radio-frequency inputs, and provides the audio-frequency output.

Two diodes, as in Fig. 14, are suitable for this part of the circuit. However, with home-wound reference coils, there will be no coupling winding, as shown, so the method of using the diodes will be slightly modified.

Fig. 29 indicates how the signals from the two oscillators may be taken to the diode stage. C1 and C2 are small coupling capacitors one being used for each oscillator. Their value is not critical, but should be quite small. Any capacitors of about 10pF to 27pF or so will normally be satisfactory. If the values are very small, audio output is reduced. Alternatively, if the capacitors are too large, there is a greater tendency of one oscillator to "pull" the other in terms of frequency. With this in mind, 10pF components can be fitted, and the need to use larger values would only arise if the audio amplifier is a little inadequate in terms of gain, so that volume is rather meagre. In fact, when plenty of amplification is available, C1 and C2 may be wholly omitted. Instead, leads can run from the diodes to the oscillatory circuits, and the *insulated* ends of connecting wire can be given a turn or two round the base circuit conductors, thus forming a small coupling capacitance.

Any detector diodes in working order are likely to prove suitable, and they need not be the same. Inexpensive surplus point-contact diodes, as used for detectors in radio receivers, are satisfactory.

The audio output from this stage is quite low – sufficient for a test of the locator with a good pair of high resistance headphones, but insufficient for normal usage. So output will be taken to the audio amplifier.

Where an audio volume control VR1 is provided, this can be connected directly across C3. With most circuits its value is not too important, and a 10k potentiometer is suggested.

TRANSISTOR DETECTOR

Fig. 30 is a grounded-base emitter detector, and this will work satisfactorily with the 2N3704 and many other transistors. Unless the following amplifier is one giving very small gain and audio output, R3 and C5 will most probably need to be included, to avoid low-frequency instability. This is a continuous whistle or howl, which usually ceases when the audio gain control is turned back. It arises because of unwanted feedback in the amplifier and detector, which causes oscillation at an audible frequency.

The values of the emitter resistor R1 and collector resistor R2 are not very critical, and this also applies to the capacitor values. C4 is an isolating capacitor, added because of the positive voltage present at the collector.

The main advantage of this circuit, compared with the diodes in Fig. 29, is that it provides a fair amount of extra audio output. This can be useful when only a modest audio amplifier follows the detector, with the result that volume tends to be inadequate. In such circumstances, where a little free space is available, the diodes in Fig. 29 can be replaced by the transistor in Fig. 30. There would of course be no point in using the transistor in a circuit having diodes, and already giving adequate volume.

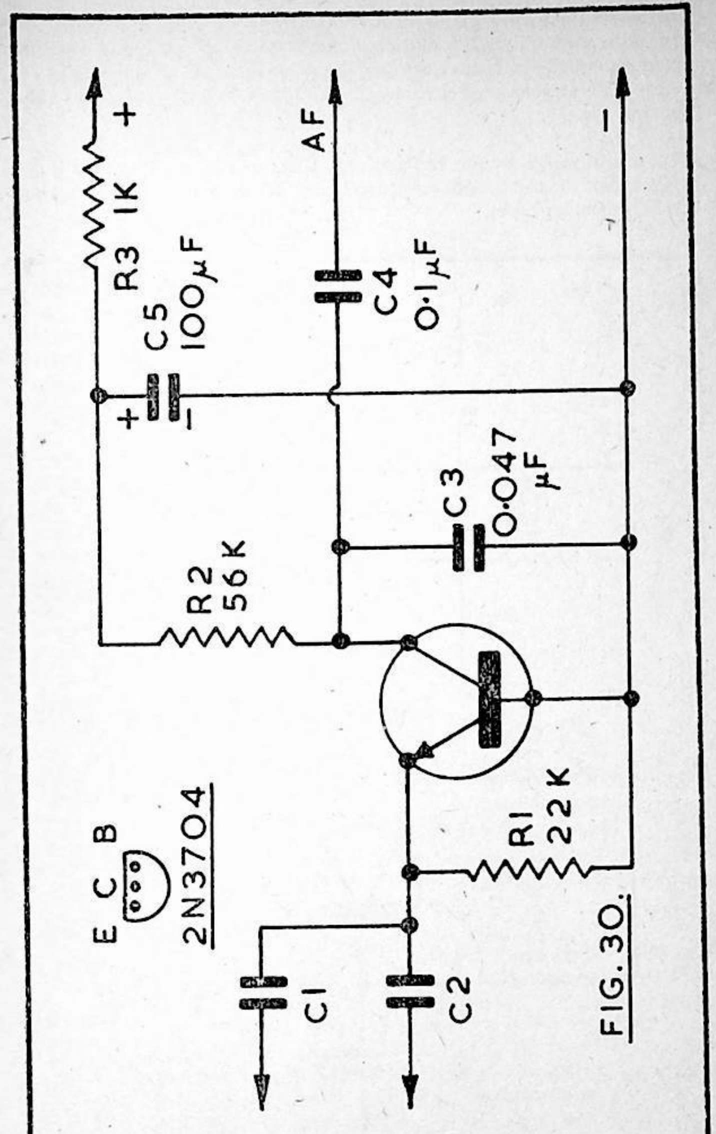

R3 1K
+
AF
-
C5 100μF
C4 0·1μF
C3 0·047 μF
R2 56K
E C B
2N3704
R1 22K
C1
C2

FIG. 30.

Circuits which are more complicated than this are seldom used, but Fig. 31 requires only a few extra components, and affords good isolation between inputs. These are from the two oscillators, via C1 and C2, as before. This stage also gives some gain, and thus an improved audio output over Fig. 29.

Component values are not critical, and others may be used or tried if wished. Nor are the transistors critical, and BC108s or 2N3704s may be fitted, or similar types.

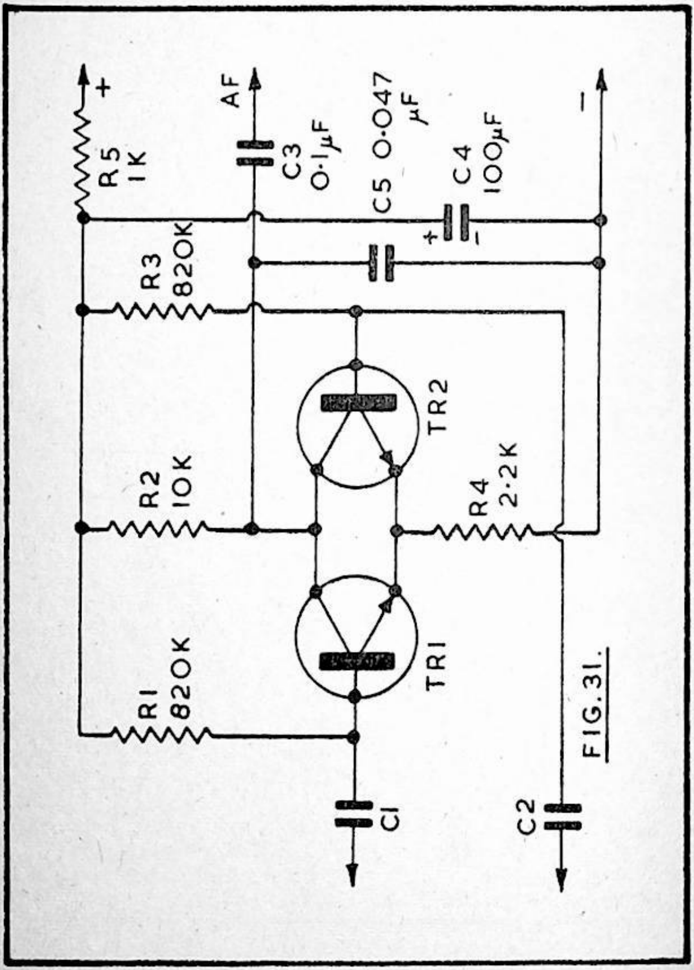


FIG. 31.

DETECTOR FAULTS

With a stage using a simple circuit such as that in Fig. 29, it is very unlikely that any fault can exist. A fault might be suspected if phones are used to check for audio output, and no tone is obtained.

If this should happen, first check wiring. If this appears to be correct, tune the two oscillators in the way explained earlier, and check that they can be placed on the same frequency. If both oscillators are working, and the detector stage is correct, but a tone cannot be heard, despite this, when the oscillators are too removed from each other in frequency.

A check that the oscillators can operate on the same frequency becomes more important with a circuit such as that in Fig. 30, or Fig. 31, if no audio signal is obtained. In such circumstances, no actual wiring or similar fault may be present, so repeated checking of components and connections would be pointless.

Should the circuit in Fig. 29 operate, but Figs. 30 or 31 prove to give no results in the same locator, then it may be assumed that some actual fault is present in the new detector stage. This might be an omitted connection, short-circuit between wiring or joints, or wrong use of transistor leads. It is not very likely that resistors or capacitors will be faulty, if new.

In general, the detector stage is likely to prove troublefree, because there are no adjustments to be made to it. But it can only provide an audio output when supplied with suitable inputs, which in turn depends on the oscillators and their tuning.

AUDIO AMPLIFIERS

There is considerable choice in the type of audio amplifier which is fitted after the detector. The use of headphones avoids irritation to other persons nearby, and is quite popular. For this purpose, a very simple single-stage amplifier can easily give all the amplification and volume which will be necessary.

A comfortable headset, probably with padded ear-muffs, will be most suitable, and will help to exclude external noise. For simple single-stage and similar amplifiers, headphones of the kind intended for use with crystal receivers and simple transistor receivers, and also for general short wave listening, will be excellent. These have a direct current resistance of about 500 to 2,000 ohms, and can be inexpensive. They also provide a satisfactory collector load for a small transistor amplifier, without any need for coupling or matching circuits. They may be termed medium to high impedance headsets.

Low impedance headsets will generally have an impedance of about 4 to 16 ohms. These can be used with circuits which are designed to operate with a low impedance load. Phones which may be to hand for stereo reception can be used by operating them in parallel.

It is also possible to use single miniature earpieces, though these can be less comfortable. They have the advantage of being very small to carry. Medium or high impedance magnetic units of this kind will often be about 300 to 1000 ohms, and can be employed with any amplifier where a complete medium or high impedance headset would be used. Low impedance earpieces, such as 12 ohm, require an appropriate circuit, as for low impedance headsets.

Crystal earpieces, or crystal headsets, can only operate with a suitable coupling circuit, or with an output which may take a crystal unit. Magnetic earpieces have windings which provide a direct current circuit for collector current, but crystal earpieces do not.

The choice of a headset may thus depend somewhat on the amplifier to be used, but there is generally considerable latitude. It is often practical to employ an earpiece or headset already to hand.

HEADPHONE AMPLIFIER

Where working will be exclusively with headphones, a single transistor is adequate. Fig. 32 shows a circuit which can follow the diode or similar detector stage. A BC108, or 2N3704, and similar transistors will work well here.

Best results are obtained with medium to high impedance magnetic phones, though these are not essential. Low impedance phones will provide less volume.

Should this circuit be wanted because of its simplicity, and a pair of low impedance phones be to hand, they can be pressed into service by adding a matching transformer. This can be a small component as fitted in transistor radio receivers. Its ratio will be about 8:1. Connect the transformer primary to collector and positive line, and feed the phones from the transformer secondary. There is considerable latitude in both the transformer and phones.

With a sensitive pair of medium or high impedance headphones connected as in Fig. 32, volume may be a little too great for some users. This depends on the headset, person using the locator, and possible external noise. If it is felt necessary, volume can be reduced to any wanted level by fitting a potentiometer as in Fig. 33. It may have an integral on-off switch, and need not be 10k, though about 10k to 25k is most suitable here. No further components or changes elsewhere are required.

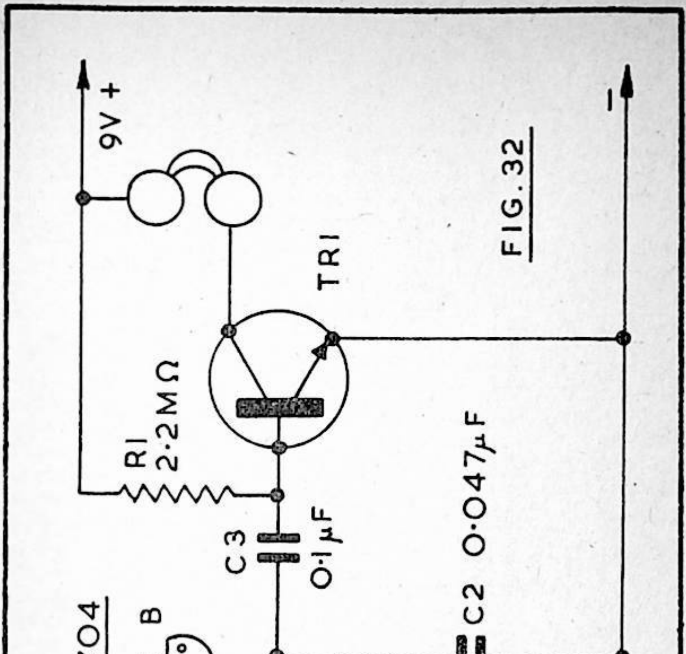


FIG. 32

Fig. 33 also shows the addition of a resistor R2 as collector load, when a crystal earpiece is to be used. Collector current flows through R2. The audio signal voltage developed across R2 reaches the output circuit via capacitor C2. The value of R2 is not critical. C2 should not be much smaller in value than 0.1uF. With this circuit, direct current operating conditions depend on R1 and R2, and are not influenced by the type of earphones.

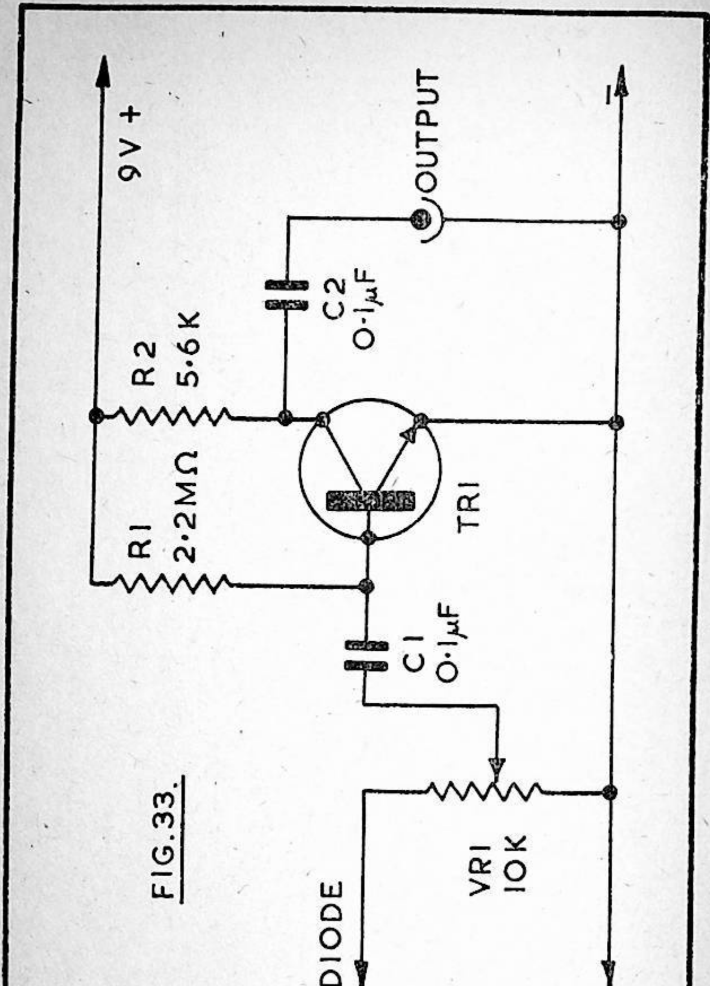


FIG.33.

LARGER AMPLIFIERS

A 2-stage audio amplifier, such as that in Fig. 16, is of course adequate for headphones, and will give moderate loudspeaker volume. Whether or not volume is adequate with the loudspeaker at all times depends to some extent on external conditions. If there is high noise or wind, and phones are not to be plugged in when this is so, a somewhat more powerful amplifier is of advantage. The more powerful type of amplifier can still be used with phones, at a lower volume control setting.

Larger audio amplifiers may be divided into three groups: (1) Two-stage or 3-stage amplifiers of relatively simple type, and with a single transistor in the output stage; (2) Amplifiers with two transistors in push-pull in the output stage; (3) Those using integrated circuits.

Amplifiers of type (1) are often used, and can be perfectly satisfactory for reasonable output levels, bearing in mind that high fidelity is unnecessary. Their main disadvantage lies in the fact that if they are to be capable of a fairly powerful loudspeaker output they are not very economical in terms of battery current. An amplifier with push-pull output (2) is capable of any wanted output power. There can be some saving in battery current, but this is not equal to the saving which would be obtained for ordinary purposes (speech or music reproduction) because of the continuous tone. An IC amplifier (3) can have the advantage of enabling powerful results, with relatively few components.

It should be remembered that high volume loudspeaker operation is likely to be a nuisance to other pepple. No amplifier need be planned with an output of more than about 200mW, except when quite unusual levels of noise are possible.

TWO-STAGE AMPLIFIER

Fig. 34 shows a 2-stage amplifier which will give moderate loudspeaker results. The loudspeaker should be of 75 to 100 ohm impedance, and an efficient unit, fitted in a case, will provide appreciably more sound than a very small diameter speaker. Units with a rather low impedance will cause too much loss of volume.

The amplifier is also suitable for headphones, and these may be plugged into a switched jack socket (see Fig. 16), so that the internal speaker is then silenced. There is enough output for low, medium or high impedance headphones, while the capacitor coupling also allows a crystal earpiece to be used instead, if preferred.

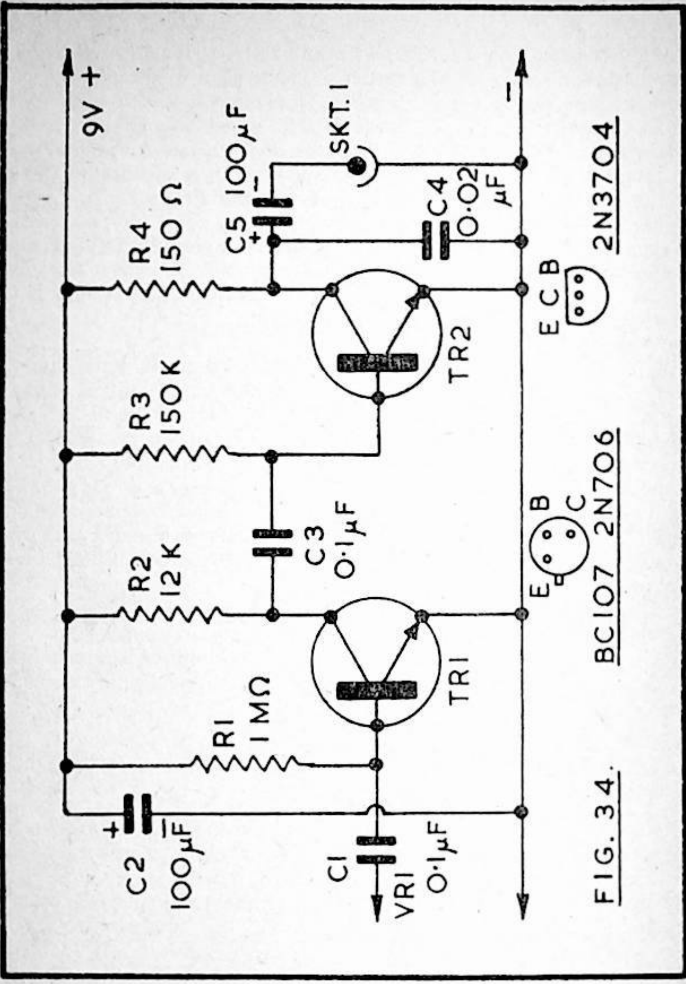


FIG. 34.

The circuit requires few components, and draws about 15mA from a 9v battery, so that reasonably economical running is obtained. Other transistors than those indicated may be used. If so, it may be found that volume is improved by modifying the values of R1 and R2, for TR1; or R3 and R4, for TR2. These resistors can best be a compromise between maximum volume but higher battery drain, and reasonable volume with some drop in the current required from the battery.

THREE-STAGE AMPLIFIER

A 3-transistor amplifier will provide substantially greater gain and output, so that a loudspeaker can be operated at higher volume than can be obtained from the 2-transistor circuit. This results in easier listening, when using the speaker out of doors in windy or noisy conditions. In fact, it is always worth while checking output under actual working conditions. A locator which has only a small amplifier, with a very modest power output, may seem satisfactory when first assembled and tested indoors, where external noise is likely to be at a low level. Outside, wind and other sounds may result in the same amplifier proving to be inadequate, so that it is almost essential to plug in a headset.

Fig. 35 is a 3-stage amplifier which will give adequate volume for most ordinary purposes, when used with an efficient speaker of about 15 to 100 ohm impedance. Though a relatively low impedance speaker may be used if to hand, an impedance of 25 ohm or higher impedance is most suitable, and will give slightly more volume.

The circuit may be used with headphones. In this case, the impedance is not very important. More output than required will be available, so that any loss due to the use of an unsuitable impedance load is not important.

The first amplifier TR1 has base current from R1, and R2 is the collector load. Audio input is from the slider of the volume control to C1. Should an alternative transistor be used here, it might in some cases be worth trying alternative values for R1 and R2 also.

C3 provides the audio input for the base of the second amplifier TR2, which has base current from R4, and R5 as collector load. Operating conditions are arranged so that the collector voltage of TR2 is a suitable base voltage for TR3, so that direct coupling is used. The audio output of TR3 is developed across the emitter load resistor R6, and coupled to the reproducer by C5. With this form of speaker (or headphone) coupling direct current working conditions are not changed by the DC resistance of the reproducer.

Many other small audio type transistors will prove to be satisfactory in this circuit, but the working conditions of TR2 and TR3 are set by the values of R4, R5 and R6. This means that if transistors of rather different characteristics than those shown are fitted in the TR2 and TR3 positions, changes might have to be made to these resistor values.

TR1 is supplied from a decoupled point, with decoupling capacitor C2 and resistor R3. This is to prevent audio-frequency voltages in the positive circuit from reaching TR1, and causing instability, or continuous audio oscillation. Such decoupling becomes necessary with an amplifier having several stages.

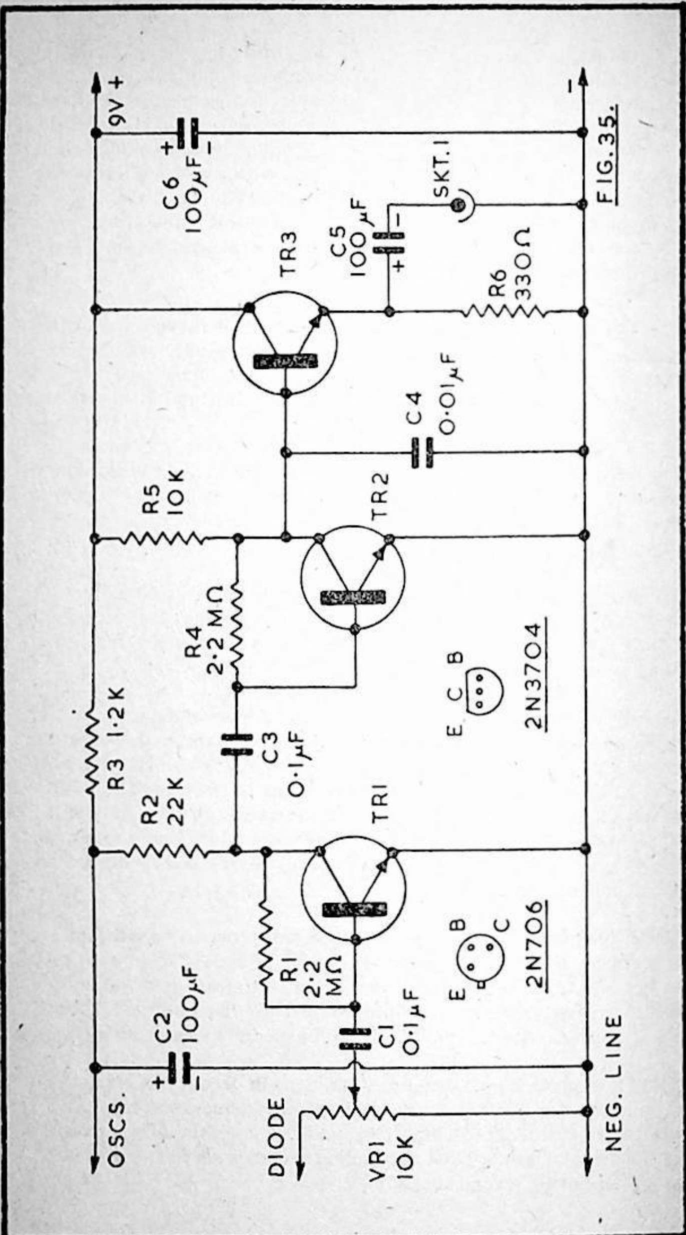

9V +
C6
100μF
SKT.1
C5
100μF
TR3
R6
330Ω
C4
0·01μF
R5
10K
TR2
R4
2·2 MΩ
R3 1·2K
C3
0·1μF
R2
22K
TR1
E C B
2N3704
R1
2·2
MΩ
E B C
2N706
C2
100μF
C1
0·1μF
OSCS.
DIODE
VR1
10K
NEG. LINE

FIG. 35.

Where other than a very small signal voltage may arise on the positive line, it is also wise to supply the high-frequency oscillators from a decoupled point, as in Fig. 35. A capacitor of 100uF or larger value, across the battery supply (C6) is also helpful in avoiding instability.

Low frequency instability is generally shown by a continuous whistle or howling. When this is present for all settings of a volume control such as VR1, it is arising in the audio amplifier itself. But when it only begins with VR1 turned towards maximum volume, it is caused by feedback into earlier stages – oscillators or transistor detector, if the latter is used. Such feedback is generally through the positive supply circuit, and is avoided by C2 and R3.

Components may be assembled on a tag-strip or perforated board. The layout should keep TR3 and output circuits reasonably clear of VR1, TR1, and input circuits.

With a 9v supply, battery drain is around 20mA. The circuit gives a reasonable performance with a 6v supply. The output points may be connected permanently to the speaker. Alternatively, if a phone socket is required, wire this so that the circuit to the speaker is interrupted when the phone plug is inserted. Headphones can be a very important asset in avoiding irritation to other people.

IC AMPLIFIER

An integrated circuit consists of a compact assembly of semiconductors, and with an IC audio amplifier several stages of amplification may be present. For a metal locator, the main advantage lies in selecting an IC which will need few external components (resistors and capacitors). A large output power is not wanted. Nor is there any advantage in using an IC which needs so many other components that there is just as much wiring as if individual transistors were used. Furthermore, the very good frequency response characteristics which may so readily be obtained with an IC are of no benefit in the present circumstances.

For these reasons, the audio integrated circuits which actually offer advantages in a metal locator are somewhat limited in number. For an IC to be worthwhile, it must give more gain or volume than the simple transistor amplifiers which may be used in locators, while not imposing a heavy load on the battery, and not needing so many other components that there is no eventual advantage in terms of simplicity of construction and wiring.

Audio ICs designed for use in small radio receivers have complementary push-pull output stages. As a result, the battery drain depends largely on the volume required. This is an advantage, as current is quite low when using headphones, yet more power is available (at the cost of increased battery drain) when a loudspeaker is used.

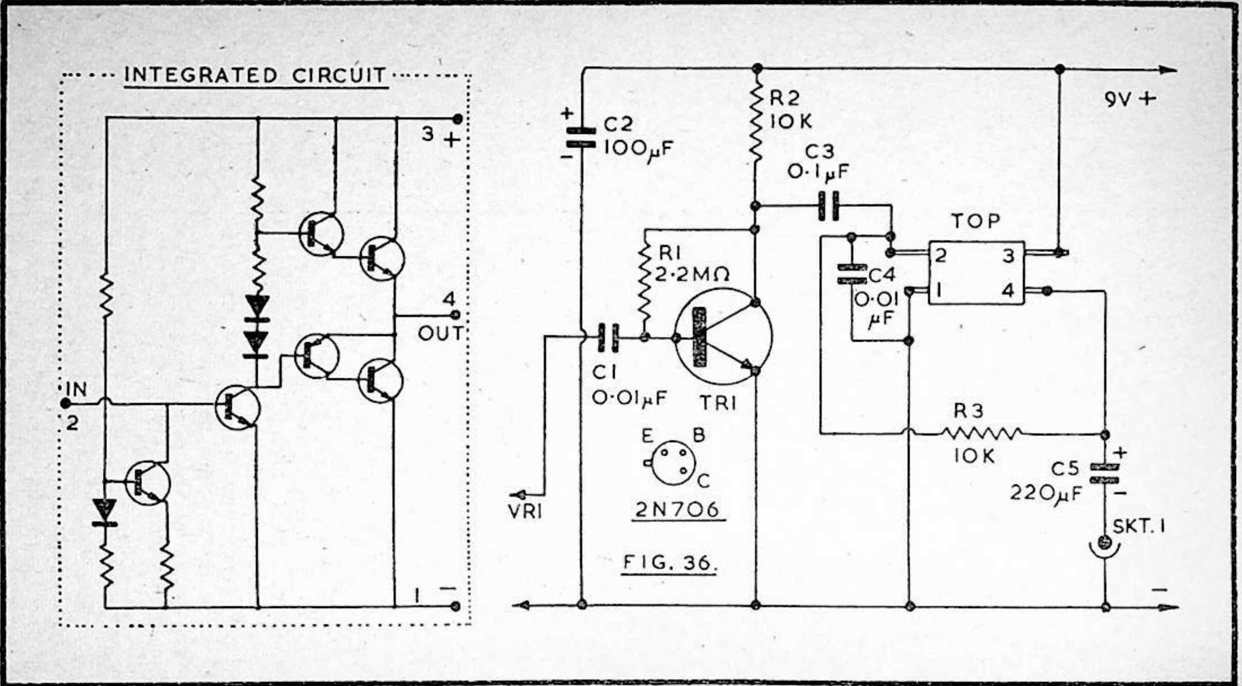

INTEGRATED CIRCUIT
3 +
4
OUT
IN
2
1 –
9V +
C2
100μF
R2
10K
C3
0·1μF
TOP
2
3
1
4
R1
2·2MΩ
C4
0·01
μF
C1
0·01μF
TR1
E
B
C
2N706
VR1
R3
10K
C5
220μF
SKT. 1
–

FIG. 36.

The MFC4000B is a suitable audio IC for a locator. It needs very few external components, and is economical in battery current. This is likely to be around 5mA or so when operating headphones, rising to 12mA to 15mA or so when providing greater output for a loudspeaker.

In Fig. 36, the audio IC is used in conjunction with a single transistor pre-amplifier. The IC itself contains the equivalent of six transistors, in a directly-coupled configuration.

Input is derived from the slider of the volume control. TR1 need not be the 2N706, as a BC108 and similar types will operate here instead, if preferred.

The most suitable output load is 16 ohms, and a 3½ in 16 ohm speaker will give good results. Volume falls off if much higher impedance speakers are used instead. With headphones the loss of output power is not important, so that medium or high impedance phones can be connected. Phones or speakers of under 16 ohms should not be employed, though 8 ohm phones can be used if a resistor of about 8 ohms is connected in series with them. (This is not recommended with a speaker. in view of the unnecessary loss of audio output in the resistor.)

The pre-amplifier stage, with IC and its periphery components, can be assembled on a perforated board, and the IC pins are spaced to fit a 0.15in matrix. No particular difficulty should arise in wiring, Fig. 36B.

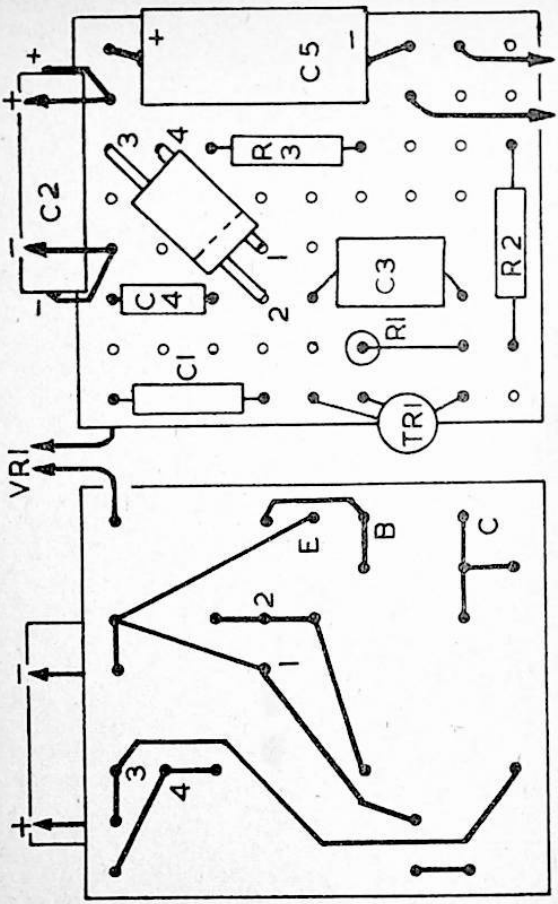


FIG. 36 B.

PART III
CONSTRUCTIONAL AND OTHER POINTS

Many details of the mechanical arrangement of items will have become clear from earlier sections. But in the interests of convenient operating and reliability, further notes on the mechanical construction of various parts, and the assembly of a locator, are worth while.

Reliability depends not only on sound wiring and joints and good workmanship when preparing the circuit boards, but also on the strength and durability of such items as search coils, handle fixings, and cases.

It is as well to keep in mind at all times that unnecessary weight is a nuisance, and will become increasingly so over a long period of using the locator. The overall weight can be quite small. It is well worthwhile to avoid an unnecessarily large and heavy battery or speaker, and to keep down the weight of the search coil, handle, and case too.

SEARCH COILS

An 8 in disc of ¾ in thick wood, with its winding and an unnecessarily large mounting block for the handle, can approach 1lb in weight. Lighter forms of construction, using thinner wood, will halve this. Some kinds of coil are inherently heavier than others, and a heavy coil, situated at the end of a handle as it is, always grows tiresome eventually. Material such as paxolin sheet allows the weight to be reduced, because thin material such as 1/16th in can be sufficiently rigid.

For reliability, the windings have to lie in a slot, or be so fixed that outer turns cannot move. It is also necessary that the whole coil is protected against damp. Untreated wood will take up moisture and probably warp. If spots of water reach the coil turns, and are absorbed between them, this will upset tuning, and may also cause corrosion later. It should be assumed that the coil assembly will almost certainly become wet, if only from dew or damp grass, so it must be made to resist this. This means at least two coatings of outdoor varnish or paint for wood, with protection for the winding itself by means of tape, or a closely-fitting cover made from a plastic plant saucer, or similar methods.

HANDLE

A piece of broomstick handle is probably most easily obtained. It can be of smaller diameter dowel, but will then need a handle or grip at the top which is large enough to hold easily. This can be fashioned from wood, a binding of tape, or similar means.

Suitable handles can also be made from the type of plastic pipe which is rigid, but can be shaped when immersed in very hot water. It is available from ironmongers and plumbers' merchants, and can be chosen in a suitable diameter to take a cycle handlebar grip at the top, which may be cemented on. It may also be bent over here, for a better holding position. A coil assembly can have a plug of wood which will pass into the bottom of the pipe.

A plastic case for the circuit boards can be fixed with screws, or by a strap of thin metal round the plastic handle. The material needs no painting to preserve it, as does wood.

CASE

One of the small plastic boxes available in various sizes will generally do well. Remember it must accommodate the speaker (if provided) and battery, as well as the circuit boards.

Various other boxes and household containers can also be pressed into good service here. For those who like woodwork, a box of any wanted size can be constructed from 4mm or similar plywood, with joints cemented, the whole being sanded and painted afterwards.

Aluminium boxes can also be obtained, either as complete units, or in the form of flanged members which are bolted together. These may be left bright, or painted.

Where a speaker is to be fitted, this is best placed on the box facing the user, as it will slope downwards a little and be less likely to become wet from rain, while being easily heard in this location. Controls can be in any convenient position, according to the layout of items inside the case. The case needs a closely-fitting lid. Should the lid be loose, one or two screws should be provided for it. In general, it should be possible to carry the whole device rather like a walking stick, without any disturbance to components. The battery can be packed round with foam rubber, or held by elastic or a shaped clip.

VERY HIGH-C LOOP

When the search coil is of very low inductance and impedance, it can give some of the advantages of a shielded coil, but without the extra constructional difficulty of the latter. A coil having very few turns needs to have exceptionally high parallel capacitance, and as a result ground capacitance effects become negligible.

The circuit in Fig. 37 will operate with a 3-turn coil 9in in diameter. Two turns are required from collector to tapping, and one turn from tapping to C1. These turns are of 18swg insulated wire, side by side round a wooden disc.

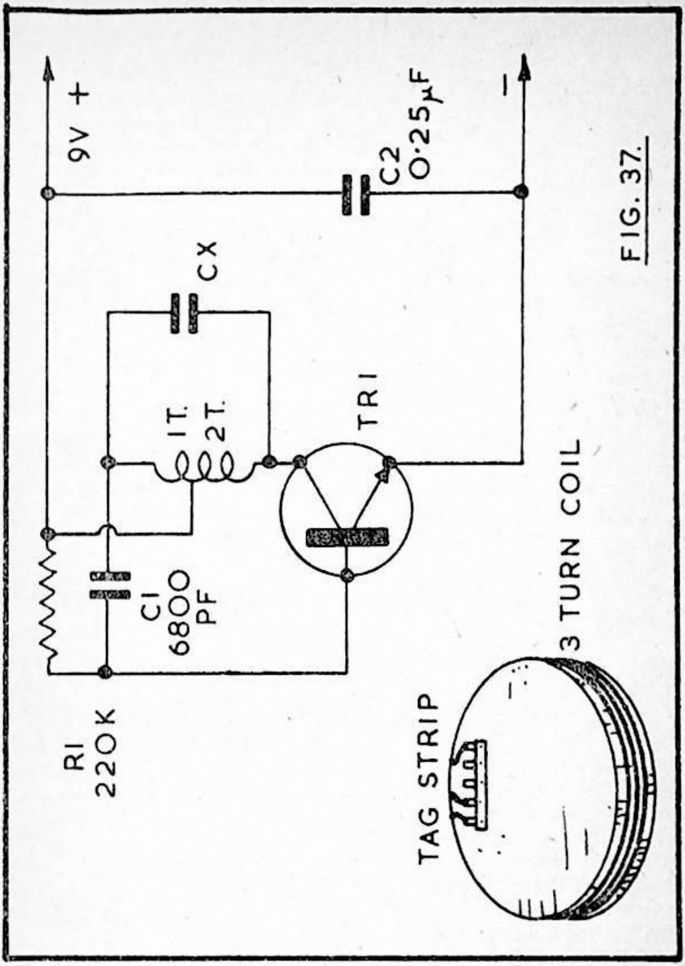


FIG. 37.

To obtain resonance at 100kHz, a total capacitance of 0.45uF, made up from 0.25uF, 0.1uF and 0.1uF capacitors in parallel, was found necessary at Cx. There is no easy means of trimming the coil circuit to the wanted frequency, as even a 1250pF parallel pre-set capacitor will have negligible effect on the frequency. It is thus necessary to experiment with various capacitors for Cx, or to separate the turns slightly, until a suitable frequency is reached. Because Cx is so large, handling the coil turns will have virtually no effect on frequency, while slight changes in inductance due to the proximity of turns to each other will modify frequency considerably. If the winding is of single core mains type cable, it will need no protection, but turns should be secured with adhesive.

It is necessary to use a transistor offering sufficient gain, or oscillation will not be obtained. The BC109 or 2N3704 may be used.

The transistor and other few items of the oscillator stage should be assembled on a tag-strip, which is situated on the search coil disc, immediately adjacent to the ends of the coil. Some trial and error can be expected with this oscillator, especially as it is impracticable to provide a trimmer of large enough value to have any significant influence on frequency, for adjustment purposes.

450-470kHz WORKING

In the British Isles, frequencies allocated for devices of this type lie between 16kHz and 150kHz, so operation cannot be allowed on frequencies around 450-470kHz, and a locator using such frequencies would not be licenceable here. However, this does not apply in some other countries, so brief details may be given of circuits for 450-470kHz.

In these circumstances, this frequency band is often chosen because most popular superhet receivers have an intermediate frequency within these limits. This means that an inexpensive, ready-made portable receiver can perform as detector and audio amplifier, with output to the internal loudspeaker (or to earphones, where a socket is provided).

The simplest locator using such frequencies consists of a single transistor as search coil oscillator. Fig. 38A is a suitable circuit for this purpose. The search coil is constructed as described for Fig. 28, and has 23 plus 14 turns, wound in slots. Here, the parallel capacitance is much lower, so that the frequency is raised.

Though the receiver may be carried separately, it is more convenient to have this fixed with elastic bands or similar means to a handle, which carries the search coil and oscillator. The necessary heterodyne is obtained by tuning in a broadcast signal, then adjusting T1 until the oscillator produces a beat note, in a similar manner to that previously described. If the oscillator is tuned to near the receiver intermediate frequency, this beat note will be heard on *all* transmissions. If it is heard on one transmission only, but not accompanying other transmissions of different frequency, then a harmonic of the oscillator is reaching the signal-frequency circuits of the receiver. The receiver must be close enough to the search coil, and so placed, that a strong enough oscillation is picked up. Failing this, an insulated lead may be run from the transistor collector to near the IF amplifier of the receiver. If tuning in a strong, local station swamps the search coil oscillator input, select a more distant, weaker signal.

The oscillator and receiver are used in the same way as the type of locator already described.

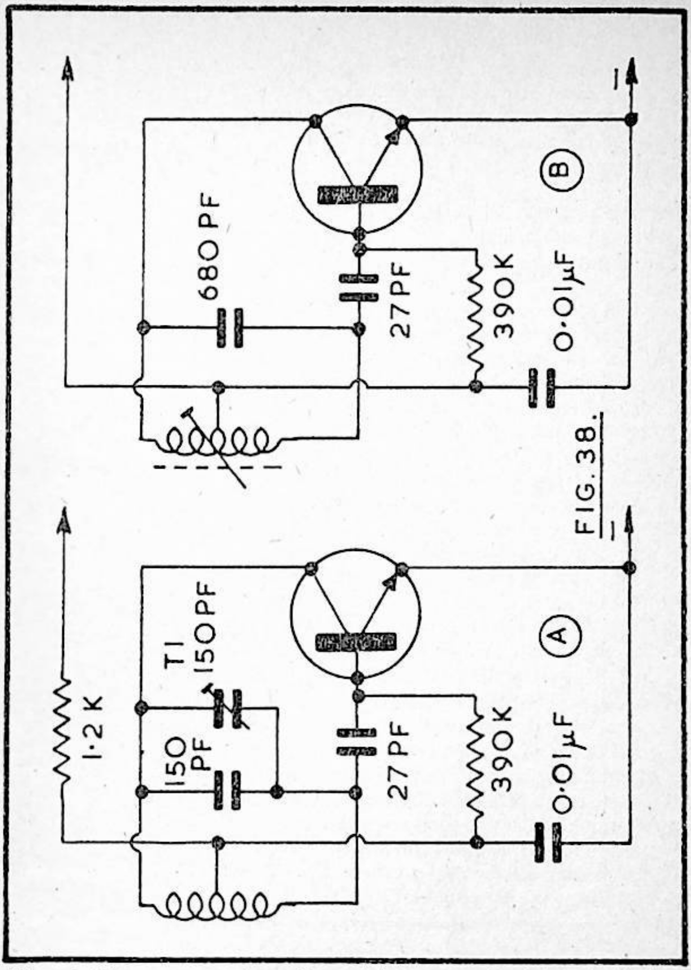


FIG. 38.

Though this arrangement can give satisfactory results, it has the limitation that the radio programme is present, and its volume will vary due to directive effects of the receiver ferrite aerial. Fig. 38B shows a reference oscillator adjustable around the range 450-470kHz. This uses the coil shown in Fig. 24. Adjustment can be by the core alone, or by means of a small trimmer (say 50pF) as shown earlier.

The two oscillators can be assembled and coupled to a detector, as shown in Fig. 29, and followed by an audio amplifier.

As mentioned, equipment operating in this band of frequencies must not be used in the British Isles.

OSCILLATOR STABILISATION

Long term stability of the frequencies of the oscillators will depend on no changes arising in the inductance of the search coil or reference oscillator coil, or in the values of the capacitances. With reasonably rigid construction, and no loose turns, the coils should prove to be satisfactory.

With high stability silver mica or similar capacitors, no particular trouble should arise here. The provision of a manual trimmer allows re-adjustment over a narrow range.

Another cause of unwanted frequency changes may arise from the transistors themselves. The effective capacitance of these devices varies with current, and thus also with battery voltage. In the circuits shown, there is a large parallel capacitance, and changes to oscillator frequency due to a failing battery are generally negligible. Some oscillators, on the other hand, will produce quite a significant change in frequency for a small drop in battery voltage. This is not important where a steady current is drawn from the battery, as re-adjustment of the manual trimmer will allow compensation for it. With the amplifiers shown, current changes very little so there is a steady load on the battery. But if a more powerful amplifier is pressed into service it will almost certainly have an output stage in which current varies considerably between silent and tone conditions. If this is combined with an oscillator whose frequency varies with voltage, and a failing battery, the oscillator may be pulled by audio output conditions.

This difficulty can be avoided by running the oscillators from a stabilised supply. Fig. 39 shows a 6.2v zener diode added for this purpose, with a series resistor R1. A 400mW diode could allow a current of 60mA, but the stabilisation current needs to be kept as low as reasonably possible, to avoid an unnecessary load on the battery. For this reason, R1 can be 270 ohm, or 330 ohm, the latter giving a little more economy, with a stabilisation current of under 10mA. The best value for R1 depends somewhat on the current drawn by the oscillators, which also passes through R1. C1 will normally be present as part of the oscillator circuit.

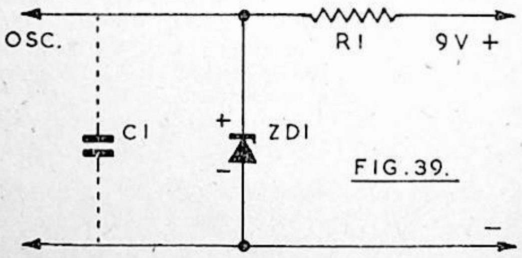


FIG.39.

KIND OF METAL

When a heterodyne metal locator is adjusted so that it is producing an audio tone of a few hundred hertz, with no metal near the search coil, it will have been noted that some metals produce a rise in pitch, while others cause a fall in pitch.

Ferreous metals have an opposite effect to non-ferreous metals. The ferreous metals include iron, steel, and numerous other iron-like materials, while the non-ferreous metals include silver, copper, aluminium, and various alloys. Ferreous metals are attracted by a permanent magnet; non-ferreous metals are not. The lists of both are too long to include, and the division is in any case an obvious one.

Whether or not the ferreous metal (or the non-ferreous) causes a drop in frequency (or the reverse) depends on whether the search coil oscillator is set above or below the reference oscillator frequency. A check with known objects is the simplest means of noting which change is produced by non-ferreous metals, as example.

It will be found that long, thin, or small objects produce much less change in pitch than objects of larger area. For localising small objects, a very large coil is generally less convenient and satisfactory. With a quite small coil, small objects can easily be detected at very limited distance, and this can be useful for finding conduit in plaster or for similar purposes.

3-TRANSISTOR LOCATOR

Fig. 40 is the complete circuit of an easily-made three-transistor locator, designed to operate headphones. By arranging components on a tagboard all wiring and parts are visible, and this may be found easier for a beginner, than having leads under the board. In fact, very little constructional work is necessary, and all is very straightforward.

SEARCH COIL

This is of basket type, as shown in Fig. 28. It can be wound on a stout card disc (which can be cut with scissors) provided it is not allowed to become wet in use. The card is 7 in across, and has eleven slots each ½ in deep. The winding is 32swg enamelled wire. The beginning of the winding is point 3. From here, wind fourteen turns, and form loop 2. Continue winding for a further twenty-three turns, ending the coil at point 1.

Fix a card or plywood disc about 7 in across under the coil, for protection and extra strength. A light handle is fixed to a piece of wood in the way shown earlier. Scrape insulation from loop 2 and ends 1 and 3, and solder on connecting wire leads about 18 in long. Tape the joints, and bring the leads up the handle to where the locator will be fitted.

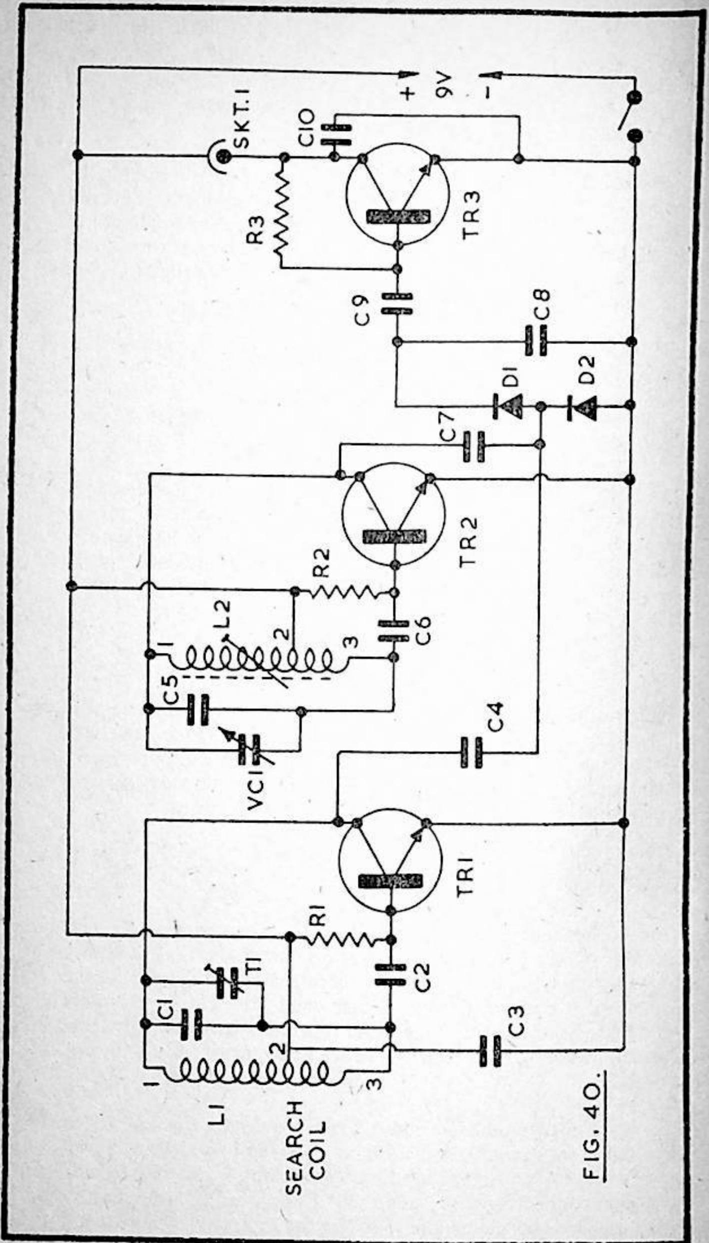

SKT.1
C10
+
9V
-
R3
TR3
C9
C8
D1
D2
C7
TR2
R2
L2
1
2
3
C6
C5
C4
VC1
TR1
R1
T1
C1
C2
C3
1
2
3
L1
SEARCH COIL

FIG. 40.

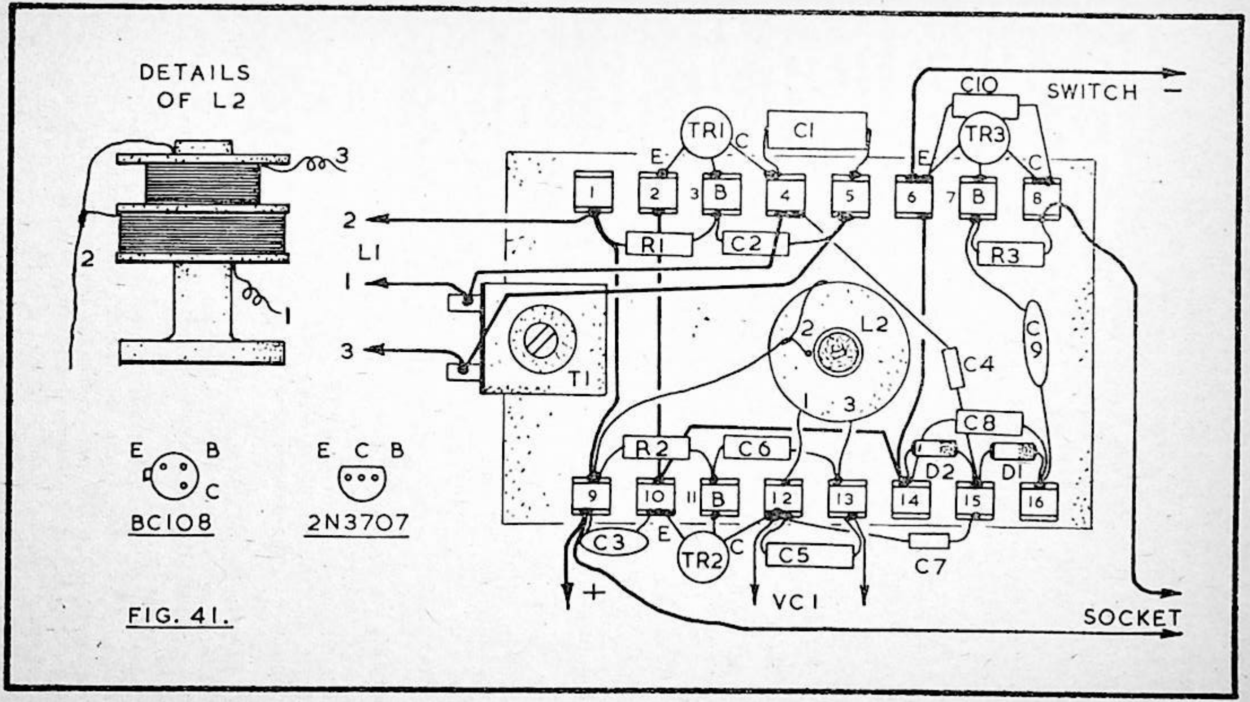

DETAILS OF L2
SWITCH –
SOCKET
TR1
TR2
TR3
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
R1
R2
R3
D1
D2
L1
L2
T1
VC1
+
E
B
C
BC108
2N3707

FIG. 41.

COIL L2

Details of this can be seen from Fig. 41. It is wound with 34swg enamelled wire, and the former is 7mm in diameter, with an adjustable core. Three discs of insulating material about 1 in in diameter are cut – these may be 1/16th paxolin or perspex, or made from strong cardboard. Each is a tight fit on the coil former, and is secured with adhesive. Place them to leave two equal winding spaces, each 5mm wide.

Bring the wire out through a small hole, for point 1, leaving enough for connecting up later. Wind on three-hundred turns. This section ends at point 2, and tape over the coil will prevent any turns coming loose. Cut off the wire, and thread it through a small hole in the top disc to begin winding the top section – this end is later soldered to point 2. Wind one hundred and thirty-five turns in the top space, in the same direction as the lower winding, and finish off at point 3. A narrow strip of insulating tape will again hold the turns in position.

CIRCUIT

In Fig. 40, TR1 is the search coil oscillator, with feedback to the base by C2. C1 and T1, in conjunction with the winding, determine the working frequency.

TR2 is the reference oscillator. As this has an adjustable core for initial adjustments,only the fixed capacitor C5 is necessary, with the manual control VC1 for fine adjustments.

C4 and C7 take the high frequency signals to the diodes D1 and D2, and the audio output reaches TR3 via C9. The socket is for medium or high impedance magnetic headphones.

TAG-BOARD

This has two rows of eight tags, Fig. 41. First drill a hole to mount T1, and for small bolts to secure L2. Connect together tags 2, 10, 14 and 6, and run a black lead from tag 6 to go to the switch and battery negative. Tags 1 and 9 are also joined, with a red lead for battery positive, and connection for the phone socket.

Components can then be fitted, cutting down the ends of capacitors and resistors where necessary. Wires can generally be well spaced from each other, so that no insulated sleeving is required with these items.

The transistors can be left until last, as this avoids repeated heating of the leads while soldering other connections. Emitter, base and collector wires can be identified from the diagram. The transistor types shown are readily obtainable, though other devices of similar type might also be satisfactory.

The board requires a small plastic box, large enough to hold the battery too. VC1 may be a solid-dielectric variable capacitor of ordinary type, or can be a 250pF compression trimmer, fitted with the type of threaded ¼in shaft which allows a control knob to be used. Place VC1, switch, and phone outlet socket conveniently on the box, which is then screwed to the handle. Bring the three leads from the search coil through a hole, and solder them to T1 and tag 1. The leads should be correctly identified.

T1 sets the search coil on frequency. Rotate the core of L2 until a strong heterodyne is heard, with VC1 half open. Final small adjustments can then be made by VC1, when using the locator.

ALTERNATIVE COIL

The cardboard search coil, though very easily made without wood-working tools, is rather fragile, and susceptible to the effects of moisture. The locator can be improved by making an alternative coil on a wooden former.

The winding is 6½ in in diameter, and 1/8 in wide. Assuming that the former is to be built up from three discs of wood, in the way shown in Fig. 8, the middle disc will thus be 6½ in across and 1/8 in thick. It can be cut from hardboard, or thin plywood. If no other means are available, it can be cut with a fretsaw, padsaw, or other narrow saw, while gripped in a vice or clamp, or held flat on the table or bench.

Both outer discs can be of any thickness, but there is little point in using hardboard or plywood much over 1/8 in thick, as this will only make the coil unnecessarily heavy. These two discs should be about 3/8 in to ½ in larger in diameter than the middle piece. Glasspaper the edges of all three pieces, as rough projections may catch up with the wire during winding. Glue the pieces securely together.

The coil can be 34swg or 32swg enamelled wire. Make a small hole and pass the wire up through this, and wind on nine turns. Form a loop, and bring this up through another hole, or a notch, taking care not to damage the insulation. Continue winding for a further twenty-two turns, in the same direction, and secure the wire with a notch or small hole.

This coil is intended to operate with the same component values as the basket type coil. For best weatherproofing, apply two coats of outdoor varnish before winding. After testing the coil, place a turn or two of insulating tape tightly round the circumference of the coil, to cover the slot holding the winding.

WOODEN CASE

It may also be preferred to construct a wooden box for the locator. When this has been made on a tag-board approximately 2¼ x 3¼ in in size, a box 4 in high, 3½ in wide, and 1¾ in deep inside will easily accommodate the board and a battery.

Dimensions may be taken from Fig. 42 using either 4mm or 6mm plywood. The exact size is clearly unimportant, but remember to allow for overlap when cutting the pieces. Glasspaper the edges so that they will meet correctly, and clear away dust. They can then be fitted together with a woodworking adhesive. When this is hard, glasspaper the edges and corners, and varnish or paint the box.

Two screws will secure the box to the locator handle. The box back is attached with small screws, so that it can be removed to replace the battery. The same method of construction is suitable where a loud-speaker will be provided, an aperture being cut of the same diameter as the speaker cone. Gauze should be stretched over this opening, inside the case, before fitting the speaker.

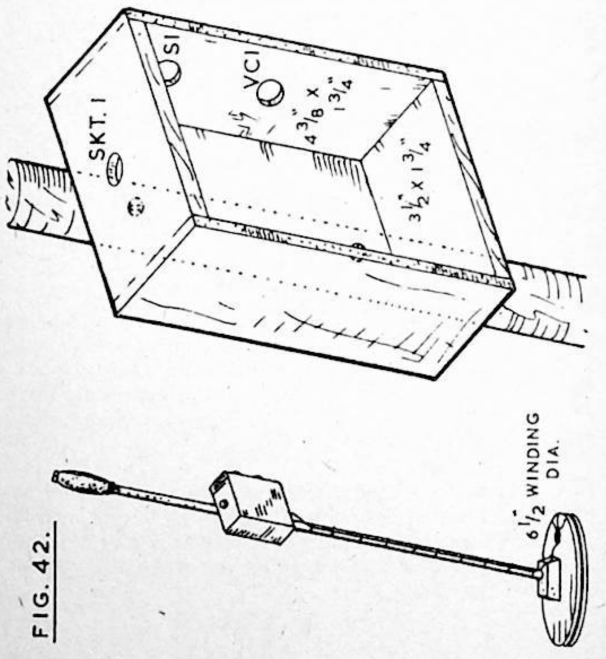


FIG. 42.

VALUES FOR FIG. 40

R1	390k
R2	220k
R3	2.2 megohm (Resistors 5% ¼ watt)
C1	4700pF
C2	560pF
C3	0.01uF
C4	8.2pF
C5	1200pF
C6	100pF
C7	8.2pF
C8	2000pF
C9	0.1uF
C10	0.01uF
T1	1250pF or 1500pF compression trimmer.
VC1	200pF or similar value variable.

L1, L2: see text.

Tag-board, coil former, jack socket, slide or toggle on-off switch, etc.

D1, D2 OA81, 1N67A or similar diodes.

TR1	BC108 or 2N3707
TR2	BC108 or 2N3707
TR3	BC108 or 2N3707

SPECIAL NOTES FOR OVERSEAS READERS

1) If you should experience any difficulty in obtaining any "DENCO" products locally, then these can always be obtained direct from the manufacturers, whose address is shown below:-

DENCO (CLACTON) LTD
355 - 359 OLD ROAD
CLACTON ON SEA
ESSEX CO15 3RH
ENGLAND

Tel: Clacton 22807

2) To help our overseas readers, the following list of possible semiconductor equivalents is shown below:-

BC107	CV9780, AM251, BC147-167-207-317, MPS6566, SK3020-3122, ZTX107, TT107, RS276-2003.
BC108	CV10541, AM252, BC148-168-208-318, MPS6520, SK3020, ZTX108, TT108, RS276-2009.
BF194	BF115-121-163-173-184-189-197-224-234-238-247B-594, G13694, MPS3694, SK3018, 40238, SE5056, 2SC460, 2N3694, RS276-2009.
BF195	BF115-125-163-185-196-173-225-235-237-273/D-595, G13693, MPS3693, SK3018, SE5056, 2SC535, 2N3693-3932, RS276-2009.
MFC 4000B	MC1306-1454-1524-1554, MFC6000-8010, SN76010.
OA81	AA117-118-132-144, AAZ15, OA91-95-161, SD38, IN38-56-476-618, 1S33, RS276-1136.
OA91	AA117-118-132-144, OA81-95-161, SD38, 1N38-55-63-617, RS276-1136.
OC44	CV5710-7003, OC170-171-410-613, 2N1303, BC126, ASY55, SK3005, 2N36-1191/2-1352-1373, RS276-2003.
1N67A	AA117-118-144, OA81-95, SK38, 1N618.
2N706	BSX19, BSY62/A, MPS706, 2N706A-964. RS276-2009.
2N3704	BC140-337/16, MPS3704, 2N2222, SK3024, RS276-2009.
2N3707	BC149-149B-167B-169B-173-173B-184-209-209B-237A-370, MPS3707-6520, 2SC458, SK3020, RS276-2009.

Although equivalent semiconductors may have similar electrical properties, physical dimensions may be different and this must be born in mind if space is tight and for mounting details. Remember polarities if replacing PNP with NPN types and vice versa. If in doubt always be advised by your local dealer for suitable equivalent semiconductors.

3) Wire Sizes - Nearest equivalent size is shown:-

S.W.G.	B & S	METRIC
24	23	5.5
26	25	5
28	27	4
30	28	3
32	29	2.8
34	31	2.4

4) Remember 1" = 25.4 mm

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