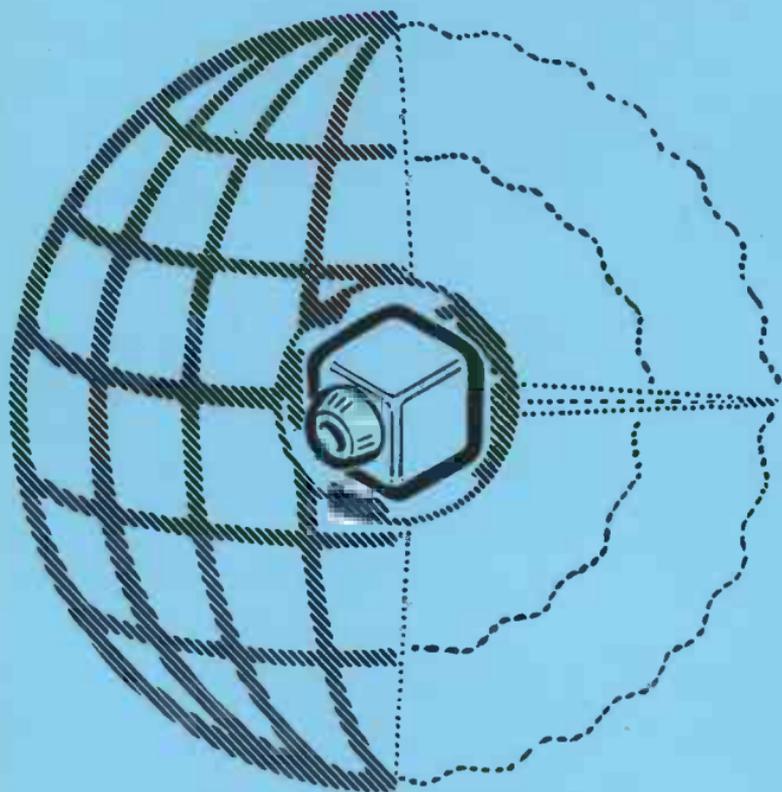


Shortwave receivers for the beginner

G. G. Dobbs



Calverton
Publications



SHORT WAVE RECEIVERS FOR THE BEGINNER

by
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INTRODUCTION.

To the casual listener, the short wave bands appear to be of little interest - a jumble of stations, mainly non-English speaking, oriental music wailing away, or the huss of incomprehensible morse code. But there is that band of keen listeners - Short Wave Listeners - to whom the short wave bands are a passport to the whole world. A little skill, rather more patience, and favourable conditions can enable even modest equipment to receive short wave transmissions from thousands of miles away. Short Wave Listening is a hobby enjoyed by thousands of people. S.W.L.'s come from all walks of life, all age-groups, and whether they be schoolboys, housewives or O.A.P.'s they all share the common enjoyment of exploring the world through the short wave bands.

There are many types of S.W.L. - some listen to Broadcast Stations - some listen to Radio Amateur Transmissions - some have expensive equipment. This book sets out to assist the S.W.L. by providing a range of simple practical short wave receivers, which can be built-up with little experience and the minimum of expense. It could provide a complete introduction to the hobby of short wave listening, or perhaps an already experienced listener can now enjoy the added thrill of hearing short wave transmissions on a receiver he has built for himself.

The book assumes that the reader can use simple handtools, and owns a small electrical soldering iron. The circuits are simple and relatively easy to get to work first time. The book also assumes a basic knowledge of electronic circuit symbols, but it is possible, using the layout diagrams, to build these receivers without being able to read electronic circuits. Follow the instructions with care and patience, and surprising results can come from these modest receivers.

DESIGN

The receivers in this book have been designed with the beginner in mind, therefore they are simple in terms of reliability and construction and so have their limitations. If it were possible to produce a first class short wave receiver for £5 - £10, then a lot of companies producing receivers in the £100 - £1,000 range would go broke! Naturally compromise is a keynote in these designs. They are straight forward, without innovation or marked originality, but they are designed to work with the minimum of trouble and will produce worthwhile results. However one cannot expect their performance to match up to expensive commercial receivers. The receivers will all work on Amateur and Broadcast Bands, but one must remember that the commercial stations of the Broadcast Bands use power far in excess of most amateur radio stations. All of these receivers give a good return in performance for their financial outlay, the final circuit being well within the class of many commercial receivers.

There are many criteria in short wave receiver design, but basically three problems have to be overcome:

1. Sensitivity.

This is the ability of the receiver to pick up weak signals. Many short wave signals are weak and require a sensitive receiver to make them intelligible. This is not a simple matter of increasing the gain (the amount of amplification the receiver gives the signal) because simply amplifying the signal will not only make the signal louder, but make any noise around the signal louder. The aim is to obtain a good "signal to noise ratio", that is receive the wanted signal without allowing it to be swamped by other signals and noise.

An added complication is the fact that receivers generate their own internal electronic noise, which adds to the received noise. Sensitivity is therefore a compromise and a complex problem in radio design. For the beginner it is enough to say

that "turning up the volume" is not the final answer to receiver sensitivity, because not only the signal becomes louder, so also does the received noise and the internal receiver noise. The use of volume and gain controls is part of the skill of short wave listening. One of the greatest aids to sensitivity is a good aerial system - this topic is discussed later in the book.

2. Selectivity.

This is the ability of the receiver to 'select' the wanted signal - to be able to sort out one signal on a crowded band. Both amateur and broadcast bands are tightly packed with radio stations and a reasonable receiver must be able to select, or tune the desired signals from the mass. This again, is a function of the receiver design which largely depends upon the number, and quality of tuned circuits in the receiver. The circuits in this book all use high quality commercial coils. It is possible to wind one's own tuning coils, but correctly designed commercial coils are a great asset in producing selective tuned circuits. Because many signals are so closely placed 'on the dial', some sort of slow-motion tuning or 'bandspreading' is also required - see the later section on *bandspreading*.

3. Stability.

Once the weak, closely packed, signals have been sorted out by the receiver, it is of little use if the receiver drifts off away from the required signal or fails to 'hold it'. A receiver has to be stable and maintain reception of the same signal. Stability is not only inherent in the design of the receiver, but is also affected by the actual construction of the receiver. A poorly built receiver using inferior components and untidy connections is likely to be unstable - if it works at all! A good receiver is usually firmly constructed inside a metal case, for stability and screening, using high quality components and good solder joints. All of these points are discussed in the next section.

CONSTRUCTION.

There is not the scope in a book of this kind to give a complete guide to electronic construction techniques. All of the receivers in this book have been built by the author - many of them several times - without the use of a workshop or expensive tools. The main working area is an old desk in a spare room, the tools used are inexpensive handtools, and a lot of the construction was done with a cat sitting on the author's lap! The following are a few hints which may prove helpful in building up these receivers. (First put out the cat...!)

1. CASES AND CHASSIS.

It has already been said that short wave receivers require stability and a great aid to stability is a good housing for the circuits. Also short wave and high frequency circuits often require electrical screening which can only be provided by metal casing. These factors have led to the receivers being built into aluminium chassis boxes.

These boxes have several advantages. They are readily available in a variety of sizes. Aluminium is an easy metal to work - all of the holes in the prototype receivers were made with hand twistdrill, with the biggest holes being enlarged with a small round file. Held in a small vice or with a G clamp, aluminium drills easily with a hand-drill. The larger holes required $\frac{3}{8}$ " $\frac{3}{4}$ " etc. can be made with a chassis punch. These are rather expensive and neat holes can be made with drill and small round file. Mark out the diameter required and either file from one drilled hole, or drill a series of small holes around the inside of the marked circle - knock out the centre and file into shape. The aluminium boxes are bought with lids, and these provide the front panels for the completed receivers.

COMPONENTS.

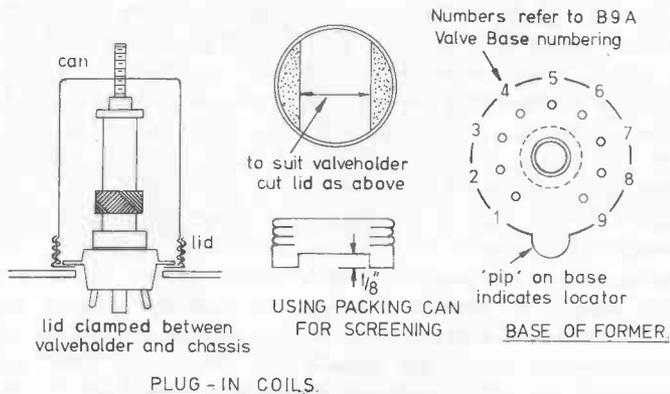
Needless to say, the electronic components used in high frequency radio work should be of good quality. Each circuit has a full list of components printed with the text. The constructor should attempt to obtain the exact values stated in the lists. In some cases the physical size of components may differ, but the receivers have been designed on a chassis which allows for the use of slightly larger or smaller sized components. The tuning capacitors should be good quality *air-spaced* types. The coils used in the receivers are from the Denco range of coils. This is a commercial range of plug-in coils available from many mail order electronics suppliers. The Denco coils are available in many combinations. There is a valve range, a transistor range, a number coding for frequency range, and a colour coding for the application of the coil within the circuit. Ensure that the *correct* coils are purchased by asking for the exact coil specified in the components list. The coils used in these receivers are ranges 3 to 5 giving a coverage of 1.67 MHz to 31.5 MHz, which represents the most useful short wave bands. The higher and lower ranges could be used, or the constructor may like to begin with only one range to cover a desired short wave spectrum. The coils fit into a B9A valve base, enabling coils from all ranges to be simply plugged into the receiver. The range of the coils is given in the table below. Full details of the coils are given in a leaflet supplied in the can with each coil. This can may also be used as a screen for the coils, see Fig. 1.

WIRING THE CIRCUITS.

A complete layout diagram is given for each part of the receivers, showing the suggested positions for the components and the connecting wires. The essential feature of wiring high frequency circuits is to keep the layout neat and the leads as short and direct as possible. A 'rat's nest' of wires is asking for trouble in short wave receiver construction.

The soldering should be neat and produce a good connection. Good soldering is a matter of practice, remembering the following points.

FIG. 1. DENCO MINIATURE PLUG-IN COILS.



RANGES TO BE USED

RANGE	FREQUENCY	COVERAGE
NUMBER	MHZ	METRES
3	1.67	180
	to 5.3	to 57
4	5.0	60
	to 15	to 20
5	10.5	28
	to 31.5	to 9.5

1. Use a small electrical pencil bit soldering iron and solder wire with a core of flux.
2. Clean both metal surfaces to be joined with a small file or glasspaper.
3. Make a good mechanical joint first, that is, join the wire to the tag so that it is firmly in place before the solder is applied.
4. Whenever possible tin the surfaces first. 'Tinning' is adding a thin film of clean solder to the surfaces - merely heat up the wire or tag and wipe some solder across it until a thin film of solder remains.
5. Apply the iron tip to the joint - NOT to the solder.
6. When the joint is heated, gently push the solder onto the junction. The solder should run with the heat of the joint.
7. Do not move the joint until the solder sets.

A good solder joint will look clear and shiny, if the joint is dull and grey it may be a 'dry joint' which will give a poor connection. If in doubt - resolder!

Avoid taking too long over soldering joints as the heat could damage components. Transistors can be damaged by heat from a soldering iron. It is a good idea to hold transistor leads with a pair of pointed pliers to conduct the heat away from the casing

BANDSPREADING.

The selectivity of a short wave receiver has been stressed. The Denco ranges are quite wide for one simple dial to give enough coverage space to make tuning easy for the listener. The tuning has to be spread-out; this is called *bandspreading*. There are two methods of bandspreading, electrical and mechanical, and both are used in the receivers in this book.

Electrical Bandspreading is a method of splitting up the whole tuning range covered by the tuning capacitor into segments. This is done by adding a tuning capacitor, with a very small value, across (in parallel) the main tuning capacitor. The small bandspread capacitor provides fine tuning of the section of the band being tuned by the main capacitor. This can be seen at it's simplest in the circuit of the one F.E.T. Receiver circuit (Fig.2.). The 350pF capacitor is used for the coarse tuning and the 10pF capacitor provides the fine tuning.

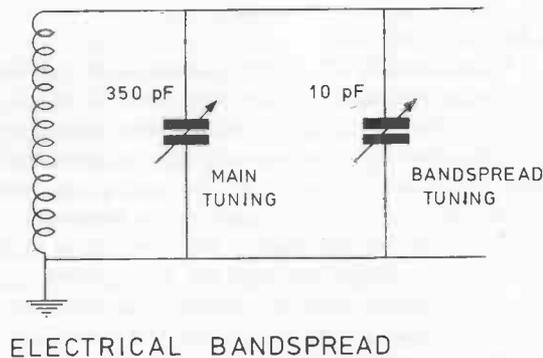
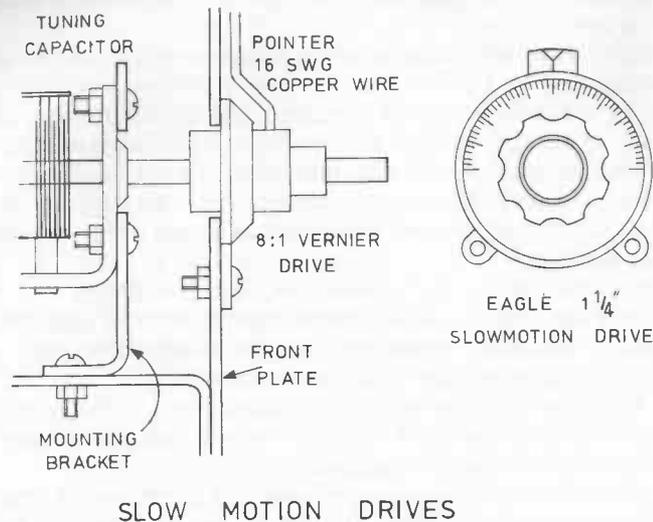


FIG. 2. BANDSPREADING

Mechanical Bandspreading is simply providing a way of turning the main tuning capacitor at a very slow rate. This entails the use of some form of gearing to drive the tuning capacitor spindle. There are many small inexpensive vernier drives that will reduce the turning rate of the spindle. Most of them have a ratio of 8:1, that is, 8 turns of the tuning knob produce one turn of the capacitor spindle. A well-known commercial range of slow-motion vernier drives, which are complete with a calibrated dial were used on the prototype receivers in this book. (see Fig.2.) It is possible to buy vernier drives without the dial. These are much cheaper and are mounted as shown in Fig.2. A pointer can be soldered onto the wide shaft of such a drive, and a home-made semi-circular scale can be mounted behind the pointer. (Fig.2.)

PRACTICAL RECEIVERS.

Any radio receiver has four basic tasks to perform:

1. It must pick up the electromagnetic Radio Waves coming from the transmitting station - this task is performed by the aerial.
2. It must select or *TUNE*, the required radio signal - this is done by one or more tuned circuits.
3. It must then convert the electromagnetic Radio Frequency (R.F.) waves into an electromagnetic sound or Audio Frequency (A.F.) signal - This process is called *DETECTION*.
4. Then the electromagnetic Audio Frequency signals must be converted into actual sound waves - This is performed by a transducer, such as a Loudspeaker or a pair of Headphones.

Fig. 3(a) shows the simplest radio receiver. The R.F. signal is tuned, detected and converted into an audio signal which can be heard in the headphones. The simple crystal set can form such a basic receiver. The simple crystal set has poor selectivity and sensitivity.

These disadvantages can be improved by a more sophisticated form of detection called *REGENERATION*. This is shown in Fig.3(b). This system feeds some of the detected signal back into the input of the detector stage. This simple system has several advantages. The signal is being passed

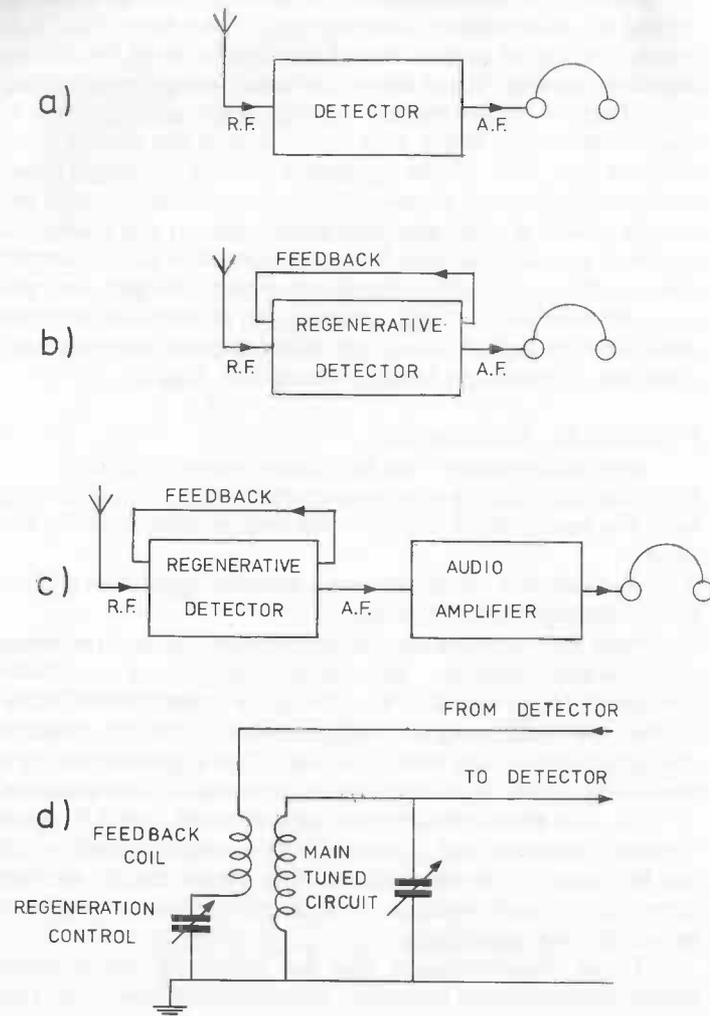


FIG. 3. PRACTICAL RECEIVERS.

through the detector stage again and being amplified, therefore increasing the sensitivity. A tuned circuit has a resistance which spoils its selectivity or 'Q'. 'Q' can be roughly defined as the 'goodness' of a tuned circuit. The feedback signal reduces the resistance losses in the tuned circuit. The tuned circuit has, therefore, a better 'Q' factor, and the receiver is more selective. Hence regeneration increases the selectivity of the receiver.

There are two difficulties in applying feedback to a detector stage. First the output from the detector is 'out of phase' with the input, and for any gain to be made by feedback the phase must be changed to match the input - this is called Positive Feedback. The problem is solved in the method of feedback. Feedback is applied to the input through an additional winding on the tuned circuit coil, and the winding is arranged to give positive feedback. Fig.3(d) shows how the feedback winding is arranged in relation to the main tuned circuit coil winding.

The second difficulty is that if too much feedback is applied to the input, the receiver will oscillate. That is, the signal will continue to go round and round in the detector stage, acting like a little transmitter, producing only a howling audio sound. This may be prevented by controlling the amount of feedback applied to the detector input. This is done by using a variable capacitor, actually called the 'Regeneration Control'. This is also shown in Fig.3(d).

Fig.3(b) shows the basic regenerative receiver. This simple arrangement can provide a useful short wave receiver. It is reasonably sensitive and selective, dependent upon the control of the level of regeneration, and a direct audio output can be taken from the detector with a pair of headphones.

The audio signal will be, rather low, but loud enough to drive the headphones for many short wave stations. Fig.3(c) shows the same arrangement, with an audio amplification stage added to give more sound output. This type of receiver can give quite surprising results on the short wave bands. If enough stages of audio amplification are added, the receiver will then drive a loudspeaker.

THE ONE F.E.T. RECEIVER.

The circuit diagram in Fig.4. shows about the simplest receiver with which one can obtain reasonable results on the short wave bands. The receiver uses one stage of regenerative detection, and gives good headphone reception of a wide range of short wave transmissions. The circuit uses easily available components and the reliable Denco range of plug-in coils. The circuit, being transistorised requires only an inexpensive 9 volt battery as a power supply. The transistor used is a Field Effect Transistor, a relatively recent development in transistor technology. The Field Effect Transistor - usually called the F.E.T. - has very similar characteristics to the radio valve. In fact this circuit is very much like the short wave receivers of the regenerative type which were, and indeed still are, used by many Short Wave Listeners. The F.E.T. used in this circuit is the common MPF102 type. The slightly cheaper 2N3819 may work in the circuit, but the operating characteristics of the 2N3819 vary so widely, as to make it's use dubious,

The signal is received from the aerial into to input coil winding L2. The desired station is tuned by the tuned circuit L1/VC1. The signal is then detected by the MPF102, by the method called 'leaky grid' detection in the old valve circuits. TR1 is biased by R2/C2 and the detected signal appears at the output of TR1.

F.E.T.transistors have three lead-outs called *SOURCE*, *GATE*, and *DRAIN*. These are marked on the circuit as s.g.d. The arrangement of the wires coming from the base of the MPF102 is shown at the side of the circuit diagram. It is most important that these leads are not confused. In the MPF102 the order of the leads does not follow the source - gate - drain sequence found in many F.E.T.'s.

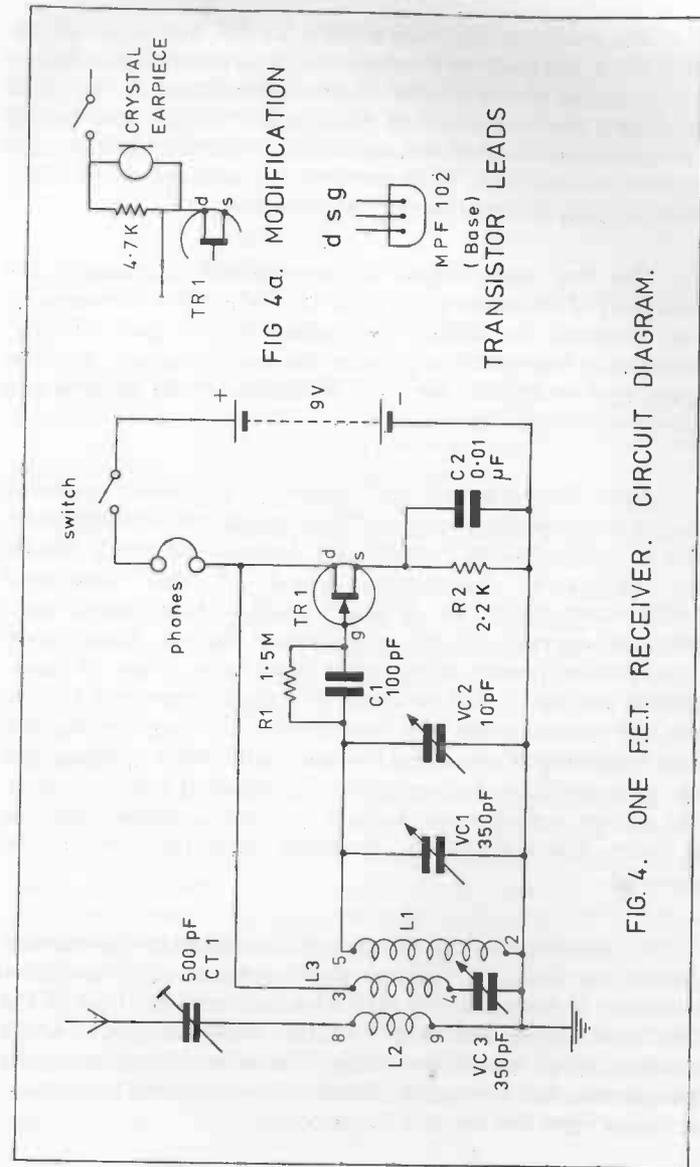


FIG. 4. ONE F.E.T. RECEIVER. CIRCUIT DIAGRAM.

The detected signal appearing at the drain lead of the MPF102 is fed back to the detector input via the coil winding L3. Because of the phase change mentioned earlier, it is important that the wires on L3 are the correct way round. This presents little problem since the pin numbers indicate the correct connections. VC3 controls the amount of regeneration applied to the input of the detector.

The fed back signal is re-amplified, increasing the sensitivity of the receiver, and the 'Q' of the coil is increased by the feedback increasing the selectivity. A pair of high impedance headphones provide the audio output, and the drain load resistance for TR1. A simple 9 volt battery and switch complete the circuit.

Apart from the coils and transistor, the most expensive item in the receiver is the pair of High Impedance Headphones. The common 'stereo headphones' found in so many homes are suitable for this circuit. A pair of high impedance headphones (resistance of about 2,000 or 4,000 ohms) are a good investment for the short wave listener. Even when Loudspeaker power radios have been built, a set of headphones are useful. Not everyone wishes to share your hobby, and with headphones, only one person can hear the signals. Also headphones are useful for hearing the weak stations and can be a real aid to concentration by reducing outside noises. The author, a short wave listener and radio amateur operator of many years standing, invariably uses headphones for listening.

If cost is an inhibiting factor, it is possible to use a cheap crystal earpiece to replace the headphones. The circuit alteration is shown in Fig.4(a). This earpiece must be of the CRYSTAL type, which is not the usual earpiece which matches small transistor radios. These earpieces are quite inexpensive, but the results cannot be expected to be as good as those from the correct headphones.

ONE F.E.T. RECEIVER - COMPONENTS LIST.

R1.	1.5M ohms ¼ or ½ watt
R2.	2.2K ohms ¼ or ½ watt
C1.	100pF Silver Mica.
C2.	0.01uF Disc Ceramic.
VC1.	300 - 350pF Variable Air-spaced Capacitor - see text.
VC2.	As VC1.
VC3.	10 or 20 pF Variable Air-spaced Capacitor.
CT1.	500pF Trimmer Capacitor.
TR1.	MPF 102 F.E.T. Transistor.
PHONES.	High Impedance type - see text.
L1, L2 and L3.	Windings on Denco "Dual Purpose", Valve Type. GREEN Coils - Range according to chart.
HARDWARE.	Aluminium Chassis Box (4" x 5 ¼" x 1 ½"), S.P.S.T. Toggle Switch, Eagle 1 ¼" vernier Dial and Drive (or similar) B9A Valve-holder, 6 Way Tagstrip, Phono Socket, Phone Jack-Socket (Fully Insulated type), PP3 Battery, Battery Snap-connector, Two Knobs, Terry Clip, Misc, 6 BA nuts and bolts and Solder tags, Connecting Wire (P.V.C. Covered).

NOTES:

VC1 and VC2 are likely to be the most expensive, and perhaps difficult to obtain, components. 500pF capacitors may be used as suggested in the text. It is also possible to use surplus two-gang 500pF Tuning Capacitors salvaged from small radio sets. In such a case only the front set of vanes are used and modified to 350pF, and extra space must be allowed on the top of the chassis.

It is also possible to obtain surplus 250 + 250pF two gang tuning capacitors. These may be used if a link wire is soldered between both sets of fixed vanes to convert to a 500pF component.

CONSTRUCTION.

The One F.E.T. Receiver is constructed on the aluminium chassis as shown in Fig.5. The base of the box forms the mounting chassis for the components, with the lid serving as a front panel. This front panel is held onto the chassis by two 6BA bolts mounted about $\frac{1}{4}$ " from the edge of the panel and about 1" from the bottom of the panel. A number of holes have to be made in the chassis and front panel for the components and controls. The exact dimensions have not been given, because these may depend upon the actual sizes of the variable capacitors. The drawing in Fig.5. will give an indication of the layout and relative spacing of the components.

Before any holes are drilled, the constructor should place the components in their relative positions. When they are in suitable places, the positions for the holes can be marked out with a soft pencil. The final positions will probably be a compromise between a symmetrical appearance and convenience of mounting the controls.

For many electronic constructors, the most irksome task of any project is the metalwork, and mechanics of chassis and case construction. This project is relatively simple to construct, even with basic hand-tools. The most difficult task is the mounting of the main Tuning Capacitor VC1 onto a bracket in line with the slow motion drive. Care must be taken to line-up the capacitor mounting bracket with the drive shaft, and to mount the capacitor firmly. The capacitor mounting should be firm enough to prevent 'backlash' - lack of instant response to the movement of the knob. Short wave tuning requires both a steady hand and firmly mounted tuning capacitors, if stations are to be selected with ease.

The required capacitor for VC1 is a 350pF Air-Spaced component. Any capacitor in the range 300 to 350pF will perform the task, a good component for this use is the Jackson Bros. Ltd Type 4507, which could also be used for the Regeneration Control. If such a capacitor is difficult to obtain, a 500pF Air-Spaced component is common, and may be used with the circuit modification in Fig.5(a). A 1000pF (0.001uF)

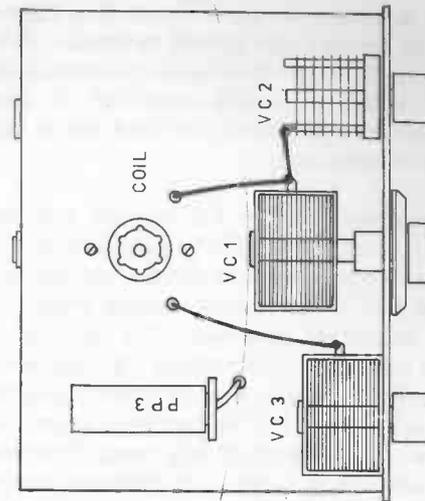
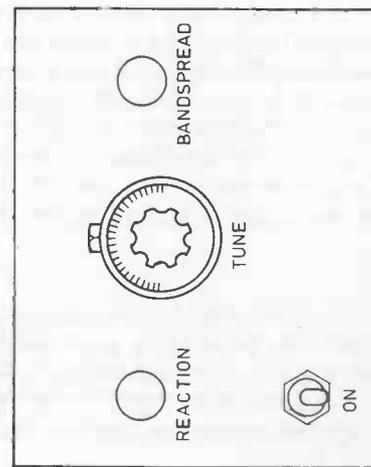
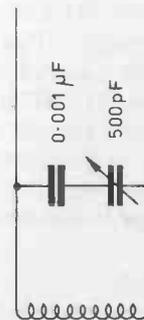


FIG. 5. ONE F.E.T. RECEIVER



TUNING MODIFICATION FIG 5a

Ensure that the capacitors VC1. and VC3. go to the correct pins on the valve base, and that VC2. is wired in parallel to VC1. In each case the earth return point for the variable capacitors is made through the frame of the capacitor (moving vanes) and the mounting to the front plate or chassis.

The under chassis wiring is shown in Fig.6. This is quite simple, being mainly centred around a 6 way tag strip. Begin by making the earth connections, as these are the connections most easily forgotten. It is common practice to use solder tags placed under the valve base nuts for such connections, but an economical method is to make one's own tags from 30 amp fuse wire. The wire is wrapped around the bolt, leaving enough spare end to form a solder anchoring point. The nut is then screwed down onto the wire.

The next stage is to wire in the various resistors and capacitors checking each connection against both circuit and layout diagram. Trim the component leads to ensure a short path between the connections. The switch and battery clip-connector, CT1 and the aerial socket and the phone socket are then wired into place.

The final component to be soldered into place should be the transistor. Transistors can be damaged by heat, so their wiring is best left until the other solder connections have been made. The author has never yet lost a transistor by soldering it into place, although it is quite possible to damage transistors with the heat from a soldering iron. The joints should be made quickly and, if possible with a heat sink - this a piece of metal held onto the lead of the transistor as it is soldered. It is possible to buy small 'heat sinks', but usually holding the lead with the end of a pair of pointed pliers will do the trick. The secret is to make a good clean solder joint in the fastest possible time.

Before the receiver is switched on, or even the battery is connected, check all the wiring carefully. Follow both circuit and layout diagrams from aerial to battery. Then check that the correct pins have been used on the valve base, and the leads on the F.E.T. transistor are correct. Is the coil plugged in? Then the receiver is ready for testing.

OPERATING THE RECEIVER.

This receiver will require an aerial - see the section on aerials later in the book. Connect a suitable aerial to the receiver. If coil ranges 3 or 4 are being used an earth connection may also help reception - again see the section on aerials. Now the basic test can be applied to the receiver.

Set the main Tuning Control (VC1.) about half open, fully open the Regeneration Control and switch on. A faint click, followed by a low hissing sound should be heard in the Headphones. Slowly close the vanes of the Regeneration Control into the fixed plates and at one point a sudden 'rushing' sound followed by a loud howl should be heard. The howling indicates that the feedback has reached the point where the detector has begun to oscillate. It is the control of this point that is the secret behind the correct use of a regenerative receiver. If the receiver does not howl, then check ALL the wiring again, especially the connections to the base pins of the coil holder. Is the battery connected the wrong way round? Once oscillation can be achieved, the skill of using a regenerative receiver can be learned. Regenerative receivers are not as easy to operate as many other forms of receiver, but once the basic skills have been mastered, amazing results can be achieved from these simple circuits.

The basic skills in the operation of a regenerative receiver lie with the correct and careful use of VC1, VC2, and VC3. The receiver will require a reasonable aerial for worthwhile reception. The aerial is coupled to L2 via CT1. The trimmer CT1 is added to the circuit as an additional precaution, and could, with some receivers be omitted. Sometimes the aerial of a regenerative receiver will inhibit it's ability to accept smooth feedback control, and CT1 provides a degree of isolation between the receiver and the aerial. The importance of CT1 will vary from band to band, and depend upon the type of aerial. Begin by using CT1 screwed about three-quarters of the way in, and experiment until the best reception conditions are obtained.

It could be found that a direct wire between the aerial and the pin 8 of the coil produces the best results - aim for the situation which produces the best control of regeneration for the aerial in use.

VC1 is the main tuning control, the complete 'swing' of this capacitor should give the full coverage of the range of the coil. The actual range covered by the coil can also be slightly modified by the setting of the dust core within the coil. This is controlled by the small screw on the top of the coil former. Again the setting of this screw is subject for experimentation, but the prototype receivers appeared to cover the correct range with the screw set about $\frac{1}{4}$ " out of the top of the coil former. The slow motion drive aids the tuning of the main tuned winding L1, to the desired frequency.

VC2 is the Bandsread Control. This control 'expands' a small portion of the Main Tuning control, and enables a finer selection of stations to be achieved. The Main Tuning control will select the area of the band to be tuned, and the Bandsread Control will sort out the closely placed stations. The author finds the most convenient way to use the Bandsread control is to begin with it set at about half-mesh, and when the Main Tuning control has been used, the Bandsread control can finely tune either side of the main setting.

The most important control for correct use of a regenerative receiver is the Regeneration Control, VC3. The skillful use of this control is the key to the success of the operation of the receiver. The initial testing of the receiver showed that this control can cause the receiver to oscillate. The oscillation (a howling sound) occurs when the Regeneration Control is set too high.

To receive normal modulated signals the Regeneration Control should be advanced until oscillation occurs and then slowly retarded until the oscillation ceases and the signals are at maximum volume. At this point the receiver will also be in its most selective state. For reception of morse or single-sideband signals the regeneration control must remain just over the point at which the oscillation occurs.

The actual setting of the regeneration control will vary with the tuning of the receiver, and the operator has to learn the art of using both controls to receive the required signal at optimum strength. Although the regeneration does control the sensitivity of the receiver, it should not be regarded as a volume control.

If the regeneration is advanced when tuning to a part of the band which contains no signals or very weak signals, the oscillation will be heard as a rushing sound, rather than a howl. Regenerative receivers do require some skill in use, but with a little practice the use of the controls becomes natural.

As already stated, such a simple receiver requires an aerial, and on some short wave frequencies, an earth is also useful. The earth is more important on the lower frequency bands - Range 3 with this receiver. The use of an earth is discussed later in the book, in the section dealing with aerials.

HINTS.

The One F.E.T. Receiver is a straight forward design based upon a form of circuit in use since the 1920's, so little difficulty should be experienced in getting the receiver to work. However regenerative receivers are 'fickle beasts'.

If the circuit has been wired correctly, the only likely problem may be the control of the regeneration process. The receiver may either oscillate over the entire range of the regeneration control or (less likely) not oscillate at all.

The regeneration point may be altered either by changing the value of the regeneration control capacitor or altering the gain of the whole F.E.T. stage. If oscillation cannot be stopped at any setting of the control - try using a smaller capacitor (say 100pF) as a regeneration control. The value of R2 could also be increased, perhaps to 10K, to reduce the gain of the stage. If the receiver refuses to oscillate at any setting of the control, the obvious fault is that pins 3 and 4 of the regeneration winding may be the wrong way round, giving out of phase

feedback. Failing this try reducing the value of R2, perhaps to 1K, but do not reduce R2 below about 100 ohms. The final resort is to try another F.E.T.

The receiver has been built up several times, with various combinations and makes of component, and no trouble has been encountered in any of the prototypes.

THE F.E.T. PLUS ONE RECEIVER.

The basic One F.E.T. Receiver provides adequate head-phone reception of a wide range of short wave transmissions. Prototypes have picked up many international broadcast stations and many amateur morse and single side-band transmissions. Referring back to Fig. 3(b), additional audio amplification is an asset when attempting to listen to the weaker signals. The F.E.T. PLUS ONE RECEIVER represents an addition to the ONE F.E.T. RECEIVER to give extra Audio Amplification. This circuit will enable the listener to hear many more stations in comfort.

CIRCUIT OPERATION.

The circuit diagram of Fig.7. shows the F.E.T. detector with it's added audio amplification stage. The named components are those which are required in addition to the One F.E.T. Receiver. The Headphones are replaced by a Radio Frequency Choke (CH1) and a resistor (R3) load. The signal appearing at the junction of CH1/R3 is fed through the capacitor C3 to the base of the amplifying transistor (TR2). This transistor amplifies the audio signal, which appears at the collector and is heard in the Headphones. The same High Impedance Headphones (or the modified crystal earpiece of Fig.4(a).) are used in this circuit. The resistor R4 provides the base bias to give the correct amplification action of the BC109. The switch and the 9 volt battery are the same components used in the One F.E.T. Receiver. A BC108 transistor also performs well in this circuit, and the base diagram for the transistor applies to either type.

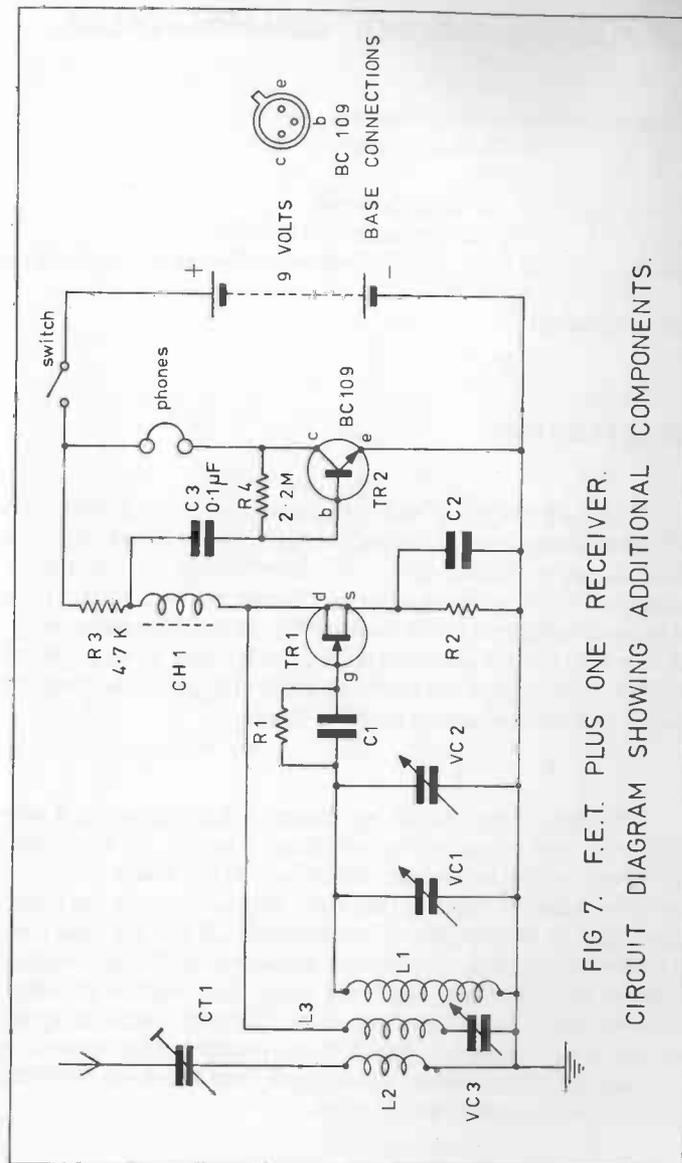


FIG 7. F.E.T. PLUS ONE RECEIVER.
CIRCUIT DIAGRAM SHOWING ADDITIONAL COMPONENTS.

F.E.T. PLUS ONE RECEIVER - COMPONENTS LIST.

Additional components required :

R3.	4.7K $\frac{1}{4}$ or $\frac{1}{2}$ watt.
R4.	2.2M " " "
C3.	0.1uF Disc Ceramic
TR1.	BC109 Transistor (or BC108)
CH1.	2.5mH Radio Frequency Choke (1.5 to 5mH suitable)

6 Way Tagstrip.

CONSTRUCTION.

The layout for the audio stage is shown in Fig.8. All of the additional components around the BC109 are wired onto the added tagstrip. This tagstrip is placed close to the phone socket, with the extreme right tag firmly earthed to the B9A valve base fixing bolt at the back of the chassis. It was found in practice that a thick earthing wire (30 amp fuse wire) soldered between this tag and the earthing solder tag provided enough rigidity to hold the whole tagstrip in place.

CH1 and R3 are wired, as shown, on the existing 6 way tagstrip, in the place of the headphone leads. An important wire to remember is the lead which carries the 9 volt + supply from the detector tagstrip (tag from the switch) to the audio stage tagstrip (tag to phone jacksocket). C3 and R4 may now be soldered in place. Finally the transistor (TR2) is carefully soldered to it's three tags. As with the original receiver, carefully check over the wiring using both the circuit diagram and the layout diagram *BEFORE* connecting the battery or switching on the receiver. Also check that the base connections of the transistor are correct.

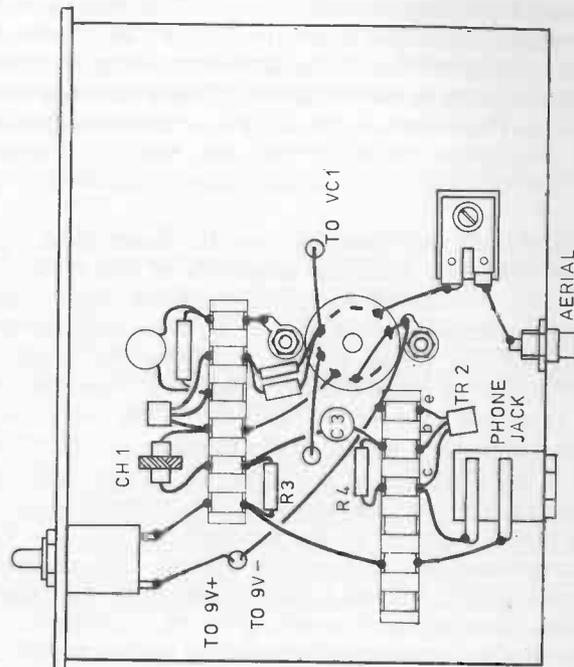


FIG 8. F.E.T. PLUS ONE RECEIVER. LAYOUT ADDITIONS.

OPERATING THE RECEIVER.

The use of this receiver is basically the same as the One F.E.T. receiver, except that one will hear more stations and many stations will be much louder. This calls for an even more careful use of the Regeneration Control. The change in the loading resistance in the drain circuit of TR1, from the Headphones to CH1/R3 will also alter the point at which the regeneration occurs at each frequency. This should not cause any problems. Regeneration should be easy to control over the whole of every range. If this is not the case, the HINTS section dealing with the One F.E.T. receiver should provide a cure.

Since many more stations may be heard, and some stations will be quite loud, the selectivity of this receiver is important. As mentioned earlier in the book, regeneration increases the selectivity of the receiver, by increasing the 'Q' or 'goodness' of the tuned circuit. It is vital for optimum selectivity that the regeneration control is handled with extreme care. The best position is *JUST* under the point of oscillation for normal A.M. Broadcast Stations and *JUST* over the point of oscillation for morse or single side-band transmissions. The best method is to 'over shoot' the control and very slowly back off to the required position. So for a normal broadcast station turn the control until oscillation occurs and *VERY SLOWLY* turn back until the station emerges as a clear signal. The setting for the regeneration will not only vary as one tunes across the tuning range, but stronger stations will require less regeneration. It is a question of a simple skill backed up by a little practice to produce the best results from this receiver.

The receiver is capable of surprising results. One prototype received amateur signals - which are much weaker than Broadcast Stations - from three continents on the 14MHz Band. The same receiver picked up local broadcast stations from North America using low power, and many English transmissions from Iron Curtain Broadcast Stations.

THE F.E.T. PLUS I.C. LOUDSPEAKER RECEIVER.

The receivers described so far in this book are only suitable for Headphone listening. The F.E.T. Plus I.C. Receiver will provide loudspeaker output from most of the signals which can be received by the F.E.T. Plus One Receiver. Apart from the advantage of more than one person being able to listen to the receiver, the listener is not "attached" to the radio by the headphone leads.

This additional circuitry introduces two ideas; the use of an I.C. and construction on veroboard. An I.C. is an INTEGRATED CIRCUIT. A whole book could be, and many have been, written on what integrated circuits are, and the various tasks they can perform. Basically the I.C. is a very small package which performs the task of a larger number of conventional components. In fact 'normal' components are now often called *DISCREET COMPONENTS*, to distinguish them from integrated components.

The I.C. used in this receiver will perform the task of a complete audio amplifier capable of delivering about a quarter of a watt of audio output to a loudspeaker. All of this is done by a small black block, measuring no more than $\frac{1}{4}$ " by $\frac{1}{8}$ ", aided by a handful of discreet components. The I.C. is the MFC 4000B and an idea of it's appearance can be gained from Fig.9.

Veroboard is a construction medium readily available to the home constructor, which allows a method of construction similar to the familiar printed circuit boards universally used in domestic radio and television sets. Veroboard is brown plastic board, with a matrix of holes, with copper strips on one side joining alternate rows of holes lengthwise across the board. The board is available with matrix spacings of 0.1" and 0.15" and a variety of sizes from most component stockists. The speaker amplifier in this receiver uses a small piece of 0.1" matrix board. Veroboard requires careful soldering using a soldering iron with a small bit.

CIRCUIT OPERATION.

Fig.9. shows the circuit diagram of the I.C. speaker amplifier attached to the audio stage of the F.E.T. Plus One Receiver. The headphones have been replaced by R5. The audio signal passes from the junction of TR2/R5 to VR1. VR1 is a variable resistance which acts as a volume control by allowing all or part of the audio signal to pass to C4.

The audio signal passes via C4 to the input of the I.C. where further amplification takes place. The output pin (4) of the I.C. delivers a strong audio signal, which is coupled through C6 to drive the small loudspeaker. Only three further components are required for the I.C. circuit. C5 reduces any high frequency signals which could cause instability. R6 provides negative feedback to the input of the I.C. to stabilise it's operation, and C7 acts as a decoupling capacitor, preventing high frequency signals entering the supply line (pin 3) of the I.C.

The small circuit line consisting of C8 and the phone socket is an optional extra to the circuit. This allows the phones to be used, if still required, in addition to the loudspeaker. C8 taps off the audio signal from TR2 and feeds it to the phone socket. This circuit line could be left out, but the use of one component (C8) allows the existing phone socket to remain in use.

This circuit uses ELECTROLYTIC CAPACITORS, C6 and C7, and special care must be taken in their wiring. These capacitors are polarized, that is, they have a positive and negative lead, and these must be wired into the circuit the correct way round. The positive (+) lead may be marked with a + sign, and the negative (-) lead may have a black line printed around the body of the capacitor at that side. Many tubular electrolytic capacitors, with a lead at either end have a ridge running around the casing at the positive end. If in doubt, ask the component dealer, or an experienced constructor about the polarity.

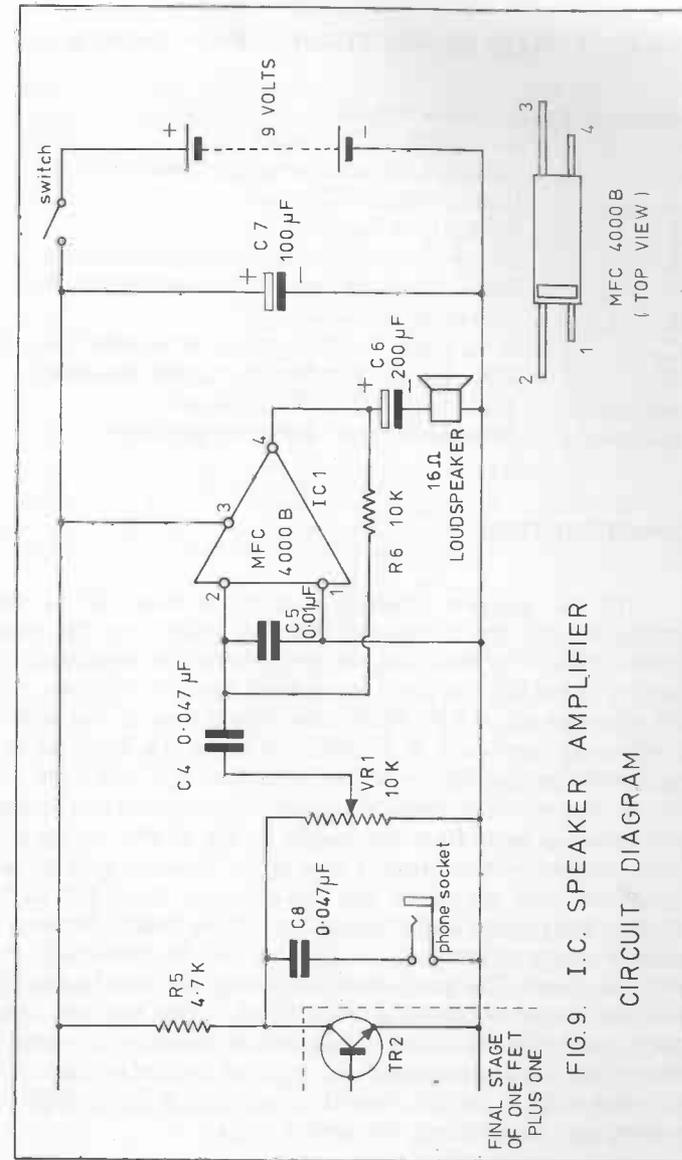


FIG. 9. I.C. SPEAKER AMPLIFIER
CIRCUIT DIAGRAM

THE F.E.T. PLUS I.C. RECEIVER - COMPONENTS LIST.

Additional Components required:

R5	4.7K ohms ¼ or ½ watt
R6	10K ohms ¼ watt (small size preferred)
C4	0.047uF Mica or Ceramic
C5	0.01uF Disc Ceramic.
C6	200uF 16volt (or more) working Electrolytic.
C7	100uF 16volt (or more) working Electrolytic.
C8	0.047uF Mica or Ceramic.
I.C.1.	MFC 4000B Audio Amplifier Integrated Circuit.
VR1.	10K Log. Variable Resistor (potentiometer)
Veroboard.	1.3" x 0.6" of 0.1" Matrix board.
Loudspeaker.	Small (2¼" dia) 16 ohms impedance.

CONSTRUCTION.

The I.C. speaker amplifier is built up as a unit on the veroboard, and the completed board is added into the main chassis later. The first stage is to prepare the veroboard. A piece of board is cut to allow the use of 5 holes by 13 holes - this will measure about 1.3" x 0.6". The board may be cut with a sharp small hack-saw. It is useful to score the lines on the copper clad side with a marking knife first, and cut from the copper clad side. This helps to prevent the edges of the copper strips pulling away from the board. In Fig.10 the matrix has been marked with a number and letter location grid to aid identification of each hole. For this circuit, a break has to be made in the copper strips across the whole board, forming a break in every strip along line G. This can be done with the small hack-saw. The saw is held level along the line of holes (G) and the copper is carefully sawn away. When this has been done check that the edges of adjacent strips are not touching where they have been sawed. If a strip has twisted and touches the next strip, it can be moved by running a knife edge (or screwdriver edge) along the plastic track.

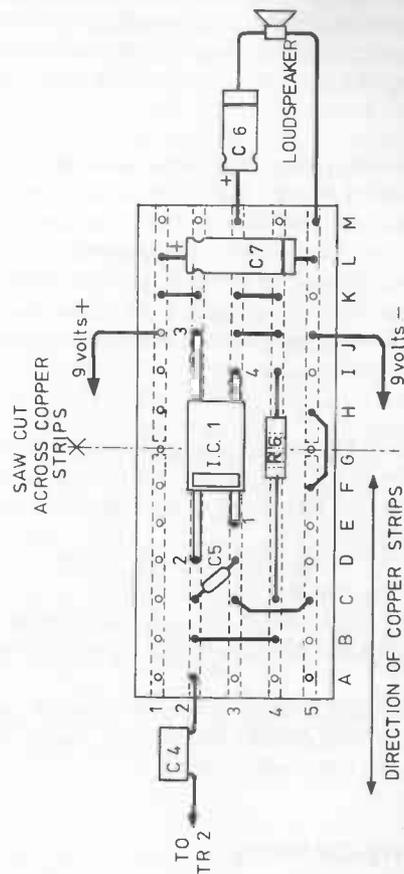


FIG. 10. I.C. AMPLIFIER - VEROBOARD LAYOUT (PLAINSIDE).

Soldering veroboard is not difficult if the board is clean (rub to a shine with fine emery paper) and a small soldering iron bit is used to make quick neat joints. Avoid holding the iron on the board longer than required to make a good joint, and avoid using too much solder. Both of these faults may cause excess solder to run along the copper track and fill other holes.

Begin by soldering the link wires which join various parts of the veroboard strips - there are six such wires. Each time a joint is made, trim off any excess lead on the copper side. Naturally all the components are mounted on the plain side, and the joints soldered on the copper side. Next solder in R6, C5 and C7, leaving enough space to place the I.C. into position. The I.C. can now be soldered into place, as if it were a transistor.

Finally, the leads for the 9 volt supply and the capacitors (C4 and C6) for the input and output may be added. At this stage the whole circuit board must be checked carefully to ensure the following:

1. the board matches the circuit diagram, Fig.9.
2. the board matches the layout plan, Fig.10
3. the I.C. pins are soldered in the correct places and the electrolytic capacitors are wired with the correct polarity, Fig.9 and Fig.10.
4. none of the adjacent copper tracks are joined by excess solder. When all of these checks have been made, the board can be mounted into the main chassis

WIRING INTO THE CHASSIS.

The position of the I.C. Amplifier Board in the main chassis is shown in Fig.11(a). This drawing shows all the components used in connection with the I.C. stage, but omits, for simplicity, the components already wired into place in

previous stages. The board could be bolted into place, but in the prototypes it was held in place by the plastic adhesive material - "Blutack". This is a plastic substance, like modelling clay, which has adhesive and insulating properties. A piece of Blutack about the size of a small walnut is softened in the hands, pressed onto the chassis, and the veroboard is pressed gently into it. This not only holds the board in place, but also insulates it from the chassis. This actual operation is probably best left until after all the connecting leads have been soldered into place.

The headphone circuit, if required, presents little problem. C8 is mounted to the spare tag on the audio tagstrip, and an earthing bolt (6BA) with a solder tag is mounted in a hole drilled close to the phone socket. The lead between the collector of TR2 and VR1 is a screened lead - television coax cable was found to be ideal for this purpose. An unscreened lead was also tried with no ill effects. The outer screening of the lead is soldered to the earth tag on the B9A holder. The inner lead has to be made long enough to reach the collector tag of TR2. The other end of the lead is connected across the outer tags of the volume control (VR1), if they are connected in the opposite way to that shown in Fig.11(a) this control will work in reverse. Care must be taken to ensure that the inner and outer connections of the screened lead do not come into contact and short out the signal.

C4 will probably require an extension wire to reach the centre pin of VR1. The supply leads are then connected to the I.C. board. The output leads to the speaker go through a small hole in the chassis to the speaker which is mounted above the chassis.

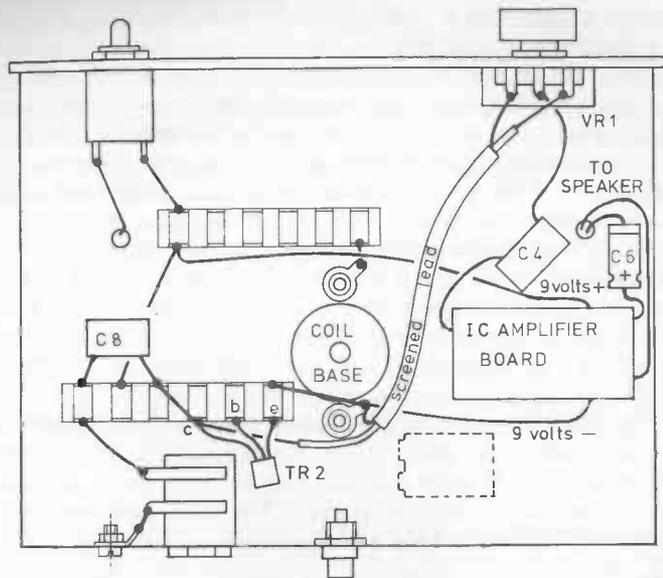


FIG 11(a). UNDER CHASSIS LAYOUT.

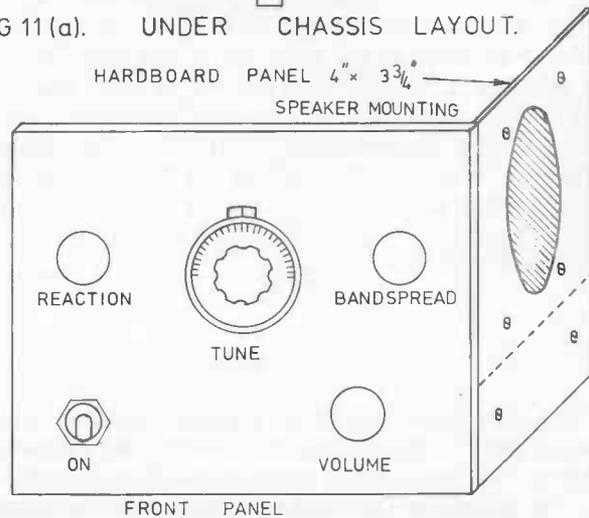


FIG 11(b) F.E.T. PLUS I.C. RECEIVER

CONSTRUCTION ALTERATIONS.

Adding the I.C. amplifier requires making a few small alterations to the chassis. Any drilling and filing done during these changes must be done with care to avoid spoiling existing wiring. A hole must be made through the front panel and chassis to hold VR1 and a small hole is required in the chassis top for the speaker leads. The loudspeaker on the prototype was mounted on a hardboard sidepanel. This panel (4" x 3 3/4" x 1/8" hardboard) is bolted with two 6 BA bolts to the side of the chassis case as shown in Fig.11(b). A hole is cut in the board to allow the sound from the loudspeaker free access. The size of this hole and the mounting of the speaker will depend upon the actual loudspeaker used for the receiver. Although a 16 ohm loudspeaker is advised, the circuit will work with an 8 ohm impedance type.

When all the electrical and mechanical connections have been made, the whole circuit should be checked in the usual manner before applying the 9 volt power. Although the original PP3 battery can be used, the IC will draw more power, and if desired a longer-life battery, for example a PP9 may be used. This will require a different method of mounting and matching guitar battery connector.

OPERATING THE RECEIVER.

With the F.E.T. Plus I.C. Receiver, the instructions about use of regeneration for the other receivers also applies, but with the added complication of a volume control. The regeneration control should be used in the same careful manner to ensure the optimum operating point. The inclusion of an audio gain (volume) control aids the ease with which the receiver can select and hold individual stations, in spite of having to contend with another control knob.

When seeking stations it is probably best to have the volume control set about $\frac{3}{4}$ high and to follow the careful procedure for operating the tuning and regeneration controls. Weak stations can be aided by turning the volume control higher. Strong stations can, with this receiver be set to the optimum regeneration setting to give maximum selectivity, and the volume can be reduced with the volume control.

Once again this requires a little practice, but the receiver will be found to be very flexible in use. The temptation to use the regeneration control as a volume control, thus affecting selectivity, is not long present, since VR1 will control the audio output to the speaker. Use the regeneration control to obtain maximum sensitivity and selectivity. If the volume has to be reduced use VR1. It is also better to obtain the maximum sensitivity from the detector stage, because if VR1 is turned up to overcome a weakness in signal, the noise level in the receiver will also increase. The I.C. generates a small amount of internal noise (a slight hiss) and the higher the volume control is set, the more this will be heard.

The headphone socket has been left in for private listening, but it is also possible to place headphones *after* the I.C. amplifier. These should be LOW IMPEDANCE headphones.

THE AERIAL AND EARTH.

Apart from the actual receiver, the aerial system is the most important part of any Short Wave Listeners equipment. Without an adequate aerial system, even the most expensive short wave receiver is incapable of good results. The aerial picks up the signals, and if little or no signals are picked up by the aerial, the receiver is useless. This does not imply that a massive array of wires is required, but careful consideration must be given to providing the most adequate aerial that circumstances permit.

The simplest aerial to use is a *LONG WIRE* aerial. This is merely a length of wire, one end of which is plugged into the aerial socket. Such a wire could be from 20 to 150ft long, any cheap copper wire, covered or bare can be used. A simple rule of thumb for a long wire aerial is to have it "as long as possible, and as high as possible". A good arrangement is shown in Fig.12(a). This type of aerial is sometimes called the *INVERTED L*, a good length for general short wave usage being 66ft. The far end can be attached to a pole, or a convenient tree, or even a friendly neighbour's house.

Failing this, try to run a length of wire around the loft of the house (avoid placing it close to electrical cables) then through the eaves into the window of the receiving room. If the receiver is being used in a downstairs room, a basic aerial could be a wire from the roof eaves running down to the receiver. This was tried with a prototype of the One F.E.T. Receiver, and a wide variety of stations were received.

There are many sophisticated aerial systems which can be employed, but these are outside the scope of this book. Some aerials are resonant, that is, they work best at a selected frequency. About the simplest of such aerials is the *DIPOLE*, or doublet aerial. This is a horizontal (if possible) wire, tuned to a certain length, and divided in the centre, being fed with two wires. See Fig.12(b). A dipole is usually connected to screened coax (television type) cable, but it is possible to use simple twisted wires between the dipole and the receiver. The overall length of a dipole controls its optimum operating frequency, this length can be worked out from the simple formula:

$$\text{Overall length in Feet} = \frac{468}{\text{Frequency in MHz}}$$

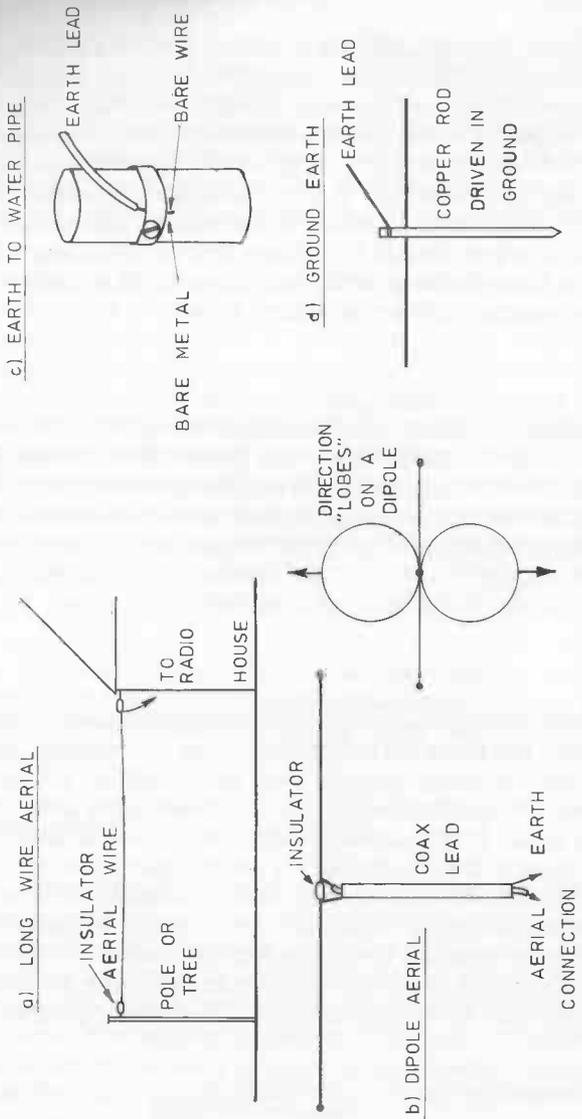


FIG. 12. AERIAL AND EARTH SYSTEMS

For example if the listener wishes to concentrate on the 14 MHz Amateur Band, divide 468 by the rough centre frequency of that band, 14.15, and the overall length is 33 feet.

The dipole is really the aerial for a specialist who wishes to concentrate his listening on one band, although the dipole will still work as an aerial at other frequencies, with reduced results. It is also directional and receives signals at maximum strength, for an area covered by two "lobes" at right angles to the direction of the wire. See Fig.12(b).

An earth socket has not been included in the construction of these receivers, partly because it is not really essential since an earth lead can be fastened to any part of the receiver metal chassis, and also because an earth is not an asset on every band. Probably an earth will improve the reception on the bands covered by coil range 3, but be little help on the higher frequency bands.

The simplest form of earth is to take a lead to a metal water pipe or radiator pipe in the house. The pipe must be exposed to the bare metal and the bare end of the earth lead connected firmly onto the metal. The lead can be held by a hose clip or Terry Clip. For serious lower frequency short wave listening, a ground earth ought to be considered. This is a copper pipe or rod, at *LEAST* 4ft long, driven into the ground with the earth wire connected to the top. Both forms of earth are shown in Fig.12(d). There are two further points worth considering - it is useless to connect an earth lead to plastic water pipes, and it is illegal to connect an earth lead to a gas supply pipe.

Aerials are a complex subject, but it is enough to say here, that the receivers in this book require some form of aerial, and the better the aerial the better the results. If in doubt, try the best long wire that is possible within the confines of one's property. For further advice on aerials, the serious listener can consult any of the books written on the subject, or seek the advice of other short wave listeners.

LISTENING TO THE SHORT WAVE BANDS.

What to listen to, and where to hear it, on the short wave bands is a vast subject. The short wave spectrum is filled with radio signals of all kinds. It is illegal to listen to some of these signals. According to law, the ordinary listener may only listen to signals on the BROADCAST and AMATEUR BANDS.

Most S.W.L.'s begin by listening to Broadcast Stations on the short wave bands. Many stations from all over the world broadcast programmes in English, and many of these stations can be picked up by the simple receivers in this book. Other S.W.L.'s prefer to listen to Amateur Radio Signals. This is more difficult with a simple receiver, because not only are the signals weaker, but they are usually either transmitted in morse code or single side-band telephony.

Broadcast stations are usually AMPLITUDE MODULATED (A.M.) signals, which are best received with the regeneration just backed off from the oscillating point. Morse code is usually transmitted by simply switching the transmitter on and off, this is called CONTINUOUS WAVE (C.W.) transmission, and is best received with the regeneration set over the point of oscillation. The oscillation adds an audio note which enables the morse to be heard. SINGLE SIDE-BAND (S.S.B.) is a complex method of sending voice signals, in which only a portion of the total signal is transmitted.

S.S.B. signals can be received by using the same method employed for C.W. signals. S.S.B. signals also require a skilful use of the band-spreading control to prevent the voice sounding like 'Donald Duck'. This requires extra practice, but the author has received many Amateur S.S.B. signals on the F.E.T. Plus One Receiver.

The listener has to know where to find the signals on his receiver. This can be done by guessing where one is tuned to on the particular coil range, but many Broadcast stations give frequent announcements of their location and operating frequency.

The following list gives the main bands covered by the three coil ranges used in these receivers.

RANGE	BROADCAST BANDS	AMATEUR BANDS
3	2.30 to 2.498MHz 3.20 to 3.40 MHz 3.90 to 4.00 MHz 4.75 to 5.06 MHz	1.80 to 2.00 MHz 3.50 to 3.80 MHz
4	5.95 to 6.20 MHz 7.10 to 7.30 MHz 9.50 to 9.775MHz 11.70 to 11.975MHz	7.00 to 7.10 MHz 14.00 to 14.35 MHz
5	15.10 to 15.45 MHz 17.70 to 17.90 MHz 21.45 to 21.75 MHz 25.60 to 26.10 MHz	14.00 to 14.35 MHz 21.00 to 21.45 MHz 28.00 to 29.70 MHz

The simple receivers described in this book are well tested, and should give adequate results on all three ranges. A wide variety of stations may be heard by beginning with only a Range 3 coil and adding 4 and 5 later. The author has been surprised at just how much can be heard using these simple receivers. So construct with care, learn operating technique, and good listening!

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