F.E.T. REFLEX RECEIVER

by

A. W. WHITTINGTON

Adding an f.e.t. input stage to a well-tried reflex circuit improves selectivity and offers a wide latitude in ferrite aerial design

THE CIRCUIT TO BE DESCRIBED IS A MODIFICATION to a very successful *Radio Constructor* design, and it takes advantage of an f.e.t. to increase selectivity.

Anyone who has built the silicon reflex circuit described by G. W. Short in the January 1968 and September 1969 issues* will have been amazed at the sensitivity of this receiver. The writer has carried out a number of experiments with the circuit, including the use of coils for coverage up to 6MHz.

Since f.e.t.'s are now available to amateur constructors at reasonable prices, it was decided to employ one of these devices to provide an aerial input stage preceding the basic reflex circuit due to G. W. Short. The chief advantages conferred by an f.e.t. are low noise, high input impedance and low cross-modulation. The high input impedance is of particular importance here since there is then less damping of the aerial tuned circuit, which becomes capable of offering greater selectivity. Also, the use of an f.e.t. allows a panel-controlled reaction circuit to be incorporated.

*G. W. Short, 'Silicon Transistor Reflex T.R.F.', *The Radio Constructor*, January 1968; ''Milliwatt' Silicon Reflex T.R.F. Receiver', *The Radio Constructor*, September 1969.

MODIFIED CIRCUIT

The circuit of the complete receiver appears in Fig. 1, the circuitry to the right of C4 which incorporates TR2 and TR3 being based on the receiver design previously published. In the original, D1 was returned to the earthy end of a coupling winding on the aerial ferrite rod, this winding being by-passed to the lower supply rail via a 0.01μF capacitor. The non-earthy end of the coupling winding connected to the base of what is now TR2. In the present circuit the diode couples direct to the base of TR2.

The f.e.t., TR1, is a 2N3819 operated in the common source mode. Gate-source bias is provided by R2 and C3. The ferrite rod aerial tuned circuit

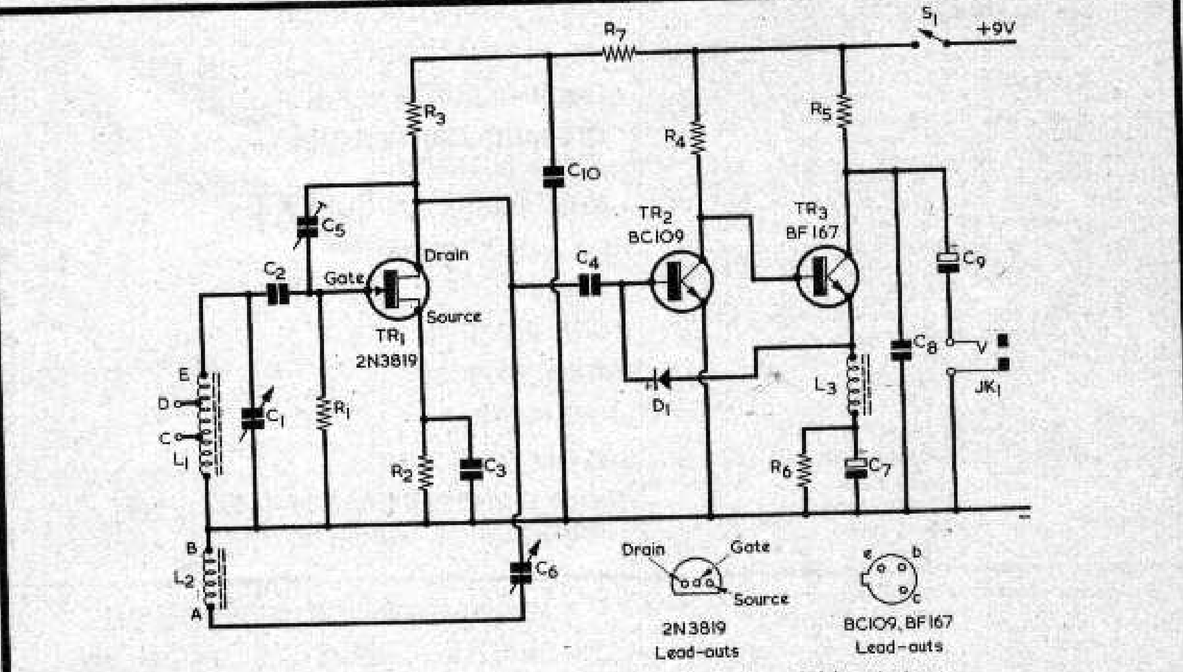


Fig. 1. Circuit of the reflex receiver with the f.e.t. aerial input stage

is applied directly to the gate via C2. The relatively low value drain load resistor, R3, provides adequate matching to TR2. Regeneration is obtained from the drain and is controlled by capacitor C6. Trimmer C5 is incorporated to provide neutralisation.

The aerial coil is wound on a 4in. length of $\frac{3}{8}$in. diameter ferrite rod as shown in Fig. 2. The winding wire was Radiospares 'Miniature' p.v.c. covered flexible wire with a 7/0.0048 (or 7/40 s.w.g.) stranded core and an insulation wall thickness of 0.01in. Similar thin p.v.c. covered connecting wire should work equally well. Start $\frac{1}{2}$in. from one end and close-wind directly onto the rod. The section of the coil between points A and B is the regeneration winding, and that between points B and E the tuned winding. This gives a range of 2.5MHz to 620kHz with the tuning capacitor specified. Taps C and D can be used for the conection of a short aerial, if desired. This should only be a few feet in length and is applied via a 100pF variable capacitor, the latter being adjusted for best results.

CONSTRUCTION

The author's prototype was assembled on a perforated matrix board of 0.15in. hole pitch measuring 7in. long by $2\frac{1}{2}$in. wide. Layout follows the circuit diagram, with the tuning capacitor at the left and the on-off switch to the right. The ferrite rod lies longitudinally at the back and the negative supply rail wire along the front of the board. There is 1in. spacing between the centre lines of the core of L3 and the ferrite aerial rod, the two cores being parallel with each other. Components are connected by means of terminal pins passed through the holes in the board as required. The two variable capacitors, the headphone output jack and the on-off switch are mounted on a small Paxolin front panel. Tuning capacitor C1 is fitted with a slow-motion drive.

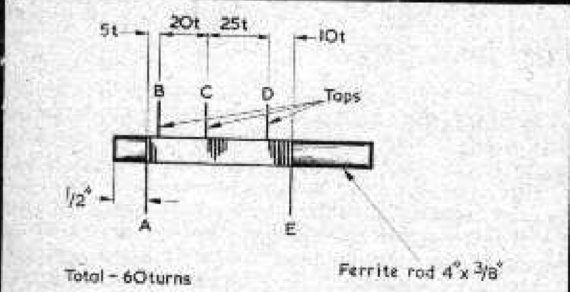


Fig. 2. Winding details of the ferrite rod aerial coil

To avoid damage to the f.e.t. resulting from static voltages on soldering irons, etc., this device must be fitted in a transistor holder. All connections in the receiver, including those to the holder, are soldered before the f.e.t. is inserted. It is necessary to drill out the matrix board in order that it may take the transistor holder. If desired, TR2 and TR3 can also be fitted in transistor holders, whereupon it becomes possible to check a number of transistors for operation in the receiver.

When the assembly and wiring have been completed and carefully checked, the current consumption from the 9 volt battery should be measured.

COMPONENTS

Resistors
(All $\frac{1}{4}$ watt 10%)

R1	2.2MΩ
R2	3.3kΩ
R3	1.8kΩ
R4	12kΩ
R5	3.9kΩ
R6	680Ω
R7	220Ω

Capacitors

C1	365pF variable, Type 01 (Jackson Bros.)
C2	100pF silver-mica
C3	0.022μF paper or plastic foil
C4	220pF silver-mica
C5	30pF trimmer
C6	300pF variable, solid dielectric
C7	100μF electrolytic, 3V wkg.
C8	0.022μF paper or plastic foil
C9	8μF electrolytic, 10V wkg.
C10	0.1μF paper or plastic foil

Inductors

L1, L2	Home-wound aerial coil on ferrite rod, 4in. by $\frac{3}{8}$in. dia. (see text)
L3	2.5mH r.f. choke Type CH1 (Repanco)

Semiconductors

TR1	2N3819
TR2	BC109
TR3	BF167
D1	OA81

Switch

S1	s.p.s.t. toggle

Socket

JK1	Headphone jack

Miscellaneous

Headphones, 2,000Ω to 4,000Ω, with jack plug
Slow-motion drive
2 knobs
Material for chassis, front panel, etc.

This should be of the order of 2 to 3mA. A strong local signal at the high frequency end of the band is then tuned in and C5 adjusted to eliminate any instability that may be present. Some r.f. feedback is provided by the inductive coupling between L3 and the ferrite rod. If necessary, this feedback may be adjusted by rotating L3.

TRAWLER BAND

Because the tuned circuit only has two connections it is possible to experiment with a wide variety of different aerial inductances.

The 'trawler band' can offer hours of interesting listening for those who live in coastal locations. This band was tuned in with an aerial coil wound on a 6in. length of $\frac{3}{8}$in. diameter ferrite rod, and employing 40 turns of 0.032in. (21 s.w.g.) solid core p.v.c. covered connecting wire. The winding commences about $\frac{1}{2}$in. from one end and the turns should be spread over the greater length of the rod. An extra four turns for regeneration will be adequate. An aerial, of 2ft. *only*, may be connected to the non-earthy end of the tuned coil. ■

CHAPTER IX

SUB-MINIATURE RECEIVERS

WHILST the circuits described in the previous chapters can be described as "miniature" in that the complete receiver, with its batteries, can be accommodated in quite a small case, transistor circuits also lend themselves to further compacting and space reduction resulting in the sub-miniature receiver, which is smaller in size than a box of matches. The use of a loudspeaker is precluded in such a small volume, so receivers of this type invariably utilize a deaf-aid type earpiece for listening, plugging into a matching jack on the side of the receiver case. Also, again to save space and reduce the number of components to a minimum, fairly simple circuits are usually employed and the smallest sizes of Mallory-mercury batteries.

The main limitation with such circuits is the rather low aerial efficiency which can be realized in a necessarily small size of aerial coil and ferrite rod or slab. Nevertheless, well-designed sub-miniature receivers are capable of providing satisfactory listening in areas of good reception and good sensitivity over a wide range of broadcast frequencies. In less favourable areas reception may be marginal and variable with conditions. In particular the final signal volume may be quite low with a suitable level for listening dependent on fairly precise alignment of the aerial relative to the source of signal. Such circuits, however, are readily adaptable to a further stage of a.f. amplication for working a speaker, although the combined volume of basic receiver, amplifier and speaker no longer conforms to the conception of a sub-miniature receiver.

In order to achieve minimum spacing of components together with a practical method of mounting and wiring up, sub-miniature receivers are invariably built on a printed circuit board. The original design of such a circuit is tricky and demands some experience to tackle successfully. For this reason the sub-miniature receivers are normally best built from kits which include a printed circuit board ready prepared and drilled for the mounting of components. Building the receiver then becomes a matter of simple assembly, locating each component in its correct position on the printed board and

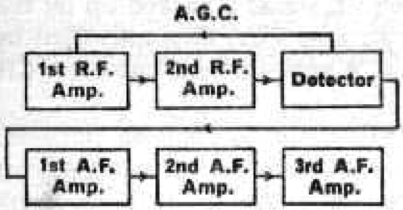


FIG. 57.

soldering the leads in place to the copper lands. Since the positioning of components can be quite critical—one component assembled in the wrong order may interfere with the mounting of a subsequent component—a definite sequence is usually specified for building. Certain precautions may also have to be observed, specific to the design. Thus, building from kits, the main point to remember is to follow the instructions for that kit specifically and not attempt what may appear to be "short cuts."

An outstanding example of a sub-miniature receiver of this

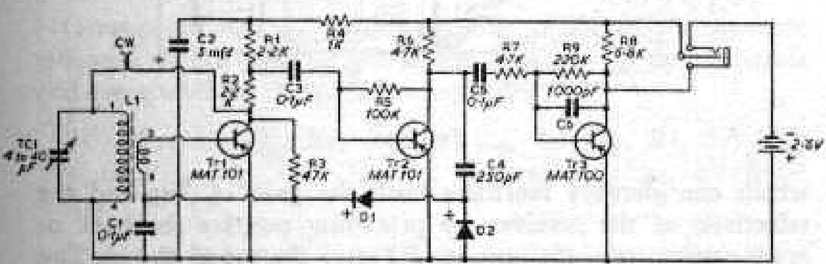


FIG. 58.

type is the Sinclair Micro-6. This is designed to fit into a case measuring only 1·8 × 1·3 × 0·5 inches and weighs less than one ounce, complete with batteries. The circuit is ingenious in that although only three transistors are employed the performance is generally comparable to that of a six-transistor superhet. This is achieved by reflexing both the first and second transistors so that each amplifies successively at both a.f. and r.f, in the block diagram Fig. 57.

A circuit diagram of the Sinclair Micro-6 is shown in Fig. 58. The incoming r.f. signal is picked up by the aerial coil *L1* and selected by *L1* and *TC1*, then amplified by *Tr1* and *Tr2* prior to detection. A semi-variable capacitor *CW* is introduced

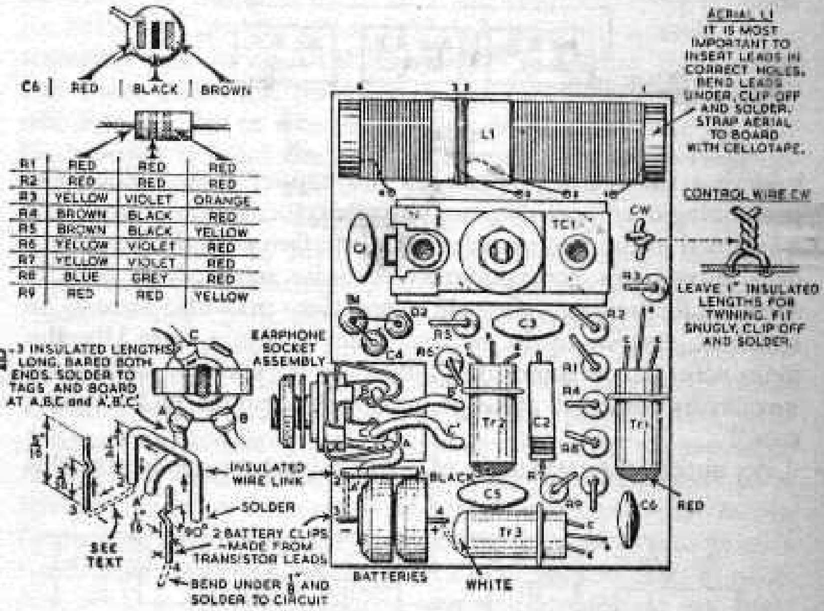


FIG. 59.

which considerably increases both the gain of *Tr1* and the selectivity of the receiver by providing positive feedback or regeneration from the output of *Tr1* to the tuned circuit. The level of regeneration is automatically controlled by the a.g.c. circuit. In practice, *CW* is simply two pieces of single stranded insulated wire twisted together, adjusted for best performance merely by twisting or untwisting the "coupling" until best performance is achieved.

The r.f. output from *Tr2* is coupled directly to the double diode detector *D1* and *D2* by capacitor *C4*. The output from the detector stage consists of three parts:

(i) a D.C. voltage which is proportional to the signal strength and which controls the collector current and thus the gain of *Tr1*.

(ii) an a.f. signal which is fed to the base of *Tr1*. This a.f. signal is then amplified in turn by *Tr1*, *Tr2* and *Tr3*.

(iii) an unwanted residual r.f. signal which is removed by capacitor *C1*.

The three transistors used are of micro-alloy type, enabling a satisfactory performance to be realized on a low battery voltage with very low current consumption. The batteries are

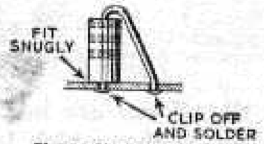


Fig. 60.

Mallory ZM312 or RM312 mercury cells of 1·2 volts each. In areas of strong signals a single cell (1·3 volts) may be satisfactory but for most areas two batteries (2·6 volts) are required for working.

Component assembly is shown in Fig. 59. All components are mounted on the opposite side of the board to the copper lands and are assembled in the following order:

TC1, *C1*, *R5*, *C3*, *R2*, *R3*, *R1*, *R4*, *R8*, *R9*, *R7*, *Tr1*, *C6*, *Tr2*, *C2*, *C5*, *Tr3*, *R6*, *D2*, *D1*, *C4*, battery clips, earphone socket, *CW*, *L1*.

It is very important that all the components used to build this set are mounted as close to the board as possible. The leads must be clipped to within about $\frac{1}{32}$ inch from the board and then soldered. The solder must not protrude from the board more than absolutely necessary. To ensure a good joint the solder should be held against the wire and the copper and the joint made quickly with the iron at full heat. The transistors can be damaged by excess heat and it is wise to grip the transistor lead being soldered with tweezers or pliers to act as a heat sink. It is not essential to hold the solder to the joint in the case of the transistors as the leads are gold plated.

Remove any insulation from the leads of *C1*, *C3* and *C5* as shown in Fig. 61.

The assembly of *D1*, *D2*, and *C4* is shown in Fig. 62. Take

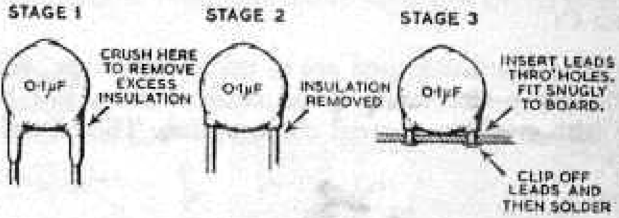


Fig. 61.

care to ensure that the diodes are inserted the correct way round. The positive end is that which looks like a tiny front arrow inside the glass body of the diode. *C4* (250 *pF*) is mounted flush to bring the top to the level of *D1* and *D2*. The top lead of *C4* is wound round the top leads of *D1* and *D2* as shown in Stage 3. Solder *C4* to *D1* and *D2* as quickly as possible to avoid damaging the diodes and then clip off the rest of the diode leads

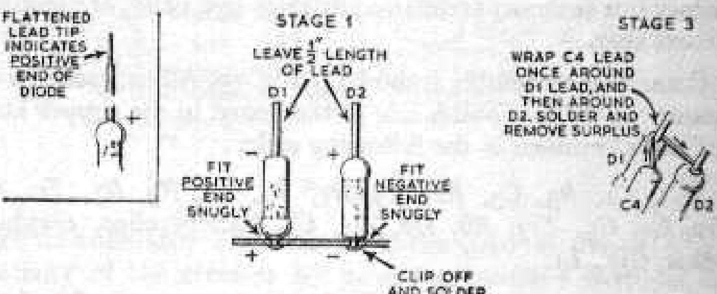


Fig. 62.

as close to the diodes as possible. Unless the leads are clipped close to the diodes the final assembly might not fit into the case.

Bend the transistor leads so that they can be assembled on to the board as shown in Fig. 63. Clip off the leads after mounting and keep them, as two are required to make the battery clips. Remember to make the solder joints quickly and to use a heat sink if possible to avoid damaging the transistors.

TC1, the tuning capacitor, must lie flat on the board as shown in Fig. 59. The eyelet and the bush protrude slightly into holes provided on the board. It may be necessary to bend the leads slightly so that they coincide with the copper on the board to which they must be soldered. The leads, when clipped, must not extend more than $\frac{1}{16}$ inch from the board and should be soldered as in Fig. 64.

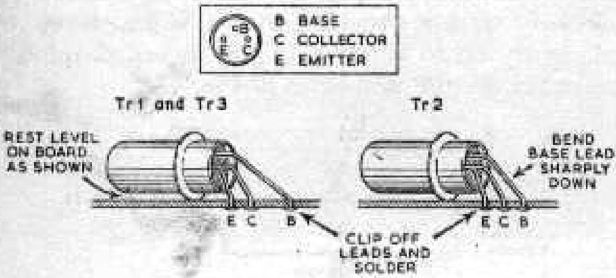


FIG. 63.

Mount *L1* on to the board as shown in Fig. 59 and then fix it to the board carefully with clear cellotape so that it cannot move. If wished, the aerial may further be glued to the board for extra security.

For *CW* use two pieces of the single stranded, plastic insulated wire just over 1 inch in length. Bare one end of each and solder into position as shown in Fig. 59. It is not necessary to twist these wires together at this stage. The single stranded wire is only required for *CW*.

The assembly of the battery clips is shown in Fig. 59. These are bent from the transistor leads you will have saved. The positive clip (numbered 4 on the diagrams) requires about $\frac{1}{2}$ inch of lead. The negative lead (numbered 3) extends under the board, up through the hole numbered 2, across and down again through hole 1. The section between 1 and 2 must be covered with $\frac{3}{4}$ inch of plastic sleeving taken from the 4 inches length of single strand wire. This insulated wire link helps to keep the batteries in position. The clips must be soldered very firmly under the board to ensure sufficient rigidity. They must be clean at all times. Corrosion or dirt must be removed by gently filing or scraping.

Solder the earpiece socket to the board using three $\frac{3}{4}$ inch lengths of the multi-stranded, plastic insulated wire as shown in Fig. 59. Be careful to join the tags to the correct holes.

Remove the nut and washer from the earpiece socket and fit the entire assembly into the case passing the threaded neck through the hole on the side. Now replace the washer and nut of the socket on the outside of the case and tighten the screw firmly but carefully.

Remove the screw and two washers from *TC1* and screw in the dial from the front of the case until the spindle projects through *TC1*. Replace the paxolin washer and fit the specially shaped locking washer provided over this and screw the nut provided tightly on to the end of the threaded spindle. The whole assembly should now be as in Fig. 64.

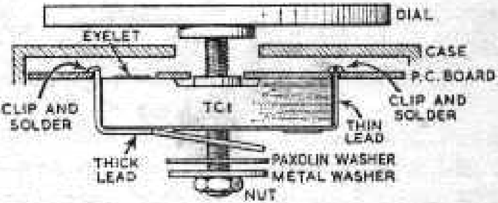
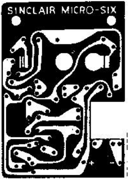


Fig. 64.

The Micro-6 uses two Mallory ZM312 (or RM312) mercury cells. These may be obtained from Boots the Chemists, or from most radio shops. Fit the cells between the battery clips, being very careful to insert them the correct way round as shown in Fig. 59. You will probably need to bend the battery clips inwards to ensure that they grip the cells tightly enough. Make sure the clips are always clean.

Plug the earpiece into the socket. This automatically switches the set on and you should now be able to tune in a station or two. Tune to the high frequency end of the band, that is with the dial turned clockwise as far as it will go, and twist the wires of *CW* tightly together until you hear a rushing or whistling noise. Now untwist them slightly so that the noise just stops. *CW* may be adjusted slightly for best performance and then bent over so that the lid can be fitted. Two lids are provided; one in white plastic and one in clear to give you a choice. The lid slides into place from the end of the box.

The kit for the construction of the Sinclair Micro-6 is produced by Sinclair Radionics Ltd, Comberton, Cambridge.


SINCLAIR MICRO-SIX
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HIGH-GAIN SILICON REFLEX RECEIVER

by

G. W. Short

A sensitive 2-transistor receiver which requires few components and which can be adapted for a wide range of speaker impedances and battery voltages.

A FEW YEARS AGO THE 'RADIO CONSTRUCTOR' PUBLISHED the writer's design for a simple but effective reflex t.r.f. receiver using silicon planar transistors. This proved to be a reliable circuit with a good performance. Several modifications have appeared, including a low-consumption version for use with a crystal earpiece and a version with an f.e.t. input stage.*

The receiver described here is a new and improved version of the original circuit. Like the original, it has been kept very simple and straightforward. Nevertheless, it has proved possible to obtain a very useful increase in r.f. gain, and to provide enough audio output for low-volume loudspeaker listening indoors. The new circuit works from a 3 volt battery and is easily adapted to other voltages.

CIRCUIT DETAILS

Referring now to the circuit diagram, which is shown in Fig. 1, the heart of the receiver is a 2-stage amplifier with direct coupling between stages and d.c. negative voltage feedback to stabilize the operating conditions of the two transistors. Each transistor operates as a common-emitter amplifier to both a.f. and r.f. signals, giving very high overall gain.

R.F. signals picked up by the ferrite rod aerial L1 are stepped down and applied to the base of TR1 via L2, whose lower end, in the circuit diagram, is earthed to r.f. by C2. At the output of the 2-stage amplifier the r.f. signals are picked out and stepped up in voltage by an r.f. transformer (L3, L4) and applied to the detector D1, this being a point-contact germanium diode. The audio signals which appear across the detector load R4 (which is also the volume control) are fed back to TR1 and are then amplified by both transistors before application to the directly driven 75Ω loudspeaker.

A d.c. bias is applied to the diode by R5, which bleeds a little of the emitter current of TR2. Negative feedback at d.c. is taken via R4 from the emitter of TR2 to the base of TR1.

CONSTRUCTION

There is nothing special about the ferrite rod aerial and tuning capacitor C1. The prototype employed a 300pF Jackson Bros. 'Dilemin' tuning capacitor. This covers the medium wave band when L1 consists of about 70 turns of 5/46 litz wire close-wound on a paper former at the centre of a 4in. by ⅜in. ferrite rod. The secondary winding has 4 turns of insulated wire wound over the earthy end of L1. The precise gauge of wire is not important. (A suitable rod is available from Ama-tronix Ltd., 396 Selsdon Road, S. Croydon, Surrey, CR2 0DE. The same company also stocks wound rods to suit a 300pF tuning capacitance, but the secondary has too many turns for this receiver and six turns should be removed.)

The r.f. transformer L3, L4 is made by winding 50 turns of 32 s.w.g. enamelled, silk or cotton insulated wire on top of the existing winding of a 2.5mH r.f. choke,

* G. W. Short, "Silicon Transistor Reflex T.R.F.", *The Radio Constructor*, January 1968; G. W. Short, "'Milli-watt' Silicon Reflex T.R.F. Receiver", *The Radio Constructor*, September 1969; A. W. Whittington, "F.E.T. Reflex Receiver", *The Radio Constructor*, August 1971.

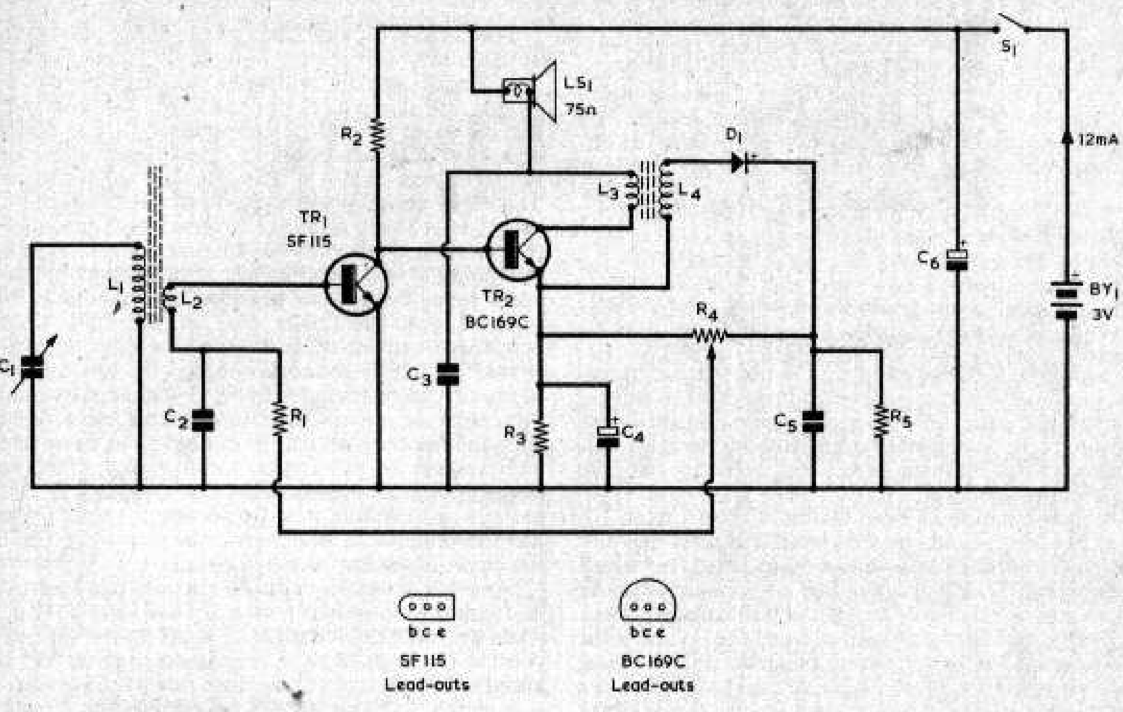


Fig. 1. The circuit of the high-gain silicon reflex receiver

COMPONENTS

Resistors
(All fixed values $\frac{1}{10}$ watt 10%)

R1	3.3kΩ
R2	1.2kΩ
R3	68Ω
R4	10kΩ potentiometer, log track
R5	22kΩ

Inductors

L1, L2	Windings on 4in. × ⅜in. ferrite rod (see text)
L3	Overwind on L4 (see text)
L4	R.F. choke type CH1 (Repanco)

Semiconductors

TR1	SF115
TR2	BC169C
D1	OA90

Capacitors

C1	Tuning capacitor, to suit L1 (see text)
C2	0.1μF
C3	0.1μF (see text)
C4	320μF electrolytic, 2.5 V.Wkg.
C5	0.01μF
C6	125μF electrolytic, 4 V.Wkg. (see text)

Switch

S1	s.p.s.t. switch (may be ganged with R4)

Loudspeaker

LS1	75Ω approx. (see text)

Battery

BY1	3 volt battery

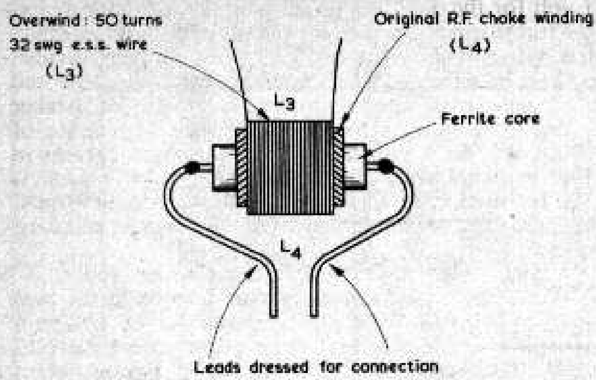


Fig. 2. Making up the r.f. transformer L3, L4

Repanco type CH1. See Fig. 2. Do not use a different kind of choke – it may not be suitable for the present purpose. The gauge of wire used for the added 50-turn winding is not important and any moderately fine insulated wire may be used. The winding may be 'scramble-wound'.

A wiring diagram is given in Fig. 3. Apart from L1, L2, all the components may be fitted to a small piece of insulating material fitted with a front panel, on which are mounted C1, R4 and S1. The components may be anchored to metal pins or tags at the positions indicated. For clarity, the transistors are omitted. The layout of the circuit should follow the circuit diagram and it is most important, in view of the high r.f. gain, to keep the output clear of the input or else screen the relevant portions.

A convenient means of providing the 3 volt supply consists of employing an Eagle battery holder type BH2, in which are fitted two U7 cells.

OVERCOMING INSTABILITY

The receiver is wide open to two quite distinct forms of instability, fortunately both easily cured. First, there is a chance that a.f. will break through the r.f. transformer and set up a continuous howl. This is cured, if it occurs, by reversing the connections to L3. Secondly, it is inevitable, unless the r.f. transformer is put into a screening box, that it will couple with the ferrite aerial. This may cause positive feedback and instability or negative feedback and loss of sensitivity, depending on the winding directions. To minimise such undesirable interactions, the transformer should be kept as far away from the rod as possible, and it should be so oriented that the ferrite core of the CH1 choke is pointing broadside off to L1 (like the down stroke of a capital T). Before connecting up L3, L4, dress the leads of the r.f. choke as shown in Fig. 2, so that the two ends of the leads can be soldered into circuit close together. This enables the choke to be twisted so as to re-orient it with respect to the ferrite aerial rod. In this way a position can be found where the coupling is zero or perhaps just slightly positive so that a useful improvement is obtained in selectivity. Varying the position of the ferrite aerial can also be helpful.

No other setting up adjustments are required. It will be found however that a sort of false instability occurs when the receiver is tuned in to a strong station with the volume too high. This is merely an overloading effect and the remedy is obvious – turn down the volume.

A simple test that the d.c. conditions are correct can be made by measuring the voltage drop across R3. This should be in the range 0.65 to 0.75V.

If desired, the on-off switch, S1, may be ganged to the volume control.

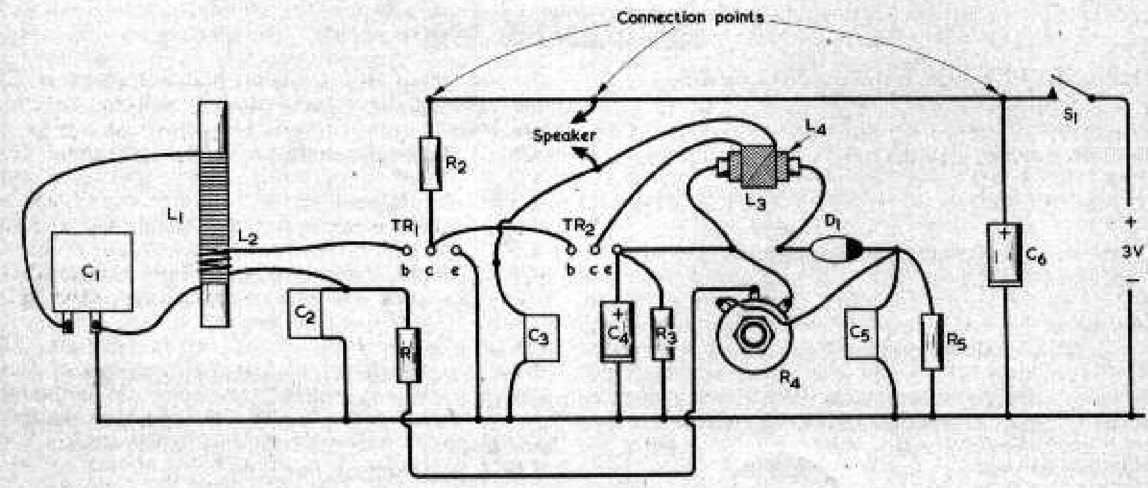


Fig. 3. A suitable component layout

LONG WAVE RECEPTION

The circuit will work on long waves given a suitable ferrite rod with long wave windings. (There is not room on a 4in. rod for both medium wave and long wave windings.) Alternatively, a single long wave station could be received by switching a suitable fixed capacitor across L1 and using C1 for fine tuning, as shown in Fig. 4. For reception of the Radio 2 transmission on 200kHz the added capacitor should be 2,200pF. A polystyrene film or silvered mica capacitor should be used.

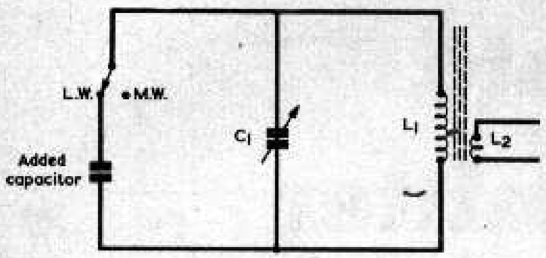


Fig. 4. Reception of a single long wave transmission is possible by switching an added capacitor across C1

OTHER SUPPLY VOLTAGES AND LOADS

In this direct-drive circuit it is essential to use a high impedance loudspeaker. The preferred impedance is 70 to 80Ω but speakers of somewhat different impedance may work: it depends upon how sensitive they are. A transformer may be used to match speakers of low impedance.

The voltage across R3 is stabilized at about 0.7 volt irrespective of the battery voltage. This makes it easy to set TR2 to take some particular collector current. At present, with R3 at 68Ω, TR2 takes a little over 10mA. If it were required to set the current at 1mA to suit an earphone of around 500Ω impedance in place of the speaker, R3 would be 680Ω.

With a 75Ω speaker, some increase in volume is obtainable by using the present resistor values but increasing the supply voltage to 4.5 volts. The circuit will go on working quite happily at higher voltages, up to 9 volts, but 75Ω is not then the optimum speaker impedance. (This rises to about 800Ω at 9 volts.)

Some constructors will want to use 3Ω speakers, which must be matched with a transformer. It is then useful to tailor the current in TR2 and the supply voltage to suit the load and transformer ratio. Allowing 1 volt for the drop across R3 plus the d.c. drop across the transformer primary, we are left with 1 volt less than the battery voltage across TR2. This voltage, divided by the transformed speaker impedance, should equal the collector current. Suppose we have a 3Ω speaker and a 10:1 transformer, giving a load impedance of 300Ω. With a 3 volt supply, the optimum current in TR2 is then 2 volts divided by 300Ω, which is 6.7mA. The required value of R3 is 0.7 volt divided by 6.7mA, or 106Ω, and we could use 100Ω, the nearest standard value.

Again, if we have a 20:1 transformer and a 5Ω speaker, the transformed speaker impedance is then $400 \times 5 = 2{,}000\Omega$. With a 3 volt supply the optimum current is 1mA, but since the power input to TR2 would then only be 2mW the audio power output cannot exceed 1mW, which may well be inadequate. The remedy is to use a higher battery voltage. With a 9 volt supply, the optimum current becomes 8 volts divided by 2,000Ω, or 4mA, and the d.c. input power to TR2 32mW, giving a possible 16mW of audio output (and a likely 8mW, assuming 50% transformer efficiency). The value of R2 for 4mA is 0.7 volt divided by 4mA, or 175Ω, so the appropriate standard resistor in this case is 180Ω.

When a high load impedance is used it may be necessary to reduce the value of the r.f. bypass capacitor C3, to avoid cutting the treble. Values down to 0.01μF may be used.

When working with supply voltages much above 3 volts it may be helpful, in the interests of battery economy, to reduce the current in TR1. This is done by increasing the value of R2. The voltage drop in R2 is held, by the d.c. feedback, at 1.4 volts less than the battery voltage, and a current in it of 1 to 2mA is adequate.

The working voltage of C6 must be increased for supply voltages greater than 3 volts. Constructors who intend experimenting with different supply voltages will find it useful to initially fit a capacitor here of 10 V.Wkg.

SEMICONDUCTORS

It is essential to use silicon planar transistors. The types specified have been carefully selected to give a good performance. (The SF115 transistor can be obtained from Amatronix Ltd., as can the other semiconductors and components.) Other transistor types will probably work, but less well. The input transistor must be an r.f. type with a low feedback capacitance and the SF115 specified has the added advantage of low a.f. noise as well. It should be possible to substitute BF115, which is the same transistor in a metal case. The BF167 will also work in this position.

The requirement for TR2 is rather different. This transistor may have to handle peak currents of 20mA or more, which rules out some r.f. types. It should have a low input capacitance and a fairly low feedback capacitance as well, to avoid putting too great a stray capacitance across R2 and so reducing the r.f. gain. Fortunately the BC169C has these features, and also the added one of very high hfe: some other high-gain audio types are much worse in the matter of capacitances.

In principle any point-contact diode will be satisfactory for D1, but here again some are better than others, and the OA90 is very suitable. ■

SELECTIVE REFLEX RECEIVER

by J. B. Jobe

The medium wave receiver described here combines two of our earlier designs to obtain an enhanced overall performance.

THE AUTHOR TEACHES AT A SCHOOL FOR BOYS WHERE he runs a radio and electronics club. Most of the boys start off by building the ubiquitous crystal set and some of them eventually graduate to the construction of G. W. Short's "Silicon Transistor Reflex T.R.F."[1]

This is, in the writer's opinion, the best set of its type yet published, being virtually fool-proof, almost guaranteed to work first time and extremely tolerant as regards transistor types, component values and layout. There is, however, one comment which is frequently heard from boys who have completed the set, and this concerns its rather low selectivity. In the writer's region the local Radio 4 programme is on 285 metres and, with the reflex receiver, this signal interferes with the weaker Radio 1 programme on 247 metres.

MODIFICATION

It was therefore decided to see what could be done to improve the selectivity of this otherwise excellent set. Any modification which was to be made had to conform to the following rules: it must not detract from the basic simplicity of the receiver, the set must be reliable and sure to work after completion, and the modification should add as little as possible to building costs.

The original design has a single tuned circuit with the coil being wound on a ferrite rod. A second coil on the same rod couples the tuned winding to the first transistor. It was considered that the low input impedance of the first transistor was damping the tuned circuit.

The idea of adding a second tuned circuit to increase selectivity was discarded as this would not adhere to the requirement that the modification must not detract from the simplicity of the receiver. The possible use of an f.e.t. input stage was also ruled out as it was felt that f.e.t.'s were expensive and too delicate to be handled by young newcomers to radio.

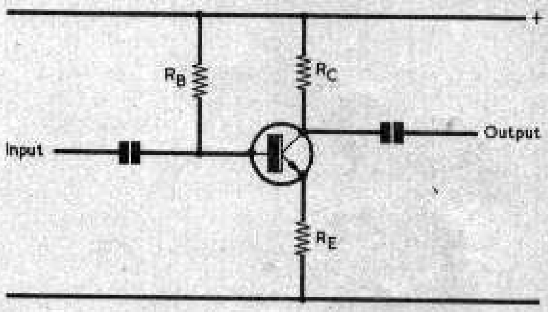


Fig. 1. A high to low impedance 'converter' circuit

What was needed was a simple high impedance unity gain buffer stage incorporating a bipolar transistor, this stage being easy to construct and requiring as few components as possible. The basic circuit eventually chosen is shown in Fig. 1. This has been described before, also by G. W. Short, but for a.f. applications only. It was subsequently found to function very well at r.f. as well.[2]

The voltage gain of this circuit is approximately RC devided by RE and the input impedance is given roughly by the parallel combination of RE multiplied by the small signal current gain, and RB. Since RC has to provide a reasonable match to the following stage a value of 10kΩ is chosen for it, this offering a useful compromise. A high gain transistor is employed, enabling a high value to be used for RB and, consequently, giving the circuit a high input impedance.

[1] G. W. Short, "Silicon Transistor Reflex T.R.F.", *The Radio Constructor*, January 1968.

[2] G. W. Short, "Simple 'Impedance Converter'," *The Radio Constructor*, April 1969.

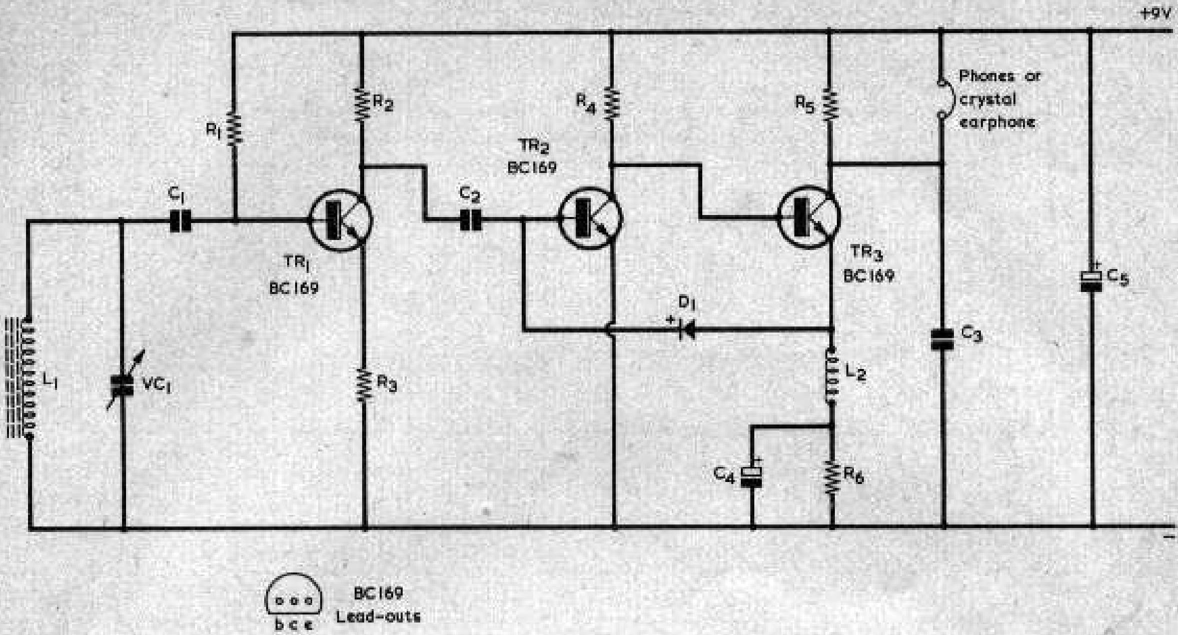


Fig. 2. Circuit of the receiver. TR1 presents a high impedance to the aerial tuned circuit, which is connected directly to its base

COMPLETE CIRCUIT

The complete circuit of the new receiver may be seen in Fig. 2. The circuit to the left of C2 is the same as that of the "Impedance Converter" previously published, and that to the right of C2 is virtually the same as the reflex t.r.f. receiver. The resistor values are unaltered.

The signal from the tuned circuit given by L1 and VC1 is applied via C1 to the high impedance buffer stage incorporating TR1 and thence, by C2, to TR2 where it is amplified and fed to the directly coupled transistor TR3. TR3 operates as an emitter follower at r.f., and the r.f. signal is detected by diode D1 and fed back to the base of TR1. The detected signal is again amplified, this time at a.f., by TR2 and TR3, and is finally fed to the headphones or earphone connected across R5.

R5 is only strictly necessary if a crystal earphone is to be used and it may be omitted if magnetic earphones are employed. However, it is worth including R5, as it increases the versatility of the set and enables it to be coupled up, also, to an a.f. amplifier.

EDITOR'S NOTE

The January 1968 and April 1969 issues of 'The Radio Constructor' referred to in this article are now out of print and cannot be obtained from us. They are not, of course, necessary for the building of the receiver described here, as the present article gives all the assembly and constructional information that is required

COMPONENTS

Resistors
(All values ¼ or ½ watt 10%)

R1	10MΩ
R2	10kΩ
R3	10kΩ
R4	15kΩ
R5	3.9kΩ
R6	680Ω

Capacitors

C1	1,000pF ceramic
C2	1,000pF ceramic
C3	0.01μF paper or plastic foil
C4	32μF electrolytic, 4 V.Wkg.
C5	50μF electrolytic, 10 V.Wkg.
VC1	300pF variable, solid dielectric, "Dilemin" (Jackson Bros.)

Inductors

L1	Ferrite slab aerial – see text
L2	R.F. choke – see text

Semiconductors

TR1, 2, 3	BC169
D1	OA81

Miscellaneous
Headphones, 2000Ω, or crystal earphone
9 volt battery
Battery connectors
Knob
Plywood baseboard

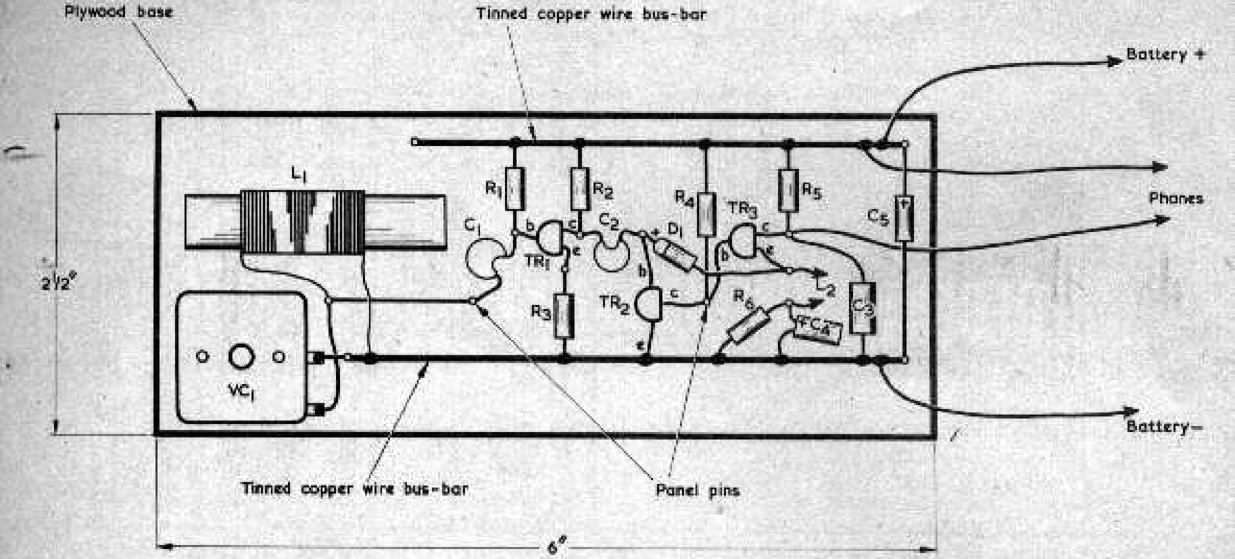


Fig. 3. How the receiver is assembled. The baseboard is a piece of plywood

CONSTRUCTION

The method of construction favoured by the author's pupils is shown in Fig. 3. This extremely economical approach involves the use of a plywood baseboard measuring 6 by 2½in., into which cheap panel pins are driven at the appropriate connection points. Component lead-outs are then soldered to these pins. The general layout of the components is shown in the diagram, and it is by no means critical. The tuning capacitor, VC1, may be secured by a suitable bracket made from scrap aluminium sheet, or similar.

A little experimenting is required with the ferrite slab aerial to obtain precise coverage of the medium wave band. The author's version consists of approximately 65 turns close-wound of 30 s.w.g. enamelled wire on a 2½in. ferrite slab, as shown in Fig. 4. However, ferrite slabs of this size are not generally available, and a suitable alternative would be the 2¼in. slab that is obtainable from Amatronix Ltd., 396 Selsdon Road, South Croydon, Surrey, CR2 0DE. Longer ferrite rods could also be used and these would require fewer turns. The best approach is to purposely wind on too many turns, say 75, at first and then remove these as required after the receiver has been brought into working order.

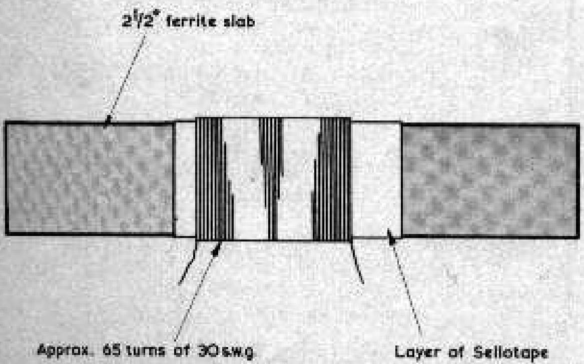


Fig. 4. Details of the ferrite aerial employed with the prototype

Choke L2 simply consists of 150 turns of thin wire around 36 s.w.g. pile-wound on a match-stick or an insulated 'former' of similar small dimensions. Lead-out wires of 28 s.w.g. tinned copper may be secured to this 'former' for connection into the circuit. These lead-outs should be some 3 to 4in. long so that the choke can be moved around the board until the best position is found for it. The choke inductance is of the order of 1mH.

TESTING

A wide variety of transducers was tried with the prototype, best results being obtained with high impedance headphones, as specified in the Components List. Good results were also given with a crystal earphone and balanced armature headphones; even a 3Ω speaker gave audible – albeit faint – results!

To test the completed receiver, connect up the headphones or earphone and a 9 volt battery. Tune in a station and rotate the set horizontally for maximum volume. (The ferrite aerial is highly directional.) L2 may now be moved around. It will be found that some positions of this component will cause the set to oscillate whilst in others signal strength will decrease or the signal will disappear completely. The choke may be experimentally turned, to alter its coupling with L1, whilst finding its optimum position. The best position for L2 will probably be found to be perpendicular to L1 and as far away from it as possible. Some regeneration *can* be obtained, if desired, by allowing L1 and L2 to interact, but this can be a finicky business and should not normally be necessary as selectivity and sensitivity are quite adequate without it. To give an idea of performance, good signals are received from Radio Luxembourg on the prototype, which is sited in the Midlands.

COMPONENTS

The components are not very critical. Any small resistors or capacitors of the stated values may be used. C4 and C5 can have high working voltages than those specified. It is desirable for the transistors to be high gain silicon types, and BC169's were used in the author's version. The "Dilemin" capacitor specified for VC1 is available from Home Radio under Cat. No. VC40B.

CONCLUSION

Up to the time of writing, about a dozen samples of this receiver have been built by club members and all have worked first time with very little trouble being experienced in the constructional work. The sensitivity of these sets has been very good and there have been no complaints about lack of selectivity.

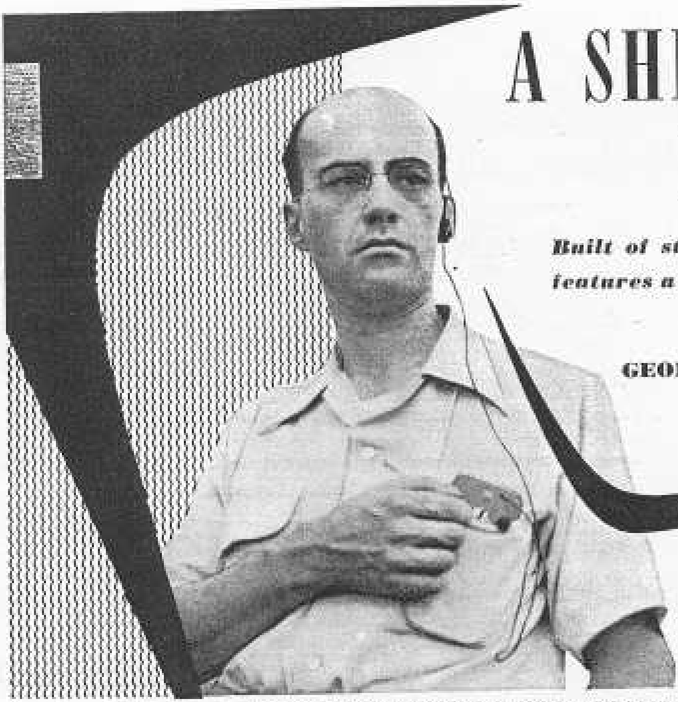
■

A SHIRT POCKET RADIO

Built of standard parts, this receiver features a loop antenna and low drain.

By

GEORGE L. JOHNSON, JR.
W9LQX



Separate controls for tuning and regeneration allow signals to be peaked for best reception.

POCKET radios are not new, yet the design of a truly pocket-sized set which combines real performance with simplicity of construction and extreme battery economy is new and this author believes that he has achieved such a design in the little radio described in this article.

The current drain of the set is only 140 μa. on the "B" battery and 20 ma. on the "A" battery. Under these conditions the "B" battery gives practically shelf life (about 1000 hours or one year of normal use) while the "A" battery, a ten cent penlite cell, will give about 100 hours' service. This should set an all-time low for cost-per-hour of listening as the "B" battery practically never wears out and the "A" cell, which will run the set two hours a day for a month, costs a dime.

The output voltage is ample for comfortable earphone volume on the average local (25 miles distant or less) station. For all its economy of plate current, this little radio is capable of delivering a "rattling the cans" signal on nearby stations. The over-all dimensions of the set are: 6 inches long, 3 inches wide, and ¾ inch thick—a size that will fit easily into the average shirt pocket.

The antenna is a self-contained loop wound on the outside of the case to provide approximately 18 square inches of loop pickup area. This is equal to the size of the loops found in most commercially-built "personal" portables.

Thus, we have a personal radio which may be worn, not carried. If the pocket is large enough for concealment and a hearing aid type earphone is used, the wearer may listen to the radio in a public place and no one will be the wiser! Other places for use of this set are; sports events, beaches, picnics, or one may do as the author did—catch a morning newscast while riding to work on a streetcar!

Enough of this idle chit-chat. Just what is this little marvel, you say, and how do I go about building it? Which brings us to a discussion of the circuit. To be brief, it is a pentode regenerative detector feeding a one-stage pentode audio amplifier. The main loop winding is in the grid circuit of the detector, and conventional plate feedback is applied through a small "tickler" winding, wound on top of the loop over a layer of *Scotch* masking tape. Both the detector and amplifier tubes are *Raytheon* type CK512AX flat hearing aid type voltage amplifier pentodes. They are designed for a maximum plate voltage of 22½, and each tube's nominal filament rating is .625 volt at 20 milliamps. Thus the tubes' filaments are connected in series across a single 1.5 volt dry cell for "A" supply. The "B" supply is a *Burgess* type U15E 22½ volt battery. Tuning of the set over a range of 540-1300 kc. is done with a standard 9-180 μμfd. compression mica trimmer. This is easily modified from screwdriver to knob tuning as will be described later. Control over the regeneration is accomplished by varying the amount of r.f. bypass in the plate circuit of the detector, and another 9-180 μμfd. condenser is used here. The control is very smooth and gradual to the point of maximum feedback, and the detector finally breaks into oscillation but with no "plop" or instability. As with all regenerative sets, maximum sensitivity is secured with the maximum amount of feedback obtainable without oscillation. Selectivity of the set is good, as 15 local stations in the Chicago area were easily tuned in and separated. This includes one fifty kilowatter only ten miles away.

Earphones

The earphone of the original set is a prewar vintage *Brush* single unit crystal headset. The efficiency of this type of phone is quite good, and what is more important, the high impedance of a crystal phone matches the output load impedance of the tiny CK512 tube. With such a small power output stage, it is absolutely necessary not to lose any useful audio power through poor impedance matching. Any crystal type phone, single or double unit, may be used in the set with no circuit changes. A good quality magnetic phone may also be employed with good results if the phone has high impedance. One word of caution on this. There are certain types of cheap headsets on the market now which have very low efficiency. They may require as much as three or four volts of signal across their terminals in order to deliver a good, usable signal to the ear, whereas with the crystal type one volt is plenty. Beware of the "98 cent special" phones when buying for this set. They are OK for bigger radios, but not this one. When using a magnetic type phone, the 180,000 ohm resistor in the audio plate circuit may be omitted.

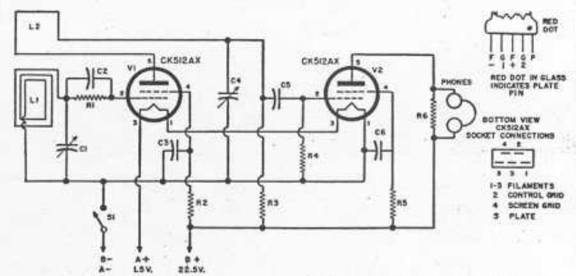
Should a hearing aid "ear plug" type phone be used? Admittedly, for a pocket radio, the appeal of this type is high. It is of course the lightest in weight of all phones. The air seal from the diaphragm of the phone to the ear drum is perfect, and so the maximum transfer of sound energy into the ear is possible. This means an apparent increase in loudness when compared to an earphone that does not plug into the ear. All this is well and good, however, hearing aid phones have certain disadvantages which it is well to consider before deciding on this type. First of all, there is the price, which may easily run double the cost of even a first class single unit crystal phone. Second, is the problem of fitting the phone to the ear of the individual concerned. In fitting a person with a hearing aid, a mold is made of the individual's ear. From this a custom fit plug is made, and of course, it fits well and is comfortable to the one person for whom it is designed. However, this is very expensive and hardly practical for pocket radio use. The average builder who tries to use a hearing aid earpiece will have to get along with a so-called "universal ear mold." These are just about as "universal" as a "universal" hat or "universal" pair of shoes would be. The phone is likely to be too loose or too tight or be uncomfortable. It may fall out at just the wrong time. It is certain to become messy due to the natural secretions of the ear, and cannot be readily passed around to friends, as one would like to do with a novel radio such as this. For these reasons, this author says of hearing aid phones—"Not recommended for the average builder." Should you decide to use one anyway, a crystal type is preferable, and if a magnetic type is used, a matching transformer to match the phone to the CK512 plate must be used. Most magnetic hearing aid plugs have about 125 ohms impedance. The CK512 operates best with 100,000 to 200,000 ohms in the plate circuit, hence the need for a matching transformer. Such a transformer is small, and may be easily incorporated into the set as there is extra space.

The Receiver Chassis

The major component parts of the receiver are mounted on a 3"x6"x3/32" bakelite board which also serves as the front panel of the cabinet. Two such boards are required, for the front and back, and together they form all the cabinet that is necessary as the sides are formed by the loop antenna and its protective cover. The corners of the plates are rounded off just a bit, to permit easy insertion into a pocket.

The Loop Antenna

One of the major problems in pocket radio design is *getting the signal into the set.* Conventional wire antennas are practically useless for a radio which must be carried on the person. Attempts to use the earphone cord as the antenna have been made, but the amount of signal such an antenna can deliver across the primary of an antenna coil is very small for two reasons. The most obvious is that the cord is very short. The second reason, and just as important, is that there is no



R_1, R_4—10 megohm, ½ w. res.
R_2—2.2 megohm, ½ w. res.
R_3—1 megohm, ½ w. res.
R_5—390,000 ohm, ½ w. res.
R_6—180,000 ohm, ½ w. res.
C_1, C_4—9-180 µµfd. compression mica trimmer (See text)
C_2—200 µµfd. plate or disc ceramic cond. ± 20%
C_3, C_6—.005 µfd. plate or disc ceramic cond. ± 20%
C_5—.002 µfd. plate or disc ceramic cond. ± 20%
L_1, L_2—Loop antenna (See text)
S_1—S.p.s.t. canopy-type sw.
V_1, V_2—CK512AX tube (Raytheon)
1—22½ volt "B" battery (Burgess Type U15E)
1—1.5 volt "A" battery, pencell

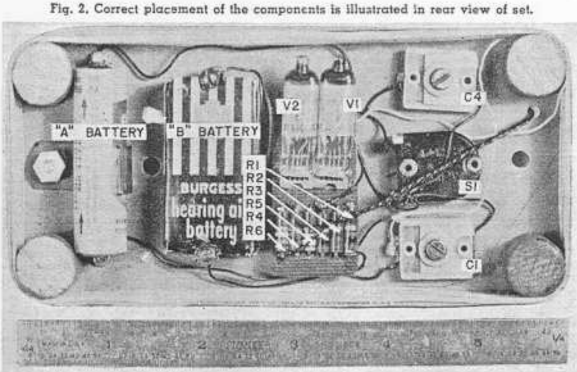
Fig. 1. Complete schematic diagram and parts list for the "Shirt Pocket" radio.

ground return for a tiny chassis carried on the person. There is certainly no direct ground, and very little capacitive ground as the capacity of the person to the set and that of the person's body to the ground are effectively in series, and so the resulting capacity path is high impedance. Also, wire antennas are even less desirable for regenerative receivers, as the moving antenna causes detuning and general instability. For these reasons, the loop type of antenna, which requires no ground, is used in the majority of portable receivers.

The loop antenna L_1 is wound on a form consisting of four pieces of ⅝" dia. dowel rod ⅝" long which are nailed into place on the four corners of the main chassis with ½" carpet tacks. The main winding, which consists of 50 turns of #30 double cotton covered wire, is wound directly on the four dowels. There is not sufficient room to wind 50 turns in a single layer on the ⅝" long dowel, so the author resorted to a form of "bank winding." First, three turns are wound on the form. Then the next two turns are wound in the two grooves directly on top of the first three turns. Then the next three turns are wound on the form; the next two on top of them, and so on. Thus, the winding is composed of ten little groups or "banks" of five turns each. But only a linear winding space for thirty turns is required. This method of winding gives as low a distributed capacity as a single layer winding, yet permits almost twice as many turns to be wound in a given space. Too much distributed capacity in the loop would decrease the tuning range. Should your local stations fall in the 1300-1650 kc. range, wind the loop with eight turns less. This will make the tuning range approximately 600-1650 kc.

After the loop is wound, a coat of quick drying cement is applied to give the required rigidity. Model cement may be used for this purpose. After this cement has dried, wrap a layer

Fig. 2. Correct placement of the components is illustrated in rear view of set.



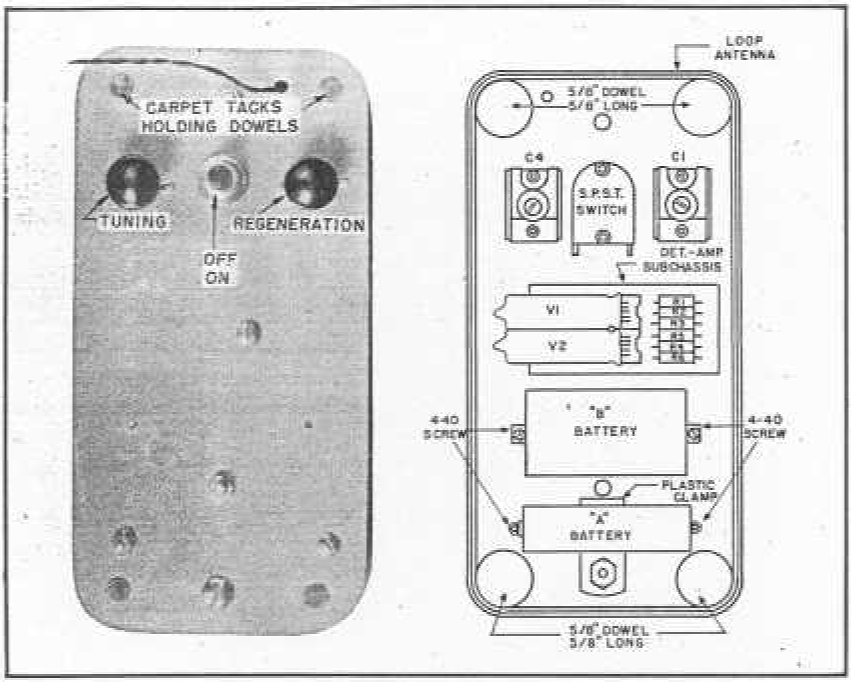


Fig. 3. Front view of the receiver (left) showing location of the various controls. Mechanical drawing indicates how the various component parts should be placed.

of *Scotch* masking tape around the loop to serve as additional protection, and as a base for the tickler winding L_2. This may now be wound at the filament end of the loop using 20 turns of #36 plain enameled wire, close spaced. The loop should be connected so that the end nearest the body (when the set is worn) connects to C_4. This minimizes detuning effects from the set swinging back and forth away from the body. After the tickler winding is wound, coat it with a layer of cement, and then a strip of leatherette may be wrapped around the finished loop both for protection and to give a decorative touch to the cabinet.

Modifying the Condensers

The next step in the construction of the set is to change over the screwdriver adjustment compression mica trimmers to knob tuning. First, prepare the shafts. Take a 6-32 bolt, and cut two ⅜" long pieces from it. File the ends flat and remove the burrs. Next make a center punch mark in one end of each piece, being as careful as possible to get it in the center. If a lathe is available to do this, so much the better, but a fair job of centering can be done by hand. Now drill a ⅛" deep hole with a #44 drill on the center punch marks. This hole just fits the small unthreaded end of the #3 screw in the trimmer. Place a small dab of soldering paste in the hole and a small chunk of solder (about 1/16" square) on top of the paste. Using a small hammer, gently drive the little shafts on to the ends of the trimmer screws. Place a tiny drop of oil (light machine oil) on the threads of the trimmer. This guards against any solder running down into them. Holding the trimmer in a vise, carefully align the shaft. Then apply a hot soldering iron to the free end of the shaft. If all the previous steps have been followed, the flux and solder will melt and just "sweat" the shaft into place.

For knobs, a pair of common bakelite "B" battery terminal nuts serve very well. All that is necessary is to drill and tap them for a 4-40 setscrew and screw them into place on the modified shafts.

Detector-Amplifier Subchassis

The two tubes and their associated small resistors and condensers are mounted on a 1" x 2" piece of 1/16" bakelite. The holes for the tube sockets are first drilled, then filed to size, and the sockets are cemented in place with model cement. The resistors are mounted by bending their leads at right angles, poking them through small holes in the bakelite board, and then crimping and clipping them off on the opposite side. They make a fine little terminal board for this size chassis. The ceramic condensers are mounted by their wire leads, and lie flat next to the board. Wiring may be done with an ordinary 100 watt iron, but it is best to provide a small tip for the iron to facilitate a neat job. For hookup wire, the #30 d.c.c. used in the antenna serves well and is fairly easy to handle, as the bare copper wire tins easily. The wiring layout is not critical. No particular precautions must be taken as to lead length or dressing, and this makes the electrical end of building this set quite easy. Concentrate on doing a sound mechanical job and the rest will take care of itself.

Final Assembly

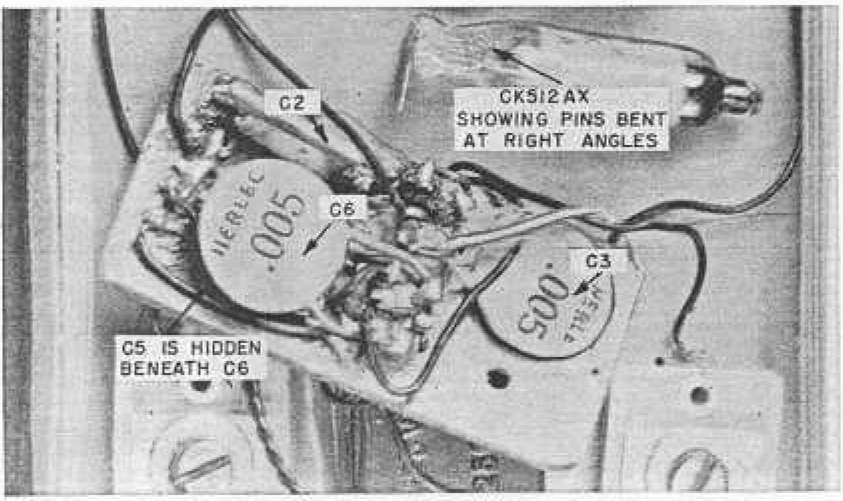
After the subchassis is finished, it is laid in place and the leads from the batteries, loop, switch, and tuning condensers are wired in. Then it is fastened to the main chassis board with a single 4-40 screw and ¼" spacer. The 4-40 screw fits into a tapped hole in the subchassis board (see photo). The trimmer condensers are mounted to the main chassis by their own crimp lug mountings. The "B" battery is bolted into place with two 4-40 bolts and then the leads are soldered to it. A plastic cable clamp is used as the holder for the "A" cell, which makes its contacts to a pair of 4-40 screws fastened to the main chassis. The earphone lead feeds in through a small hole in the front of the case. Connect it up, bolt on the "back" of the case, and the set is complete.

Tuning the Receiver

The sensitivity of the set is such that, if it has been properly built, nearby stations should be heard at once. Some degree of volume will be obtained even if the regeneration control is not set for maximum sensitivity. In fact, on the original set, station WCFL (seven miles from the author's home) is so loud that no regeneration

(*Continued on page* 94)

Fig. 4. A detailed under chassis view showing the detector-amplifier subchassis.



Shirt Pocket Radio

(*Continued from page 44*)

is required. If the regeneration control is advanced to maximum, this station may be heard clearly all over the room if the headphone is held in the cupped hand. For weak signals and also those at the extreme low frequency end of the broadcast band more care is required in tuning. For best results, first tune the station for best reception without adjusting the regeneration. Next, advance the regeneration control until the detector just oscillates, as will be evidenced by a slight rushing sound. Then back off the regeneration control until the rushing stops. Now retune the station, which will now be at its maximum volume. Using this method, the author has received (in the daytime) station WTMJ in Milwaukee, a distance of 85 miles. Its signal could be called "barely understandable," but nevertheless audible. Station WIND whose transmitter is in Gary, Indiana, a distance of 40 miles, can be heard easily. At night, reception is not limited to locals. The original set has "pulled in" large, clear channel stations from as far as 400 miles away!

It will be noted that the antenna is bi-directional. If the set is rotated until the signal fades completely, then the knobs point either towards or directly away from the station being received. This could conceivably serve as a kind of radio direction finder for a person lost in the woods, provided he were able to tell general directions. For purposes of general reception, the directivity of the antenna bothers us little, as the nulls are very sharp, whereas the peaks are very broad. This means that a given station can be received over about 340 degrees rotation of the set. There will be two ten degree nulls where the station fades out. This is not objectionable, as one may turn a corner while listening, and very seldom hit the ten degree null!!

Litz Wire Loops

The performance of the receiver, as outlined in this article, is good. However, there is one way that it may be improved, *i.e.*, introduce a larger signal at the input grid! The signal pickup of a loop antenna is proportional to the area thereof. However the *voltage* across any tuned circuit, loop antennas included, is also proportional to the "*Q*" of the circuit. "*Q*" is the ratio of the reactance to the resistance of a coil. To raise the "*Q*" of the antenna loop, it is only necessary to use a heavy litz wire. By using 35-44 litz wire, the "*Q*" of the antenna is raised from 75 to 220. The signal delivered by such an antenna will be almost three times that delivered by one wound with #30 solid wire. The author has not specified litz wire for the loop in this article, due to the general unavailability of litz, however, he recommends it highly to those who may be able to get some. Use 20-44 to 55-44 single silk enameled for best results. If the highest possible performance is desired, the set may be redesigned mechanically so that the "A" cell, switch, and tuning condensers are outside the loop. The "shorted turn" effect of these components will materially affect the "*Q*" of a loop wound of litz reducing its efficiency as much as 40%. Do not use small litz wires, such as 5-44 or 10-44. They are virtually no better than solid wire and the additional difficulty in handling these sizes is not justified by any notable increase in performance.

—30—

Service Aids

(*Continued from page 51*)

shown in Figs. 3 and 6. Basically this is a two-section balanced attenuator giving a total attenuation of approximately 35 db, unshielded, up to about 220 mc. For convenience we have mounted the resistors on an insulating board and added a set of alligator clips in such a manner that they fit all standard TV antenna terminals. *Scotch* tape helps keep the clips in place and prevents them from shorting to the chassis. The input and output impedance of the attenuator is normally about 300 ohms, but by shorting out the two series resistors in each lead, a 50 ohm input or output can be achieved.

The application of this attenuator lies mostly in checking TV receiver sensitivity and fringe area operation. In many instances a technician may get strong signals at his shop, but service receivers in a weak signal area. By connecting this attenuator between the antenna lead-in and the receiver under test, weak signals will be obtained. Occasionally a set will tend to be regenerative under weak signals and bench testing is difficult because strong signals are found at the shop. Using only one side of the antenna is not always permissible because unbalance occurs and in many receivers unbalanced input will greatly alter the response of the r.f. tuner. Using this attenuator reduces the signal to any desired level while maintaining proper balance and impedance match. If the circuit shown in Fig. 3, gives too much attenuation, remove one set of resistors and use only one I-section. On the other hand, if more attenuation is desired, another section can be added.

Other applications of this balanced attenuator network include signal reduction to avoid overloading on one particularly strong station, demonstrating sensitivity characteristics of different receivers, and checking booster operation. When a booster is connected to a receiver having an efficient automatic gain control circuit, little difference will be observed as long as strong signals are received. Often a booster is tagged as weak for that reason. To check its performance under weak signal conditions, connect the attenuator pad between the antenna and

Kit Review

The Sinclair "Slimline" Micro-Radio Receiver

THE MOST POPULAR CONSTRUCTIONAL PROJECT amongst amateurs is the small pocket radio and, as long as there is no loss of performance, the smaller the receiver is the more popular it will be. In the past, the design of really small high performance receivers has been hindered by the lack of sufficiently small components and by the expense of high grade transistors. These problems have been overcome in the "Slimline", which is the result of an intensive effort to produce the smallest possible radio design with full scale performance and still to retain simplicity of construction.

Circuit Description

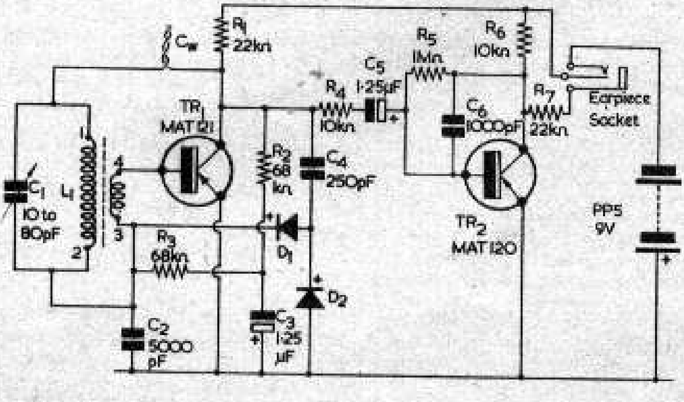
The high performance of the "Slimline" has been made possible by the introduction of Micro-Alloy transistors on to the amateur market. These transistors are the first to combine excellent a.f. performance with cut-off frequencies in the region of 100 Mc/s. The r.f. power gain of a conventional r.f. alloy transistor in a reflex circuit is only about 20dB or 100 times whilst a micro-alloy transistor (MAT) can provide a gain of 40dB or 10,000 times. Furthermore the a.f. gain of a MAT is much higher than that of an ordinary alloy type.

By combining MAT's with careful design it has been found possible to achieve really remarkable performance with only two transistors and relatively few associated components. The sensitivity compares well with that of many superhets and the volume is sufficient to enable the set to be used in a car or train. The "Slimline" is free from noise or distortion and gives excellent fidelity of reproduction.

The "Slimline" circuit is shown in the accompanying diagram. L_1 is a miniature ferrite rod aerial which picks up the signal and, with C_1, tunes to the required station. A secondary winding on L_1 couples the signal to TR_1, MAT 121, which then amplifies at r.f. The r.f. output from TR_1 is fed to a voltage doubling detector via C_4. D_1 and D_2 demodulate the signal and feed an a.f. voltage back to the input of TR_1. Any residual r.f. voltage is removed by C_2.

In addition to detecting the signal, D_1 and D_2 provide an automatic gain control voltage for TR_1. This prevents overloading on strong stations and is an important feature not normally found on simple receivers.

The base bias for TR_1 is provided by resistive feedback from the collector via R_2 and R_3. Taking



Circuit of the "Slimline" transistor receiver the bias from the collector ensures adequate d.c. stabilisation but would normally result in unwanted negative feedback at a.f. This is prevented by decoupling the junction of R_2 and R_3 with C_3, an electrolytic capacitor. The addition of C_3, another novel feature of the circuit, results in a considerable increase in the a.f. gain of the stage.

The r.f. gain of TR_1 is increased by positive feedback or regeneration applied via C_w from the collector to the top of L_1. C_w consists simply of two short lengths of insulated wire twisted together. Its main purpose is to enhance the performance of the radio at the high frequency end of the band, where Radio Luxembourg is situated, thus overcoming the poor sensitivity in this region which is a feature of many reflex sets.

Once the set is constructed C_w does not have to be adjusted because the r.f. gain is automatically controlled by the a.g.c. system.

TR_1 provides about 35dB gain at a.f. and the output is fed to TR_2, and MAT 120, via R_4 and C_5. The circuit around TR_2 is designed to obtain the maximum possible voltage gain from the transistor because the earpiece used, a piezo-electric crystal type, requires a voltage drive for good quality. Crystal earpieces normally give higher sensitivity at high frequencies than they do at low frequencies. This is compensated for by C_6 which provides frequency selective negative feedback from the collector to the base of TR_2.

The total current consumption of the circuit is only 1mA making the battery life several hundred hours with the type specified.

Practical Details

The "Slimline" receiver uses a printed circuit board and the case employed, besides being remarkably small, is both elegant and carefully designed. The case and the dial are both made specially for this receiver.

Particular attention was paid to small details when the layout of the "Slimline" was considered.

This illustration shows the extremely small size of the "Slimline" receiver

For example battery clips are provided making it unnecessary to solder the battery into the circuit. The receiver is automatically switched on when the earpiece plug is inserted and switched off again when the plug is removed. Thus it is virtually impossible to leave the set on unintentionally.

The "Slimline" operates in the vertical position with the dial at the top. The tuning capacitor provided gives full coverage of the Medium wave band and may be detuned slightly to give control over the volume. Alteration of the volume may also be achieved by rotating the receiver, because the aerial is directional.

TR - 2 REFLEX RECEIVER

By
A. SAPCIYAN

A simple 2-transistor receiver intended for personal earphone medium wave reception

BUILDING RADIO RECEIVERS MIGHT SEEM, TO SOME people, to be a very complicated hobby. However, the beginner often starts by tackling simple receivers and then graduates to more complicated ones. This enables him to recognise radio components and to learn the best way of handling them. Many commence with simple diode plus a.f. amplifier circuits. But, after a time, these seem to be unsatisfactory since they often require a long aerial and a good earth, and sensitivity and selectivity may still not be really adequate.

To satisfy beginners at this stage, a reflex circuit becomes attractive, provided that a miraculous performance is not expected. A reflex circuit will usually be able to hold its own in most areas without an external aerial and earth and, in addition to this, should bring in foreign stations after dark. The receiver to be described can be built easily from readily available components and it will play almost anywhere. Its sensitivity control also enables regeneration to take place, with a consequent increase in selectivity.

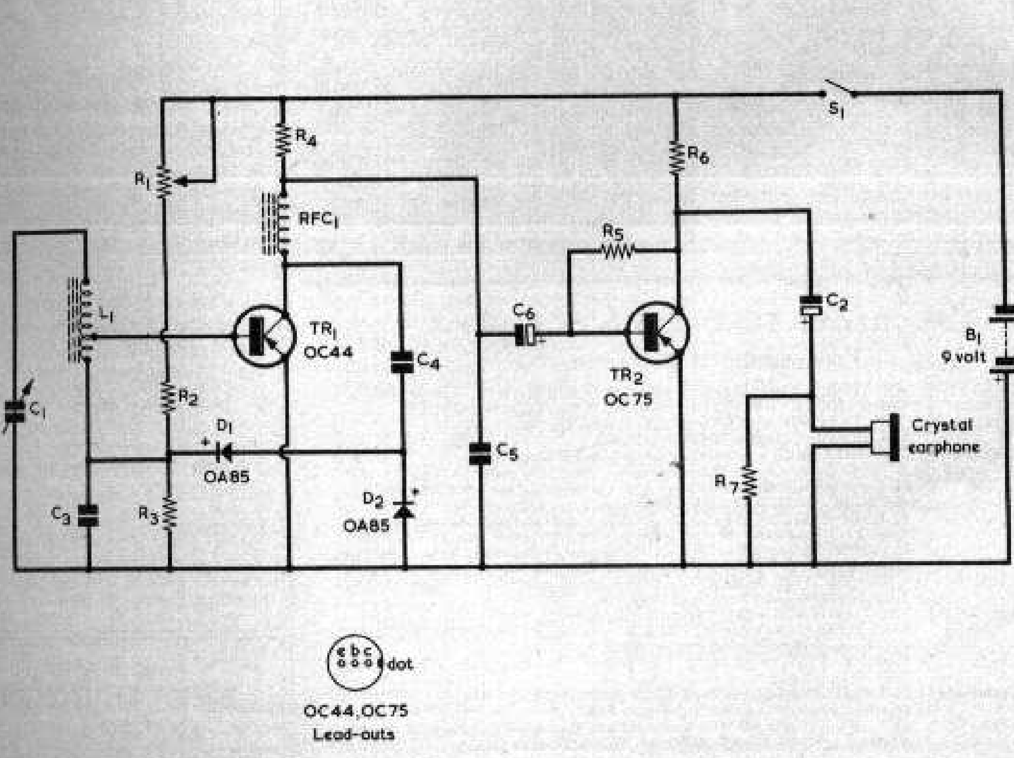


Fig. 1. The circuit of the reflex receiver

THE CIRCUIT

The circuit is given in Fig. 1. As with all reflex receivers of this nature the first stage amplifies at two different frequencies, with the result that the receiver offers greater gain than would be given by two transistors in a conventional circuit. The ferrite rod aerial coil, L1, is tuned by C1, and the selected signals are then passed to the base of TR1. This transistor functions first as an r.f. amplifier, the amplified signals at its collector being passed to the diodes D1 and D2 for detection. These signals cannot pass to the subsequent section of the receiver since their passage is blocked by the r.f. choke RFC1. The detected signals are now returned to the base of TR1 as an audio frequency, and this transistor once more provides amplification, this time at a.f. The amplified a.f. signals pass through the r.f. choke and appear across R4. The base bias for TR1 is controlled by R1, R2 and R3. R1 is the sensitivity control and is adjusted for best reception conditions.

The second stage is a straightforward a.f. amplifier using feedback resistor R5 for stabilisation. The a.f. output at the collector of TR2 is coupled to the crystal earphone via electrolytic capacitor C2. R7 is included to ensure that C2 has a polarising voltage and to prevent the appearance of a direct voltage across the earphone.

COMPONENTS

Resistors
(All fixed values $\frac{1}{4}$ watt 10%)

R1	100kΩ potentiometer, linear, with switch S1
R2	100kΩ
R3	10kΩ
R4	3.9kΩ
R5	390kΩ
R6	5.6kΩ
R7	100kΩ

Capacitors

C1	300pF variable, solid dielectric
C2	4μF electrolytic, 10 V. wkg.
C3	0.01μF paper or plastic foil
C4	200pF silvered mica.
C5	0.01μF paper or plastic foil
C6	4μF electrolytic, 10 V. wkg.

Inductors

L1	See text
RFC1	See text

Semiconductors

TR1	OC44
TR2	OC75
D1	OA85
D2	OA85

Switch

S1	s.p.s.t., part of R1

Battery

B1	9-volt battery type PP3 (Ever Ready)

Miscellaneous
Crystal earphone with jack plug
Jack socket (to suit earphone plug)
2 knobs
Battery connectors
Material for chassis and panel

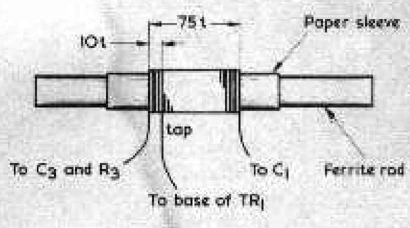


Fig. 2. Winding details of the ferrite rod aerial coil. It is advised that a few extra turns are put on initially, as described in the text, so that the coil inductance may be adjusted for the desired tuning range after the receiver is completed

The total current consumption of the receiver is about 2.5mA.

COMPONENTS

The two transistors are inexpensive and easily obtainable types. It may be necessary to make slight changes to component values if either of the transistors is at an extreme of its gain spread. With TR1 it may be necessary to slightly increase or decrease the value of R2. Whether this is necessary will be indicated by the performance offered as VR1 is adjusted. If TR2 is a low gain specimen the value of R5 may need to be slightly reduced.

The ferrite aerial coil consists of a total of 75 turns of 30 s.w.g. enamelled wire close-wound on a ferrite rod 4in. long with a diameter of $\frac{3}{8}$in. The tap is made at the 10th turn, as shown in Fig. 2, and the coil is wound on a paper sleeve which is free to slide along the rod. It is possible that different grades of ferrite rod may give slightly varying values of inductance to the coil and the constructor is advised to commence with 85 turns overall (the tap still being made at the 10th turn). After the set has been completed turns are then, if necessary, taken off at the end remote from C3 until the desired medium wave range is covered.

The r.f. choke is a home-made component and is wound on a polystyrene coil former of $\frac{1}{4}$in. diameter fitted with a dust core. Cat. Nos. CR4 and CR5 respectively, from Home Radio, would be suitable. The winding consists of 200 turns pile-wound of 38 s.w.g. enamelled wire. The inductance of the choke is not critical and a few turns more or less will not make any difference.

ADJUSTMENT AND OPERATION

The receiver may be built up on a small piece of perforated insulated board fitted with a front panel for C1 and R1. If metal, this panel should be connected to the positive supply line. Alternatively, the components may be mounted on tagstrips or on a tagboard fitted to a small metal chassis and panel, which should similarly be connected to the positive supply line. L1 should be kept well away from either the metal panel or the metal chassis, if these are used, as it will otherwise lose efficiency. Layout is not critical provided wiring is kept reasonably short and the collector circuit of TR2 is spaced away from the base circuit of TR1. An earphone jack socket may be positioned on the front panel at the end remote from C1. R1 should be wired up such that the resistance it inserts into circuit reduces as its spindle is rotated clockwise. The leads to the battery should not be longer than about 6in. RFC1 should not be fitted permanently in position during wiring, as it may be necessary to rotate it when setting up. It should be spaced away from the ferrite rod by about 1 to 2in.

Set L1 winding near the centre of the ferrite rod, switch on and turn R1 fully anticlockwise. If all is well the receiver should then pick up signals, it being at its most sensitive if R1 spindle is turned clockwise to the setting just below that at which oscillation commences. A different setting of R1 is required for each station, although a single setting will suffice for two stations which are close together in frequency. If oscillation is excessive and cannot be controlled by R1 slide L1 coil towards the end of the ferrite rod. The position of RFC1 relative to the rod may have an effect on oscillation and this component should be oriented, if necessary, to see if this reduces or otherwise alters the degree of feedback. In extreme cases, particularly where the transistor used in TR1 position has a high gain, R2 may need to be increased in value, as was mentioned earlier. Suitable alternative values are 120kΩ and 150kΩ. It should be noted that the regeneration effect reduces as the battery ages so that, if R2 is increased to an unnecessarily high value with a new battery, the battery may have to be discarded at an earlier time as its voltage reduces.

The frequency range can be checked by identifying received signals, whereupon the final number of turns required on L1 can be ascertained. The process of finding the frequency range can be made easier if a standard medium wave transistor radio is available since, if VR1 is advanced beyond oscillation point, the reflex receiver acts as a small transmitter whose signal can be picked up by the standard receiver. However, do not allow the reflex receiver to remain in the oscillating condition for more than short periods as it could interfere with other radios. Also, avoid tuning the standard receiver incorrectly to harmonics; the best plan is to set both receivers to an easily identifiable transmission, such as Radio 1 on 247 metres, advance VR1 beyond oscillation point, and then adjust the tuning capacitors of both receivers across the medium wave band, keeping them in step with each other. The range covered by the reflex receiver will then be shown on the tuning scale of the standard receiver. ■