Transistor Circuits for the Constructor

No. 1

E. N. BRADLEY

All the information is strictly practical and covers the construction of SMALL LOUDSPEAKER BEDSIDE RECEIVERS; A HIGHLY SENSITIVE POCKET SUPERHET (with easily-wound aerial, coils and i.f. transformers); A NOVEL SUPERREGENERATIVE SHORT WAVE RECEIVER; and A TEST OSCILLATOR.

A minimum of proprietary items have been specified and the tagboard layouts described and used make it possible for the constructor to utilize many existing or inexpensive components.

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I

USING TRANSISTORS

To the home constructor, transistors are the most exciting development to appear in the fields of radio and electronics for several years. For a full understanding of the way in which they work a careful study of their various characteristics is essential, but the newcomer to transistor techniques can build any of the circuits to be described, leaving a study of the principles involved until a later time.

It is recommended that the constructor of these transistor circuits should have some experience in building conventional valve equipment, and should be practised in the handling and soldering of small components.

Only a brief mention need be made of the many advantages that transistors have for the constructor. More robust than valves, they are far smaller, give high gains, generate practically no heat and operate at low voltages and low currents, so that small batteries will provide power for many working hours. Various types of transistors cover such applications as audio amplification, i.f. amplification and r.f. oscillation and amplification up to television frequencies. Their disadvantages (such as changes of characteristic with temperature, restricted power dissipations and so on) do not unduly bother the constructor since the designer can allow for such effects in his circuits.

The main precaution that must be observed by the newcomer to transistors is to check most carefully all the circuit connections, and the connections to the supply battery, BEFORE SWITCHING ON FOR THE FIRST TIME. A reversal of battery polarity will almost always ruin the transistors with, perhaps, other components as well.

It is only necessary to remember in the case of all the transistor types at present available on the British market, that the collector, *c* in the diagrams, must be negative, the emitter *e* must be positive, and the base *b* biased to some potential between the collector, and emitter. It is very well worth while to colour-code all the main supply leads in a circuit, using red and black plastic covered flex connecting wire respectively for the positive and negative lines. A green covered flex may be used for connections to the base circuits, or for signal-carrying lines.

Just as important as the observation of correct polarity is the need for care when testing circuits with an ohmmeter, or when adding components or extra wiring to an experimental unit. The supply voltages quoted on the circuit diagrams which follow must be regarded as **maximum** values. Since an ohmmeter contains its own source of supply its connection into a transistor circuit might lead to overloading, even with the circuit disconnected from its own battery; also it is very easy to impose a reverse voltage from an ohmmeter. In this connection it may be remembered that the normal multirange test meter has the positive pole of its internal battery connected to the negative terminal or socket on the meter case.

In experimental circuits components, especially capacitors, must never be wired in with the circuit switched on. The charging surge of current into even an 0·01μFd capacitor can cause irreparable damage to a transistor, should such a surge be drawn through its internal junctions.

Finally, transistors should be handled with care. Although they are very robust, many have glass envelopes which could be fractured, whilst the connecting leads should never be bent or twisted near to the seal at which they enter the body of the component. Some of these leads are gold-plated; this plating should not be mistaken for tarnish, and must not be cleaned off.

If transistors are soldered into circuit the leads should be left as long as possible, and must be gripped between the body and the soldered joint by broad flat-nosed pliers while the iron is applied. This prevents over-heating of the transistor elements, the excess heat being drawn from the leads by the relatively large mass of metal in the jaws of the pliers. Even so the joint should be made as quickly as possible.

The author prefers not to solder transistors into circuit, but to mount them on a tagboard by means of 6 B.A. bolts. The method is shown in Fig. 1.

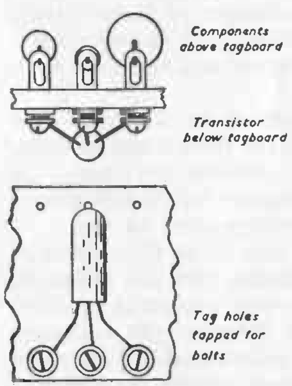

FIG. 1. A METHOD OF MOUNTING TRANSISTORS

Practically all the circuits in this book were originally built on miniature tagboards, $1\frac{7}{16}''$ wide and up to $4\frac{5}{8}''$ long, the tags being spaced $\frac{1}{4}''$ apart along both edges. In the upper part of Fig. 1 an edgewise view of such a tagboard shows components such as resistors and capacitors mounted on the top side of the board in the usual manner. On the underside of the board a transistor is mounted by its connecting wires. The central fixing holes in the appropriate tags were tapped to take 6 B.A. bolts, these being run home before any components were soldered in place, so that the tapped holes may not be fouled by stray solder. Each transistor lead was gently shaped with light tweezers to end in a loop just large enough to take a 6 B.A. bolt, the length of the leads being arranged

to bring the transistor centrally on the tagboard. After the loop was twisted any excess wire was cut away.

With the tagboard wiring completed and all components in place, the 6 B.A. bolts are then run out, passed through the loops in the transistor leads with a plain washer on each side of the wire, and screwed home. The transistor leads must be gripped with tweezers as the bolts are gently tightened down, to prevent twisting and straining of the leads. Neighbouring washers must not touch.

There must obviously be no possibility of error when mounting the transistor, and it is as well to code each appropriate tag on the board, as it is wired, with the letter *e*, *b* or *c* to denote the correct transistor connection. This coding should also be made on the rear of the board at the same time.

Fig. 3 shows a complete tagboard. Note the codings below the tags to which the transistor leads are taken. In this particular case the codings run in the sequence: emitter; base; collector. When the board is turned over the sequence will, of course, be reversed into: collector; base; emitter. This point must be borne in mind. In other circuits the transistor is connected in the sequence: collector; base; emitter—looking at the front of the board, as in Fig. 11.

To the experienced constructor these precautionary notes may seem unnecessarily stressed, but care in all these matters is essential.

Transistor lead codings vary with make and are shown on the circuit diagrams for the specified types.

When testing any transistor circuit for the first time it is a wise precaution to connect a milliameter in the lead to the negative battery terminal, so that an unexpectedly high current can be detected immediately and the circuit switched off. It is also a good idea to commence testing with no more than a $1\frac{1}{2}$V supply; some circuits will not operate correctly at such a low voltage but any mistake in the wiring or in connecting up the battery will be shown by a relatively high current reading, whilst the voltage will probably be sufficiently low to prevent damage to the transistors.

Including a milliameter in series with the equipment and battery may cause instability in some cases, leading to howling or motor-boating. Such instability is sometimes caused by the inductance of the meter coil and can often be cured by switching to the next higher current range, where the coil is shunted by a low resistance. It can also be cured by connecting a low working voltage 2μFd paper capacitor across the meter terminals.

2

A BEDSIDE RECEIVER

THE two-stage receiver shown in Fig. 2 is called a bedside receiver since it gives very pleasing loudspeaker results in a quiet location. The actual audio output power available may be judged by the fact that the total current consumption from a 6V battery is less than 1mA. Clearly at such a power level the receiver is not suitable for use in a noisy location, but it can be built into a small case and used as a portable when an aerial and earth are available. For outdoor use a wire fence generally serves as a satisfactory aerial; in the bedroom the bedspring or frame is an old-fashioned but still an excellent solution.

The receiver circuit consists of a regenerative detector followed by an audio amplifying stage. The tuning coil, a Repanco DRR2, is tapped on both medium and long waves to present the correct impedance to the base of Tr_1, reaction being obtained by feeding back energy from the collector into a secondary winding. Control over the reaction is provided by varying the bias on the base of Tr_1 *via* R_2, whose slider should be adjusted so that the detector is just not oscillating. A more common method of controlling reaction is to return R_1 directly to the negative supply line, C_2 being made a variable capacitor; the present method was chosen by trial as it was found possible to set R_2 for correct operation over wide sweeps of the tuning capacitance C_3.

Manufacturing tolerances are generally wider for transistors than for valves, and in some cases it may be found necessary to increase the value of C_2 for good long-wave operation. This capacitance may also have to be varied if any other type of r.f. transistor is used in place of the OC45 specified. The OC44 works well in this circuit with an increase in C_2 which should be determined by trial; "surplus" r.f. transistors should also prove satisfactory though these types have not been tested.

The collector of Tr_1 is isolated from the following circuits by a high frequency choke, which in the prototype had a value of 14mH. A resistor can be used in place of the choke, though the output will then be slightly reduced. If the receiver is to be built into a very small case the consequent saving in space by using a resistor might be thought worth while; a value of 820 ohms will be found satisfactory.

The audio coupling from the detector to the amplifier stage is *via* C_6, a 2μFd electrolytic capacitor. The large capacitance is a common feature of practically all transistor audio amplifiers of the resistance-capacitance type, and is made necessary by the relatively low input impedance of transistors. An 0·01 or 0·1μFd capacitor here would cause serious loss of the low frequencies and give a thin, reedy tone.

The capacitor C_6 should be of the midget type made for transistor operation, with a working voltage of 6V or so. Note the

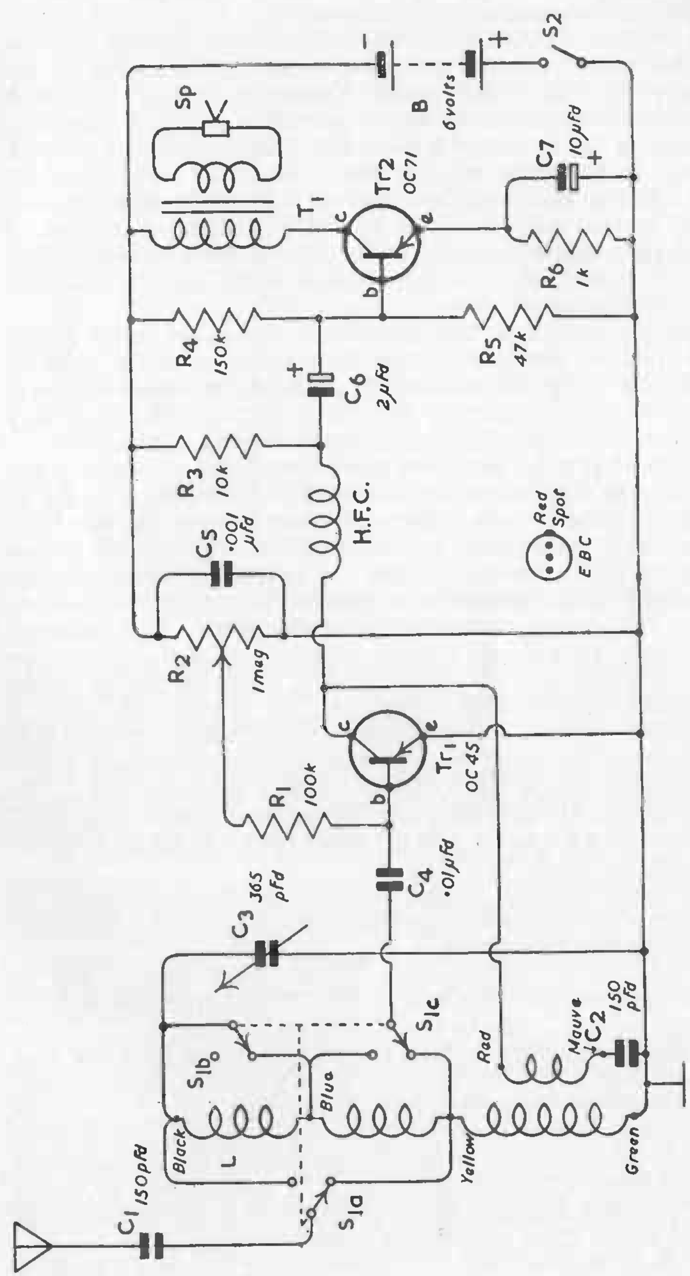

FIG. 2. THE BEDSIDE RECEIVER

polarity coding in the diagram and ensure that the positive tag of the capacitor is connected to the base of Tr_2.

The resistors R_4, R_5 and R_6 round Tr_2 provide bias for the base of the transistor and also stabilization against variation of the working point with temperature. Transistor current rises with temperature unless steps are taken to prevent or minimize this effect. In the case of the detector the bias, and thus the collector current, is adjusted to suit reception conditions, but in the audio amplifier no such adjustment is possible. The base is therefore held at a fixed potential by the voltage divider R_4 and R_5, when an increase of collector current due to temperature rise causes a corresponding increase in emitter voltage and a decrease in the base current, one effect counteracting the other.

In this particular case the values of R_4 and R_5 are rather higher than ideal values—desirable values here would be of the order of 33k and 3·9k for good stabilization. The higher resistances were used after tests which showed that better output with satisfactory stabilization was thus obtained in poor reception areas.

For best results the transistor must be matched correctly to the loudspeaker by the output transformer T_1. Fortunately, so far as power gain in the stage is concerned, there is some latitude here, and reasonably good results can be obtained from a small output transformer of the universal type, the correct primary tappings being found by trial. REMEMBER TO SWITCH OFF THE RECEIVER BEFORE ALTERING THE CONNECTIONS TO THE TRANSFORMER. The optimum load resistance for a simple Class-A output stage of this type varies with the working point of the transistor, which is usually set to pass a predetermined collector current. An approximate value is given by dividing the collector voltage by the collector current in mA, calling the resulting figure the load resistance in thousands of ohms. In the present circuit the collector voltage is about $-4·5$, the collector current about 0·5mA and the required load is thus about 9,000 ohms. For a speaker with a 3 ohms voice coil the transformer ratio should be about 55 : 1.

In any transistorized output stage the loudspeaker should be chosen for good quality and for maximum size which will fit into the mounting space available.

The value of C_1 will depend on local conditions and may be varied in order to obtain the best results. With a strong local signal and a large aerial C_1 may be much reduced in value.

The resistors used throughout the circuit need be no larger than 1/10th or 1/20th watt. As these sizes are not always readily obtainable ¼ watt ratings are quoted in all parts lists.

The specified tuner is midget sized and permits the receiver to be housed in a small case. If very full coverage of the medium wave range is required a 500pFd tuner should be used instead, to extend the low frequency tuning limit; or alternatively a trimmer could be connected across C_3 to increase the minimum capacitance.

The whole receiver, with a 3″ loudspeaker, can easily be fitted into a plastic food box as in Fig. 3. Battery life is good and as the batteries aged no instability occurred in the prototype; if any howling is heard under these conditions a midget 10μFd electrolytic capacitor connected from the negative end of R_4 to the positive end of R_5 will provide a cure.

COMPONENTS LIST FOR THE BEDSIDE RECEIVER, FIG. 2

L	Repanco DRR2. (Repanco Ltd., 203-269 Foleshill Road, Coventry.)
C_1, C_2	150pFd midget mica. *See below.*
C_3	365pFd Jackson Bros. Type O Tuner.
C_4	0·01μFd midget tubular ceramic.
C_5	0·001μFd midget mica.
C_6	2μFd 6 v.w. miniature electrolytic.
C_7	10μFd 6 v.w. miniature electrolytic.
R_1	100k ¼ watt.
R_2	1Meg. midget reaction/volume control.
R_3	10k ¼ watt.
R_4	150k ¼ watt.
R_5	47k ¼ watt.
R_6	1k ¼ watt.
Tr_1	Mullard OC44 or OC45.
Tr_2	Mullard OC71.
$H.F.C.$	14mH r.f. choke or similar.
S_1	3-pole 2-way rotary wavechange switch.
S_2	S.P. on-off switch ganged with R_2.
T_1, Sp	Loudspeaker with tapped output transformer. *See text.*
Miniature tagboard.	
B	6V battery. 2 "Fountain Pen" 3V batteries in series, or similar.

Some audio howl or squeal may be heard at a critical setting of the reaction control R_2, but this can be stopped by a slight reduction in feedback.

The detector circuit alone can be built as a very small single-transistor receiver, R_3 being replaced by high impedance (2,000 ohms) earphones, when the battery voltage can be reduced to 3V. C_6 and the following circuits are then omitted. A personal or deaf-aid type earpiece might also be used if it is matched into the collector circuit by a suitable transformer—the Fortiphone Type L earpiece with an N22 transformer is suitable.

A constructor who wishes to "use up" a point-contact transistor can build a very similar two stage bedside receiver with the circuit shown in Fig. 4. The chief differences lie in the detector circuit, where the emitter of a point-contact transistor such as the Brimar TP2 is tapped directly on to the tuning coil, reaction being applied by a variable capacitor directly from the collector back to the emitter. As there is no change in phase between the emitter and collector, feedback can readily be obtained in this simple manner, though there is some detuning of the signal when C_3 is varied, necessitating a resetting of the main tuner, C_2.

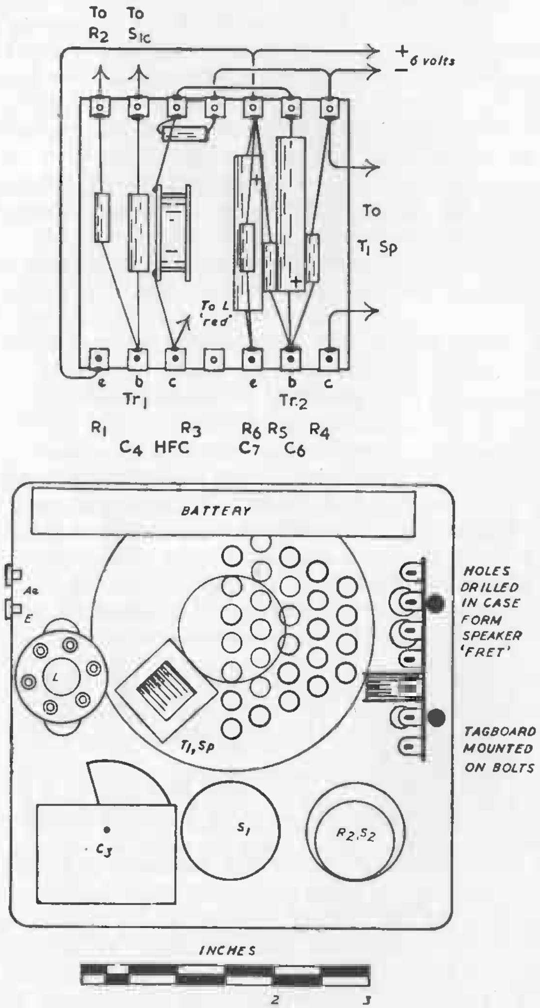

FIG. 3. TAGBOARD AND CASE LAYOUT

The detector base is connected to the positive supply line through a preset 1k resistor, which must be adjusted to give maximum sensitivity and smooth reaction. This is best done by tuning in the local station with R_1 set to full resistance, turning down R_1 (and resetting C_2 and C_3 as necessary) until the signal is at best volume. The setting of R_1 should then be checked on weak stations, when it will be found possible to choose the correct resistance value for best all-round results.

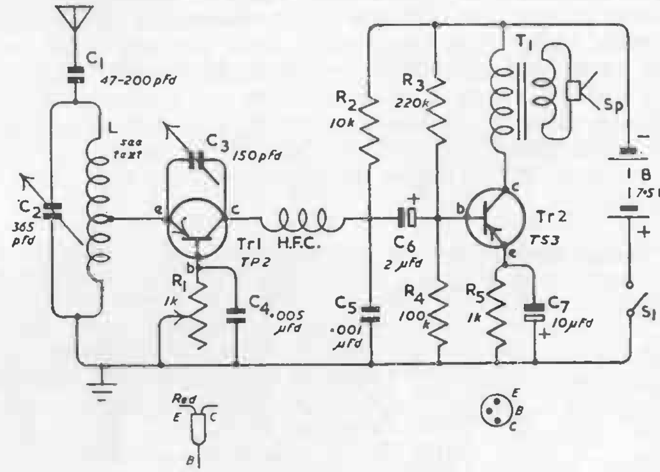

FIG. 4. A BEDSIDE RECEIVER USING A POINT-CONTACT DETECTOR

The tuning coil, *L*, may be home-made or adapted from a commercial coil. In good reception areas a ferrite rod aerial would bring in the local stations without an external aerial and earth. Two ferrite rods should be used, assembled side by side with cellophane tape (as shown in Fig. 7), a winding of 40 turns of 30 s.w.g., d.c.c. copper wire being placed centrally on the rods. This winding should be tapped 6 turns from the positive or earthed end for the connection to the emitter of Tr_1.

Good results have been had from a medium wave oscillator coil, the feedback secondary winding being connected to the main tuned winding to provide the smaller tapped section of the inductance. To connect the two windings in the correct sense, first identify the START and FINISH of each coil. Connect the FINISH of the main winding to the stator of C_2 and to C_1. Take the START of the main winding to the FINISH of the smaller secondary winding, this junction providing the tap connection to the emitter of Tr_1. The START of the smaller winding then becomes the earthed end of the whole coil, being taken to the rotor of C_2. The coil used in the original receiver was a Teletron H02 with the iron dust core screwed centrally between the coils, though practically any iron or air cored medium wave oscillator coil should serve.

If long wave tuning is required a long wave oscillator coil may be connected in the same way. The aerial, tuning capacitor and emitter tap connections may then be switched from coil to coil.

In Fig. 4 the output stage employs a Brimar TS3 transistor, the whole receiver working from a 7·5V battery. The approximate output load required in this case is 12,000 ohms, the transformer ratio for a 3 ohms voice coil being roughly 60 : 1. The output load could be reduced to a much smaller figure by allowing the TS3 to pass more current, but here again the resistances in the circuit have been made higher than ideal values since this was found to give overall better performance in this particular circuit. The experimenter with experience in transistor work may care to try the effect of different values in the bias network R_3, R_4 and R_5. (See Fig. 12).

As in the circuit of Fig. 2 the detector can be used as a single stage receiver, R_2 in Fig. 4 being replaced by high impedance earphones.

COMPONENTS LIST FOR THE BEDSIDE RECEIVER, FIG. 4

L	Medium wave coil. *See text.*
C_1	Aerial capacitor. *See below.*
C_2	365pFd Jackson Bros. Type O Tuner.
C_3	150pFd variable or semi-variable. *See below.*
C_4	0·005μFd midget tubular ceramic.
C_5	0·001μFd midget mica.
C_6	2μFd 12 v.w. miniature electrolytic.
C_7	10μFd 6 v.w. miniature electrolytic.
R_1	1k midget preset potentiometer.
R_2	10k $\frac{1}{4}$ watt.
R_3	220k $\frac{1}{4}$ watt.
R_4	100k $\frac{1}{4}$ watt.
R_5	1k $\frac{1}{4}$ watt.
Tr_1	Brimar TP2.
Tr_2	Brimar TS3.
H.F.C.	14mH high frequency choke.
S_1	S.P. on-off switch.
Sp, T_1	Loudspeaker with output transformer. *See text.*
Miniature tagboard.	
B	7·5V battery.

The value of C_1 should be found by trial, which will depend on local conditions. A good aerial will need only a small capacitance.

C_3, the reaction capacitor (and thus the volume control) can be fully variable, when a Jackson Bros type O tuner is a suitable component, or semi-variable. In the latter case a 150pFd compression padder capacitor can be used. To make the adjustment more convenient a short length of brass spindling can be sweated on to the head of the compression screw, when a knob can be fitted as a panel control.

The point-contact version of the receiver can be built up in the same manner as the junction transistor set, shown in Fig. 3.

3

A POCKET SUPERHET

In Figs. 5 to 9 inclusive are shown the circuits and constructional details of a 5 transistor medium wave superhet which can be built to fit into a coat or jacket pocket. It is entirely self-contained, including a ferrite rod aerial, and is intended for earphone reception though it will drive a small loudspeaker on local stations with sufficient audio power for quiet listening conditions. When used with a personal or deaf-aid earpiece the set is as sensitive and selective as the average valve portable receiver.

It is convenient to build the transistor superhet in two units or sections. The frequency changer unit is shown in Fig. 5 and the complete i.f. amplifier, detector and audio amplifier unit in Fig. 6. Only three interconnections, coded *a*, *b*, *c*, are needed.

In the frequency changer section L_1 and L_2 are the windings of the ferrite aerial which, like all the coils, is easily wound by hand. L_2 matches the aerial into the base circuit of a Mullard OC44 transistor, the oscillator coil windings being connected to its emitter and collector. The tuned oscillator winding, L_4, is tapped on to the emitter, the coil thus being lightly loaded and the oscillator tuning sharp. The feedback winding, L_3, is in series between the collector and the primary of the first i.f. transformer, $I.F.T._1$ of Fig. 6.

The Mullard OC44 was chosen as the frequency changer for it has a relatively high frequency limit, oscillates readily at a low voltage and is a good converter. It is probable that other r.f. transistors could be used in the circuit but no other types have been

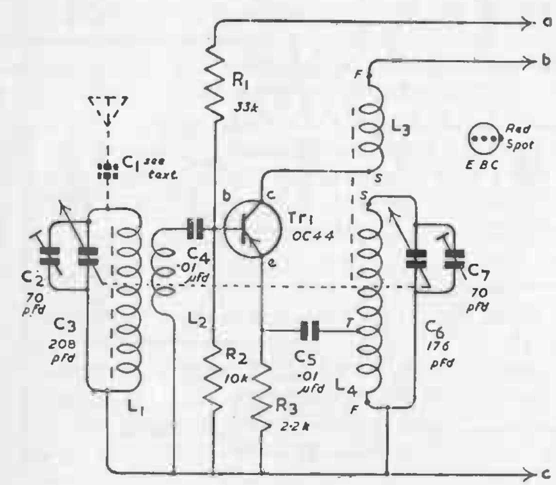

FIG. 5. THE FREQUENCY CHANGER

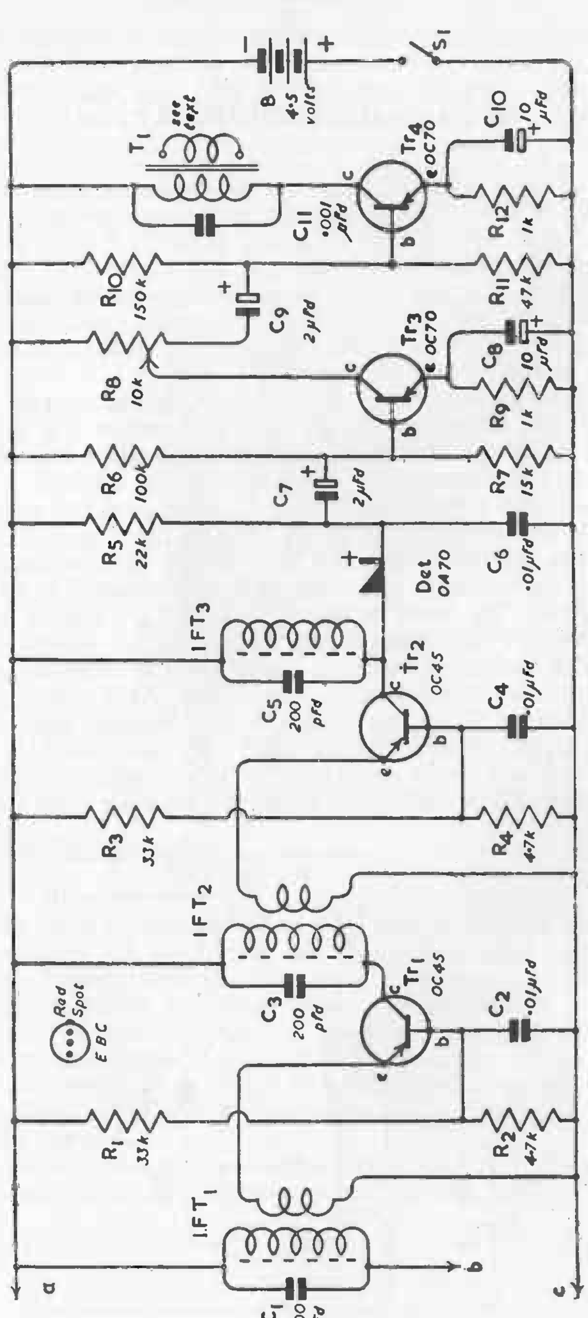

FIG. 6. THE I.F./AUDIO UNIT

tested by the writer, apart from the OC45 which will also serve in this position. In the i.f./audio unit, Fig. 6, two Mullard OC45 transistors are used as common base i.f. amplifiers. Various types have been tested in these positions and if only local station reception is required it is possible to use OC71s. The i.f. gain is poor with these types however; "surplus" r.f. transistors should prove satisfactory and the specified OC45s give excellent results.

I.F.T.$_1$ and *I.F.T.*$_2$ are wound with step-down ratios of 10 : 1 to match into the emitters of the two i.f. amplifiers, the i.f. frequency being 300kc/s. Whilst the i.f. circuits employed do not give all the gain which can be obtained from common emitter circuits they have the advantage of being completely stable and easy to adjust. The second i.f. amplifier feeds directly into a crystal diode detector whose audio output is amplified by Tr_3. The collector load of this transistor forms the volume control from which the signal is passed to Tr_4 for further amplification and matching into the earpiece or loudspeaker. In the original receiver OC70s are used as the audio amplifiers in the interests of low noise level, but OC71s can be employed with no changes in the circuit.

Ideal values for R_6 and R_{10} would be 18k; for R_7 and R_{11} 2·7k; and for R_8 3k. These values could be used in a first-class reception area. The higher values shown give less effective stabilization but greater audio output.

It will be noted that in Fig. 5 the ganged tuners, C_3, C_6, have the unusual values of 208 and 176pFd respectively. These are the values of the tuning sections in a very small tuner by Jackson Bros, Type OO. Using the coils to be specified this tuner gave a slightly restricted tuning range over the medium wave band, and if full coverage is required the larger Type O, 365pFd or Type M 500pFd tuner should be used, with a consequent increase in case size. Generally, however, it is possible to set up the desired range over the smaller tuner by careful adjustment of C_2 and C_7: to cover the lowest frequencies in the medium wave range these two trimmers might be increased to 100 or 150pFd capacitances.

The aerial coils are wound on two ferrite rods 4″ in length which can be the two halves of a standard 8″ rod $\frac{5}{16}$″ in diameter. To cut ferrite rod it should be nicked fairly deeply with a file or hacksaw at two opposite points, then snapped firmly and decisively, holding half the rod in each hand. The aerial rods are supported side by side with a turn of cellophane tape at each end, as shown in Fig. 7.

The main tuned winding consists of 32 turns of 30 s.w.g., d.c.c. copper wire. In the original receiver the coil is closewound, but until the receiver is aligned and tested this coil should not be too firmly secured at its ends, as it may prove helpful to the tracking to space out the winding. At the earthy end of L_1, 5 turns of the same 30 d.c.c. wire are overwound to form L_2.

When the receiver is aligned and the final form of the aerial winding decided the coils should be varnished with coil varnish, or

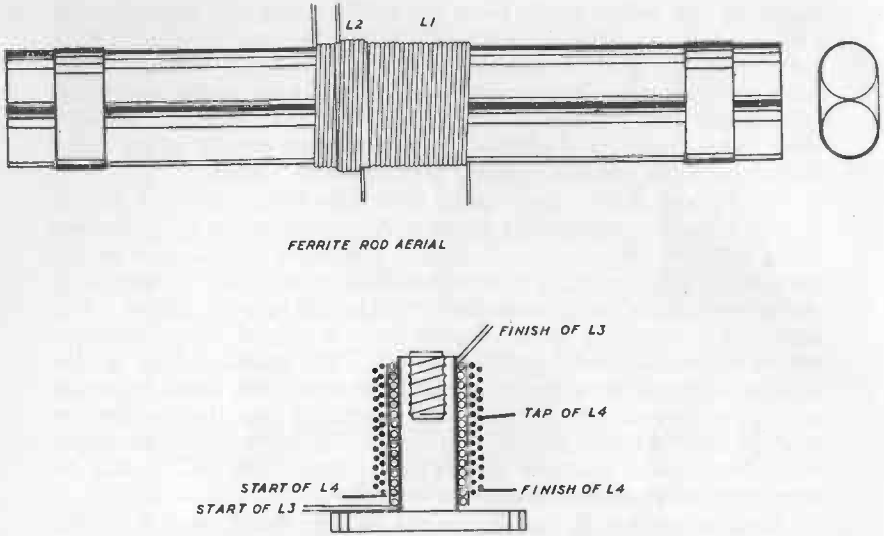

FIG. 7. AERIAL AND OSCILLATOR COIL DETAILS

covered with self-adhesive polythene tape to prevent their taking up moisture from the air.

The oscillator coil and i.f. transformer are all wound on Aladdin formers of clear polystyrene, ¼″ in diameter and 1″ long, each fitted with an iron dust core. Four of these formers are required.

In the oscillator coil L_3 consists of 25 turns of 30 s.w.g., d.c.c. copper wire wound directly on the former in a single layer, turns touching. (See Fig. 7.) This winding is covered with a layer of cellophane or polythene tape, over which is wound the main tuned coil L_4, consisting of 80 turns of 36 s.w.g., d.c.c. copper wire tapped at 70 turns. This winding, if made neatly, will go on in three layers, the 70 turn tap falling in the top layer. To make this tap, twist the wire on itself to form a pigtail about 2″ long, then continue the winding in the same direction for the final 10 turns. If the pigtail is longer than required, and is trimmed, remember to solder both leads together at the cut end.

Transformers $I.F.T_1$ and $I.F.T_2$ are wound in the same manner. The secondary consists of 33 turns of 30 s.w.g., d.c.c. copper wire and this is closewound on the former—the 1″ winding length giving just sufficient room for this coil to go on in a single layer. This winding is covered by a turn of cellophane or polythene tape, and the tuned primary is wound over this. The primary winding consists of 330 turns of 36 s.w.g., d.c.c. copper wire.

While this winding is being made it is as well to support the reel of wire on a long nail or peg driven into the edge of the work-bench so that the wire can be drawn off the reel without kinking. The 330 turns must be put on in layers; unless small cheeks of card or paxolin are fitted to the coil former each successive layer must be

a turn or two shorter than the one before and the final coil will be barrel-shaped, but the coil is still satisfactory. When the winding is complete the whole coil should be covered with a turn or two of cellophane tape to secure and protect the wire.

$I.F.T._3$ has the 330 turns winding only, with no secondary.

COMPONENTS LIST FOR THE POCKET SUPERHET.
THE FREQUENCY CHANGER, FIG. 5

L_1, L_2	32 turns 30 s.w.g., d.c.c. overwound with 5 turns 30 s.w.g., d.c.c. at earthy end, on 4″ ferrite rods.		
L_3, L_4	25 turns 30 s.w.g., d.c.c. overwound with 80 turns 36 s.w.g., d.c.c. tapped at 70 turns, on ¼″ diam. former.		
C_1	*See text below.*		
C_2, C_7	70pFd postage stamp trimmers.		
C_3, C_6	208-176pFd Jackson Bros. Type OO Tuner.		
C_4, C_5	0·01μFd midget tubular ceramic.		
R_1	33k ¼ watt.	R_2	10k ¼ watt.
R_3	2·2k ¼ watt.	Tr_1	Mullard OC44.

Small tag or mounting board.

COMPONENTS LIST FOR THE POCKET SUPERHET.
THE I.F./AUDIO UNIT, FIG. 6

$I.F.T._{1, 2}$	33 turns 30 s.w.g., d.c.c. overwound with 330 turns 36 s.w.g., d.c.c.		
$I.F.T._3$	330 turns 36 s.w.g., d.c.c.		
C_1, C_3, C_5	200pFd midget mica.		
C_2, C_4, C_6	0·01μFd midget tubular ceramic.		
C_7, C_9	2μFd 6 v.w. miniature electrolytic.		
C_8, C_{10}	10μFd 6 v.w. miniature electrolytic.		
C_{11}	0·001μFd midget mica.		
R_1, R_3	33k ¼ watt.	R_2, R_4	4·7k ¼ watt.
R_5	22k ¼ watt.	R_6	100k ¼ watt.
R_7	15k ¼ watt.		
R_8	10k midget volume control.		
R_9	1k ¼ watt.	R_{10}	150k ¼ watt.
R_{11}	47k ¼ watt.	R_{12}	1k ¼ watt.
$Tr_{1, 2}$	Mullard OC45.		
$Tr_{3, 4}$	Mullard OC70 or OC71.		
Det.	Mullard OA70.		
T_1	Output transformer to suit loudspeaker or earpiece. With Fortiphone earpiece Type L, use Type N22 transformer.		
S_1	S.P. on-off switch, ganged with R_8.		
Miniature 18-way tagboard.			
B	4·5V battery. Three "Fountain Pen" cells, or similar.		

In Fig. 5 an optional aerial, connected in by C_1, is shown in dotted lines. Whilst the receiver is sufficiently sensitive for all normal purposes the medium wave Light Programme (247 metres) is notoriously weak in some reception areas and the ferrite rod aerial may need some assistance in a few places if this programme is to be heard. If the receiver is used with a deaf-aid earpiece the flex cord to the earpiece will serve as a built-in aerial, C_1 being connected between the stator of C_3 and either side of the secondary of T_1. The value of C_1 should be found by trial. If the aerial is in close proximity to the i.f. circuits (as it will be in a small case) C_1 will cause feedback if it is too large, and values from about 10pFd upwards may be tried.

The original receiver was built into a plastic food box $4\frac{5}{8}''$ square and $1\frac{3}{8}''$ deep. The frequency changer unit was built directly into the box, the twin gang tuner and volume control being mounted as shown in Fig. 9. The oscillator coil was mounted inside the box, its foot being fixed with balsa cement. The transistor was mounted on a 3-way tagstrip which also supported R_1, R_2 and R_3, C_4 and C_5 being mounted in the wiring.

The i.f./audio unit was built up on a miniature 18-way tagboard, the arrangement of parts being shown (not to scale) in Fig. 8. The tagboard used measured $4\frac{5}{8}''$ long by $1\frac{7}{16}''$ wide, the ends being rubbed down until the board was a push-fit into the $4\frac{5}{8}''$ plastic box. The transistors, as already described, were fastened by 6 B.A. bolts on the rear of the board, the connection codings being shown in the diagram along the lower edge of the board.

The trimmers C_2 and C_7 are mounted in the original on the i.f./audio tagboard, short lengths of 16 s.w.g. tinned copper wire from spare tags supporting them; the tags used are the second, third, fifth and seventh from the left on the upper edge of the board, Fig. 8.

The 4·5V battery can be made out of three 1·5V cells from "Fountain Pen" batteries. The writer favours soldered connections between the cells, also for the leads from the receiver to the battery, though clip connectors could be made up from springy brass. Since battery life is long the soldered connections need only be made occasionally. The cells must not be overheated and the brass caps and zinc bases should be cleaned before tinning, the joints being made quickly with a clean hot iron. The cardboard battery cases must be kept on the cells, or they must be insulated with a wrapping of tape so that there is no chance of an accidental short circuit.

Aligning the receiver is not difficult. The i.f. unit can be tuned before the whole receiver is assembled by connecting a short aerial or length of wire to the connection on *I.F.T.*$_1$ marked *b*. With the i.f. unit switched on (R_8 being connected in by short leads and turned up for maximum volume) it is possible to trim the cores for maximum noise. If a signal generator is available this can of course be connected in to the first i.f. transformer instead. The output should be kept low to avoid any chance of overloading.

When the whole receiver is assembled it is as well to make the

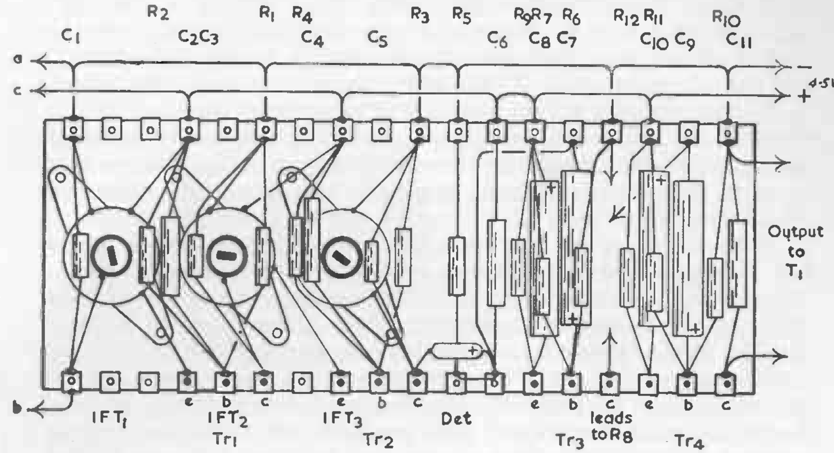

FIG. 8. THE I.F./AUDIO STRIP

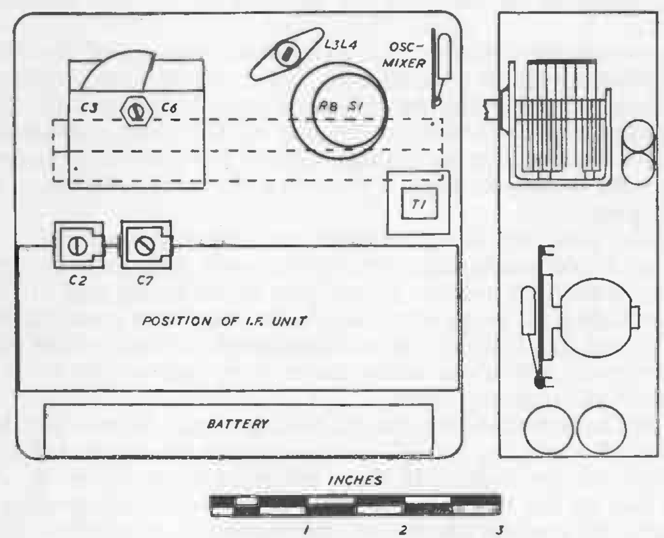

FIG. 9. THE ORIGINAL LAYOUT FOR THE POCKET SUPERHET

first tests with the ferrite rod aerial connected in by leads long enough to allow the aerial to rest outside the case. C_2 and C_7, Fig. 5, should both be set to about half capacitance and the core of L_3, L_4 screwed in until its top is flush with the top of the former. It should then be possible to receive the local station: remember that the aerial is directional, greatest pick up being broadside to the coil, the rods being turned away from the station. If no signals can be heard when the tuner is turned through its travel connect a short aerial wire through a temporary C_1 of 100pFd. When the local station can be heard, even if only faintly, adjust C_2 to bring up the volume and disconnect the temporary aerial. Readjust C_2 and trim the core of *I.F.T.*$_1$ for best volume.

It now remains to set the tuning range and tracking. Constructors with signal generators will naturally use these instead of relying on broadcast signals; those without can adjust the receiver on home and foreign stations, preferably during evening reception conditions.

With the tuner set to practically minimum capacitance adjust first C_7, then C_2, in small steps, until the West Home Service on 206 metres, or Luxembourg on 208 metres is received at best strength. There should be sufficient hiss in the earpiece to indicate that the two trimmers are being kept in step one with the other until the signal is found. Now tune along the band; a number of stations should be received one after another, including various Home Services. Results will most probably fall off as the tuner is turned until finally no more signals can be heard. Retune to the last faint signal detected and adjust the core of the oscillator coils, L_3, L_4, either in or out until the signal is at the best obtainable volume.

Now retune the receiver to the high frequency end of the scale—to the West Home or Luxembourg signal. Quite possibly this will have vanished altogether, the trimmer C_7 requiring resetting. If the oscillator core was turned in, slightly reduce the capacitance of C_7; or, if the core was turned out, slightly increase the capacitance of C_7, until the required signal is again heard at the original setting of the tuner.

Again turn the tuner towards maximum capacitance. The tracking should now be considerably improved, with stations coming in at good strength over the greater part of the tuning dial. If there is some falling off in results towards the maximum capacitance of C_3, C_6, once again adjust the oscillator core for best results at the low frequency end of the tuning range, then again adjust C_7 on the original high frequency signal.

Now check results over the full tuning range. Signals should be received all along the arc of the tuner, when the ferrite rod aerial windings can be sealed. If there are poor spots, however, or if either end of the tuning range is decidedly weak, try spacing out the turns of L_1 on the ferrite rods, retrimming C_2 on the West Home or Luxembourg signals after each adjustment of L_1. If spacing out the turns of L_1 in this way makes matters worse close up the turns again and add a further two or three turns of wire to the winding. By experimenting with the core setting in the oscillator coil and, if necessary, spacing out or increasing the turns of L_1 it will be found possible to make the receiver lively over its whole tuning range. L_1 should then be protected by sealing the turns with coil dope or varnish, or with a wrapping of adhesive polythene tape.

The aerial leads can now be shortened and the aerial fitted into the case, resting across the rear of the tuner and the volume control

if the layout in Fig. 9 is used. If the aerial is too close to the i.f. strip instability may occur. The aerial will probably clamp into position when the lid of the case is secured. Before closing the lid check the setting of C_2 in case the shortening of the leads has affected the aerial tuning, and trim the i.f. transformers.

The case and its lid can be drilled at two or three points along their common edges, the holes being tapped to take 6 or 8 B.A. bolts, but in the original receiver it was found that the plastic did not take well to this method of sealing the lid. Instead, a single turn of decorative adhesive tape was run round the join, and proved to be strong, durable and attractive.

The tuning range of the original receiver, which is used in the West Country, covers from the West Home service down to the London Home service, the actual range being approximately 1,450kc/s to 850kc/s. In some areas it would be desirable to tune to a lower frequency; in this case C_2 and C_7 must be adjusted to a higher capacitance and the high frequency end of the band discarded. Tuners such as the Jackson Bros Type O with a frequency swing of 365pFd can be fitted into the same type of plastic case if they are mounted on the side wall, the tuning knob then being on the side of the receiver. The same oscillator coil and aerial windings will serve equally well with these or with 500pFd tuners.

A fairly pronounced carrier hiss seems to be a feature common to most transistor receivers. C_{11}, Fig. 6, can be increased by trial to give further hiss reduction should this seem desirable.

The consumption of the receiver varies with temperature, but under normal conditions is approximately 3mA.

4

A SUPERREGENERATIVE RECEIVER FOR TRAWLER AND AMATEUR BANDS

THE circuit shown in Fig. 10 is of a single transistor superregenerative receiver covering the tuning range 1·5 to 4Mc/s. It is therefore suitable for trawler reception and covers the two "top" amateur bands, so that it would make an excellent "emergency" set for the amateur interested in low frequency working. Apart from considerable novelty value the receiver illustrates well the capabilities of the r.f. junction transistor and is very sensitive and broadly tuned. On a short aerial WWV is received at excellent strength, as are lighthouses, lifeboats, trawlers and the other users of this particular frequency range, especially in coastal areas.

Whilst the circuit has an unusual appearance its operation is easily understood. The main tuned circuit, L_1 and C_2, is connected to the collector of a Mullard OC44, feedback being applied from the base *via* L_2. (Other transistor types have failed to work in this circuit and the OC44 is strongly recommended.) The emitter current is fed through a relatively large resistance, R_2, with the result that oscillation, ignoring the effect of R_1 and C_4, is barely maintained.

The emitter and base of the transistor form a diode which, as oscillation starts, rectifies the r.f. and charges C_4 negatively. The charge on C_4 grows more quickly than it can leak away through R_1, so that the emitter becomes less positive and the circuit ceases to oscillate. No further charge passes to C_4, the existing charge leaks

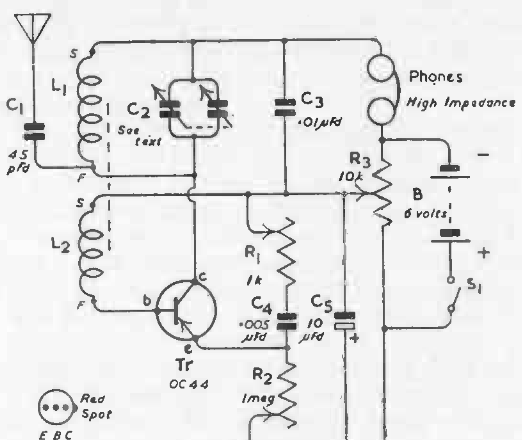

FIG. 10. A SUPERREGENERATIVE RECEIVER

away through R_1, and oscillation recommences, the cycle continuing and the receiver passing into and out of oscillation at a rate determined by the settings of the various controls.

All the characteristics of a valve superregenerator are well exhibited in that there is a steady hiss heard in the earphones which stops when a carrier is tuned in. There is automatic provision of a.v.c. and a fair degree of automatic interference rejection.

The two windings of the coil require to be tightly coupled, the feedback winding being relatively large, and it is necessary to adhere to the specification if correct results are to be obtained. The windings, both of 36 s.w.g., d.c.c. copper wire, are made on a ¼″ diameter Aladdin polystyrene former, 1″ long, fitted with an iron dust core. The collector winding is put on first and consists of 30 turns, closewound. This winding is covered with a single layer of Sellotape, and the base winding is wound centrally over it, consisting of 20 turns put on in the same direction, and again closewound. The start and finish of each winding is connected as shown by *S* and *F* in Fig. 10. Turn the core fully into the coils.

The tight coupling between the windings together with the superregenerative action causes the tuning to be very broad, and to cover the range 1·5 to 4Mc/s it was found necessary to use a tuning capacitor with a maximum value of 0·001μFd. This is easily obtained by joining the stators of a 500pFd twin gang tuner in parallel. Although such a broad sweep of capacitance is used it is possible by careful setting of the controls to obtain a good working point over the whole tuning range. The superregenerative action can be adjusted for best performance on individual signals.

As the circuit is ideal for experimentation it is best assembled on a tagboard, the layout of the prototype being shown in Fig. 11.

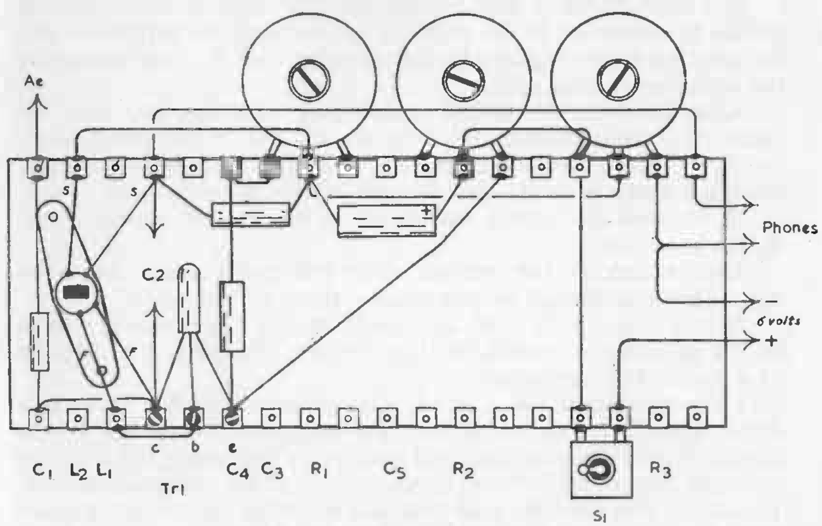

FIG. 11. EXPERIMENTAL LAYOUT

The receiver could of course be cased, when the controls would be panel mounted. In the original receiver they were supported solely by the soldering tags on the board, which in turn could be bolted to the tuner if a fairly large component were used here. The transistor in this case was mounted on top of the tagboard so that the assembly could be placed flat on the bench.

COMPONENTS LIST FOR THE SUPERREGENERATIVE RECEIVER. FIG. 10

L_1 L_2 . .	30 turns 36 s.w.g. d.c.c. copper wire close-wound, overwound with 20 turns close-wound on ¼″ diameter former with iron dust core.
C_1 . .	45pFd midget mica. (*Or see text below.*)
C_2 . .	0·001μFd tuner. *See text above.*
C_3 . .	0·01μFd midget tubular ceramic.
C_4 . .	0·005μFd midget tubular ceramic.
C_5 . .	10μFd 6 v.w. miniature electrolytic.
R_1 . .	1k wirewound, midget potentiometer.
R_2 . .	1Meg. midget potentiometer.
R_3 . .	10k wirewound midget potentiometer.
Tr . .	Mullard OC44.
High impedance (2,000 ohms) earphones.	
S_1 . .	S.P. on-off switch.
Miniature tagboard.	
B . .	6V battery, two "Fountain Pen" batteries or similar.

If a milliameter is used during the first trials of this circuit it should be connected in the negative line between the earphones and the junction of the negative battery terminal and R_3, thus measuring the collector current only.

After checking the circuit and before switching on, turn the slider of R_1 very slightly up from the C_4 end of the component. Set R_2 for maximum resistance. Set R_3 slider about one-quarter of the track away from the positive end of this potentiometer.

R_1 controls the quench frequency, R_2 the level of feedback, and R_3 the base bias.

Now switch on the receiver. The collector current shown by the milliameter should be very small—about 0·1mA or so.

Slowly turn up R_2 until the circuit squegs. The current shown by the milliameter should be about 0·7mA. Squegging is detected as a hiss in the earphones.

Connect an aerial to C_1 and, if necessary, reset R_2. Tune in a signal with C_2 and adjust R_1 for best volume and least hiss on the signal. Now tune over the band—probably the squegging will stop or break into an audio howl at some point of the tuner adjustment. To correct this reset R_3, and continue adjusting R_2 and R_3 in small steps by trial until the tuner can be turned right round the band with fairly even squegging at all points. It should now be possible to obtain the best results on any required signal by slightly re-adjusting R_1.

Disconnect the milliameter and check the tuning range by means of a signal generator, if possible. The range can be set by adjustment of the iron dust core in the coils, though this must not be withdrawn too far or the feedback will be affected.

Since there are three controls besides the main tuner this circuit needs careful adjustment, and some practice will be required before the best results are obtained.

The value of C_1 was found to suit a range of aerials but there is no reason why C_1 should not be made adjustable; a 50pFd trimmer could be used here in place of the fixed capacitor, and the value set either for best results over the tuning range or for maximum volume on a chosen signal.

5

A PHASE SHIFT OSCILLATOR

THERE are many occasions when an audio oscillator is needed in a hurry for work such as testing suspected distortion in amplifiers, as a substandard generator for Lissajou figures tests with oscilloscopes, for modulating a test oscillator, for powering a capacitance or inductance bridge and so forth. As a general rule a high power output is not necessary—a more common requirement is good wave shape over a "middle" range of audio frequencies. For many of these applications the little audio oscillator shown in Fig. 12 is perfectly suitable.

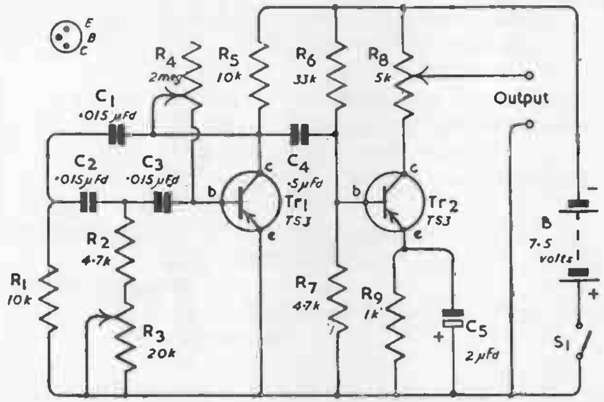

FIG. 12. A PHASE SHIFT OSCILLATOR

Tr_1, a Brimar TS3 transistor, is connected as a single-stage phase shift oscillator. Feedback from the collector is arranged through C_1, C_2 and C_3 to the base in such a way that at one particular frequency, determined by the time constants of the capacitors with the associated resistors R_1, R_2, R_3 and R_4, the feedback is in the correct phase to cause sustained oscillation. The frequency of oscillation can be varied by altering either the capacitance or resistance in the feedback circuit: it is, of course, more convenient to alter resistance and R_3 is made variable for this purpose.

The waveform, which can be adjusted to a very good sine wave shape, is controlled by R_4. This varies the base bias and also supplies a degree of negative feedback to the base directly from the collector, so preventing overdriving and permitting control over the strength of oscillation. R_4 is best adjusted by inspecting the waveform on an oscilloscope, the control being set for good wave shape over the full range of R_3.

The lowest frequency with a good sine wave shape obtained from the original circuit was 200 c.p.s., with the three capacitances

each 0·015μFd. The range given by R_3 was then from 200 to 500 c.p.s. The frequency can be increased by using 0·005μFd capacitances, when the range over R_3 on the original was from 500 to 1,000 c.p.s. It was found under these conditions that some transistors required the battery voltage to be increased to 10·5V.

The output stage using Tr_2 is optional since, for many purposes, the output from the oscillator alone will suffice. The second stage is added to give an amplified output and to isolate the oscillator from the output load. The oscillator output impedance is relatively low, however, and it is possible to make R_5 a variable output control (using the circuit of R_8 and a 10k potentiometer) compensating for any distortion of the output waveform caused by various loads by resetting R_4. Where only a low power audio output is required the oscillator section might well be tried alone during the first tests, the output stage being added later if necessary.

The coupling capacitor C_4 has a lower value than that used in ordinary audio amplifiers since the lowest frequency to be passed will be of the order of 200 c.p.s.

Various transistors were tested in the oscillator circuit and it is recommended that the specified TS3 be used. Different types could be tried in the amplifier section.

COMPONENTS LIST FOR THE PHASE SHIFT OSCILLATOR, FIG. 12

C_1, C_2, C_3	0·015 or 0·005μFd midget mica.
C_4 . .	0·5μFd midget paper tubular.
C_5 . .	2μFd 6 v.w. miniature electrolytic.
R_1, R_5 . .	10k ¼ watt.
R_2, R_7 . .	4·7k ¼ watt.
R_3 . .	20k midget potentiometer.
R_4 . .	2Meg. midget potentiometer.
R_6 . .	33k ¼ watt.
R_8 . .	5k midget potentiometer.
R_9 . .	1k ¼ watt.
Tr_1, Tr_2 .	Brimar TS3.
S_1 . .	S.P. on-off switch.
Miniature tagboard.	
B . .	7·5V battery.

S_1 could be ganged with R_8 but is best fitted as a separate component, leaving R_8 free to be set permanently at any desired value (wired anticlockwise in Fig. 13 as an attenuator).

Overloading of the amplifier did not occur in the original circuit but variations in transistor characteristics, or the use of different types of transistors, might cause this to happen. If so, C_4 should be tapped up R_5, this 10k resistance then being made up of two resistors chosen by trial (*e.g.* 6·8k plus 3·3k; 4·7k plus 4·7k, etc.) with C_4 taken to their junction.

The oscillator can be built up on a midget tagboard for experimental purposes, a suitable layout being shown (not to scale) in

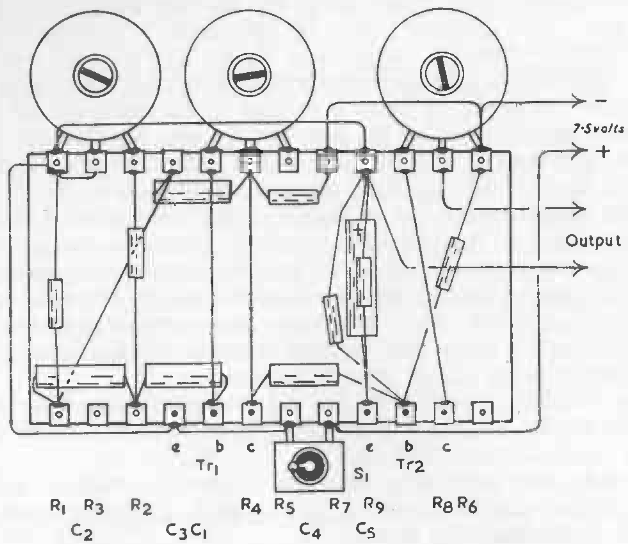

FIG. 13. EXPERIMENTAL LAYOUT

Fig. 13. Such a unit can easily be enclosed, with batteries, in a small plastic or metal case. If the latter is used, suitable precautions should be taken against short circuits or accidental contacts.

Consumption of the oscillator and amplifier is approximately 1·5mA.