

TRANSISTOR CIRCUITS MANUAL

No. 2

by

CLIVE SINCLAIR

CIRCUITS AND INSTRUCTIONS FOR BUILDING

1. Single transistor metal detector.
2. Subminiature Power Amplifier.
3. Broadcast Band Receiver Booster.
4. Simple Electronic Organ.
5. Two transistor pocket radio with speaker.
6. Transistor F.M. tuner.
7. 1 Watt Hi-Fi Amplifier.
8. Subminiature Pocket Transmitter.
9. Subminiature Shortwave receiver.
10. Shortwave frequency changer.
11. 30 mc/s Voice Modulated Transmitter
12. 10 to 30 mc/s Superregenerative receiver
13. Subminiature hearing Aid.

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**TRANSISTOR
CIRCUITS MANUAL**

No. 2

by

CLIVE SINCLAIR

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INTRODUCTION

The tremendous popularity of Transistor Circuits Manual No. 1 has prompted me to bring out No. 2 considerably sooner than originally anticipated. This, however, is all to the good for in the short time since No. 1 was published a great many exciting new transistors have become available on the home constructor market. Various types are now available for operation up to and beyond the F.M. band and the best possible use of these has been made in the simple but high performance F.M. tuner described in this book.

Really subminiature transistors have also made their appearance and the types used in the subminiature hearing aid are actually smaller than the head of a match. Despite their minute size these transistors have extremely high gain so that direct coupling can now be used in a three transistor circuit where transformer coupling was required before.

The shortwave enthusiast should find much to his liking in this volume. The availability of surface barrier and drift transistors has encouraged the design of compact shortwave receivers and transmitters. Several types are described and none of them presents any real constructional difficulties.

The single transistor metal detector and the little electronic organ will appeal to those of you who like to build something out of the ordinary. Incidentally these two projects are ideal for beginners because of their simplicity.

The two transistor M.W. radio, shown in Fig. 5, may surprise some of you by its economy of components. Although only two transistors, five resistors and six capacitors are used the receiver drives a loudspeaker without using an external aerial or earth.

If you have already built or possess a transistor superhet you can now increase its range and usefulness by converting the frequency changer circuit to use an OC170 thereby giving you coverage of the shortwave band. The improvement in performance on the medium wave band is also considerable because of the high gain of the OC170 at these frequencies.

A considerable number of small amplifiers giving an output of about 250 mw. have been described. Unfortunately the frequency response of these has usually not extended beyond 8 Kc/s. Whilst this is quite sufficient for use in A.M. receivers, because of the narrow bandwidth of the transmitted signal, it falls very far short of normally accepted Hi-Fi standards. In this book, however, a one watt amplifier is described with a frequency response of from

60 - 25,000 c/s \pm 1.5 db. 1 watt may not seem a great deal to those of you who have read of, or perhaps possess, 50 watt valve amplifiers. However, having built and used this amplifier for some time now I can assure you that when turned up to maximum volume it drives a loudspeaker to quite a painful level.

If there are any particular types of circuit you would like to see in future circuit manuals please let me know and I will do my best to see that what you want is included.

Clive Sinclair.

SINGLE TRANSISTOR METAL DETECTOR

The metal detectors used by the army to find buried mines and other metal objects will probably be familiar to most of you. This little unit works on the same principle but uses only a single transistor instead of several valves making it simple to build and carry. The current drain from the battery is only 1.5 ma. and, with the specified battery, this will last about 150 hours before a change is necessary. The detector may be used to find metal hidden by walls, floors or buried underground to a depth of one foot. Underground pipes and electric cable can be traced and you may even come across some buried treasure.

The mode of operation of the detector is fairly simple. The OC45 oscillates in the common emitter configuration at a frequency of about 200 Kc/s, using the Hartley type of circuit. The frequency of oscillation can be altered by means of the tuning condenser. At most frequencies the output from the oscillator has a low frequency component which, after detection by the diode, is heard in the earpiece. When the coil is brought near a metal it is damped and the inductance is reduced. This reduces the frequency of oscillation and of the note heard in the earpiece. With certain settings of the tuning condenser the note stops completely giving a very positive indication.

All the components may be built in a single case except for the coil. This should be wound on an old table tennis bat. Pile wind 160 turns using a diameter of 5 inches and tapping the coil after the first 30 and 70 turns.

Transistors other than OC45 will work but they must have an alpha cut off frequency of at least 6 mc/s. Do not use a surface barrier as it would be destroyed in this circuit.

L	160 turns of 28 gauge wire on 5" dia. former
R1	4.7K $\frac{1}{2}$ watt
R2, R3	2.2K $\frac{1}{2}$ watt
C1	0.005 mf.
C2, C5	0.1 mf.
C3	0.001 mf.
C4	400 or 500 pf variable
R.F.C.	2.5 mhy. R.F. choke
B.	EverReady PP3—9 volts
SW.	Single pole on/off switch
D.	Mullard OA70
TR.	Mullard OC45
E.	Ardente ER1600 earpiece

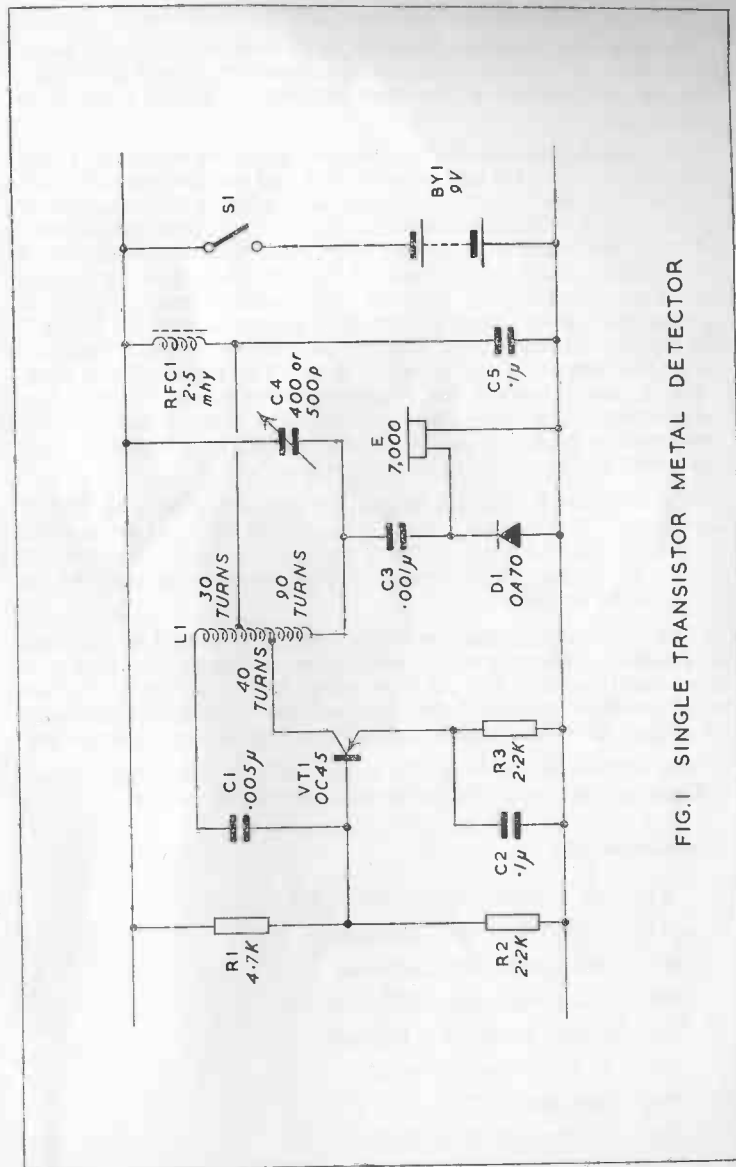


FIG.1 SINGLE TRANSISTOR METAL DETECTOR

SUBMINIATURE POWER AMPLIFIER

Because of its simplicity this amplifier may be built on a board only 2" x 3" in size. Despite this, however, it will give a full 200 mw. output with a frequency response of ± 2 db from 12 to 12,000 cps.

To minimise the number of components, direct coupling is used between Tr1 and Tr2 and between Tr2 and the loudspeaker. Tr1 acts as a common collector amplifier feeding into a common emitter amplifier Tr2. The base bias for Tr1 is taken from the collector of Tr2. As this is out of phase with Tr1's base a high degree of stabilisation is achieved. Part of the standing collector current of Tr1 also flows through Tr2 from base to emitter thereby supplying the necessary bias. Negative feedback is provided by R5 and R3. R3 applies feedback over both stages and R5 applies feedback from the output to the input of Tr2. The result of this feedback is an extremely flat response curve down to very low frequencies. The high frequency response can be considerably improved by replacing the OC16 with an OC22. Using this transistor will also result in an increase in gain.

The amplifier is ideal for amplifying the output from an FM or AM tuner. If you have a small radio, which only has an earpiece output, it may be used to bring the volume up to loudspeaker level. To do this simply connect the output from the radio to the input of the amplifier.

The loudspeaker, used with this amplifier, should be as large as possible, preferably a 12 inch type in an enclosure. Use of a very small speaker will result in some inefficiency because there will be sufficient current flowing through the winding, in the absence of a signal, to push it partially out of the strongest part of the magnet.

The current drawn from the battery will be fairly high, about 150 ma. so this should be as large as convenience allows.

Components List

- R1 5K volume control with switch
- R2 6.8K $\frac{1}{4}$ watt 10% tolerance
- R3 39K $\frac{1}{4}$ watt 10% tolerance
- R4 240 ohms $\frac{1}{4}$ watt 10% tolerance
- R5 1 ohm $\frac{1}{4}$ watt 10% tolerance
- C1 15 mf. 3 v.w. (or more)
- Tr1 Mullard OC72
- Tr2 Mullard OC16 or OC22

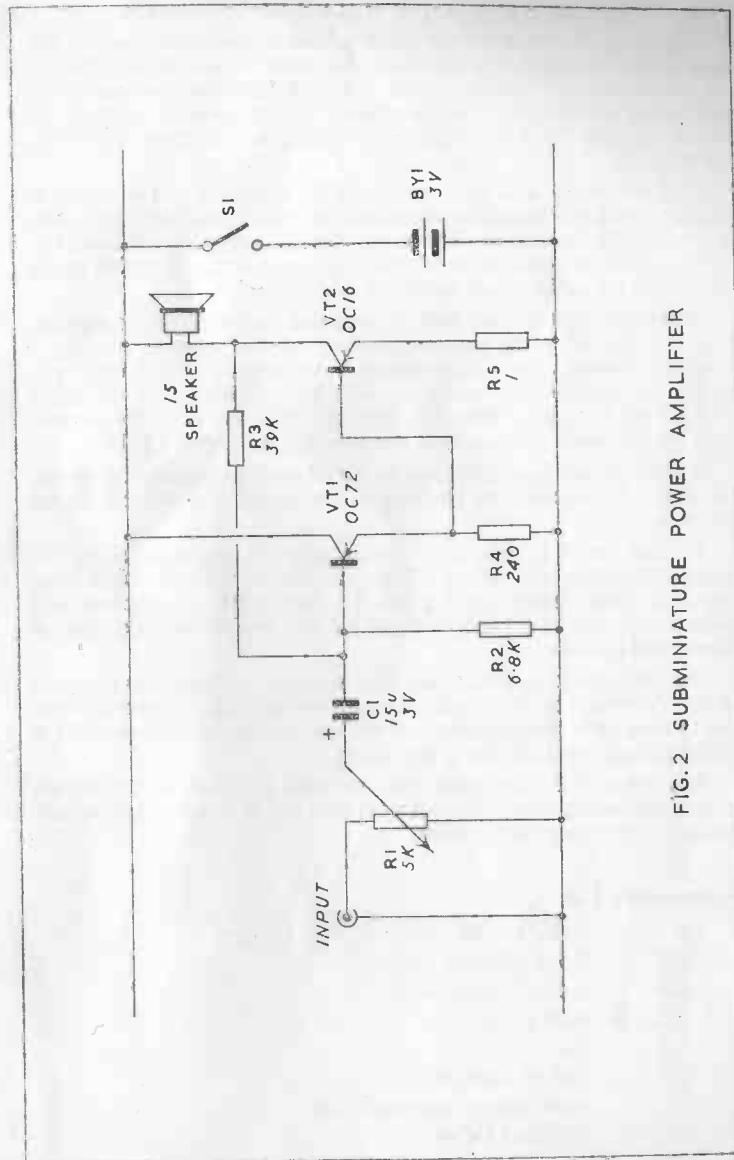


FIG. 2 SUBMINIATURE POWER AMPLIFIER

BROADCAST BAND RECEIVER BOOSTER

Many of the pocket and small portable receivers now on the market have insufficient sensitivity in areas of low signal strength or for use as car radios. This unit will improve the sensitivity, selectivity and signal to noise ratio of such a receiver without too much expense. It will probably not cost you more than about 25s. to build.

The circuit is that of a simple R.F. amplifier. The input is untuned and the transistor amplifies the entire band of frequencies picked up by the aerial. The tuned circuit, consisting of L and C3, offers a low impedance to all but the required signal which is fed via C4 to the aerial input socket of the receiver.

When this unit is used with a transistor radio, direct connection may be made to the internal battery of the receiver making a separate power supply unnecessary. Although a 9 volt battery is specified, satisfactory operation will be obtained with anything from 3 to 12 volts. When 9 volts are used the collector current will be just over 1.5 ma. and the power gain about 15 db.

If the receiver does not have an aerial socket connect the output of the R.F. amplifier to the end of the aerial coil not connected to ground.

To use the R.F. amplifier merely tune in the receiver to the required station and adjust C3 for maximum volume. If a large aerial is found necessary, replace C1 with a 100 pf. trimmer and adjust this for maximum volume or for maximum rejection of unwanted signals.

For the coil L you may use any medium or long wave tuning coil. A crystal set type will be quite satisfactory. If the coil has more than one winding just use the one normally connected to a tuning capacitor and ignore the others.

Any good R.F. transistor may be used in place of the OC44. A surface barrier type will work very well but in this case the battery must not be more than 3 volts.

Components List

R1	12K, $\frac{1}{4}$ watt, 10%
R2	2.7 K, $\frac{1}{4}$ watt, 10%
R3	1.5K, $\frac{1}{4}$ watt, 10%
C1, C4	0.01 mf.
C2	0.1 mf.
C3	500 pf. variable
L	Medium or long wave coil
Tr1	Mullard OC44

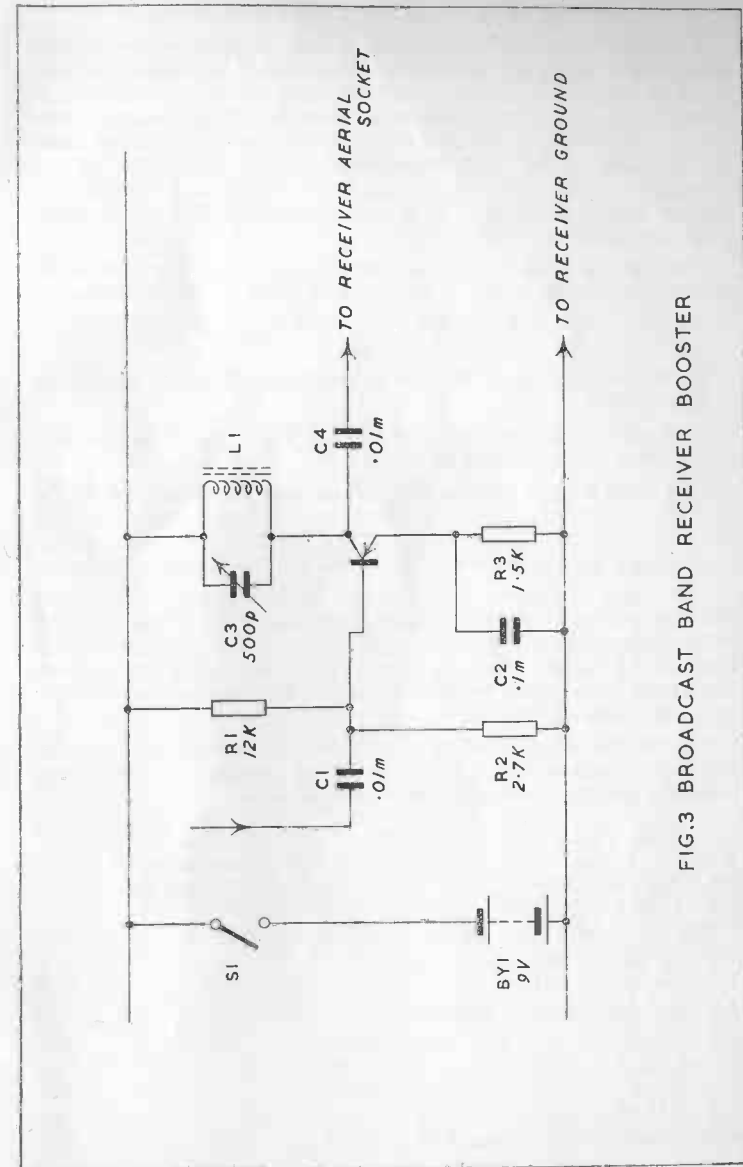


FIG.3 BROADCAST BAND RECEIVER BOOSTER

SIMPLE ELECTRONIC ORGAN

Although electronic organs are usually large, complicated and expensive to build, it is possible to build a small toy version without much trouble. This model covers two complete octaves with 8 keys, an auxiliary switch being thrown to change from one octave to the other. Tr1 is a variation of the Colpitts type of oscillator using the primary of an A.F. transformer as the inductance of the resonant circuit. This A.F. transformer (T1) also couples the output from the oscillator to a power transistor Tr2 which drives a 15 ohm speaker.

The various keys bring into circuit capacitors C1 to C8 which correspond to the notes of the musical scale as shown below:—

C1	C2	C3	C4	C5	C6	C7	C8
C	D	E	F	G	A	B	C

To reduce each note by one octave bring C10 into circuit by means of SW1.

Only one key should be pressed at any time. If two are pressed at once two notes will not be heard.

Odd notes may be obtained in this manner, however, and with a little experimentation you should be able to get rough approximation to sharps and flats. For example, with C7 and C8 in circuit together you will get G sharp and with C5, C8 and C7 you should get E sharp.

Toy shops frequently sell a range of toy pianos which have resonant pieces of metal in place of strings. One of those would make an excellent case for this organ. The keys of the piano would have to be turned into switches so that they bring the various capacitors into circuit when depressed. The end key on the left could be reserved for C10.

The ambitious constructor could probably increase the range of the organ considerably by adding further capacitors between the collector and the emitter of Tr1.

R1 3.3K, $\frac{1}{4}$ watt
 R2 1K, $\frac{1}{4}$ watt
 R3 10K, variable
 R4 15K, $\frac{1}{4}$ watt
 R5 8.2K, $\frac{1}{4}$ watt
 R6 22ohms, $\frac{1}{4}$ watt
 R7 10ohms, 1 watt

Tr1 Mullard OC72
 Tr2 Newmarket V15/20IP
 Speaker 15 ohm speech coil.

All fixed resistors 10% tolerance.

C1 0.6mf	C6 0.068mf
C2 0.33mf	C7 0.05mf
C3 0.2mf	C8 0.04mf
C4 0.15mf	C9 0.01mf
C5 0.1mf	C10 0.04mf

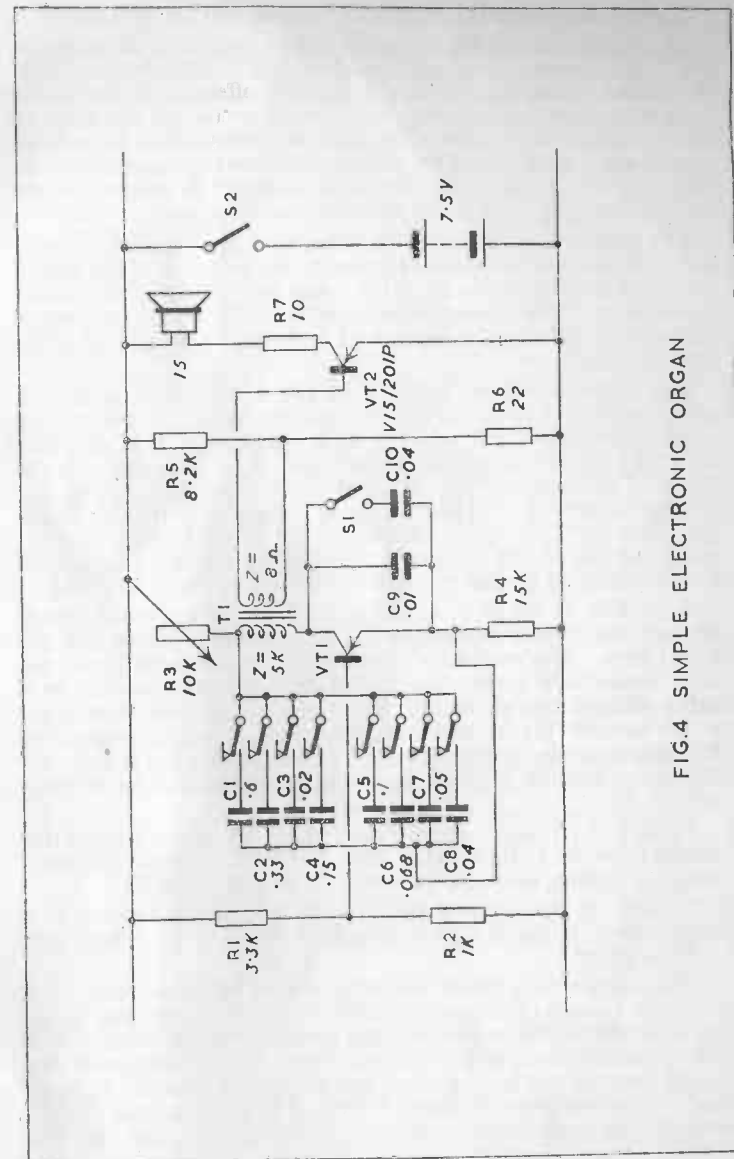


FIG.4 SIMPLE ELECTRONIC ORGAN

TWO TRANSISTOR POCKET RADIO WITH SPEAKER

Quite a few loudspeaker pocket radios have been described in the home constructor magazines and sold in the form of kits. Whilst the performance of these is generally quite good, they suffer from two disadvantages; they are too expensive and too large to satisfy many constructors. The main stumbling block in building smaller receivers has been the lack of suitable loudspeakers but such units are now readily available from Technical Suppliers Limited from whom your local dealer can obtain one for you.

The speaker used in this set is, then, of a new type having been specially designed for direct coupling to the collector of the output transistor thereby saving the price, space and weight of an output transformer. The speaker type number CMS.50, has an overall diameter of 2 inches, a depth of $\frac{3}{8}$ inch. and a weight of under half an ounce.

The circuit has been designed to use a minimum number of components to obtain the required performance. To achieve the required sensitivity Tr1 operates as a regenerative R.F. amplifier with the positive feedback controlled to keep the transistor near the point of oscillation. The required signal is picked up by the ferrite rod aerial, L1. The R.F. signal is then fed to the base of the transistor via C.3. It is amplified by Tr1 in the common emitter mode and the output appears in the collector where it is prevented from running to ground through the battery by the R.F. choke.

A portion of the R.F. signal is fed back to the tuned circuit through the trimming capacitor C2 so as to be in phase with the signal there. The rest of the signal goes to the detector circuit via C4. Two OA70 germanium diodes are used for detection in a highly efficient type of circuit. The audio output from these is fed to the base of Tr1 for audio amplification. The audio output of Tr1 passes easily through the R.F. choke, which has a very low impedance at audio frequencies, and induces a signal in the primary of T1.

T1 is a 4.5:1 audio transformer which efficiently couples the output from Tr1 to the input of Tr2. The OC72 acts as a high gain, common emitter, audio output stage driving the CMS.50.

To sum up the circuitry description: the receiver consists of a regenerative, reflex, R.F./A.F. amplifier followed by a high gain A.F. amplifier.

The tuning coil or ferrite rod aerial should be home made. Use a two inch length of $\frac{3}{8}$ " diameter ferrite rod. Ferrite rod may be cut to the required size by filing a fairly deep groove on either side of the rod and then snapping it into two pieces. Wind two layers of thin paper onto the rod leaving about half an inch of bare rod at either end. Now wind onto the paper 7 turns of 26 gauge enamel covered copper wire, make a loop, wind on a further 5 turns, make another

loop and finally wind on the remaining 28 turns. The wire may be kept in place on the rod by smearing it with a thin layer of glue such as balsa wood cement. The wire forming the loops should be bared to form the tapping connections. You now have a coil consisting of 40 turns with taps at the 7th and 12th turns.

Final adjustment of the receiver is extremely simple. Turn the volume control to the maximum position. Now adjust the 30 pf. trimmer to a point just past the point of oscillation. Turn the tuning capacitor (C1) right across the band and make sure that you obtain oscillation at all points. If oscillation ceases at any point just increase C2 a little.

If you now turn back the volume control slightly, oscillation will cease and you should be able to tune in your local stations. Re-adjust RV1 for the required volume. If your set does not work check to ensure that the connections to the ferrite rod are correct.

In weak signal areas it may be necessary to use a short aerial. Connect this to the junction of C1 and C3 via a 100 pf. capacitor.

You may not be able to buy suitable clips to fix onto the PP3 battery, however if you take an old PP3 battery to bits you can use the clips from this.

A hearing aid earpiece may be used with the set for personal listening. Either the Ardente ER250 or the Fortiphone series T.250 may be used by connecting whichever one you want across R4.

R1	1 Meg ohm submin.
R2	270 ohm submin.
R3	8.2K ohm submin.
R4	2.2K ohm submin.
R5	150 ohm submin.
RV1, SW1.	Fortiphone type VS26.
Suitable subminiature resistors are available from Ardente Limited.	
C1	400 or 500 pf. solid dielectric about 1" square.
C2	30 pf. trimmer beehive or postage stamp type.
C3	0.05 mf.
C4	100 pf.
C5	10 mf. 3 v.w.
C6	50 mf. 3 v.w.
L1	40 turns, 26 gauge enamelled wire on $\frac{3}{8}$ " ferrite rod.
D1	Mullard OA70
D2	Mullard OA70
R.F.C.	2.5 m.h. R.F. choke.
T.1	4.5:1 interstage transformer Fortiphone S.1 or Ardente D.1001 (D.1013, D.239, D.217 or D.101 may be used).
Speaker	CMS.50 from Technical Suppliers Limited.
Battery	Ever Ready PP3.
Tr1	Mullard OC44 (not OC72 as in fig. 5).
Tr2	Mullard OC72

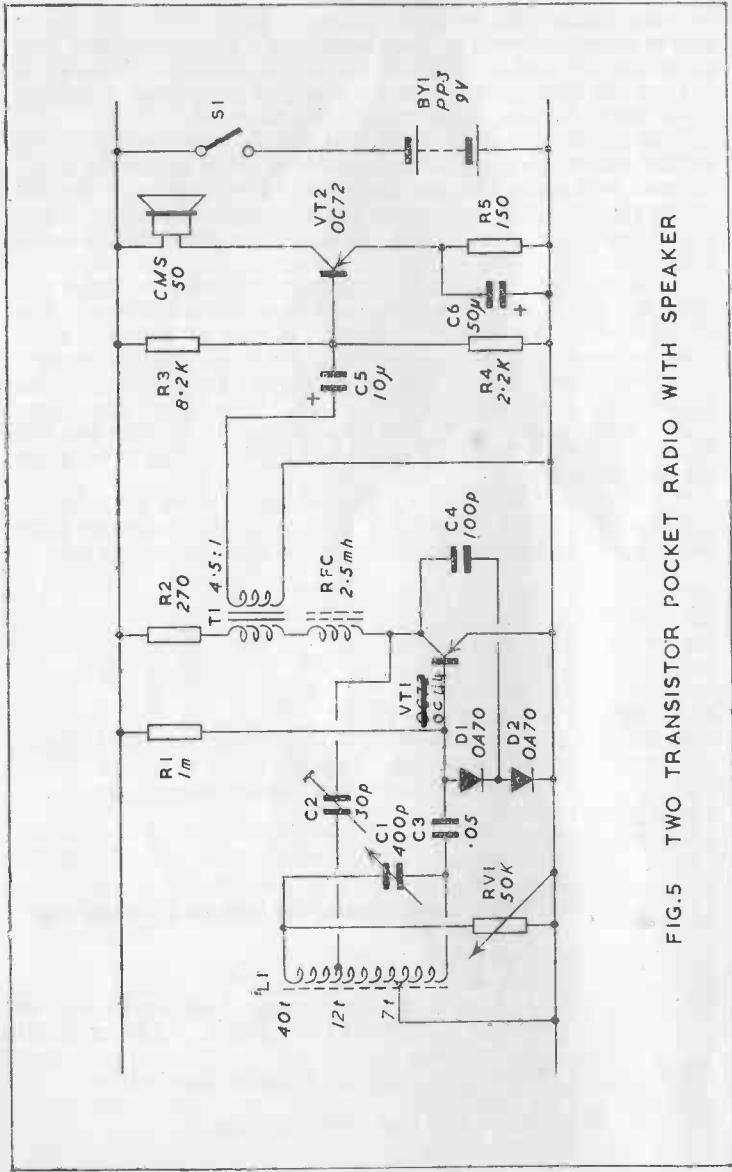


FIG.5 TWO TRANSISTOR POCKET RADIO WITH SPEAKER

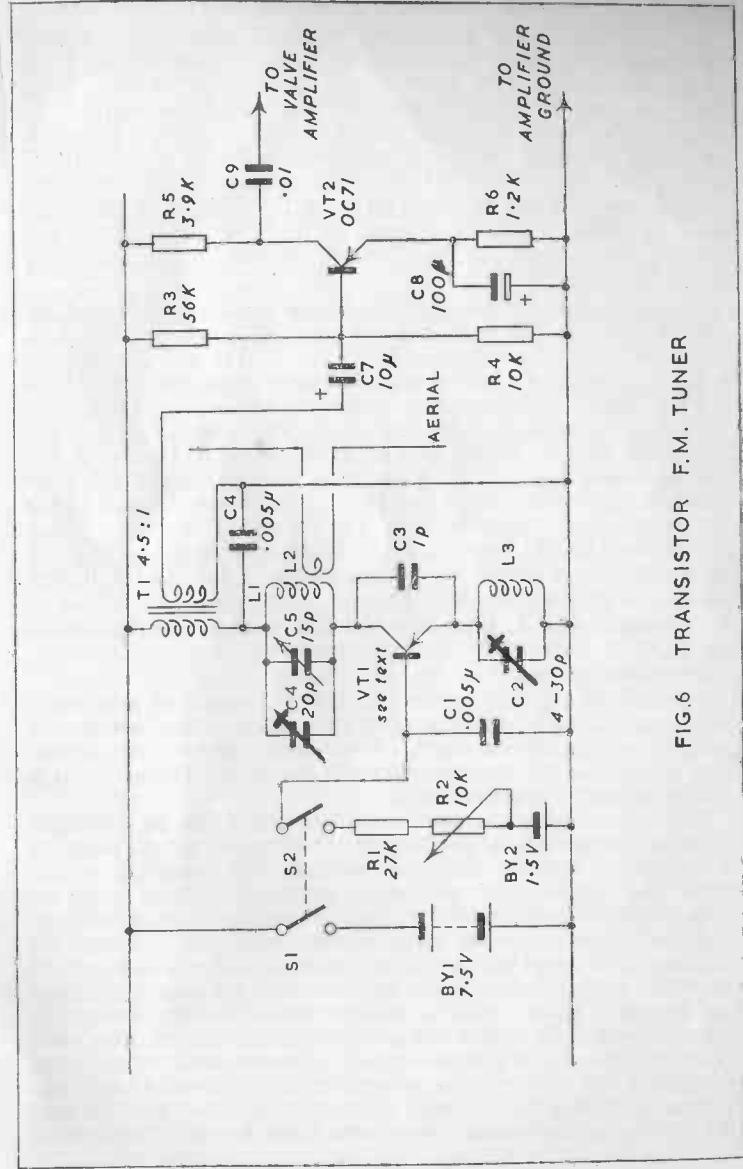


FIG.6 TRANSISTOR F.M. TUNER

TRANSISTOR F.M. TUNER

It may come as a surprise to you that transistors are now available to the home constructor which are capable of very good performance in the F.M. band, that is up to about 100 mc/s. Well they are, and furthermore, they are not unduly expensive. To build this unit will cost you from £4 to £5 depending on which transistor you use. When one considers the cost of a conventional valve F.M. tuner, even in kit form, this price appears very reasonable.

The transistor that performs all the R.F. functions of the circuit may be either a drift type, such as the Ediswan XA131, or a MADT type, such as the 2N499 or the 2N502 made by Semiconductors Limited.

The maximum frequency of oscillation for the XA131 and the 2N499 is about 250 mc/s and for the 2N502 is over 500 mc/s. Used as common emitter amplifiers the XA131 and 2N499 have maximum gains of about 9db at 100 mc/s compared with 15 db for the 2N502. All three transistors may be used for Tr1 but the 2N502 is recommended because of its much higher gain. The prices are £2 14s., £2 3s., and £3 5s. for the XA131, 2N499 and 2N502 respectively. The former may be ordered through your local retailer but the latter two have to be obtained directly from the manufacturers whose address is at the end of the book. When the Mullard OC171 becomes available this may be used and it will probably have a performance comparable to the XA131 though I have not yet been able to test one.

Although an OC71 is used for Tr1 this could well be replaced by an OC45 to improve the frequency response.

Circuit Description

Because of the high expense of V.H.F. transistors a superhet F.M. tuner, along the lines of a valve F.M. tuner, would cost rather more than it was worth. Fortunately there is a very attractive alternative, the super-regenerative detector. This is the type of circuit used in figure 6.

The super-regen. detector works on the following principle. A transistor is made to oscillate at the frequency of the signal to be received. Another oscillator, working at a frequency greater than twice that of the required audio output, is made to switch the first transistor in and out of oscillation by varying one of the bias voltages. This is known as the quench oscillator. Now in the absence of a signal the signal frequency oscillator is switched on and the amplitude of oscillation increases until the quench oscillator switches it off again. When a signal is present, however, the oscillator will build up from this rather than from the random noise level. The oscillations will therefore reach a greater level before being quenched. If, however, the oscillations were allowed to continue unquenched they would reach a certain maximum level dictated by the transistor and its associated components. The quench

oscillator can be arranged so that this peak is always reached before quenching occurs. In this case the output level will not alter but the time taken to reach this level will. Thus the magnitude of the pulse of the oscillations will alter in size in relationship to the input. In fact the output will be logarithmically proportional to the input. For this reason a super-regenerative detector is known as logarithmic when the oscillations are allowed to reach their peak before quenching and as linear when the quenching takes place before the peak is reached.

Now, as the output level of the logarithmic superregen. is independent of the level of the input signal, this type of circuit has almost 100% A.G.C. Furthermore, the circuit is only sensitive just before the beginning of a pulse which considerably reduces the response to interference. The tuned circuit is fairly heavily damped by the oscillator giving it a broad bandwidth which is just what is required for F.M.

Because of its logarithmic response the logarithmic superregen. causes rather severe distortion to an A.M. signal unless the modulation level is very low. However, with F.M. signals the situation is very different. In operation the tuned circuit is tuned so that its peak is just to one side of the signal to be received. The response of the tuned circuit will now vary considerably with the frequency of the signal so that the output is an A.M. signal. As the response is parabolic rather than linear, however, the logarithmic response of the superregen. does not matter unduly. Furthermore the depth of modulation of the A.M. output can be controlled so as to be small. The final result is that any distortion there may be is certainly far too small to be noticeable.

Rather than use a separate quench oscillator it is sometimes convenient to design superregen. detectors that quench themselves. When this is done the length and amplitude of the pulse remain constant but the time between pulses varies. The result, however, is still the same as that of a logarithmic super regen.

The circuit in Fig. 6 uses a self-quenching super regen. detector. Tr1 is connected in the common base mode for R.F. As there is no phase change between collector and emitter, oscillation is caused by feeding part of the signal from the collector back to the emitter via C3. The impedance offered to this signal can be controlled by altering the value of C2. The oscillations are demodulated by the base-emitter junction and the resultant d.c. charges C1. The positive voltage on C1 grows until it counteracts the bias provided by B2 sufficiently to prevent further oscillation. C1 then discharges through R1, R2 and the transistor, and oscillation begins again. This cycle occurs at an ultrasonic rate which increases with the application of a signal and is dependent on the signal's amplitude.

The output bandwidth is limited to half the quench frequency so that a high quench frequency is required. For optimum gain, however, a low quench frequency is desirable as it gives the

transistor a longer time to build up to the peak of oscillation and thus puts a smaller demand upon the transistor's capabilities. A compromise must therefore be made with the result that a high gain transistor can operate with a high quench frequency and thereby provide an excellent bandwidth.

Since C2 controls the rate at which the oscillation grows, it also controls the quench frequency, the gain and the bandwidth of the receiver.

R2 is merely a preset potentiometer so that the base bias may be controlled.

The output of Tr1 would consist of a series of pulses; the distance between these pulses containing the audio signal. However, detection takes place in the transistor and the primary of T1 provides the necessary audio load. T1 is relatively inefficient at the quench frequency and this inefficiency is increased by shunting the primary by C4 which also provides the necessary de-emphasis at high frequencies.

The secondary of T1 is coupled to a common emitter A.F. amplifier, Tr2. The output is taken from the collector of Tr2 via a 0.01 mf. capacitor. The output impedance is about 4K ohms which is sufficiently low to prevent hum being introduced between the tuner and the amplifier. If you want to use the tuner with a transistor amplifier change the value of C9 to 10 mf.

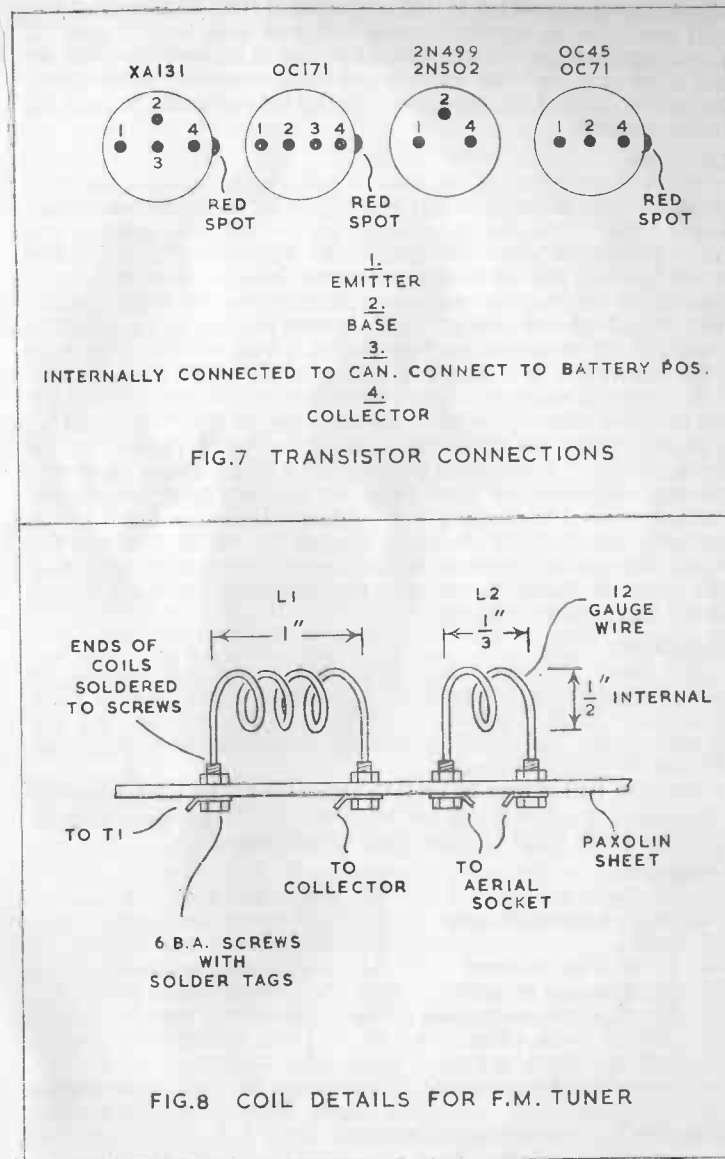
Construction

The prototype for this receiver was built on a 6" x 4" paxolin board although a much smaller piece could be used. It is important to keep all the leads as short as possible and to mount L3 at right angles to L1 and L2 to prevent mutual inductance upsetting the oscillatory circuit. If either an XA131 or an OC171 is used for Tr1, then the fourth lead, which is connected internally to the case of the transistor, should be connected to the positive side of the battery (see Fig. 7).

Fig. 8 illustrates the method used to mount L1 and L2. These are wound from 12 gauge wire with an internal diameter of $\frac{1}{2}$ ". L1 consists of three turns wound to a length of 1" and L2 of one turn wound to a length of one-third of an inch. The coils are soldered directly to 6 B.A. nuts and bolts fixed in the paxolin sheet. It is by no means essential to use this method of mounting but it happens to be convenient. The currents drawn from B1 and B2 will be only 2 ma. and 25 microamps respectively so that these may be wired into the circuit and will only have to be changed very occasionally.

It is well worth while fitting some form of reduction drive to C5 as without it tuning is rather tricky.

To cover the F.M. band, C4 will probably have to be set to about half its full value. By increasing the value of C4 you should be able to receive the B.B.C. television sound which came in very well indeed on the prototype. If a 2N502 transistor is used the receiver



should operate right up to 180 mc/s with a suitable setting of C4.

If you wish to experiment with different coils for L1 and L2 remember that they should have as high a Q as possible. The set will work quite well with a simple rod aerial connected to the collector of Tr1 via a 1 pf. capacitor. If this type of aerial is used L2 is not required.

Operation

When construction of the tuner is completed connect a meter in series with the collector of Tr1 and adjust R2 until the meter reads about 1 ma. Now plug in an aerial, set C4 to its mid position and turn C2 until you hear a shushing noise. This noise is an indication of the amazing gain of this type of circuit for it is purely the amplification of the random motion of electrons in the aerial circuit. You should now be able to tune in several stations by rotating C5. Re-adjust C2 to obtain the best quality. You will find that each F.M. station comes in with two settings of C5. This is because an F.M. signal is received without distortion only when C5 and L1 are tuned to a frequency deviating from that of the F.M. signal by a small amount (see circuit description) and the deviation may be on either side. You should be able to set C2 to obtain clear performance all over the F.M. band. Thus only one permanently variable control is required, C5. When a station is tuned in the shushing noise should disappear completely. If it does not the signal strength in your area is too low or your aerial is very bad. Normally an elaborate aerial is not required, the small indoor dipole being quite sufficient.

Applications

The tuner can easily be turned into a complete receiver by adding a simple audio amplifier. The circuit shown on Page 27 of Transistor Circuits Manual No. 1 is ideal for this purpose. R5 may be replaced by headphones or an earpiece such as the Ardente type ER1600 for private listening.

Switched tuning may be used by replacing C5 by three trimmers and a three position switch but be careful in doing this, to keep all the leads really short to avoid stray capacitances.

Components

C1, C6	0.005 mf.	R1	27K ohms $\frac{1}{2}$ watt 10%
C2	30 pf. beehive trimmer	R2	10K ohms preset pot.
C3	1 pf.	R3	56K ohms $\frac{1}{2}$ watt 10%
C4	15 or 20 pf. trimmer	R4	10K ohms $\frac{1}{2}$ watt 10%
C5	15 pf. tuning capacitor	R5	3.9K ohms $\frac{1}{2}$ watt 10%
C7	10 mf. 3 v.w. electrolytic	R6	1.2K ohms $\frac{1}{2}$ watt 10%
C8	100 mf. 3 v.w. electrolytic	B1	7.5 volt battery
C9	0.01 mf. for valve amp. or 10 mf. for transistor amp.	B2	1.5 volt battery
SW1, SW2	Two pole on/off switch.		(For B1—5 pen light cells may be used. B2 may be a tap on B1).

L1	3 turns 12 gauge copper wire, $\frac{1}{2}$ " internal diameter, 1" length, self-supporting.
L2	1 turn 12 gauge copper wire, $\frac{1}{2}$ " internal diameter, $\frac{1}{4}$ " length, self-supporting.
L3	18 turns, 30 gauge wire space wound on $\frac{3}{16}$ " former $\frac{1}{2}$ " length.
Tr1	XA131, OC171, 2N499 or 2N502.
Tr2	OC71 or OC45.
T1	Interstage Transformer. Ardente D.101 or Fortiphone R1 are suitable.

One Watt Audio Amplifier with Transformerless Output Stage

The main difficulty in designing an audio amplifier of high fidelity performance, using transistors has been the unavailability of transistors in which the current gain remained constant to high levels of collector current. G.E.C., however, make an excellent range of such transistors and I would like to thank them for their permission to publish this circuit which is their design.

The circuit diagram of the amplifier is illustrated in Fig. 9. It consists of a preamplifier stage, a driver stage and a class B push-pull output stage. The choice of class B push-pull is obvious as it leads to the maximum obtainable efficiency coupled with maximum power handling capacity for a given transistor. The output transistors are biased so that the collector current is virtually zero under quiescent conditions. In this way the transistor can only amplify negative signals because a positive signal would make the base positive with respect to the emitter and prevent any gain. For this reason two transistors must be used. When a negative signal is applied to one transistor a positive signal is applied to the other. In practice a slight forward bias is applied to the transistors to avoid crossover distortion, that is distortion occurring when the signal changes polarity and one transistor takes over from the other. In the absence of any forward bias distortion would occur due to the non-linearity of the current transfer at very low current.

The Preamplifier Stage

Either a GET114 or a GET106 may be used in the preamplifier stage, however the GET106 is recommended because of its low noise. Using the GET106, the signal to noise ratio of the amplifier as a whole is really excellent. As Tr1 has only to amplify small signals the collector current is chosen for maximum gain rather than for output power. The collector current is, in fact, 1.5 ma. and the quiescent emitter voltage is 1.8.

As R4, in the emitter lead, is not bypassed it provides negative feedback at audio frequencies thereby reducing harmonic distortion at high signal levels.

Tr1 is R-C coupled to the driver stage Tr2. Tr2 is a GET114 biased to an emitter current of 20ma., the collector dissipation being about 150mw. The quiescent emitter voltage should be 1.6. The driver is coupled to the output stage by a 3:1 + 1 step down

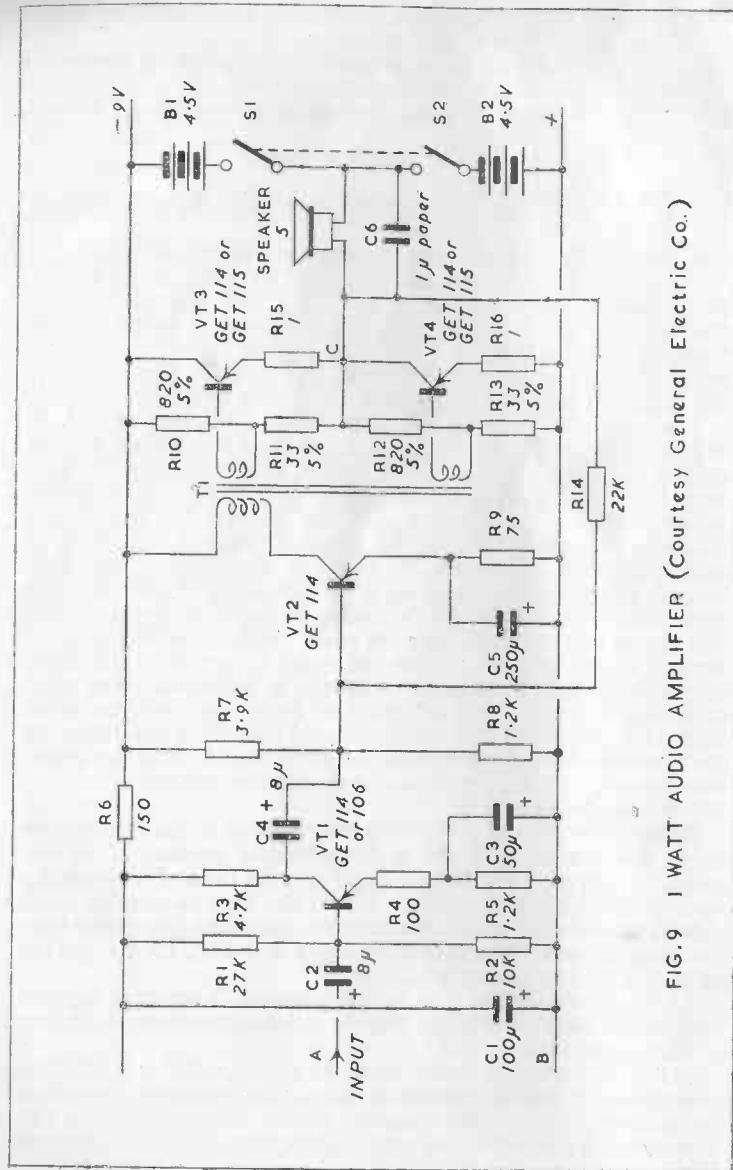


FIG. 9 1 WATT AUDIO AMPLIFIER (Courtesy General Electric Co.)

phase splitting transformer with two separate secondary windings. These should be bifilar wound to prevent ringing at the crossover point and to provide equal drive conditions for the output transistors.

The Output Stage

The output stage is of the single ended type as opposed to the symmetrical type more commonly found. The single ended type avoids the use of a transformer or of a centre tapped loudspeaker which incurs a loss of about 3db. The transistors are in series across the battery so that each one operates from only 4.5 volts. The speaker forms a load to the emitter of Tr3 and to the collector of Tr4 so that under ideal conditions there will be zero direct current flowing through the speaker. In practice the current will not be zero because of differences in the transistors and their biasing resistors, however these differences can be minimised by using a matched pair of transistors and close tolerance resistors.

The forward bias required to remove crossover distortion is derived from the potentiometer across the battery formed by R10, R11, R12 and R13.

If a centre tapped battery is a disadvantage then the speaker may be connected to ground via a high value electrolytic as shown in Fig. 12. The electrolytic should have as high a value as possible to avoid attenuation of the base frequencies but should, in any case, be not less than 100mf. The disadvantage with this system is that the capacitor accentuates any unbalance in the bridge system and the maximum available output power may be reduced.

To reduce distortion, negative feedback of about 6 db at 400 c/s is applied from the loudspeaker to the base of Tr2 via R14.

The peak output power of the amplifier, with a 5 ohm speaker is one watt.

The performance figures given for this amplifier by G.E.C. are as follows:—

Input resistance of preamplifier at 400 c/s	3.5K
Input voltage to preamplifier for 1 watt output	35 mV
Input resistance of driver at 400 c/s	230 ohms
Input voltage to driver for 1 watt output	80 mV
Power gain with preamplifier	65 db
Power gain without preamplifier	50 db
Total quiescent current drain	20 ma.
Total current for 1 watt output	200 ma.
Peak power dissipated in each output transistor	220 mw.
Frequency response	60 c/s to 25 Kc/s ± 1.5 db
Total harmonic distortion at 1 watt at 400 c/s	less than 6 db

The construction of the amplifier introduces no difficulties. The choice of output transistors depends on the maximum operating temperature required. With GET114's stable operation is possible up to 35° C. With GET115'2 the stable operation temperature increases to 55° C.

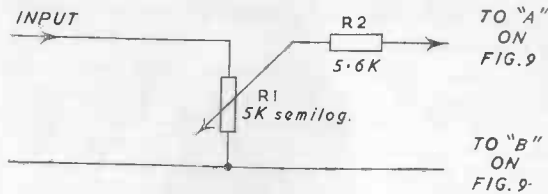


FIG. 10 VOLUME CONTROL FOR LOW IMPEDANCE INPUT

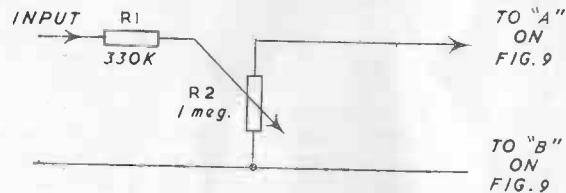
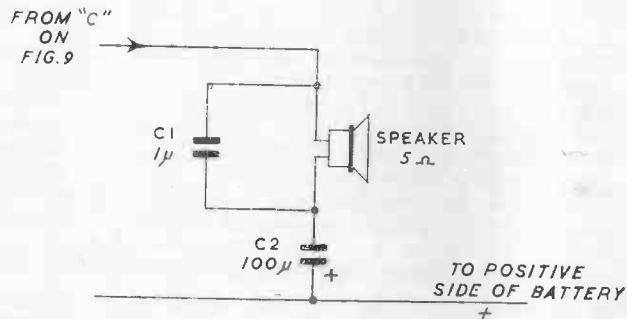


FIG. 11 VOLUME CONTROL FOR HIGH IMPEDANCE INPUT

FIG. 12
SPEAKER CONNECTION WHEN USING A SINGLE BATTERY

Figs. 10 and 11 show the type of circuits to use with this amplifier with low and high impedance inputs. The circuit of Fig. 10 is suitable for low impedance inputs and if the amplifier were equipped with this volume control it would be ideal for use with the F.M. Tuner described above. In fact, this combination would make an excellent F.M. radio for the home. The circuit could also be used to advantage to replace the normal amplifier in a transistor radio.

List of Components

R1	27K $\frac{1}{2}$ watt 10%	R 9	75 ohms $\frac{1}{2}$ watt 10%
R2	10K $\frac{1}{2}$ watt 10%	R10	820 ohms $\frac{1}{2}$ watt 5%
R3	4.7K $\frac{1}{2}$ watt 10%	R11	33 ohms $\frac{1}{2}$ watt 5%
R4	100 ohms $\frac{1}{2}$ watt 10%	R12	820 ohms $\frac{1}{2}$ watt 5%
R5	1.2K $\frac{1}{2}$ watt 10%	R13	33 ohms $\frac{1}{2}$ watt 5%
R6	150 ohms $\frac{1}{2}$ watt 10%	R14	22K $\frac{1}{2}$ watt 10%
R7	3.9K $\frac{1}{2}$ watt 10%	R15	1 ohm $\frac{1}{2}$ watt 10%
R8	1.2K $\frac{1}{2}$ watt 10%	R16	1 ohm $\frac{1}{2}$ watt 10%
C1	100 mf. 9 v.w.	C4	8 mf. 6 v.w.
C2	8 mf. 3 v.w.	C5	250 mf. 1.5 v.w.
C3	50 mf. 3 v.w.	C6	1 mf. paper

Tr1 G.E.C. type GET114 or GET106

Tr2 G.E.C. type GET114

Tr3, Tr4 G.E.C. type GET114 or GET115

SW1, SW2 Two pole on/off switch

B1, B2 4.5 v. batteries

T1 3 : 1 + 1 interstage transformer: either:—

Colne Electric Limited (Rickmansworth) type 05009,
Primary inductance at 5 v., 50 c/s, 50 ma. polarising
current 1 — 1M. Primary resistance 18 ohms.
Secondary resistance 8.5 ohms each section.

or

Parmeko Limited (Leicester) type P2943—Primary
inductance at 5 v., 100 c/s, 50 ma. polarising current
1 — 1 M. Primary resistance 32 ohms. Secondary
resistance 7.5 ohms each section.

SUBMINIATURE POCKET TRANSMITTER

Somehow the idea of a pocket transmitter is always rather more impressive than that of a pocket radio, yet it is no harder to make a tiny transmitter than it is to make a radio of similar size.

With a certain amount of care you should be able to build this unit in a case only 2" x 2" x $\frac{1}{8}$ " in size and it could be built into the same case as a pocket radio to make a miniature walkie-talkie. The range of the transmitter depends upon the sensitivity of the receiver with which it is used and the nature of the surroundings. In open country you may get a range of anything up to about half a mile.

The circuit diagram of the transmitter is perfectly straightforward. It consists of two stages of audio amplification driving a single transistor oscillator.

I have used rather unusual circuitry to keep the number of components required to a minimum. The microphone is the sub-miniature dynamic type used in hearing aids and is specifically designed to match the input impedance of a transistor. The microphone output is connected between the base and the emitter of Tr1 via C1. Tr1 is a common emitter amplifier although the load is in the emitter rather than the collector. The base bias is supplied by R1 and the current passes through the microphone. Tr2 obtains its base bias from the same resistor as Tr1 and a further component saving is obtained by using C1 again to couple the output of Tr1 to the base of Tr2.

Tr2 is directly coupled to Tr3 through which it draws its collector supply current. Tr3 is a common base oscillator with positive feedback from collector to emitter via C2. The tuned circuit is formed by L and C4. The coil may be home wound on a 1" length of $\frac{1}{8}$ " diameter ferrite rod. Use 34 gauge wire and close wind 30 turns, over a layer of paper, in the centre of the rod. C4 may be a postage stamp type trimmer to keep the size to a minimum. The aerial should be the rod type, stiff copper wire will do, and may be from 2'—4' in length.

The battery used in the prototype was a Mallory type TR153 which has a voltage of 3.9. This battery is ideal as it is only $1\frac{1}{4}$ " long by under $\frac{1}{8}$ " diameter.

Components

R1	39K (Ardente Submin.)	Tr1	OC71
R2	1K	Tr2	OC71
R3	68K	Tr3	OC44
C1	8 mf. 3 v.w.	Mike	Fortiphone type M.1
C2	100 pf.	L	See text
C3	2 mf. 3 v.w.	B	Battery-Mallory type TR153
C4	100 pf. trimmer	SW	on/off switch

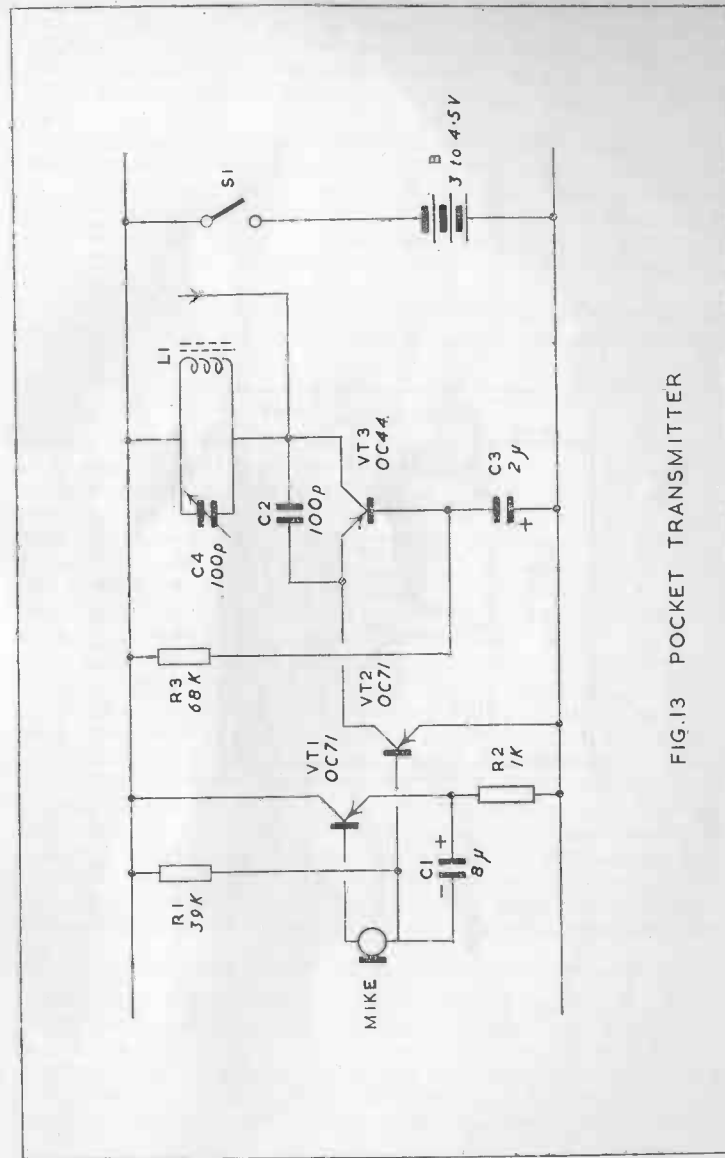


FIG.13 POCKET TRANSMITTER

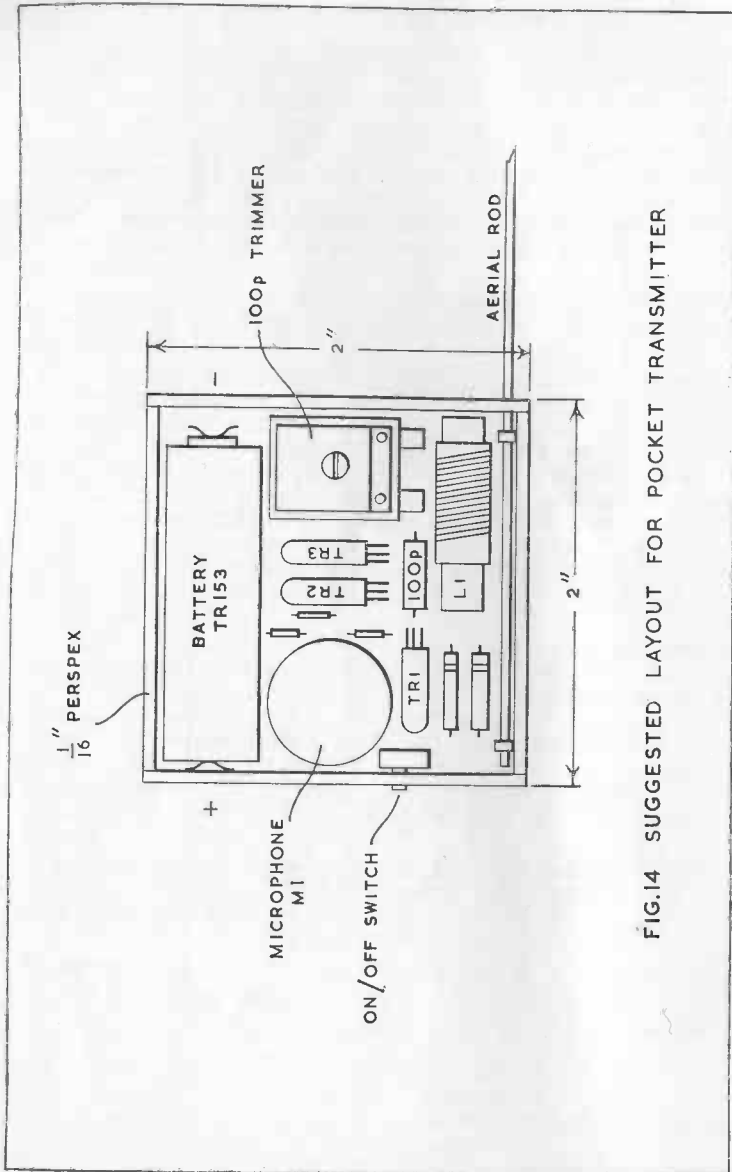


FIG.14 SUGGESTED LAYOUT FOR POCKET TRANSMITTER

The transmitter is designed to operate in the top amateur band, that is, from 1.8 to 2 mc/s. Frequency adjustments are made by varying C4. Considerable care must be taken to ensure that transmission does not occur outside the limits of the band as it is possible, with C4 near maximum, to transmit on the upper part of the M.W. band.

A suggested form of construction is illustrated in Fig. 14. The case is made from $\frac{1}{16}$ " coloured perspex or wood. The components are mounted on a small piece of 1 mm. thick clear perspex or similar plastic. The microphone should be mounted freely on a layer of sponge rubber or foam plastic to reduce its sensitivity to taps on the case. In use, the case is held in the hand with the microphone beside one's mouth.

The clips for the battery may be made from pieces of springy brass sealed into the perspex by forcing them in with a hot soldering iron.

If sockets are used with the transistors, and this is advisable, the Ardenite subminiature type should be chosen as anything else will take up too much room.

Subminiature Shortwave Receiver

This is a little receiver that would make an ideal companion to the transmitter described above. It may be built into the same sized case and, with the coil described here, will cover the same band. You may, however, like to wind coils for other bands, for example, replacing C1 with a 250 pf. trimmer and adding a few turns to L1 will convert the set to a high performance M.W. broadcast receiver. With the specified transistor the receiver will operate up to 15 mc/s or more, providing that a suitable coil is used.

To obtain the sensitivity required for operation on a ferrite rod aerial, a regenerative detector is used for the first stage.

The aerial is tuned by C1 and L1 and the signal picked up is fed to the base of Tr1. Tr1 demodulates it but also amplifies at R.F. The output is fed back through L1 to the interstage coupling transformer. As the signal contains the R.F. component of the output, passing it through L1 provides regeneration and will cause oscillation if not controlled. Normally control of regeneration, in a detector of this type, is achieved by varying the actual amount of signal fed back, but, in this case, it is more convenient to vary the gain of the transistor by means of R2 which controls the collector voltage. As a matter of interest, the gain of a regenerative amplifier

is $\frac{A}{1 - bA}$ this being the sum of a geometrical progression; where A is the gain of the amplifier in the absence of regeneration and b is the proportion of the output fed back to the input. From this it is easy to see that, as long as A is greater than one, bA must be less than one, and that if bA is nearly one, the overall gain will be very high. Variation of either A or b will effect the gain and in this case we have chosen to vary A. The reason for this choice is that it

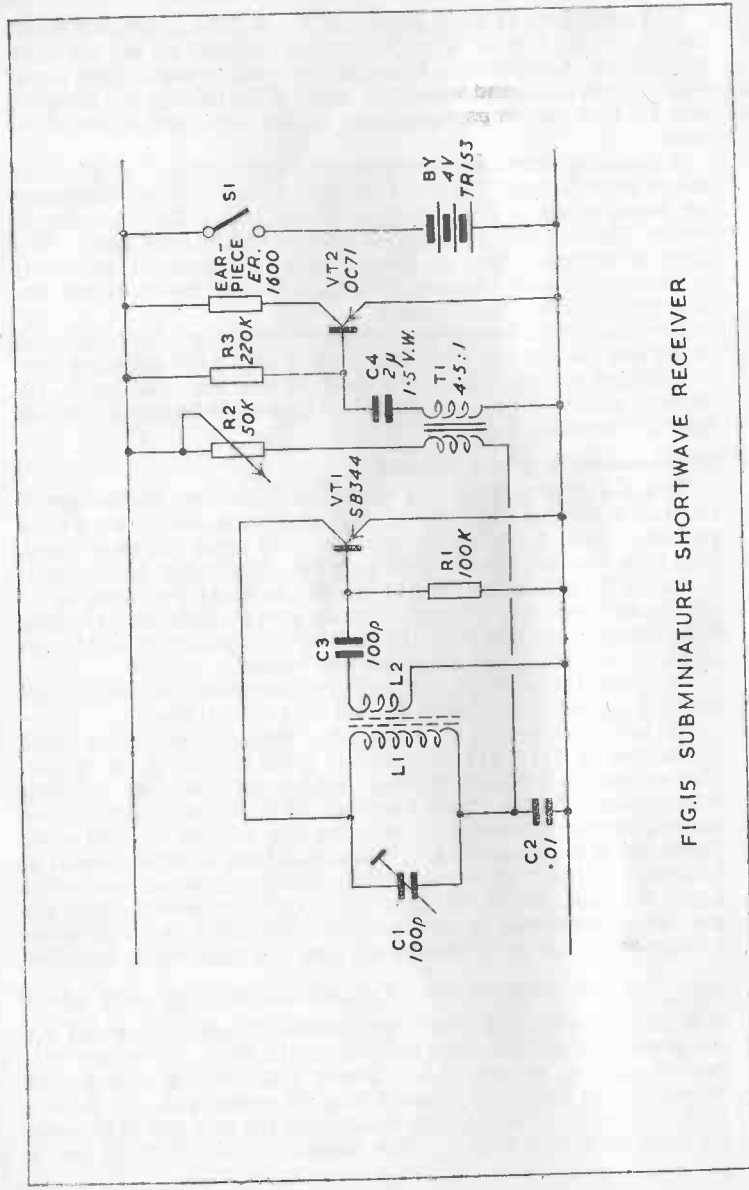


FIG.15 SUBMINIATURE SHORTWAVE RECEIVER

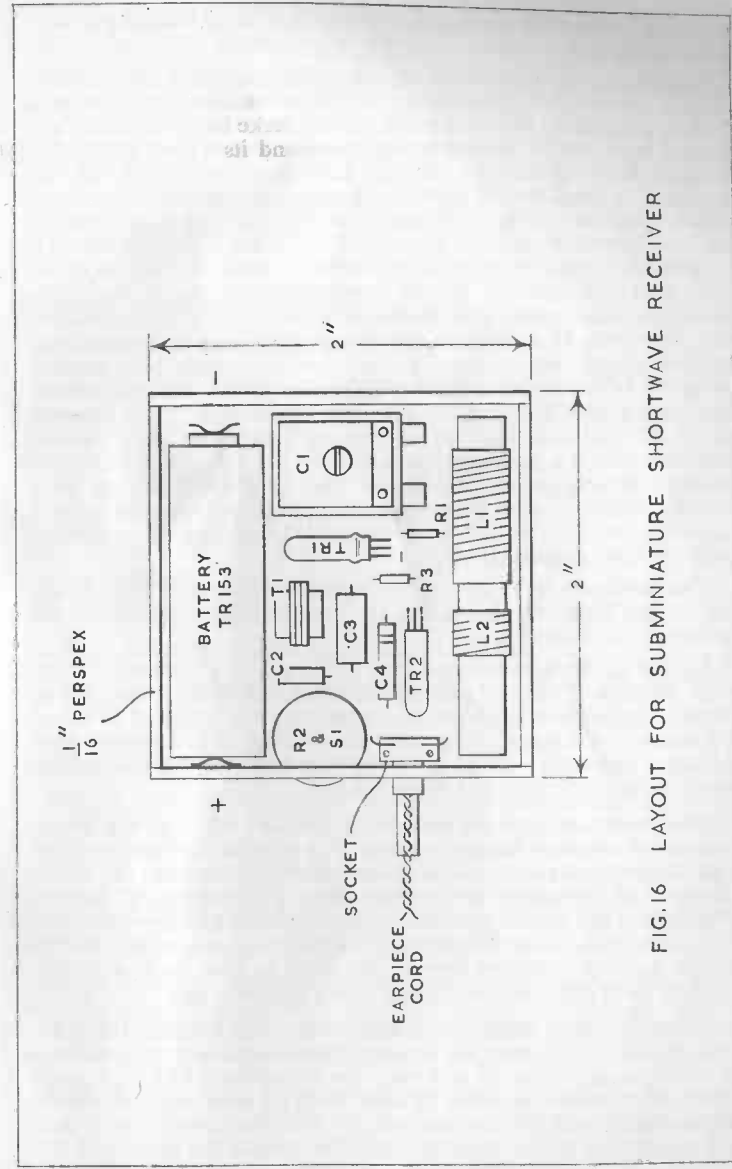


FIG.16 LAYOUT FOR SUBMINIATURE SHORTWAVE RECEIVER

provides a smoother control than can otherwise be obtained in this type of circuit.

Something may have struck you as rather odd about the first part of this circuit. R1 seems to go to the wrong side of the battery. In fact, no mistake has been made, for the first transistor is a surface barrier type and its properties are rather different from those of a normal R.F. transistor. In the first place the alpha cut off frequency is considerably higher, which has quite obvious advantages but in addition to this a S.B. transistor maintains its gain down to far lower levels of collector current. This makes it ideal for use as a regenerative detector for we do not have to sacrifice nearly so much R.F. and A.F. gain to obtain detection as we would normally. Detection takes place in a transistor at low current levels because the gain given to a negative signal is greater than that given to a positive signal, but at these current levels the gain of a normal junction transistor is considerably reduced. A surface barrier transistor's gain however, is still high. Now even in the absence of an external base bias supply there is a small collector current because there is a leakage of current from the collector through the base to the emitter and this is amplified. Normally this causes a lower collector current than is required but in this case the current caused is actually too high so we reduce it by putting R1 in parallel with the base emitter circuit.

The secondary of T1 couples the signal to the base of Tr2. Tr2 is the output transistor and drives the high impedance earpiece with an output of about 1 mw.

L1 and L2 are home wound on a $1\frac{3}{4}$ " length of $\frac{1}{4}$ " diameter ferrite rod. Wind a $\frac{3}{4}$ " strip of paper around one end, and on top of this, wind a single layer of 34 gauge enamel wire consisting of 30 turns. L2 consists of 3 turns of the same wire wound onto a narrow turn of paper beside L1. Wind in the same direction as L1 and sufficiently loose for it to be slid along the rod.

The construction of the receiver is similar to that of the transmitter and the same battery is used. A knob may be fixed to C1 if you wish to make it continuously variable. Remove the 6 BA screw from the centre and replace it with one about $\frac{3}{4}$ " longer. Drill a hole so that this can pass through the case and then bolt onto it a plastic disc about 1" diameter. If the disc tends to slip on the screw, apply a soldering iron to the bolts to heat them and then tighten them onto the plastic into which they will sink.

When you have completed construction, slide L2 right up to L1 and switch on. Rotate R1 to see if you can obtain regeneration. If you cannot, switch off and swap the connections to L2. Having obtained regeneration, slide L2 away from L1 until you only obtain regeneration with the volume control near maximum. Now seal L2 in position with a blob of wax. To operate the set, adjust R2

to just short of the oscillating point and tune in the required station, then re-adjust R2 to give yourself the right volume.

If you wish to use an aerial with the set, connect it to the junction of L2 and C3.

Components

R1	100K (Ardente Submin.)
R2, SW	Fortiphone volume control type VS26, 50K.
R3	220K (Ardente Submin.)
Earpiece	Ardente type ER.1600 with cord.
Output socket	Ardente type SK.1255.
T1	4.5:1 interstage transformer Fortiphone type S.5 or S.1.
Tr1	Semiconductors Limited SB.344 or any other surface barrier transistor.
Tr2	Mullard OC71.
C1	100 pf. postage stamp trimmer.
C2	0.01 mf.
C3	100 pf.
C4	2 mf. 1.5 v.w.
L1, L2	home wound on $\frac{1}{4}$ " ferrite rod (see text).
B	4v. battery Mallory type TR153.

Combined Transmitter-Receiver

Should you wish to combine the last two units in one case this may be done. Only one battery will be required but the receiver must be switched off when using the transmitter and vice versa. Mount the two aerials at right angles to one another to prevent them damping each other. It would be better if L1 and C1 in Fig. 15 could be switched to perform the function of L and C4 in Fig. 13, but this would require a rather bulky switch.

If you want to use the SB.344 transistor in other circuits remember that the collector to emitter and collector to base voltages must never be greater than 5 and that the collector current must not exceed 5 ma. The maximum frequency of oscillation is 50 mc/s.

The SB.344 makes an excellent frequency changer or detector for a radio set, and, because of its minute power requirements, is ideal for use in light operated equipment.

SHORTWAVE FREQUENCY CHANGER

The Mullard OC170 drift transistor will operate well as a self oscillating mixer up to a frequency of about 30 mc/s. The OC170 has an alpha cut off frequency of 70 mc/s and a feedback capacitance of 1.8pf. This circuit provides continuous coverage from 6 mc/s to 16 mc/s but coils may be wound to extend this range. The conversion gain varies from 25 db at 6 mc/s to 20 db at 16 mc/s which is similar to the conversion gain of the OC44 on the medium waveband.

The converter, an emitter injected autodyne, is very similar to the type commonly used on the medium and longwave bands. It may be used with an I.F. amplifier and A.F. amplifier similar to those shown in "Portable Transistor Radio and Radiogram" by I. F. Gregory.

An unusual feature of the circuit is the feedback winding, L6. This feeds back part of oscillator signal to the base, out of phase with that occurring in the transistor itself. This reduces the coupling and pulling between the aerial and oscillator circuits.

Components

Tuning capacitor C2 and C6 Wingrove & Rogers Type C7 312/2, with geared drive. Cap. swing 163 pf.

Trimming capacitors C1, C7 3 to 30 pf. beehive.

I.F. Transformer T.1 Wireless Telephone Co. CP.124925.

Aerial Coil L.1 33 turns of 21 gauge enamelled copper wire, close wound on 0.44" dia. former, with tap at 7 turns from earthed end.

L.2 3 turns of 34 gauge enamelled copper wire wound on earthed end of L.1.

Oscillator Coil L.3 30 turns of 21 gauge wire close wound on 0.44" dia. former. Inductance: 3.4 microH. Unloaded Q: 140 at 6 mc/s. 170 at 15 mc/s.

L.4 6 turns of 34 gauge wire wound on earthed end of L.3.

L.5 2 turns of 34 gauge wire wound on earthed end of L.4.

L.6 6 turns of 34 gauge wire wound along side earth end of L.3.

R1	10K	C3	0.002 mf.
R2	1.8K	C4	39 pf.
R3	56 ohms	C5	0.002 mf.
R4	1.2K	C8	250 pf.

All resistors at $\frac{1}{4}$ watt 10% tolerance.

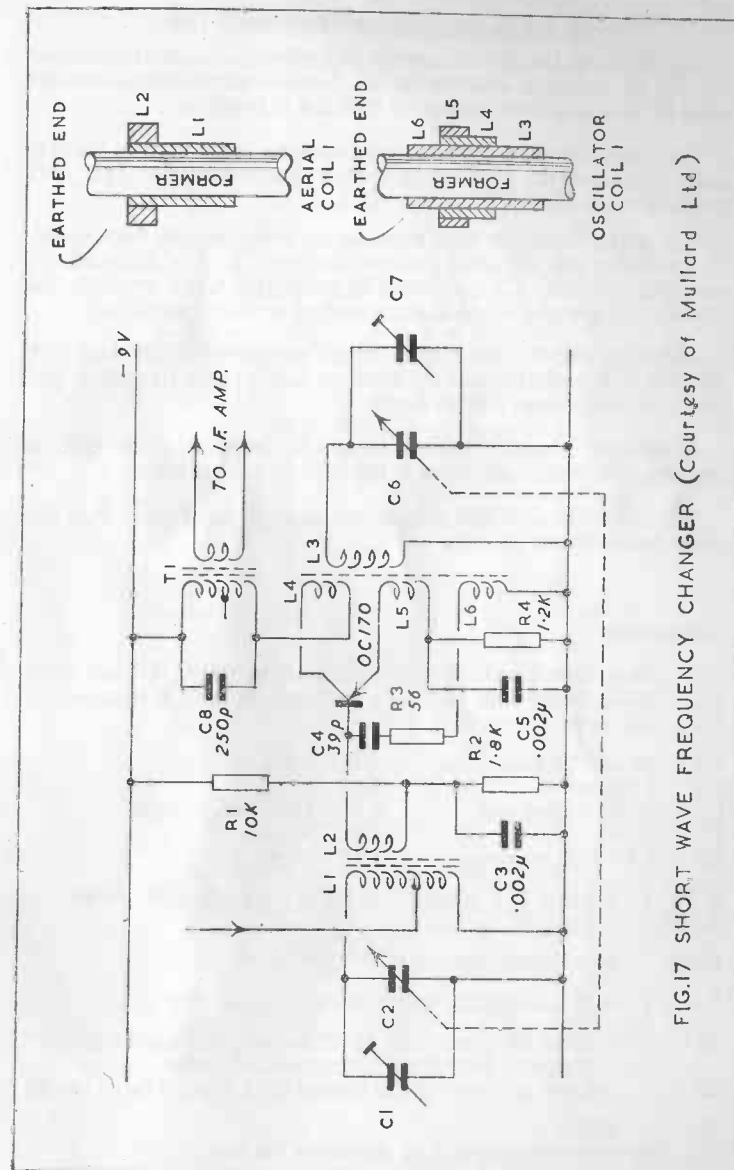


FIG.17 SHORT WAVE FREQUENCY CHANGER (Courtesy of Mullard Ltd)

30 MC/S AMATEUR TRANSMITTER

Fig. 18 shows the circuit diagram of a voice modulated transmitter for the 28—30 mc/s amateur band. Surface barrier transistors are used so that a battery voltage of only 2.6 is possible.

The microphone, a dynamic type such as those used in hearing aids, is coupled to a common emitter audio amplifier Tr1. Tr1 modulates the output transistor via T1.

Tr2 is the oscillator and operates in the common base mode. C1 provides the required positive feedback and is adjusted for maximum output. C2 is adjusted by nulling the signal output in the modulation troughs when the transmitter is over modulated.

Although SB346's are shown in the diagram for Tr2 and Tr3, SB344's will probably work almost as well at this frequency and they cost only about half as much.

A Mallory Mercury battery should be used with this unit to prevent drift which can occur if the battery voltage alters.

With suitable coils this transmitter may be used on any of the other bands below 30 mc/s.

Components

R1	100K ohm $\frac{1}{4}$ watt 10%	Subminiature types of less than $\frac{1}{4}$ watt may be used if required.	
R2	200K ohm $\frac{1}{4}$ watt 10%		
R3	27K ohm $\frac{1}{4}$ watt 10%		
C1	50 mf. 1.5 v.w.	C2	0.001 mf.
C3	0.001 mf.	C4	50 pf.
C5	30 pf. tuning cap.	C6	1.5—7 pf. trimmer
C7	15 pf.	C8	50 pf.
C9	1.5—7 pf. trimmer	C10	30 pf.
R.F.C.1	2.5 mh. R.F. choke	R.F.C.3	3.9 mh. R.F. choke
R.F.C.2	2.5 mh. R.F. choke.		
Mike	Fortiphone type M.1.		
T.1	4.5: 1 Interstage transformer		
L1	7 turns 22 gauge wire on 1" former, winding length $1\frac{1}{8}$ ", tapped 1 turn from battery and in centre.		
L2, 3	7 turns as above centre tapped for L3 and 4 turns for L2.		
Tr1	OC71		
Tr2, Tr3	Semiconductors Ltd. SB344 or SB 346.		

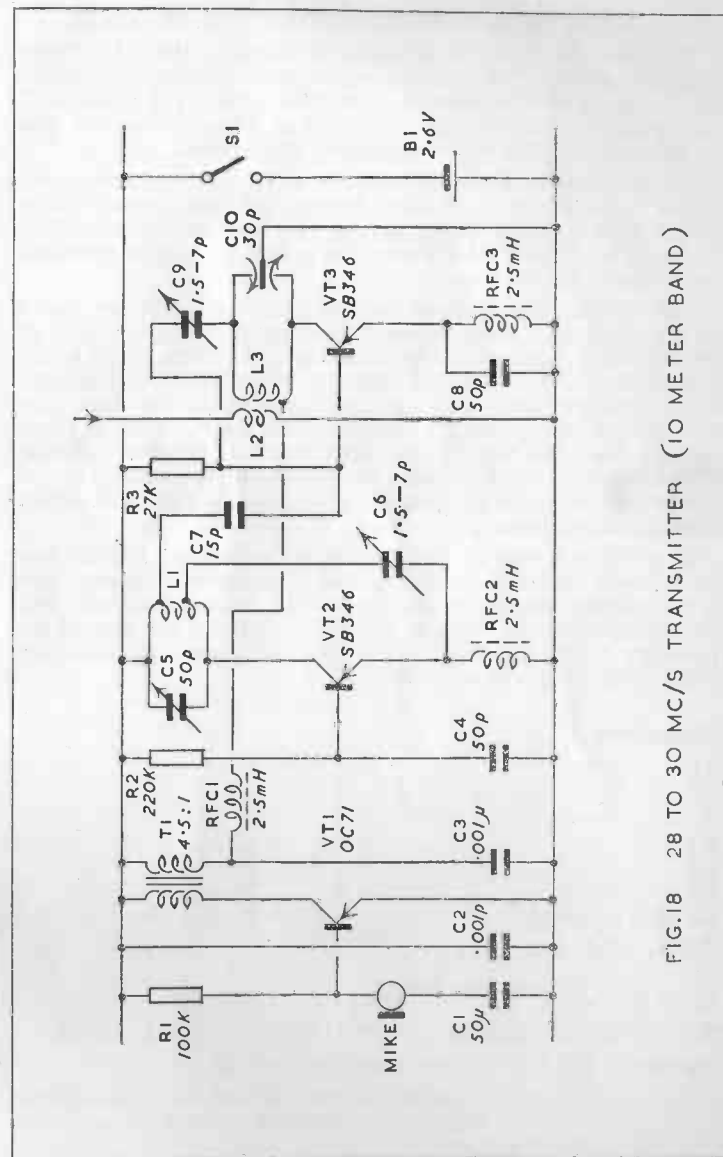


FIG.18 28 TO 30 MC/S TRANSMITTER (10 METER BAND)

10 TO 30 MC/S SUPERREGENERATIVE RECEIVER

This receiver works on a similar principle to the F.M. Tuner described above. Tr1 is a superregenerative detector followed by two stages of R-C coupled A.F. amplification. Tr3 drives a 2" loudspeaker. For reception of distant stations, the speaker may be replaced by a pair of low impedance headphones.

Tr1 oscillates at the signal frequency in the common base mode. It is a Colpitts type of oscillator because feedback is provided by means of a capacitive tap across the tuned circuit formed by C1 and C4. B1 and R1 are provided to bias the emitter positively with respect to the base.

The collector currents and voltages of Tr1 and Tr2 are shown on the diagram. These values depend upon the current gain of the transistors used and were calculated for a beta of 50 in the case of the OC71 and of 70 in the case of the OC72. To stabilize the transistors against changes of temperature the base bias resistors are taken from the collectors. As these are out of phase with the bases this form of connection results in negative feedback. This feedback is small at audio frequencies in the case of Tr2 and has been prevented in the case of Tr3 by grounding the A.F. before it can reach the base.

If an SB346 is used for Tr1, frequencies higher than 30 mc/s may be achieved by using a suitable coil. Remember, however, that it is absolutely essential to use a high "Q" coil at frequencies near the transistor's limit, because at these frequencies the gain of the transistor is very low and it is unable to overcome more than very slight losses in the tuned circuit.

Components

R1	4.7K	C1	15 pf.
R2	1.5K	C2	.01 mf.
R3	100K	C3	30 pf.
R4	1K	C4	10 pf.
R5	6.8K	C5	30 pf.
R6	6.8K	C6	0.002 mf.
All 10% tolerance		C7, 8 & 9	8 mf. 3 v.w.
R.F.C.	2.5 mh.		
B1	1.5 v.		
B2	3 v.		
			} Penlight cells
Tr1	SB344 or SB346	Tr2	OC71
		Tr3	OC72
Speaker	CMS.50 (Technical Suppliers Limited)		
L1	10 turns of 22 gauge wire space wound on 1" dia. former. Winding length 1½". Increase number of turns for lower frequencies.		

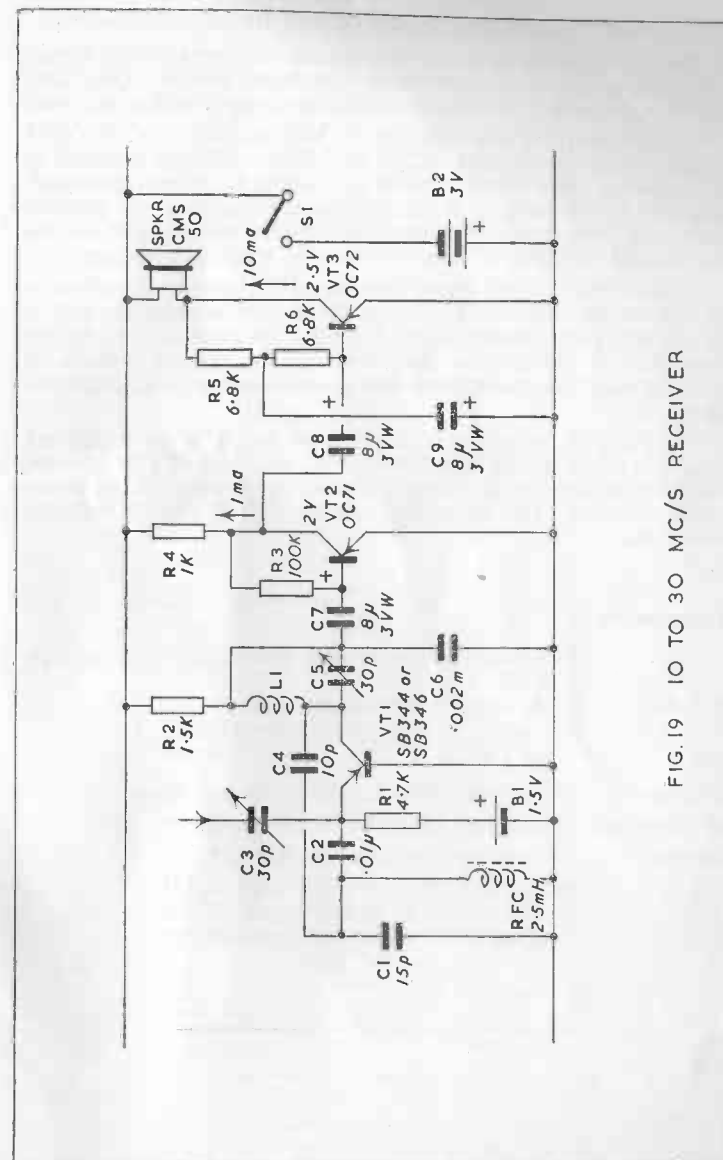


FIG. 19 10 TO 30 MC/S RECEIVER

SUBMINIATURE HEARING AID

The use of direct coupling between all the stages of this circuit (Fig. 20) results in a remarkably economical design. Only four resistors, including the volume control, and one capacitor are used.

Tr1, Tr2 and Tr3 may either be the Mullard OC57, OC58, OC59 range or Intermetall types OC331 to OC351 which are available in this country from Brush Crystal Co. Limited. These transistors are only 4 mm long by 3 mm in diameter but they can provide extremely high gain. The common emitter current gain of the OC351, for example, is 170 at 0.5 ma with a collector voltage of 2.

As there is an overall phase change of 180° between the collector of Tr3 and the base of Tr1 it is possible to stabilise the entire circuit by feeding back antiphase d.c. from the collector of Tr3 to the base of Tr1. To prevent A.F. feedback the current is made to pass through the microphone and is, at the same time, grounded by C1.

The value of Rx will depend upon the beta's of the transistors used. A meter should be inserted in the collector of Tr3, in series with the earpiece, and various values of Rx tried until the meter reads 2.2 ma. The collector currents of Tr1 and Tr2 should be 0.3 ma.

Components

R1	50K volume control with switch. Fortiphone type VS32.
R2, R3	3.9K Ardente subminiature types
Rx	See text. Ardente subminiature type
C1	6 mf. 1.5 v.w.
Earpiece	Fortiphone series T. 600 ohms impedance
Microphone	Fortiphone Type M1. 2.5K impedance
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Tr1	Mullard OC59 or Brush Crystal OC351
Tr2	Mullard OC57 or Brush Crystal OC331
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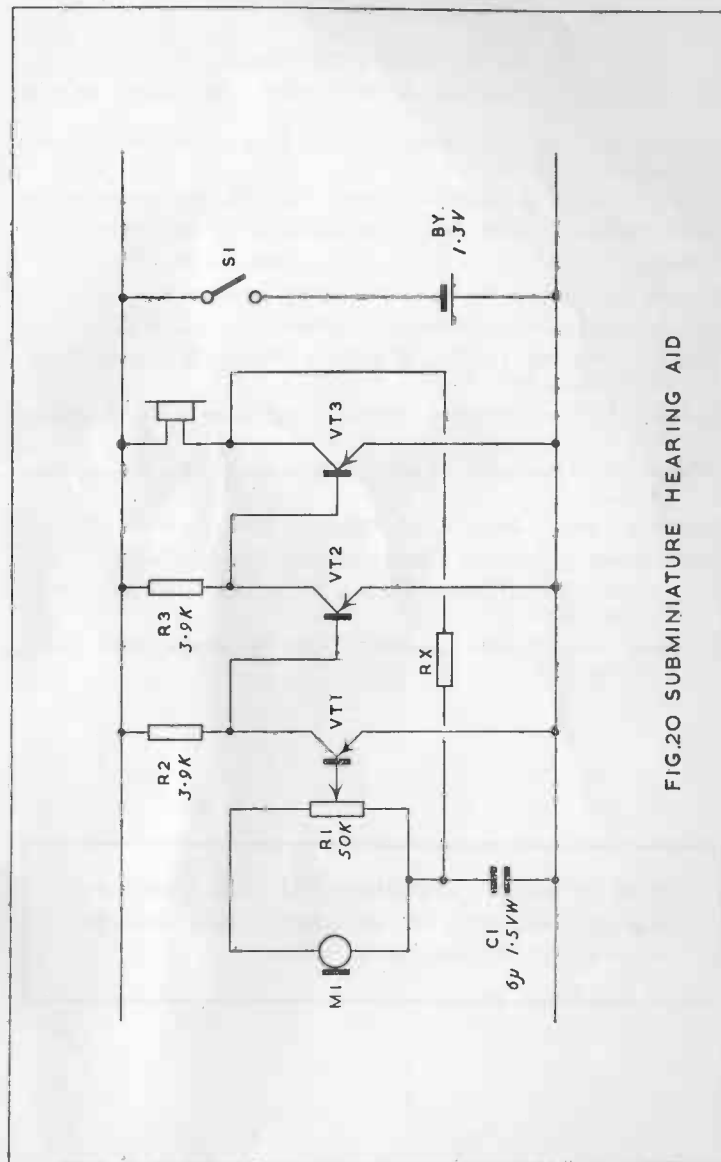


FIG.20 SUBMINIATURE HEARING AID

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