



no. 5

HANDBOOK
OF
SIMPLE
TRANSISTOR
CIRCUITS

by B. B. BABANI

BABANI PRESS

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Bernard B. Babani

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We invite all authors, whether new or well established, to submit manuscripts for publication. The manuscripts may deal with any facet of electronics but should always be practical. Any circuit diagrams that may be included should have been thoroughly checked by the author. If you are considering trying your hand at writing this type of book we suggest that you let us have a short summary of the subject you intend to cover. We will then be able to let you know the size of book required and perhaps give you some advice on presentation.

BERNARD B. BABANI

It is most strongly recommended to all readers of this handbook that they use VEROBOARD as the basis for building any of the circuits shown in this manual. The use of VEROBOARD will undoubtedly simplify, speed up and reduce any possibility of errors when building any of the circuits in this book.

VEROBOARD may be obtained in a number of suitable sizes from virtually any radio component stockist.

INTRODUCTION

The first section of the book deals with the simply crystal diode plus audio amplifier type of set which is so popular because of its low cost and basic simplicity. The receivers suffer, however, from one or two disadvantages. Firstly, due to the non-linearity of the detector, the sets have rather low sensitivity. As the signal strength decreases so the efficiency of the detector also decreases until a point is reached where no signal is being fed to the audio amplifier. This means that a good aerial must be used for best results except in areas of very high signal strength where a ferrite rod or frame type of aerial usually is sufficient. The second major disadvantage is the lack of selectivity, which means that two or more stations can often be heard at the same time. This fault may be partially overcome by careful coil design, the primary requirement being that the crystal diode or transistor and the aerial and earth system do not put too much load on the tuned circuit. On the credit side is the extremely high quality of reproduction obtainable with a good design. Where a fixed receiver is required, a long aerial is no disadvantage, this type of set is unbeatable from the point of view of quality and economy. Because of the high frequency capabilities of the germanium diode, all the circuits of this section are able to operate up to 100 Mc/s or more as long as a diode such as the OA70 is used. The actual method of operation of each type is described at the beginning of its respective section.

The second part of the book deals with the regenerative receiver as applied to transistors. This type of set, using thermionic valves, has been a great favourite both for the broadcast and the shortwave bands. Its advantages are very high sensitivity and selectivity combined with very low cost compared with a superhet or normal T.R.F. Unlike the valve types, where almost any valve will regenerate, only special R.F. types of transistor may be used. In the past many designs have been described without actually specifying the types to be used and this has led to disappointment and confusion, thus it is suggested that the components specified be fairly rigidly adhered to. The main disadvantage with the regen. is its poor quality of reproduction due to non-linear amplification. In shortwave receivers, however, this may not be very important. Another rather annoying disadvantage, of what is otherwise so useful a circuit, is the danger

of the set bursting into oscillation and acting as a small transmitter of interference. This may be overcome by isolating the detector from the aerial by a preceding stage of R.F. amplification, but this means losing the advantage of single tuning which is by no means inconsiderable. As no alignment is required with regens. the sets may be built without test equipment, however, they require a certain amount of skill for most sensitive operation.

The third section is devoted to receivers with tuned radio frequency stages. These sets are not very popular because for a really sensitive receiver two or more stages of radio frequency amplification are required and this means at least a three-gang condenser, which is both bulky and difficult to align. They are, however, slightly cheaper to build than the superhets and are capable of better quality.

The circuits in section 4 will be of special interest to the shortwave and V.H.F. enthusiasts as the receivers shown are capable of operations up to about 60 Mc/s. At first sight these circuits will appear rather unfamiliar as very little has been published about transistor super regenerative receivers in this country. Their great advantage over the other sets in this book is their unbelievable sensitivity and economy of components. A single stage super regen. is even more sensitive than a superhet having three I.F. stages; furthermore, the upper frequency limit is much higher for a given type of transistor and does, in fact, exceed the alpha frequency cut-off which is defined as the point at which the gain is 3db down on that at 1 kc/s. Because a twin gang condenser is not required, the receivers may be made very compact without the use of specially made components. The disadvantage of the super regen. are rather broad tuning, due to loading of the tuned circuit, and their tendency to radiate interference. This latter effect is virtually unimportant with transistor super regens. because only a very small aerial is used and the power of the oscillations is also small, nevertheless a certain amount of caution is called for. Unfortunately, the super regen. is rather unsatisfactory on the normal broadcast bands. The reason for this will be explained later in the book.

Finally, a few words on the use of transistors will not be out of place.

Despite their robust physical properties, transistors are easily damaged by heat, so always grip the leads with a pair of blunt-nosed pliers when soldering them. Alternatively, a transistor socket may be used and, if the set is only temporary, various transistors may be tried without the necessity for unsoldering and resoldering the connection. Another way in which transistors may be ruined permanently is to connect the battery the wrong way round. So always check for this before switching a new battery into a circuit.

Some types of transistor have glass encapsulation and the paint may scratch or peel off. If this happens repaint them, as transistors are sensitive to light and may pick up hum from electric lighting.

DIODE PLUS AMPLIFIER CIRCUITS

The block diagram of this type of receiver is shown in Fig. 1. The incoming signal is picked up by the aerial and coupled either directly, capacitively or inductively to the tuned circuit which offers a low impedance to all frequencies except that to which it is tuned. The tuning may be accomplished by varying either the condenser or the coil. It is far more usual to use a variable tuning condenser, but if a very small receiver is required then inductive or permeability tuning is more attractive.

The R.F. signal is now fed to the demodulator or detector, which may be either a crystal diode or a transistor. The crystal diode has the advantage that it will operate up to very high frequencies but, unlike the transistor, it gives no A.F. gain.

The A.F. signal is then amplified by a transistor audio amplifier which

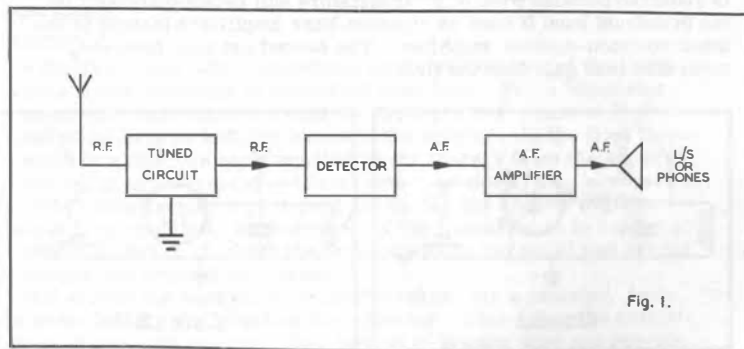


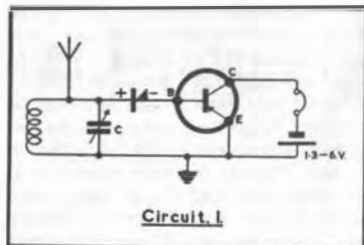
Fig. 1.

may use anything from one to six transistors, depending on the amount of gain required. If more than one transistor is used then the form of coupling between the transistors must be decided upon. Basically there are three different forms - resistance-capacity coupling, transformer coupling and direct coupling. Each of these has its advantages. If high quality is required, then resistance-capacity coupling should be used, but for maximum gain per transistor, transformer coupling is unbeatable. The advantage of the direct-coupled circuit is its extreme economy of components, thus it is very useful when building sub-miniature amplifiers and receivers.

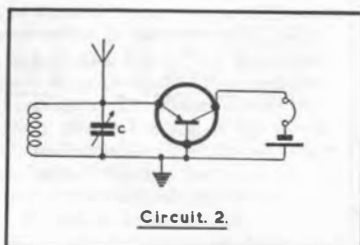
CIRCUITS 1 AND 2

The two simplest types of transistor receiver possible are shown in circuits 1 and 2. These two sets are ideal for those wishing to gain experience with transistors as they require no alignment. The entire power requirements are supplied by a single cell which may be either a zinc or a mercury type. The mercury cells, which are relatively new, are extremely useful for transistor work as they have more or less constant voltage with life. Furthermore, their weight-to-power ratio is far smaller than that of a zinc-carbon cell.

These two sets, if used with a good aerial and earth, can give amazing headphone volume. Any make of P.N.P. junction transistor may be used. In the first set the signal is demodulated by the crystal diode and then amplified by the transistor, if a high frequency transistor is used, such as the Mullard OC45 or OC44, then the crystal diode may be omitted: however, this is not normally worth while, due to the extra cost of R.F. transistors. In the second set, detection takes place in the base-emitter circuit and the resultant A.F. appears, in amplified form, in the collector-base circuit. No crystal diode is required because even A.F. transistors will detect quite well in the broadcast band if used as common-base amplifiers instead of the usual common-emitter amplifier. The second set has, however, somewhat less gain than the first.



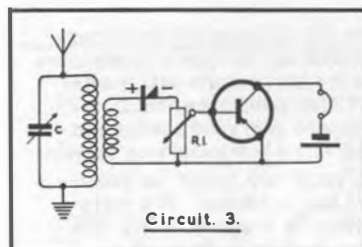
Circuit 1



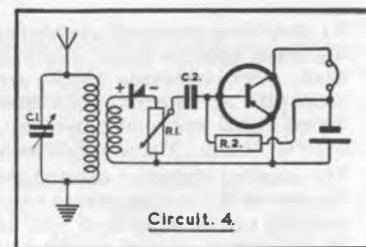
Circuit 2

CIRCUIT 3

The last two receivers suffer from two defects. Firstly, the tuning is very broad, due to the heavy loading of the tuned circuit by the detector. Secondly, there is no provision for volume control. These two points are taken care of in circuit 3. The tuned circuit is matched into the diode by means of an R.F. stepdown transformer having a turns ratio of approximately 5 to 1. If a commercial tuning coil is used then approximately 10 turns of thick enamelled copper wire should be wound immediately above the tuning coil.



Circuit 3



Circuit 4

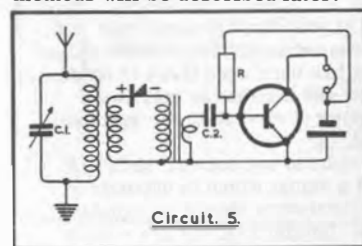
The battery supply may be anything from 1.5 to 6 volts with ordinary germanium junction transistors. If one of the American N.P.N. types of transistor is available this may be used equally well, but in this case the battery polarity should be reversed.

Those of you who like experimenting can try using the springs on a bed as an aerial. If this is done no earth is usually necessary. Another possibility, which frequently gives very good results, is connecting the aerial side of the coil to earth via a water-pipe and leaving the earthy side of the coil free. A television aerial is also quite useful.

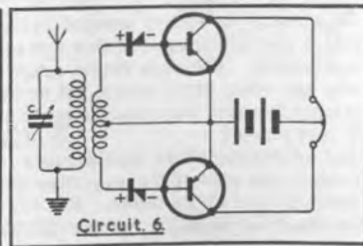
CIRCUIT 4

The fourth circuit, while embodying the improvements of the third, has the added advantage of controlled base bias. For a transistor to amplify it must receive a negative (positive in the case of N.P.N. transistors) bias on both the base and the emitter. In the first three circuits this bias has been supplied by the leakage from the collector which exists in all transistors to a certain extent. This, however, is rather unsatisfactory as it does not enable any control over the base bias current and, furthermore, if the transistor is to handle a reasonable amount of power the leakage will be too small and severe distortion and clipping will result.

In this circuit the base power supply is taken, via a resistor, from the same battery that supplies the collector. This saves the complication of a second battery. This method of biasing does not provide D.C. stabilisation, however, and sets which incorporate the various methods will be described later.



Circuit 5



Circuit 6

R_2 may have a value of anything from 100 K.ohms to 1 megohms, depending upon the power output required and the type of headphones used. High impedance 'phones gives the best results with single-stage sets and require a high value of bias resistance, but in very strong signal areas low impedance 'phones give good results and greater output. These should be used with a low value bias resistor.

The coupling capacitor should have a value of 0.5 mfd. or greater because of the low impedance input of the transistor. If a valve coupling condenser of 0.01 mfd. is used the low frequencies will be severely attenuated, giving a 'tinny' sounding output. 6 v.w. electrolytics are perfectly satisfactory because of the low supply voltage.

CIRCUIT 5

The fifth circuit diagram incorporates a still further improvement but, for the sake of simplicity, the volume control has been left out. In its place has been inserted a stepdown transformer having a turns ration of 4.5:1. This matches the output of the crystal diode to the input of the transistor and gives considerable improvement in gain. The distortion introduced by the transformer is so small that it is quite unnoticeable.

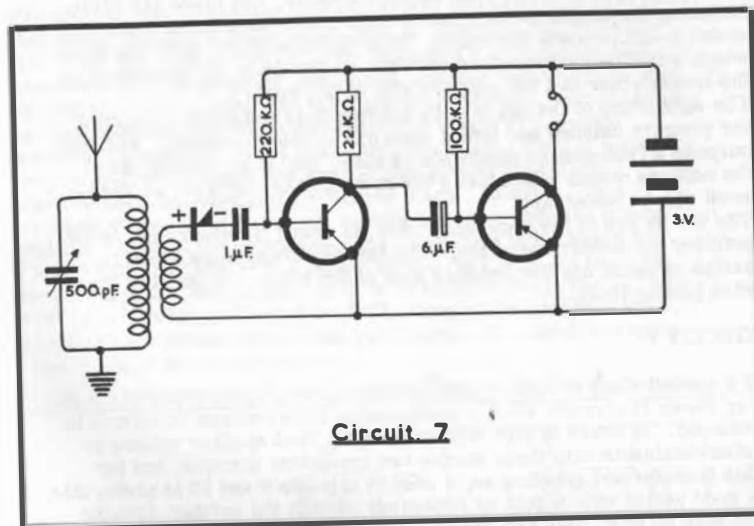
The average resistance-capacity coupled stage gives a gain of approximately 20dB compared with 40dB from a transformer coupled stage. This corresponds to gains of 100 times and 10,000 times respectively and the theoretical advantage of transformer coupling is very clear. There are a large number of different makes of transistor interstage transformers on the retail market and any of these should prove satisfactory.

The resistance, condenser and headphone values are the same as those in the last circuit and the battery voltage may again be anything from 1.3 to 6 volts. Despite the increased gain a good aerial is still usually necessary, because there is no improvement in the detector efficiency.

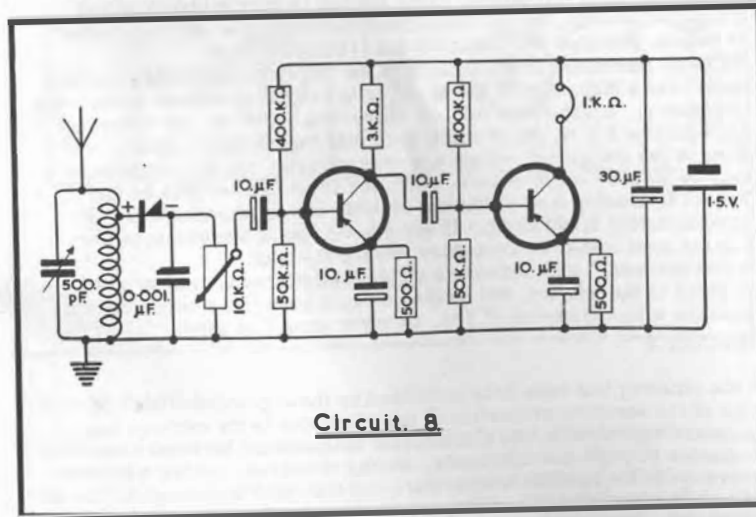
CIRCUIT 6

This circuit is rather unusual in that it uses two transistors in push-pull. The advantages of this are increased sensitivity, power output and quality. Although direct coupling has been used there is no reason why any other form should not be used and the reader will find it simple to adapt the transformer coupling of circuit 5, for example, to this circuit.

The secondary of the transformer is split in two halves, each half feeding one side of the amplifier with a signal which is opposite in phase to that of the other. The two transistors should be matched, as nearly as possible, to one another. Mullard OC72s are sold in



Circuit 7



Circuit 8

matched pairs under the code number 2-OC72, and these are ideal. Matching the diodes is not quite so important, but a severe mismatch would produce distortion. It is possible to use only one diode which would be connected between the centre top of the secondary of the transformer and the positive side of the battery.

The selectivity of the set may be considerably improved by leaving the primary untuned and tuning each half of the secondary. For this purpose a twin-ganged condenser is ideal, and if the two halves of the coil are wound with exactly the same number of turns no alignment will be necessary.

The two halves of the secondary must be wound on either side of the primary for proper operation. The two headphones are wired in series as usual and the negative side of the battery is taken to the wire joining them.

CIRCUIT 7

If a second stage of audio amplification is added to the types of receiver shown in circuits 1 - 6 a considerable improvement in volume is obtained. In areas of high signal strength, loud speaker volume is often obtainable with these simple two transistor circuits, but for this transformer coupling as is used in circuits 9 and 10 is preferable. A good aerial will be just as necessary as with the earlier circuits because no R.F. gain has been provided. Circuit 7 is resistance capacity coupled throughout. This method is very economical and gives good quality, but as the mismatch between the two transistors is not compensated for maximum gain is not obtained.

As in all transistor audio amplifiers the interstage coupling capacitor must have a high value if the signal is to be passed without undue impedance. A value of 6 mfd. is more than sufficient and since it need only be 3 v.w. the physical size may be extremely small.

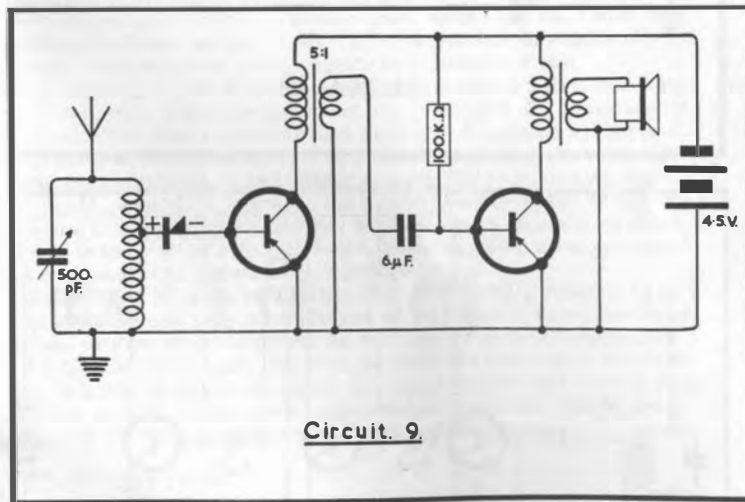
None of the component values are very critical; all the components may be 20 per cent tolerance. With the value of base bias on the second transistor the headphones should have an impedance of approximately 2,000 ohms. If any other value of headphone impedance is used it may be necessary to vary the bias.

A loudspeaker, with suitable matching transformer, may be used in place of the 'phones, but as the output is very low a sensitive speaker with a diameter of 5 in. or more should be used.

CIRCUIT 8

This receiver has been fully stabilised by the conventional method. One of the annoying properties of the transistor is its extreme temperature dependence. As the external temperature increases the collector current also increases, which, of course, causes a further increase in the junction temperature and the cycle begins again. If the stage concerned is handling a considerable amount of current to start with, this will increase until the transistor is destroyed.

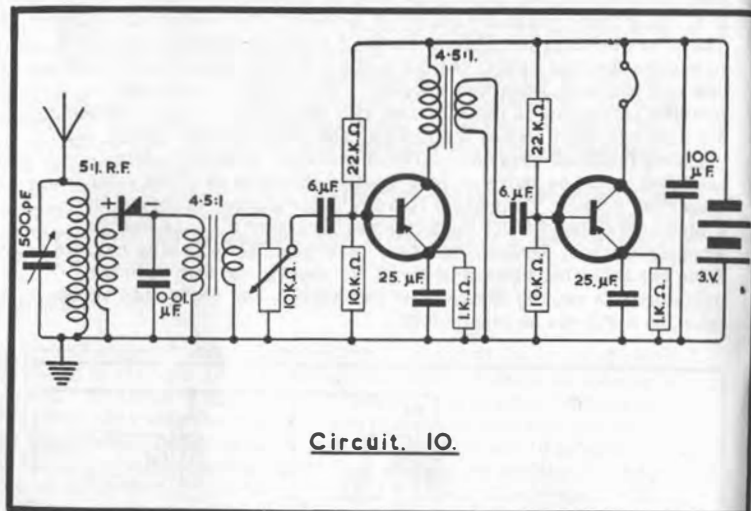
The obvious way to prevent this minor disaster is to reduce the D.C. gain of the transistor to as near unity as possible. For it is the D.C. gain that causes the collector to pass a high standing current. There are several possible methods of applying negative feedback to reduce the D.C. gain, but the method used in this circuit is the one that has been generally adopted. The output of a normal junction transistor is out of phase with the input. Thus if a resistance is inserted between the emitter and ground it will apply negative feedback over that particular stage. However, this feedback would be more or less equally effective over the entire amplified range. To prevent this the resistance is bypassed by a high value electrolytic condenser so that only D.C. is fed back. Another method, sometimes used, is to take the base bias current from the collector instead of the H.T. supply. In this case the resistance is usually divided into two halves, the centre tap being taken to earth via an electrolytic.



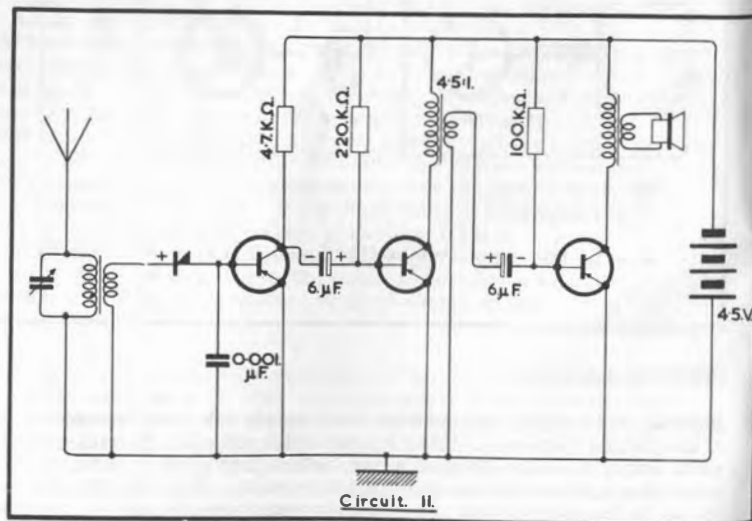
Circuit 9

CIRCUITS 9 AND 10

Building this receiver for the first time, people are often amazed at the high performance. Using a good aerial and earth 30 milli-watts output is usually obtainable and, with a good speaker, this is more than sufficient for the average living room. The high gain of the set is due to the transformer coupling used between stages.



Circuit. 10.



Circuit. 11.

With high gain transistors, the overall power gain of this set should be about 70dB or about 10 million times.

Circuit 10 is similar to circuit 9 except that the diode is transformer coupled to the first transistor and the receiver has been stabilised. If a loudspeaker is used in either of these circuits the output transformer should have a primary resistance of about 250 and a turns ratio of 18 : 1; this will match the output of the transistor to the loudspeaker voice coil, which should be 3 ohms. It is often possible to purchase single balanced armature earpieces on the surplus market, and these make ideal small speakers if connected directly to the output transistor without a matching transformer.

The high value electrolytic connected across the battery serves as a low impedance bypass as the battery resistance begins to rise. If it is omitted there is the chance of relaxation oscillations occurring towards the end of life of the battery.

CIRCUIT 11

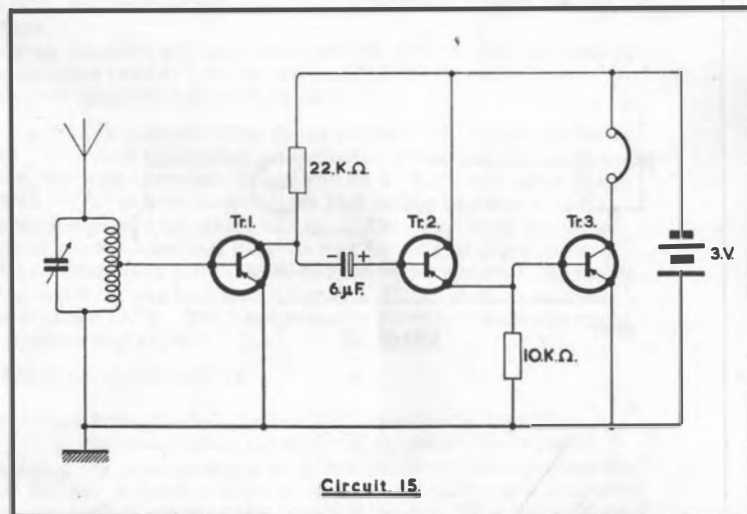
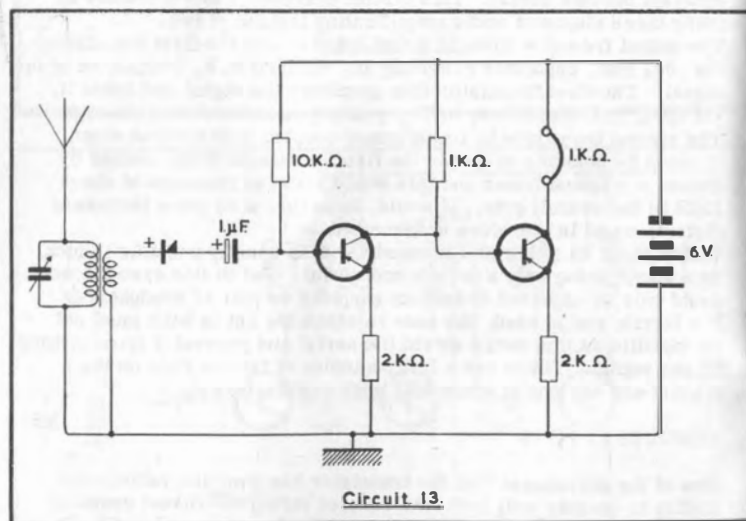
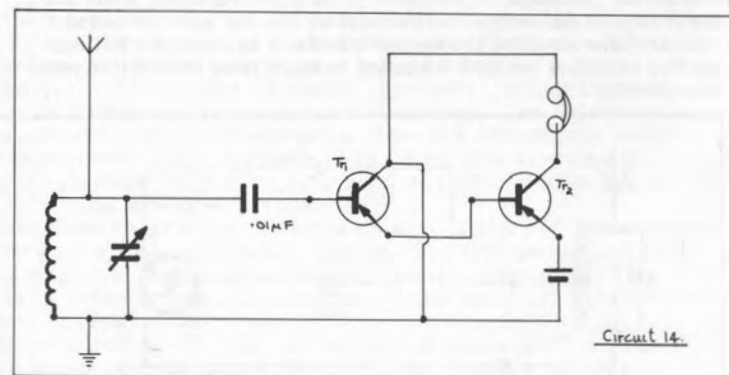
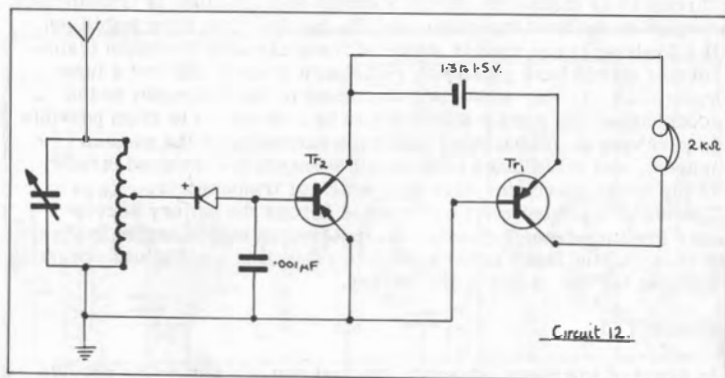
In areas of low signal strength, the last two circuits might provide insufficient gain to drive a loudspeaker, even when used with an efficient outdoor aerial. This circuit overcomes this difficulty by using three stages of audio amplification instead of two.

The output from the diode is direct coupled into the first transistor, the .001 mfd. capacitor removing any residual R.F. component of the signal. The first transistor then amplifies the signal and feeds it, via the 6 mfd. capacitor, to Tr_2 , which again amplifies the signal. The second transistor is transformer coupled to the output stage. It would be possible to couple the first transistor to the second by means of a transformer and this would mean an increase of about 15dB in the overall gain. It would, however, also mean increased distortion and is therefore undesirable.

Within about 20 miles of a transmitter it is usually possible to pick up a signal using only a ferrite rod aerial. But in this case the set could only be expected to feed an earpiece or pair of headphones. If a ferrite rod is used, the case in which the set is built must not be metallic as this would shield the aerial and prevent it from picking up any signal. There are a large number of ferrite rods on the market and any one of these will work satisfactorily.

CIRCUITS 12 TO 15

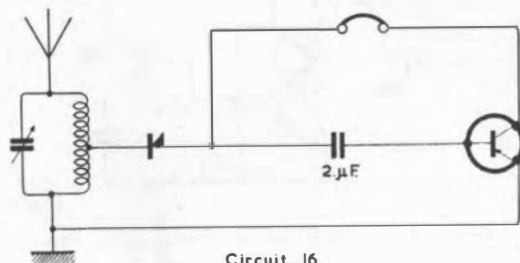
One of the advantages that the transistor has over the valve is its ability to operate well in direct-coupled circuits. Direct coupling with valves is difficult because the grid and anode supply voltages are of opposite polarity and differ from one another in value by a factor of anything up to 1,000. With the transistor, however, the situation is far more satisfactory. Both the collector and the base require negative supplies (positive for N. P. N. transistors). Direct



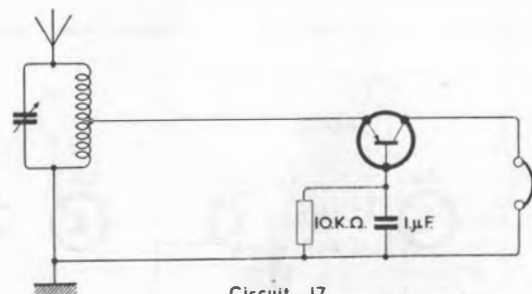
coupling has several advantages over other types when used in A.C. amplifiers. As no capacitors separate the stages the frequency response is usually superior and the receiver or amplifier requires fewer components and may, therefore, be made far more compact at extremely low cost.

The receiver in circuit 12 is a very good example of the amazing simplicity that is possible with direct coupled receivers. Despite the fact that this is a three-stage receiver, not one coupling condenser or transformer is used. A careful study of the circuit will reveal that the second transistor acts as the collector resistance for the first, and that the first transistor acts as the base resistance for the second. Thus the collector-emitter current of the first trans-

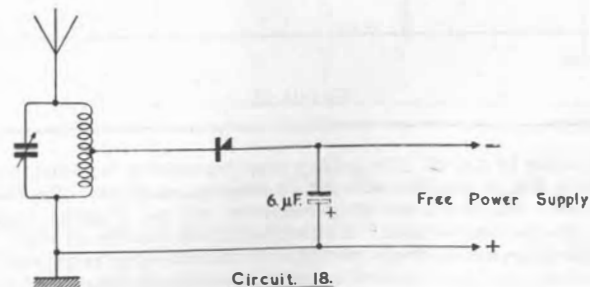
istor is always exactly equal to the base-emitter current of the second transistor. Although the collector of the first transistor feeds into the emitter of the second and the emitter into the base, as in most common base circuits, the second transistor is actually a common emitter amplifier because the output is taken from the emitter and the collector.



Circuit 16.



Circuit 17.



Circuit 18.

If the crystal diode and the .001 mfd. condenser are removed, and an R.F. transistor is used for the first stage, then the receiver becomes simpler still. In this case Tr_1 acts both as a detector and as an A.F. amplifier. The sensitivity is usually improved by this modification. Circuit 13 shows another form of direct coupling. The resistances in the emitter leads are not bypassed so there is a considerable amount of degeneration. This, however, gives the receiver very good frequency response. If higher gain is required further similar stages may be added without fear of instability.

Another extremely simple circuit is shown in circuit 14. The receiver uses what is known as a tandem amplifier. The first transistor demodulates the R.F. signal and also supplies some amplification. Tr_1 acts as a common collector amplifier and thus has a high input and low output impedance; this means that no tap is required on the coil for correct matching. Tr_1 also serves as the base bias for Tr_2 , which is a normal common emitter amplifier. Tr_1 supplies current gain and Tr_2 supplies both current and voltage gain. The battery voltage is in no way critical but should not exceed 6 volts with normal transistors.

A fixed capacitor having a value of 0.01 mfd. should be inserted between the base of Tr_1 and the tuned circuit so as to isolate the base from the negative side of the battery.

Circuit 15 is a combination direct coupled and r-c coupled receiver. The first transistor serves both as detector and audio amplifier, for best operation this should be an R.F. type such as the OC45. Tr_2 serves to match the high output impedance of Tr_1 to the low input impedance of Tr_2 . Thus Tr_2 does the same job as a 4.5:1 stepdown transformer except that there is very little voltage loss and the overall gain of the receiver is greater. Tr_2 and Tr_3 may be any low signal A.F. P.N.P. transistor such as the OC71. The headphones or earpiece should be about 1 K. ohms at 1 kc/s.

CIRCUITS 16, 17 AND 18

It may be some time yet before the transistor is capable of doing all the jobs that valves can, but there are some fields in which the transistor can do things which are quite impossible for valves. A good example of this is the transistor's ability to operate well at amazing low levels of power. This makes possible the design and construction of free power receivers, that is receivers which require neither internal batteries or connection to the mains but obtain their power from some free source such as sunlight. As silicon cells, which convert optical into electrical energy, are not generally available, there is little point in discussing them in any detail. It is sufficient to say that, with certain limitations, they may be wired into receivers in place of the more usual batteries.

There is, however, another form of free energy which is readily available and easily converted into usable form, namely, electromagnetic radiation from all forms of broadcasting stations. If a good outdoor aerial is fed into an ordinary crystal set the demodulated output is usually capable of feeding a pair of headphones without further amplification. If the headphones are removed and a smoothing circuit put in their place, a source of D.C. potential becomes available and may be used to power any single transistor receiver. This form of power supply is illustrated in circuit 18. If the receiver is to be tuned to a strong local station, an external crystal set may be unnecessary, as is the case in circuit 16. In this set the diode supplies both the signal and the power to drive the transistor. The collector of the transistor is connected to the output of the crystal diode via the headphones so that part of the current available is used to power the transistor.

Circuit 17 shows another receiver which operates in a similar manner. There the transistor is operated as a common base amplifier and the emitter-base junction acts as a diode, charging the 1 mfd. capacitor and thus producing the energy for the collector. Either a P.N.P. or an N.P.N. transistor may be used in this circuit.

REGENERATIVE RECEIVERS

All the receivers in the last section suffered from lack of sensitivity and selectivity. This is overcome in the receivers in this chapter by

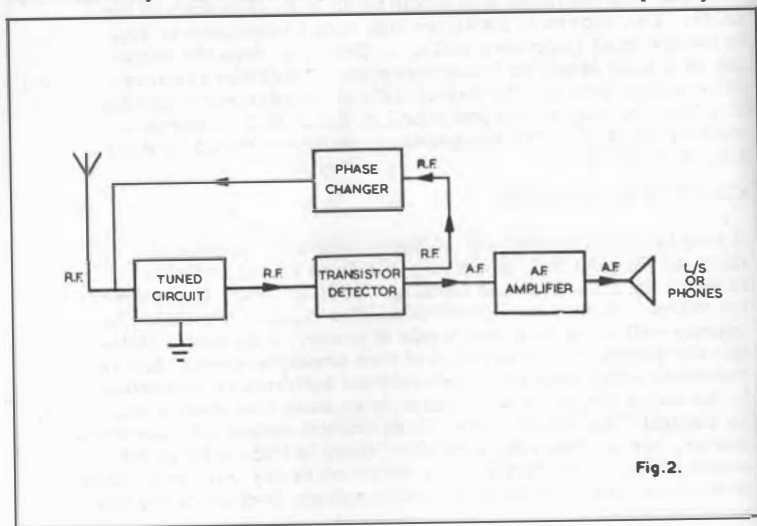


Fig. 2.

feeding energy from the output of the detector back to the input. A R.F. transistor is used as the detector. As well as detecting the signal and giving A.F. amplification, the transistor amplifies at R.F. The output of a junction transistor is out of phase with the input so some method must be used for changing the phase while the signal is fed back. If this is not done, the feedback will be negative and will tend to cancel out the signal at the input.

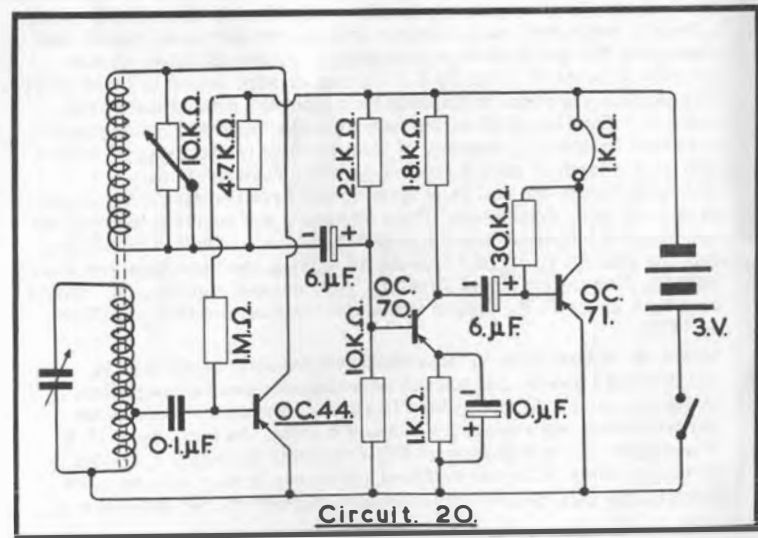
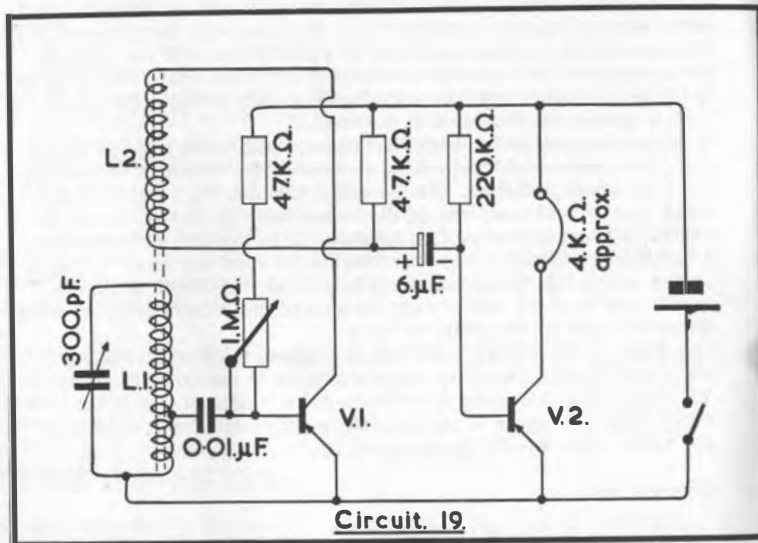
If too much signal is fed back the receiver will burst into oscillation and cause interference in nearby sets, so some means of controlling the feedback is required. As the output is normally coupled to the input by means of a winding on the tuning coil, the feedback may be varied by varying the coupling between the two coils. Alternatively, a variable condenser may be included in the feedback loop. Another system which has the advantage of improved stability is to fix the percentage feedback and to vary the gain of the transistor by altering either the base or the collector bias.

The effect of the positive feedback is to raise the Q of the tuning coil by tending to cancel out the resistances in the circuit. Thus the 'regen' has very good selectivity. The disadvantages of the regen. are the danger of causing interference with other receivers and rather poor quality of reproduction.

CIRCUIT 19

The receiver in circuit 19 uses V_1 as a common emitter regenerative detector. If the receiver is to be used without an aerial or earth then the coil should be wound on a ferrite rod. Even if an aerial is used, a ferrite rod is still an advantage as it has an extremely high Q and thus gives the set maximum sensitivity. L_1 should have approximately 60 turns of 44 or 46 d.c.c. copper wire wound in three layers. The input tap is taken at the 10th turn from the ground end of the coil. L_2 consists of 20 turns, wound in the same way, alongside L_1 . It is best to make L_2 capable of sliding along the ferrite rod as this will give a form of preset control over the regeneration. The output from the coil is coupled to the first transistor by means of the .01 mfd. condenser. Once adjusted, the coupling between the two coils is left alone and the regeneration is controlled by controlling the gain on V_1 . This is done by varying the base bias resistance and was found when tested to give a very smooth control. V_1 should be a high grade R.F. type of transistor such as the Mullard OC44 or OC45.

The A.F. output from V_2 is resistance-capacity coupled to V_2 , which should now be recognised as a common emitter amplifier. In the circuit a 1.5 volt battery is shown; however, there is no harm in using any voltage up to about 6 volts. In fact, some R.F. transistors will not operate at this frequency with only 1.5 volts. Should an external aerial be found necessary it may be connected between the coil and .01 mfd. coupling capacitor. Do not make

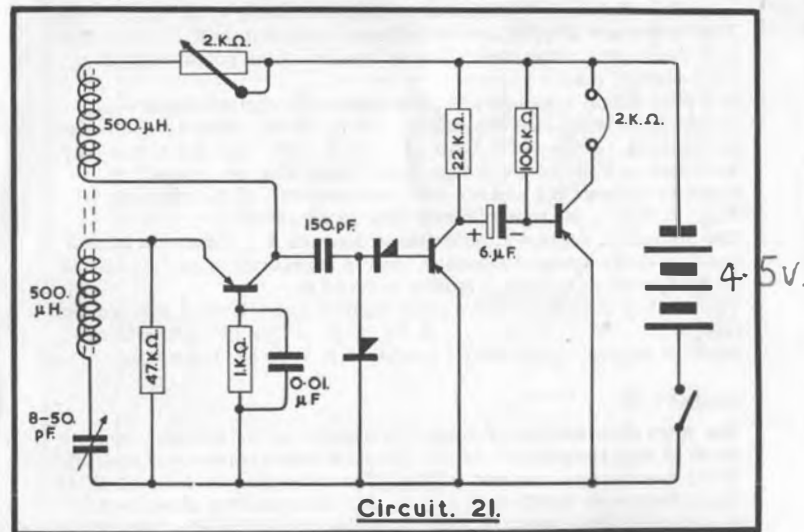


the aerial too long as it tends to damp down the tuned circuit and make oscillation difficult.

When the set is completed, switch on and connect a few feet of aerial. Now turn the tuning condenser until a local station is heard. Vary the 1 megohm pot. until the receiver oscillates, then readjust it until the set is just off the point of oscillation. This is the most sensitive setting. If oscillation is impossible try reversing the connections to L_2 , as this may be providing negative feedback instead of the positive feedback required.

CIRCUIT 20

In areas of low signal strength the receiver in circuit 19 may not have sufficient gain to drive the earpiece to a satisfactory volume. If this is the case, another stage of audio amplification is often sufficient to overcome the problem. Circuit 20 shows a set of this type, the regenerative detector is basically similar to that of the last set but is controlled in a different manner. Instead of using a variable base bias resistor, and thus controlling the transistor gain, the current through the feedback loop is varied. If there is too much feedback and the set oscillates the resistance across the coil is reduced and less current flows through this



coil and more through the resistance. If, on the other hand, there is too little regeneration the value of the resistance is raised and more current flows through the coil.

The coil winding details for this set are the same as for the last one, and if desired the same method of regeneration may be used. The second stage is stabilised in the conventional way, that is with D.C. feedback applied by a resistance in the emitter lead. The last stage, however, is stabilised by means of a feedback resistor. As this resistor feeds back A.C. as well as D.C. there is some loss of gain, but this may be overcome by splitting the resistance into two halves, each of 15 K.ohms and shorting the junction of the two halves to earth (as far as A.C. is concerned) via a 6 mfd. electrolytic.

If desired, a small loudspeaker may be used with the set; the transformer for this should have a turns ratio of about 18 : 1 if it is to feed into a 3 ohm loudspeaker.

CIRCUIT 21

Wrist radios have long been featured in science fiction and comic strips, but it was only the advent of the transistor that made the design of such sets possible. This remarkably simple receiver was originally designed by Lieut. Paul Cooper and Joseph O'Brien of the American Signal Corps Engineering Laboratory.

According to the designers, the set is tuneable from 1 Mc/s to 1.6 Mc/s and has the remarkably high sensitivity of 50 micro volts. The first stage acts as a common base regenerative R.F. amplifier with the regeneration controlled by the 2 K.ohms potentiometer in the collector lead.

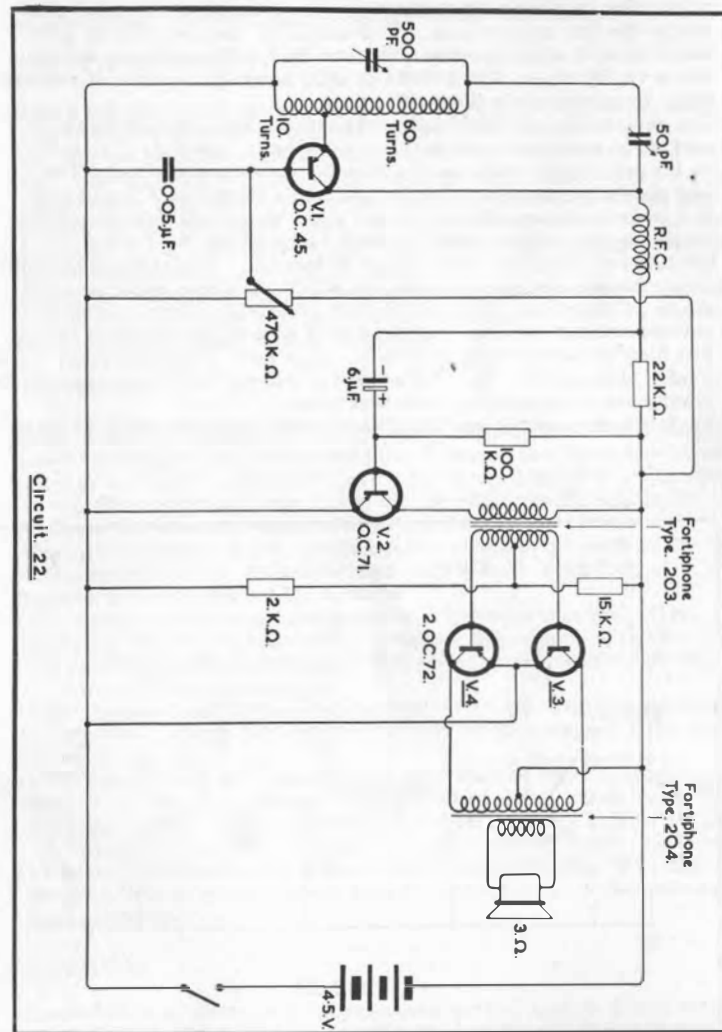
In strong signal areas no aerial is needed, sufficient signal being picked up by the coils themselves, but normally a foot or so of wire is required. If the set is built as a wrist radio then the aerial may be wound on to or in the strap; there would then be a capacitive coupling between the wearer and the tuning coil of the receiver so that, in effect, the owner's body acts as an aerial.

The amount of regeneration obtained depends somewhat upon the position of the tuning condenser, so the regeneration control should be readjusted each time a station is tuned in.

The original receiver used a point-contact type of transistor for the first stage, but if a P.N.P. - R.F. junction type of transistor is used the supply voltage may be reduced to 1.3 or 1.5 volts.

CIRCUIT 22

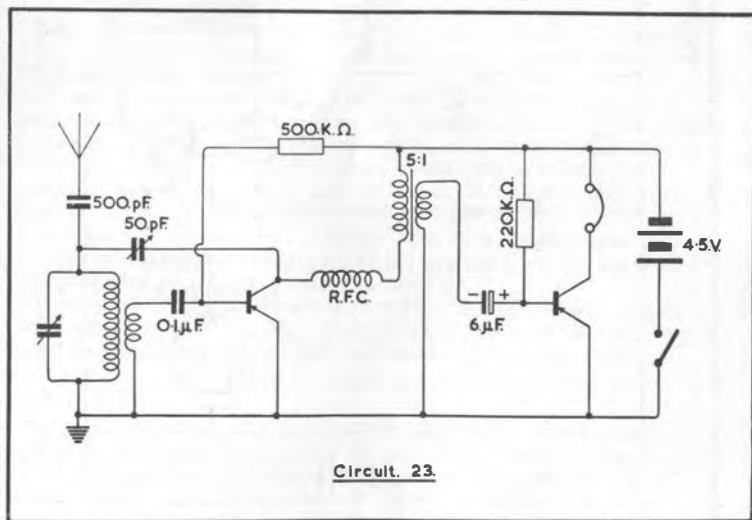
The main disadvantage of using a transistor in the common-emitter mode at high frequencies is that the maximum frequency of operation of the transistor is not obtainable. For example, the Mullard OC44 has a frequency cutoff of 15 Mc/s, which means that when used in the common-base mode the gain at 15 Mc/s is 3dB below the gain at



1 kc/s, and with careful design the transistor will operate as a common-base amplifier up to this frequency. In the common-emitter mode, however, the position is far less satisfactory, the cutoff point being reached at approximately the alpha frequency cutoff divided by the beta current gain. With the OC44, the beta current gain has a value of approximately 100, thus the cutoff is reached at 0.15 Mc/s or 150 kc/s. The transistor will, however, operate at reduced gain, somewhat above the cutoff value.

The receiver in circuit 22 takes this into account and is designed to operate at maximum frequency for any given transistor. The turns on the coil are shown in the diagram for medium wave-band. The coil should be wound on a ferrite rod aerial about 6 to 8 inches long. If it is desired to use the set on any other wave-band then the appropriate number of turns must be used, but maintain the ratio of 6 to 1 between the upper and lower halves of the coil. Two methods of controlling the reaction are provided, the 470 K. ohm base resistance and the 50 pf. trimmer. The pot. is first adjusted to obtain roughly the correct setting, and then the trimmer is adjusted for the final setting. The first transistor is coupled to V_2 via a radio frequency choke and the 6 mfd. electrolytic. The choke ensures that the R. F. is fed back to the tuned circuit and not lost in the next stage.

V_2 feeds into a phase-splitting transformer which couples it to the push-



pull output stage. The advantages of this type of output are increased fidelity, output power and battery economy because the current drawn from the battery is proportional to the input signal instead of inversely proportional, as is the case in a single-ended output stage.

CIRCUITS 23 AND 24

These two receivers are merely variations on the preceding sets and they introduce no really new ideas. Circuit 24 is interesting, however, because the feedback winding is tuned instead of the base-emitter winding. The signals are picked up by the ferrite rod and tuned to L_1 ; as L_1 is tightly coupled to L_2 only the required signal is amplified and detected by the transistor. As L_1 is not the tuning coil it may be wound to provide a correct impedance for the transistor and should have one-sixth the number of turns that L_2 has.

In neither of these circuits are the supply voltages very important, but it is preferable to use mercury cells as these have far more constant voltage with life than the zinc ones have.

CIRCUIT 25

This circuit is analogous to the well-known tuned - grid-tuned anode valve oscillator. With transistors this is known as a tuned base-tuned emitter oscillator. This set is prevented from oscillating (or allowed to oscillate as the case may be) by the 500 pfd. variable condenser which controls the amount of signal fed to the transistor.

The first transistor is not a regenerative detector, as were all the other in the section; it is, in fact, a regenerative R. F. amplifier, thus a crystal diode is required for detection.

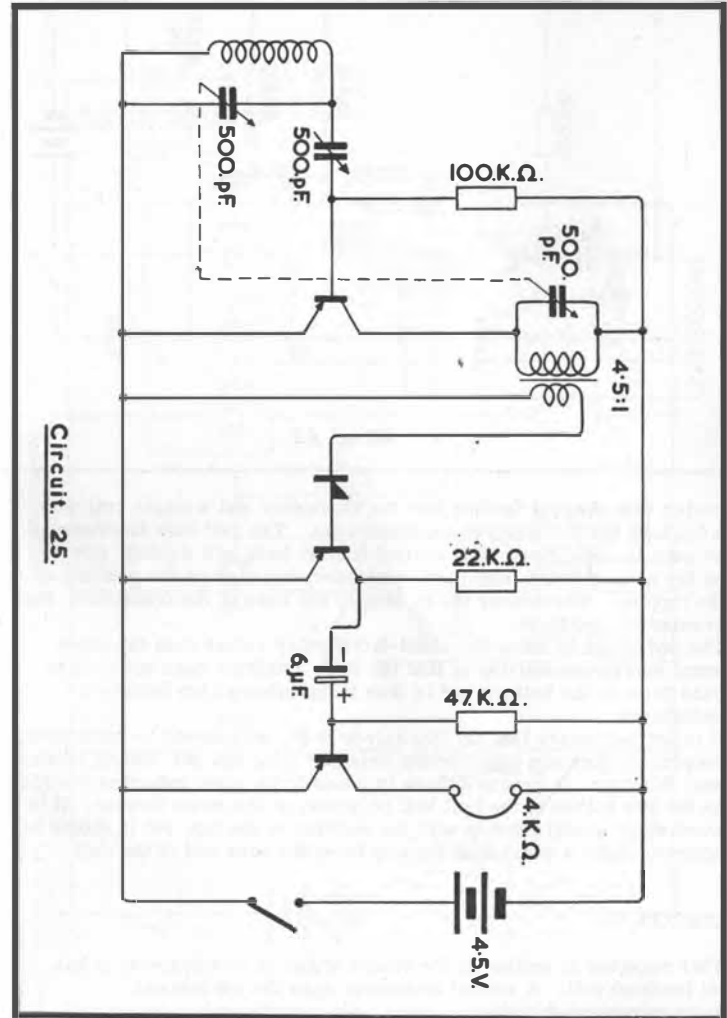
This system has several advantages over previous circuits. First, as there are two tuned circuits instead of one, the selectivity is still better and secondly, the transistor gives higher gain because of the greatly increased collector impedance.

After the tuned circuit the receiver follows the same lines as those in section one, and any of these circuits may be used instead of the one shown if desired.

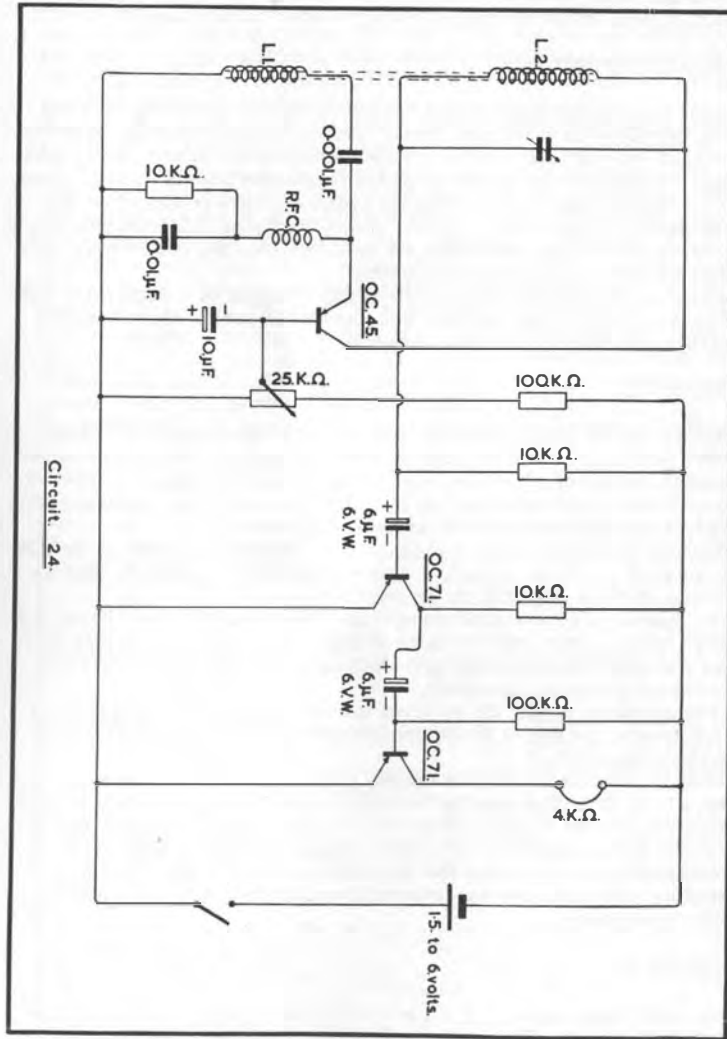
When building this set, considerable care must be taken to ensure that there is no inductive coupling between the two coils, either shield them from one another or mount them so that their axes are at right angles. The two tuning condensers should be ganged together and the set must be aligned in the same way that is used in valve circuits. For this purpose, trimming condensers must be connected in parallel with the tuning condenser.

CIRCUIT 26

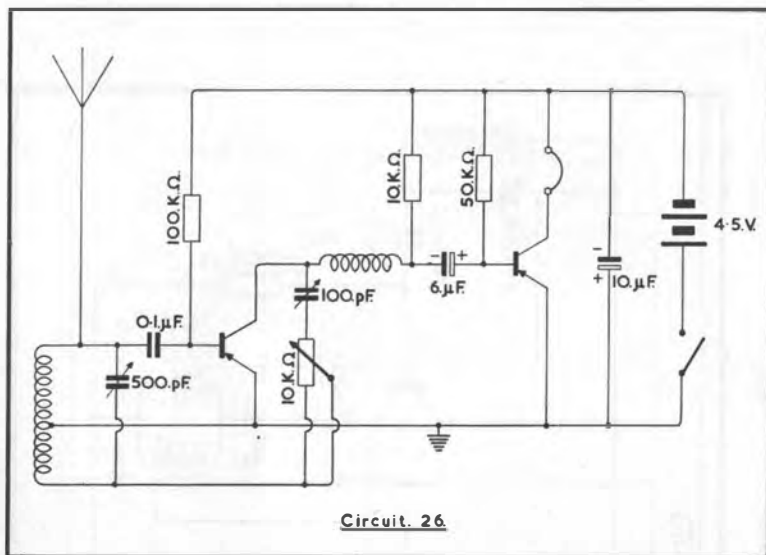
Circuit 26 is an example of the shunt-fed Hartley type of circuit being applied to a transistor receiver. In this circuit the tickler coil is in



Circuit. 25.



Circuit. 24.



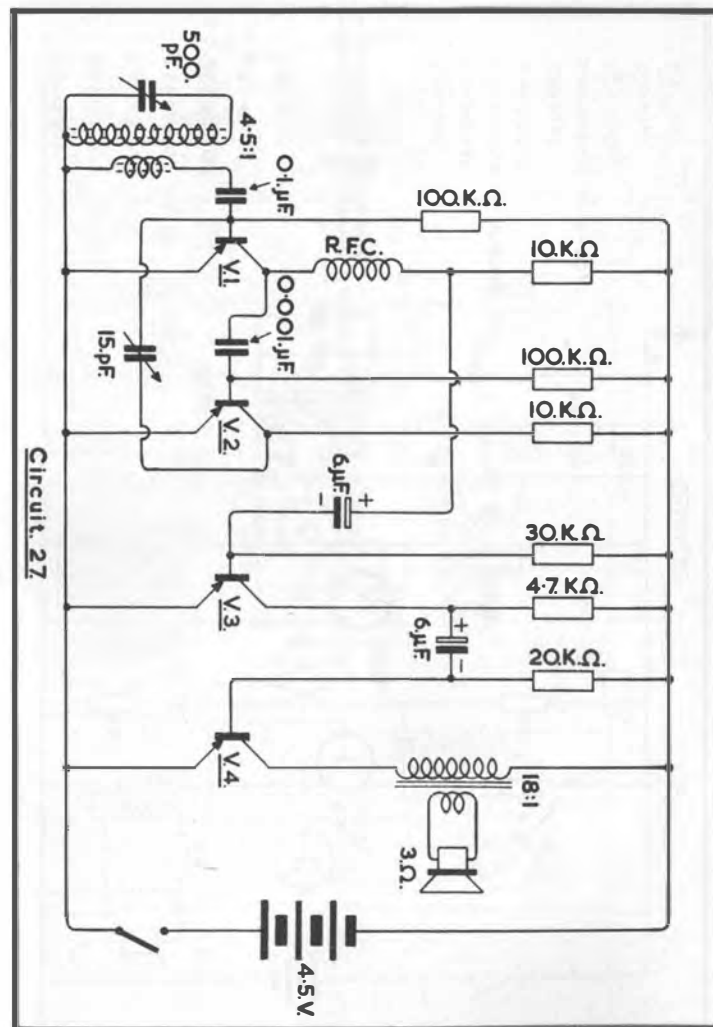
series with the coil feeding into the transistor and a single coil with a tap take the place of two separate coils. The coil thus functions as an auto-transformer. The amount of feed-back will depend, not only on the setting of the feed-back condenser, but also on the position of the tapping. The nearer the tapping to the base of the transistor, the greater the feedback.

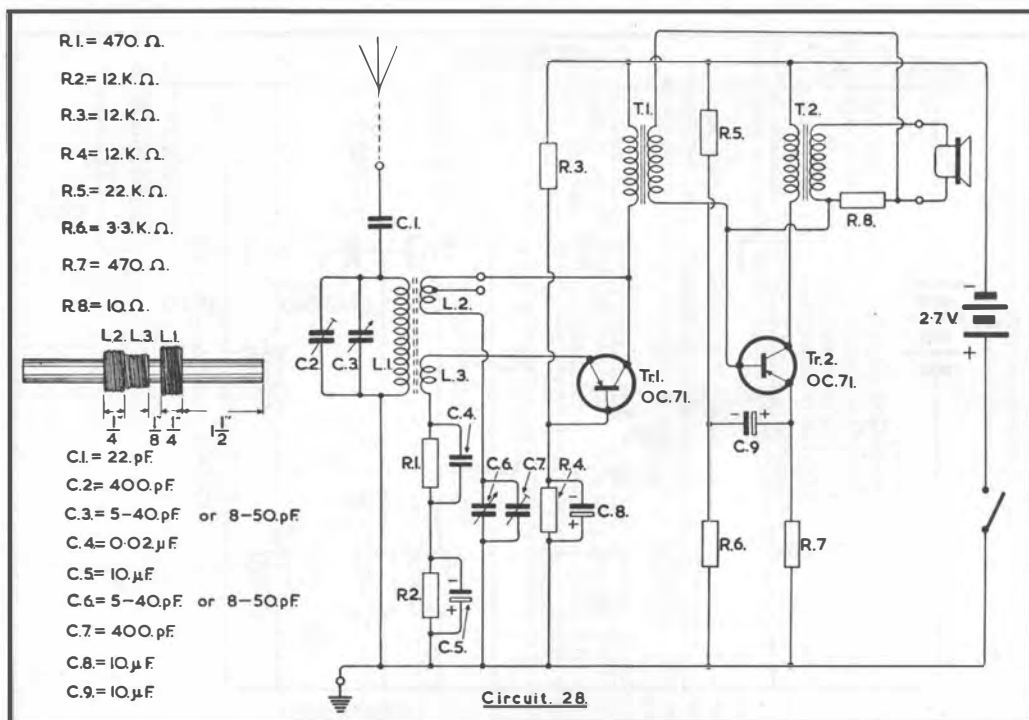
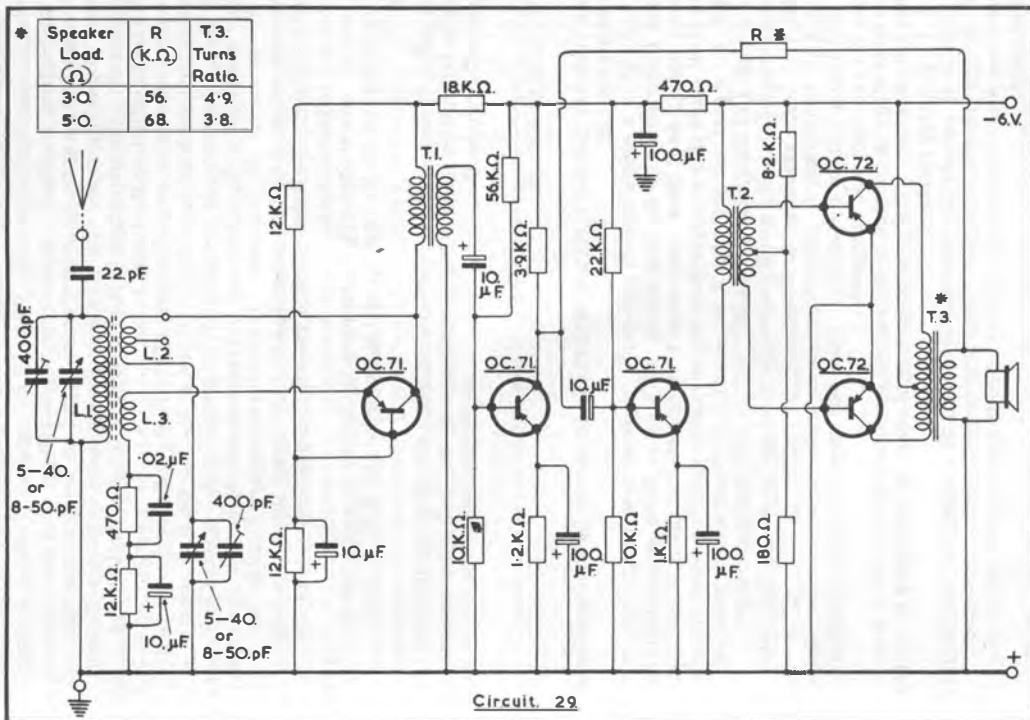
The advantage of using the shunt-fed Hartley rather than the more usual series-fed Hartley is that the R.F. feedback does not have to pass through the battery and is thus independent of the battery's resistance.

It is not necessary that the two halves of the coil should be inductively coupled as they are capacitively coupled by the 500 pfd. tuning condenser; however, in practice there is bound to be some inductive coupling as the two halves of the coil will be wound on the same former. It is worthwhile experimenting with the position of the tap, but it should be approximately a quarter of the way from the base end of the coil.

CIRCUIT 27

This receiver is unlike all the others shown in this respect, it has no feedback coil. A second transistor does the job instead. A transistor used in the common emitter configuration inverts the





signal between its base and collector. That is, the output is 180° out of phase with the input. Thus, if there is some direct feedback from the collector to the base, this will be negative feedback instead of the positive feedback required for regeneration. Normally this difficulty is overcome by inverting the signal on its way back with a coil. However, a second transistor may be used instead with very good results, the advantage being that control of the reaction has little or no effect on the tuning.

The first transistor amplifies part of the R.F. and detects the rest passing the resultant amplified A.F. on to V_3 via the R.F. choke. The R.F., however, is prevented from reaching V_3 by this R.F. choke and is fed to V_2 , where it is inverted and fed back to the base of V_1 via the 15 pfd. trimmer. It may be necessary to alter the maximum value of this trimmer to bring the transistor to its most sensitive point. No definite value can be laid down because of the variations in transistors.

V_1 and V_2 must both be R.F. transistors having an alpha cutoff value of at least 10 Mc/s. V_3 and V_4 may be any P.N.P. transistors.

The output transformer should have a turns ratio of about 18 : 1 if it is to feed into a normal 3 ohm loudspeaker, but this value is not particularly critical.

CIRCUITS 28 AND 29

This receiver and the variation of it shown in circuit 29 was developed by Mullards Ltd.

Circuit 28 is a single station pre-tuned receiver designed to tune in the Light Programme on the long wave. This set is more economical than usual, using, as it does, only an A.F. transistor in the R.F. section. The first stage is a common base regenerative detector which detects the R.F. signal and provides R.F. positive feedback which reduces the damping of the tuned circuit and thus enables the transistor to achieve high gain. R_3 and R_4 provide the base bias and, together with R_2 , D.C. stabilise the transistor.

Maximum sensitivity is achieved when the receiver is near the point of oscillation without instability. This was taken into consideration when the receiver was designed.

The first stage is coupled to the second by means of an 8.5 : 1 step-down transformer. The gain of the output stage is increased by means of A.F. positive feedback.

Circuit 29 is merely the front end of circuit 28 feeding into the Mullard 6V, 200 milliwatts amplifier. With this combination a first-class pocket receiver can be built capable of sufficient output to fill a fair sized room.

T. R. F. RECEIVERS

The tuned radio frequency receiver, using valves, has been, perhaps, the most popular type with the more advanced constructor ever since the principle was first discovered, and it would seem natural that this should also be true with transistors. This, however, is by no means so. Present-day R.F. transistors have less gain than their valve counterparts and so more R.F. stages are required for equivalent sensitivity which, in turn, means more variably tuned stages to complicate the alignment. Furthermore, the transistors presently available are mainly triodes and therefore require neutralisation if used in the common emitter configuration. (The common base configuration provides less gain and still more stages are necessary to obtain a satisfactory degree of sensitivity.)

For these reasons the author has not devoted more space than is necessary for comprehensiveness to T.R.F.s. The types of circuit used in R.F. amplifiers are, of course, the same as those for I.F. amplifiers, and examples of these are shown in Section 5.

The block diagram for these sets is shown in Fig. 3. The difference between these receivers and those shown in Section 1 is that the signal is amplified before it reaches the detector, with a resultant increase in sensitivity. As there are several tuned circuits the selectivity is normally very good.

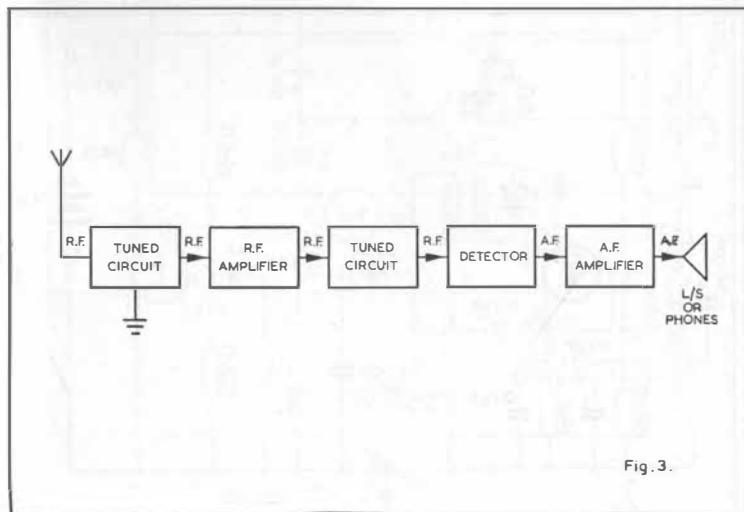
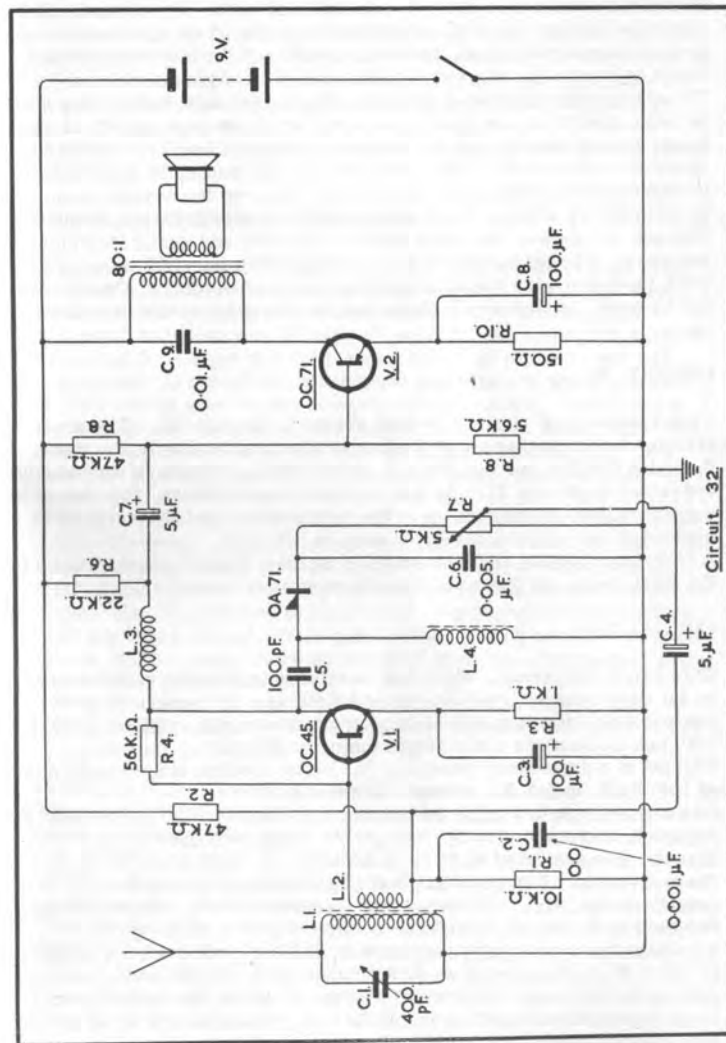
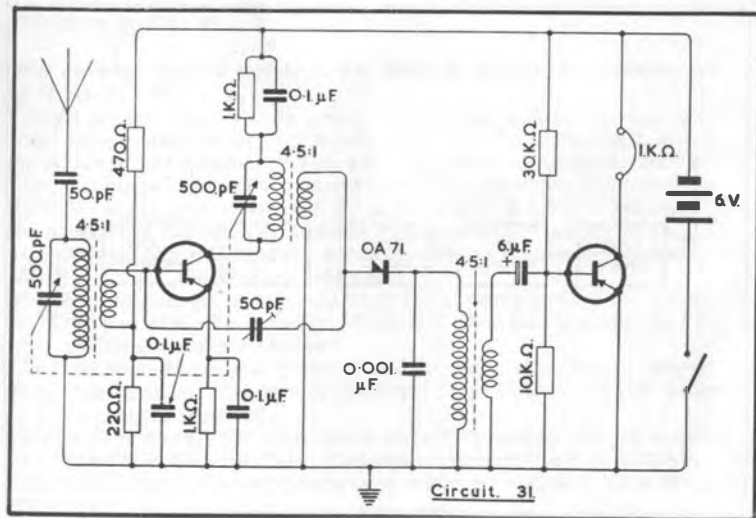
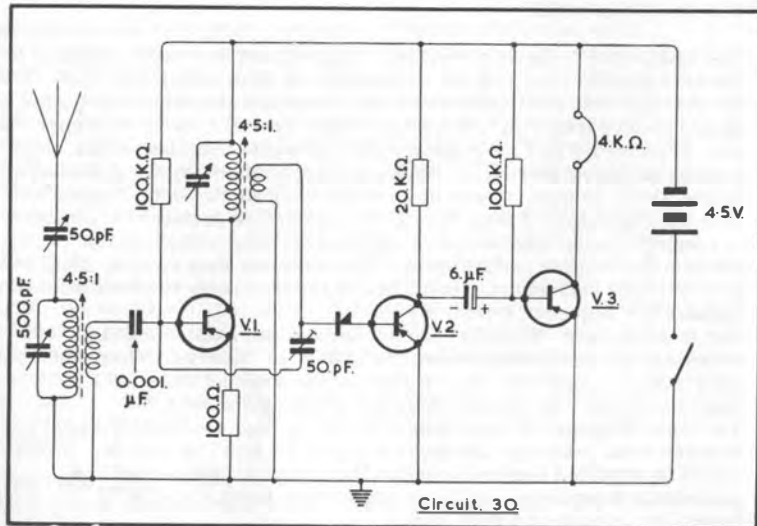


Fig. 3.



CIRCUIT 30

This little receiver is perfectly straight forward. V_1 acts as a R.F. amplifier without and D.C. stabilisation. The 50 pf. trimmer is used to provide neutralisation, that is to neutralise the internal feedback which is due to the internal capacitances of the transistor. To avoid feedback between the coils, by mutual inductance, they should be separated from one another as much as the case permits. If a very small case is used it may be necessary to use a metal screen and to mount the coils so that their axes are at right angles to one another. If high quality loudspeaker operation is required the crystal diode may be followed by a three-stage audio amplifier with push-pull output. The set, as shown, will work with only ferrite rod aerial in almost any area. The secondary of this coil should be about 15 turns of fairly thick insulated wire wound alongside the tuned winding. A metal case must not be used, as this would shield the ferrite and prevent any signal pick-up.

CIRCUIT 31

This receiver is similar to that shown in circuit 30. The main difference is the inclusion of D.C. stabilisation in the R.F. stage. As the coils for this and the last set are identical, circuit 30 may easily be converted to circuit 31. As has been mentioned before, the type of audio amplifier used is entirely up to the constructor, and if circuit 30 is converted the original amplifier may be retained. A transistor having an alpha cutoff of at least 6 Mc/s must be used for the first stage, as this uses a common emitter amplifier.

CIRCUIT 32

This ingenious circuit, which has been used in slightly modified form by kit suppliers in Great Britain and America, is capable of good loudspeaker operation with only a ferrite rod aerial, and yet it uses only two transistors and a single tuning condenser. The set is a four-stage receiver, V_1 being a reflex stage amplifying at both R.F. and A.F. without regeneration. The signal is picked up by the ferrite rod, tuned by L_1 and the 400 pf. capacitor and coupled to V_1 by L_2 . V_1 then amplifies the R.F. signal. The amplified R.F. is blocked by L_3 and passed by C_5 to the diode detector. The resultant A.F. is developed across the 5 K.ohm potentiometer, R_4 . R_4 serves as a volume control, the output being fed back to V_1 via C_{10} which has a value of 5 or 6 mfd. V_1 then amplifies the signal gain, this time at A.F. L_3 offers a low impedance to the A.F. output, being an R.F. choke which should have a value of approximately 1 mh. The small amount of signal that does bypass C_5 is prevented from reaching the diode by L_4 which offers a low impedance path to earth.

The output from V_1 is fed to V_2 , the audio output stage, which is transformer coupled to the loudspeaker. The output transformer should have a turns ratio of about 80 to 1 as it must match the 20 K.ohms output from the transistor to the 3 ohm voice coil of the speaker.

Despite its apparent complexity, this is an ideal receiver for the inexperienced constructor as there is no reaction to control and no alignment problems. The only disadvantage is the signal tuned circuit, which makes the tuning somewhat broader than would normally be desired.

In difficult areas it may be necessary to add an earth and an aerial of between 10 and 15 feet.

SUPER REGENERATIVE RECEIVERS

The super regenerative receiver is the most sensitive type ever designed. Furthermore, it has the advantages of single tuning, basic simplicity, economy and reasonably high fidelity (this last point depends upon the type of super regen. used). It would appear at first sight that this is then the ideal circuit, and yet it has never achieved the widespread popularity it deserves, and is very rarely used in any commercial equipment. The reasons for this do not really lie in the circuit, but in the people who first tried to use it without really understanding it sufficiently. The result of this was that the super regen. earned itself a name for a tendency to oscillate and be uncontrollable. It was thought far too unstable to ever be used in any really good mass-produced equipment. However, during the last war the super regen. at last came into its own as it was used in radar and I.F.F. receivers with first-class results. For any given valve or transistor, a super regen. may be designed to operate at a far higher frequency than with any other circuit. This makes it especially useful with transistors as it is vastly more economical than, say, a superhet with comparable performance.

The super regen. is really a development of the regenerative receiver. The sensitivity of the latter is limited by the point at which it bursts into oscillation.

The super regen. is really a development of the regenerative receiver. The sensitivity of the latter is limited by the point at which it bursts into oscillation. The super regen. consists of a regen. R.F. amplifier or detector which is adjusted so as to be near the point of oscillation. The detector may now be switched in and out of oscillation by varying any of the supply currents a small amount. In operation this transistor or valve is switched in and out of operation at super-sonic rate by another oscillator which is designed to vary either the base or the collector bias and is known as the quench oscillator. Now, the R.F. oscillations may start from any level but will always build up to the same peak value (this value being the limit that the

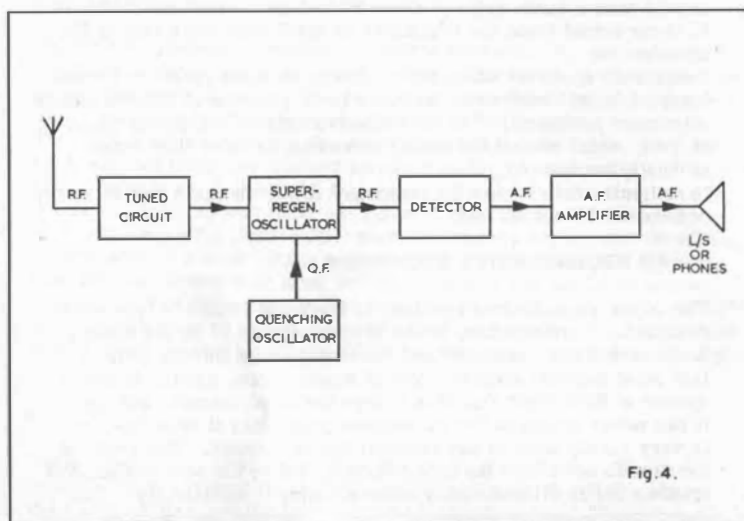


Fig. 4.

transistor used can handle). The time it takes the oscillations to build up to their peak will depend on the amplitude of the modulated signal picked up by the aerial, then the variation in the start to peak oscillation times will be, in some way, proportional to the original modulation signal.

If the oscillations are always allowed to reach their peak before being quenched, then the output will be logarithmically proportional to the input and not really suitable for the reception of words or music. If, however, the oscillations are always quenched before they reach their peak then the output will be linearly proportional to the input. The gain achieved in this way may be 100 million times for a single stage.

Whether the set operates in the linear or logarithmic mode depends upon the amplitude and frequency of the quench oscillator, and so the adjustment for this is somewhat critical.

The oscillations induced by one quench cycle must always die away before the next cycle commences. If this does not happen then the next cycle will build up from the cycle before and not from the signal. For this and other reasons the wavelength of the quench oscillator should normally be at least 100 times that of the signal frequency oscillator. This makes the design of a medium wave super regen. extremely difficult. It is not, however, impossible, as is so often stated, and very good results have been obtained from the circuits shown in this section.

Although the quench oscillation is often a separate transistor it is possible to make the super regenerative detector supply its own quench frequency, and some of the receivers are of this type. The operation of a self-quenched super regen. detector is somewhat different from that of the other types mentioned above. In this case the bursts of oscillation maintain the same amplitude, but the time between each one varies as the input signal varies.

Owing to this somewhat complex mode of operation, the reader is not advised to attempt the construction of a super regen. until he or she has built some of the circuits in Sections 1 and 2.

CIRCUIT 33

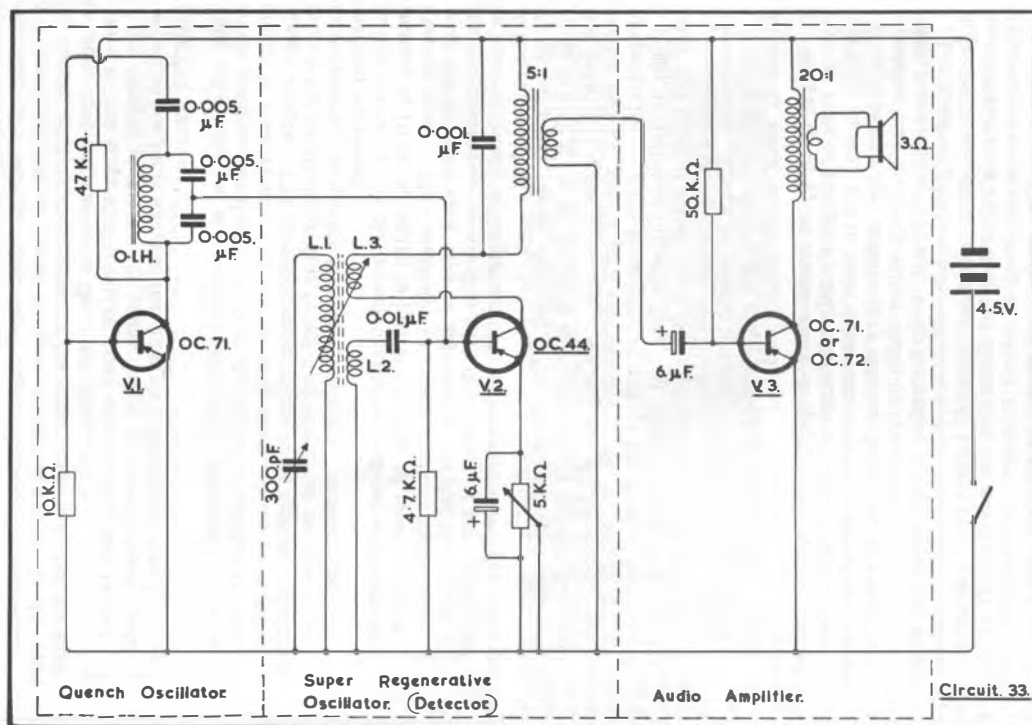
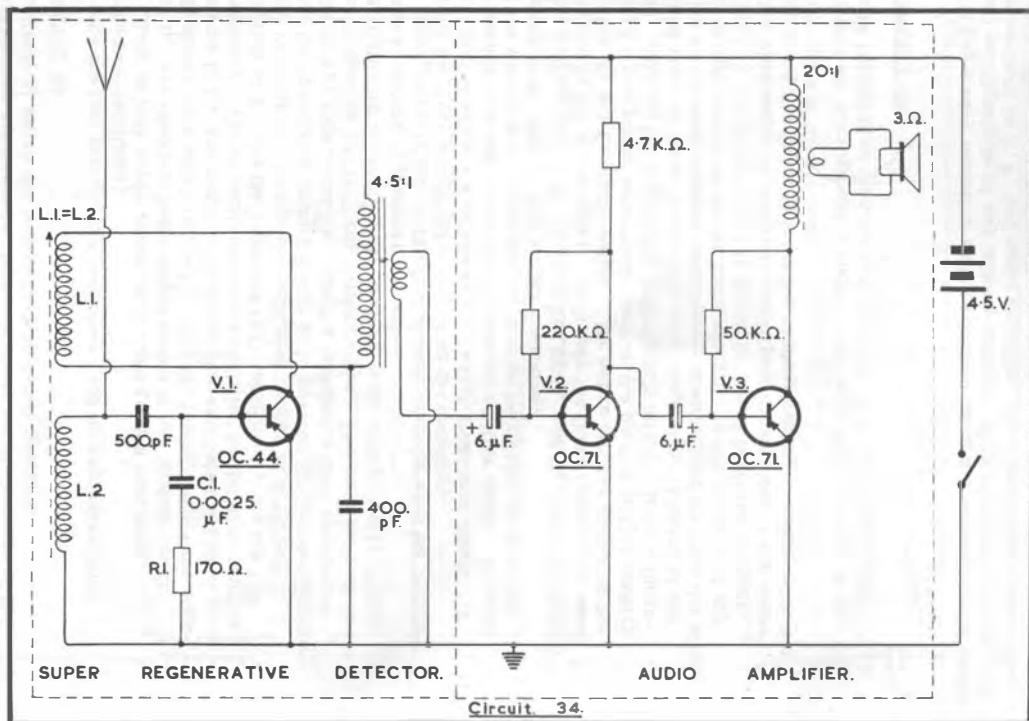
This rather unusual and original receiver is designed to operate on the medium waveband. As has already been mentioned, the design of a satisfactory broadcast band super regen. is by no means simple. The quench frequency has to be kept to a minimum to give the oscillations time to build up and decay in each cycle; furthermore, the quench frequency must not encroach upon the medium waveband.

In this circuit V_1 is the quench oscillator and operates approximately at 10 kc/s, which is just at the limit of most people's hearing range. This oscillator is a capacitatively tapped colpitts and the frequency may be adjusted by varying the values of the two condensers in parallel with the choke. If any adjustment is made it should be slight and both condensers should be adjusted to the same extent.

V_2 is the super regen. detector. This is permanently adjusted so as to be almost on the point of oscillation by varying the coupling between L_3 and L_2 . L_1 , L_2 and L_3 are all wound on a ferrite rod and should have approximately 80, 15 and 20 turns respectively. As the transistor is just on the point of oscillation a slight variation of the base bias will alter the gain of the transistor and bring it either in or out of oscillation. But the base of V_2 is coupled to the quench oscillator, V_1 , and so V_2 super regenerates. There is nothing unusual about the design of this second stage and almost any regenerative detector, shown in Section 2, would serve equally well.

The output from V_2 is transformer-coupled to the audio amplifier. For the sake of simplicity only one stage of audio amplification has been shown, and in most cases this will be insufficient to drive the loudspeaker to a satisfactory volume; however, any audio amplifier may be used, either valve or transistor.

When constructing this set, keep the coils, transformers and choke as far apart as possible to avoid interaction. As there are three different frequencies at any one moment, interaction is liable to cause disastrous instability and distortion, so the receiver is really unsuitable for miniaturisation; however, with suitable screening it could be made small enough to slip in a pocket.



As this receiver oscillates at signal frequencies during operation no aerial should be used. The danger of causing interference with neighbouring receivers is, however, very small, because of the amplitude at which the transistor concerned operates.

CIRCUIT 34

Unlike the last circuit, this receiver uses no separate quench frequency oscillator.

V_1 acts as both super regenerative and quench oscillator. L_1 and L_2 are identical coils wound on top of one another on an adjustable core which is used to vary the tuning. When the connections to L_2 are correct the transistor oscillates at signal frequency. These oscillations are rectified by the base emitter junction of V_1 and the resultant D.C. charges C_1 via the 170 ohm resistance. Eventually sufficient charge is developed to bias the transistor in such a way as to prevent further oscillation. The charge then leaks away via the resistance until oscillation recommences and the cycle begins again. The wave form of this oscillation is approximately sawtooth and, with properly chosen values, occurs at a supersonic rate.

A short aerial of only a few feet of wire must be used but because of the receiver's high gain, this is no disadvantage.

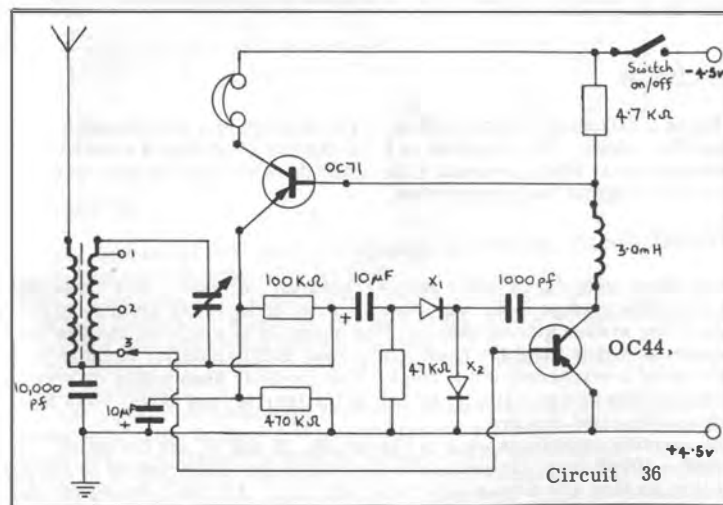
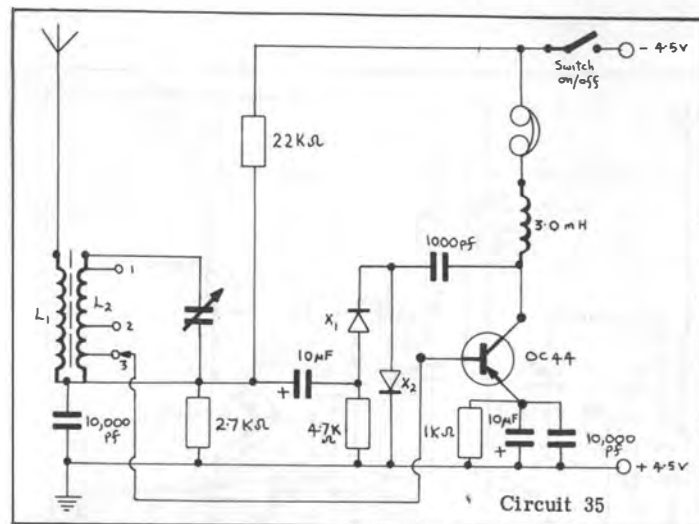
In order to achieve maximum gain, a high frequency cutoff R.F. transistor has been used in the common emitter mode. Because of the variation in transistors it may be necessary to alter the values of R_1 and C_1 for proper operation.

The audio output of V_1 is amplified by V_2 and V_3 and transformer coupled to the loudspeaker. With only the three transistors used in this circuit the audio output of the set is similar to that of the small 5 transistor superhets - now on the market in this country and, although the selectivity is definitely inferior from a theoretical point of view, in practice only one station is heard at any time as the super regen. oscillations always build up from the strongest signal passed on by the tuned circuit. In the absence of any signal, a 'shushing' noise is normally heard from the speaker. This illustrates the fantastic amplifying capabilities of the super regen. as it originates from the random motion of electrons in the first parts of the circuits.

As this set does not use a choke in the quenching circuit, it may be made far smaller than the last one without fear of instability.

CIRCUIT 35

This is a very sensitive reflex receiver using a standard ferrite aerial coil which may be of any make available. This receiver uses the transistor both as R.F. and audio amplifier, thus providing an increased performance to that normally expected on single transistor receivers.



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