NO 3

HANDBOOK OF TESTED TRANSISTOR CIRCUITS

H. NESS

40p

BABANI PRESS

HANDBOOK
of
TESTED
TRANSISTOR
CIRCUITS

●

by

H. NESS

BABANI PRESS
The Publishing division of
Babani Trading and Finance Co. Ltd.
The Grampians
Western Gate, London W.6.

CONTENTS

Introduction 5
Radio Circuits 8
Amplified Crystal Set 8
One Transistor Regenerative Receiver .. 9
One Transistor Reflex Receiver 12
Two Transistor Reflex Receiver 14
Three Transistor Loudspeaker Receiver . 18
Short Wave Receiver 21
Superhet Tuner 23
Amplifier Introduction 26
Two Transistor Amplifier 26
Three Transistor Amplifier 29
Short Wave Amplifier 31
Tone Control 33
Test Introduction 35
Multi Purpose Tester 35
Injector-Tracer 38
Capacitance Bridge 40
Miscellaneous Circuits 43
Morse Practice Oscillator 43
Burglar Alarm 45
Light Operated Switch 48
Metronome 52
B.F.O. 54
Lie Detector 57
One Transistor Electronic Organ 59
G.P. Power Supply 63

INTRODUCTION

The field of electronics is a rapidly moving one and now is an exciting time for those who consider it their hobby. Never have component prices been lower or the range more extensive. New devices and techniques appear daily and the growth is so rapid that, whereas fifteen years ago many engineers were conversant with the whole field, today it is doubtful if more than a handful of people are familiar with more than their own particular interest.

For this reason a comprehensive circuit book, containing all types of circuit, would be impossible. This book contains a variety covering the field fairly widely, but of course there are tens of thousands of other circuits suitable for the home constructor.

All the components mentioned in this book are widely available from component stockists and have been for at least a year at the time of writing. The use of more recent devices involves the risk that they may quickly disappear and their use has been deliberately avoided. The components suggested should be available for a number of years to come.

This book does not set out to educate the reader. It assumes a very basic knowledge, including the ability to read a circuit. Few details are given on the constructional side save where these are important and the method of construction and layout used are largely left up to the reader. Circuit operation is described in some detail and in certain sections the design problems are discussed in order to show how the final circuit was developed, but these pieces of information refer only to the circuit in question.

A wide range of circuits have been included covering a wide field. There are several radio circuits, each of which has it's own particular attractions as far as price, operation and level reached by the reader is concerned. A number of amplifier circuits, including a tone control, are featured; again each circuit has a particular area in which it will be found to be best.

Three test gear circuits are included to assist the reader in fault-finding etc. All are simple but they do the job for which they are intended at small cost and little effort.

At the end of the book there are several miscellaneous circuits which the reader may find of interest. Again simplicity is the main objective but as well as being practical hours of fun can be had from their construction and use.

COMPONENTS

As mentioned, most of the circuits are simple and a deliberate effort has been made to keep down the variety of components specified.

The majority of the transistors specified are silicon N-P-N types and the 2N2926 and BC109 appear quite often. These are similar to each other in many ways and can often be directly substituted for each other in the circuits shown here, though there is a reason for the particular choice in each of the circuits. There are a wide range of transistors which are again similar to both of these types - the BC184, BC168, BC169, 2N706 to name just a few - and these can often be employed.

The 2N4292 is an inexpensive r.f. type and will be found in some circuits - here again most silicon N-P-N r.f. types can be used with no circuit modifications except perhaps a small change in the value of the bias resistor.

Some circuits need a P-N-P type and in the silicon range the 2N4289 has been suggested, largely because of price, but other type will usually do.

The AC128 is mentioned in some circuits. This is a germanium P-N-P type capable of handling greater current than other types mentioned. It is very similar to the OC81, a transistor that many readers will be familiar with.

The complementary pair transistors in the amplifier section are discussed in the text and any changes in these should be made only after reading the relevant section.

That clever little device, the unijunction transistor, is used in one circuit and here again alternatives are possible, and are mentioned in the text.

Many transistors are sold by "gain grouping" and various letters or colours are placed at the end of the type number such as 2N2926G (for green). This will not normally matter but generally the higher the gain, the better the device in the circuits used here. The G for this particular transistor is the highest gain type but for others different codings are used and in these the 'C'.is usually the highest.

Certain of the circuits make use of a transistor output transformer. Type numbers vary greatly and to mention any particular one may lead to confusion. These are all used single ended (although the centre tap is used in a couple of cases) and such devices are not common, however, push-pull types are available and by using either half the primary or the whole primary these work very well.

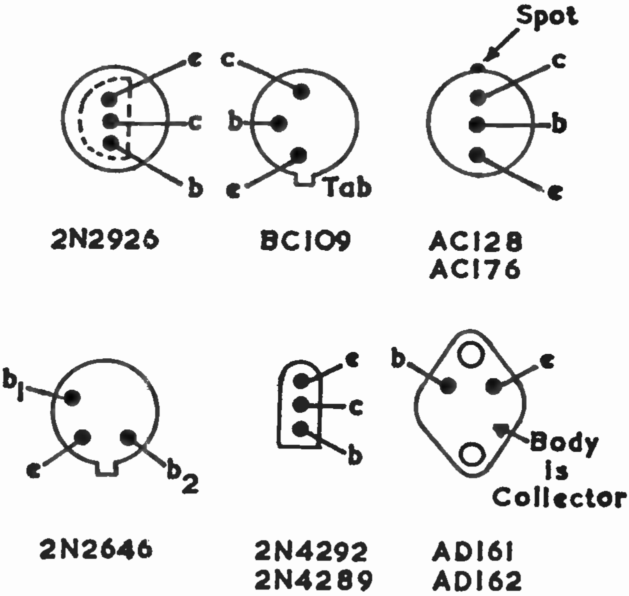
The turns ratio is not particularly critical - like many things it is amazing what you can get away with - and anything between 4 : 1 and 20 : 1 will be alright, though 8 : 1 is about the best if it can be obtained.

Many constructors become confused over voltage ratings of electrolytic capacitors and looking at the huge range available, this is not surprising. The rules are, however quite simple. The voltage rating of the capacitor must be at least as high as the voltage applied across it, but there is no upper limit. A 100V component will work fine at 3V but it will be large and expensive compared to a 3V type, so there is little point in using it.

Non-electrolytic capacitors are used in most of the circuits and the type is not too important. In any of the circuits described here paper, polyester, ceramic or silvered mica (for low values) will do.

On-off switches are shown in several places and these can, of course, be combined with one of the potentiometers in the circuit.

The base connections of the transistors specified are shown in Fig. 1.



2N2926 BC109 AC128 AC176

2N2646 2N4292 2N4289 AD161 AD162

Fig 1

RADIO CIRCUITS

Simple transistor radio circuits are always in demand. There is a good reason for this - excellent results can be achieved with a few components and the finished product has a very real use.

The normal domestic radio uses one basic circuit, the superhet, and six, seven or possibly more transistors are employed. There is little doubt that the superhet is the best type of circuit - it would not be so universal if it were not - but excellent results can be achieved using far fewer components and using techniques not applicable to mass production. Output and selectivity are sacrificed but there is a considerable saving in cost.

Several circuits are included here to give not only a choice but because each circuit has factors which make it especially suitable for one particular type of operation or construction.

The circuit for a sub-miniature radio may serve that purpose very well, but it would not be nearly so good if built into a table top cabinet. Very low current drain may be important or it may be of little consequence and this again determines the best circuit to use in a particular application.

Amplified Crystal Set

The basic radio, as anyone who has read a beginner's book will know, is the crystal set. This is made up from very few components indeed, these comprising an aerial, usually 20 ft. or longer which is connected to a basic parallel tuned circuit made from a coil of wire and a variable capacitor which in turn connects to a detector diode. This enables the audio component of the radio signal to be extracted from the modulated radio signal.

The circuit for this is shown in Fig. 2 and comprises those components to the left of the points marked X - X.

Headphones can be connected at this point of the circuit and powerful local radio stations can be heard. The sound level is however low and selectivity poor and although the crystal set is pretty wonderful, mainly because of it's simplicity, it can be regarded as little more than a novelty. The addition of a few components which should cost no more than 40p will however greatly improve the sound level, though it will do little to improve the selectivity. The additional circuitry is that to the right of the points X - X. No great claims are made for this improved circuit - it still has a lot of disadvantages compared to the circuits shown later in the book, but at least it is simple.

The aerial, L1 (the coil), VC1 (the variable capacitor) and D1 (the detector diode) are the basic parts of the crystal set. A capacitor with a value of around 0.01μF is often connected across the points X - X to smooth the r.f. from the demodulated signal but although this is needed in theory, in practice the selt capacity of the headphones is sufficient in all but a few cases.

C1 is included to d.c. block the base of the transistor; if it were left out, the base of the transistor would be shorted to earth via the diode and the coil. The value of C1 is uncritical and successful operation can be expected with values ranging from 1000pF to 10μF. The radio signals which are selected by the tuned circuit are fed via the detector and the blocking capacitor to the base of Tr1 which is connected as a common-emitter amplifier.

The headphones are connected into the collector circuit and all that is necessary to make this arrangement to work is to apply a bias voltage to the base: this is done by R1, a 1MΩ resistor.

Although the recommended transistor works well, almost any type will do for this function. The 2N2926 has however a very high amplification factor and is cheap; that is the main reason for using it.

The amplification introduced by the transistor should be high and it will be a considerable improvement over the basic crystal set. For further improvement an earth wire can be connected - this is shown as a dotted line but it is not usually necessary.

As mentioned before, this circuit is only an improved crystal set and it still is not very practical; it is included only for those who have tried their hands and want to improve their set as quickly, simply and cheaply as possible. The coil of wire, if one has not already got this, should be 80 turns on a cardboard former - about 1½ inch in diameter - the cardboard tubes inside toilet rolls are very suitable; the type of wire itself is not critical but the turns must be insulated from each other.

Components list

R1	1MΩ
C1	0.01μF
VC1	350pF variable
Tr1	2N2926
D1	OA91
L1	80 turns on 1½" diameter former
SW1	On-off switch
B1	PP3 9V battery

High impedance magnetic earpiece or headphones

One Transistor Regenerative Receiver

Apart from the lack of sensitivity and selectivity of the amplified crystal set circuit described in Circuit 1, there is the nuisance of the aerial and earth connections. However, with only a few modifications it is possible to rearrange this circuit to result in a vastly improved and thoroughly practical circuit, one that is also highly suitable for minaturisation.

For this modification the earpiece or headphones of Circuit 1 must be replaced with a crystal type and the aerial coil, which was wound on a cardboard former, by a ferrite rod with not only the aerial winding but also a second one. One resistor extra is also needed.

A crystal earpiece is used here and in other circuits in this book. They are cheap - usually 25p or about a third the cost of headphones; they are also sensitive and are high impedance devices - that is, as far as circuit conditions are concerned they look like a very high value resistor (2MΩ or more) and this has many advantages in some circuits, including this one.

Unfortunately, they vary enormously in sensitivity - most of them are excellent while others are poor. If possible try to get a good one for although the poorer ones will work, they may not give an output loud enough for comfortable listening.

The coil, as we have already mentioned, must be different for this circuit. To avoid the necessity for too many turns and to improve signal pickup, a ferrite rod is used. Plain ferrite rods are available from nearly all components suppliers and they are not expensive. Enamelled copper wire, which should be used for the coil itself, is available from the same source and is sold in reels, in various gauges. The actual gauge used is not very important but 32 s.w.g. is pretty common and is about the right size. Only a tiny part of the reel will be needed for the coil used in this circuit but in other circuits where coils are needed we shall be specifying the same gauge wire.

Like the wire, the ferrite rod diameter is not critical. 3/8 inch is a good general size and this is usually sold in 6 in. lengths. The length of the ferrite rod does affect the characteristics of the coil, but not to any great extent. For a table model radio or for a quick lash-up there is no disadvantage in using the whole length but a 6 in. rod for a miniature radio is obviously out of the question. Any length can be cust from the basic rod by filing a V shaped groove in it and breaking it. Sawing, even with a hacksaw is almost impossible.

As mentioned, the length is not over critical and one about 3 inches should be about right.

To wind the coil, a narrow band of plastic adhesive tape should be wound around one end and a few inches of wire trapped in this (the tape only serves as an anchoring point).

Eighty turns of wire should then be made, then a further band of adhesive tape wound at the point you reach and the wire trapped in this. A second winding consisting of a further eight turns is made next to this, again trapping the ends in tape.

Ferrite rods are also available in "slab" form and these are just as good. The majority of ready made medium wave coils are wound on slabs and ready made ones can be used instead of the one shown.

The use of the secondary winding is important. The radio currents induced in the tuned circuit are of a very high impedance and for good results should be connected to a high impedance.

If a low impedance is connected directly to the tuned circuit this damps the tuned circuit and makes it flat and inefficient - stations tend to blend into one another - this is what happens in a crystal set - the headphones representing the low impedance.

Transistors are basically low impedance devices and it is not possible with a simple circuit of the type shown here to make the impedance high, but there is an alternative.

The high impedance of the tuned circuit can be transformed to a low impedance by using a second, smaller winding. The typical input impedance of a transistor in the common emitter mode which we are using here is about 20kΩ - enough to seriously damp the tuned circuit but when this is transformed by the square of the turns ratio (100) this looks like 10kΩ x 100 or 1MΩ across the circuit.

The primary is connected exactly as in the crystal set with the variable capacitor across it and one end going to the common negative line.

One wire of the secondary must go to the common line but since this would d.c. couple the base of the transistor to earth, a blocking capacitor is included, this being C1, a 0.01μF. The collector load is a 2.2kΩ resistor and the base bias is provided by R1, a 1MΩ resistor from the positive line to the base via the secondary winding. The detector diode D1 is connected directly to the collector and this feeds the crystal earpiece.

In the amplified crystal set we described previously we detected the signal before amplification by the transistor; here we amplify it first and this allows us to improve the operation enormously using a simple but very effective technique - regeneration.

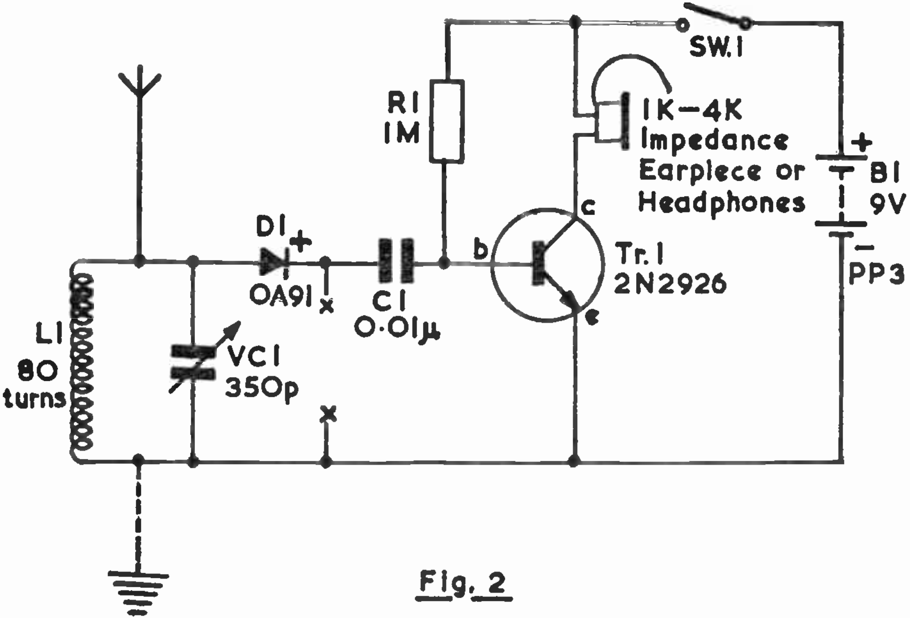

SW.1
R1
1M
1K—4K
Impedance
Earpiece or
Headphones
+
B1
9V
–
PP3
D1
+
c
b
Tr. 1
2N2926
e
OA91
x
C1
0·01μ
L1
80
turns
VC1
350p
x

Fig. 2

We have already established that the r.f. (radio frequency) signal is amplified before detection. If we take a tiny part of this signal and feed it back to the tuned circuit this will be amplified again. If too much of this feedback is employed the radio will oscillate and will be no use, but if the correct amount is fed back, it has the effect of improving performance. It gives considerable improvement to both selectivity and sensitivity.

Since the proportion of regeneration is critical, a variable component is needed and it's value will depend on many factors including even the layout used. The cheapest and simplest way of incorporating this is to use two lengths of insulated wire - each about 3 in. long and twist these together. This forms a low value capacitor and is shown in Fig 3a as VC2 - for it is a variable capacitor. To reduce the feedback the wires are untwisted a bit, for more they are twisted more.

Just one point has to be watched with this. It is important that the feedback is positive. If the secondary winding is one way around the feedback will be negative and this has the opposite effect of regeneration - the performance will be reduced. If the effect of increasing VC2 is not noticeable, or worsens performance, reverse the connections of the secondary.

The circuit shown here will work even without regeneration but performance will, of course, then be poorer. The component values are not too critical and there should be no difficulty in getting the circuit to work well. The current drain is low - in the order of 1 or 2mA and this is about the tenth of the average transistor radio, so the battery should last a fair while. Reception of the BBC stations can be expected, at least those on the medium waves, and after dark a number of foreign stations may also be heard.

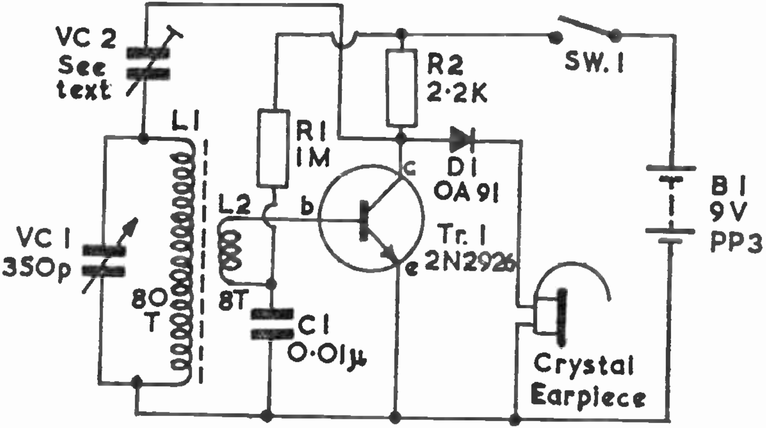
Components List

R1	1MΩ
R2	2.2kΩ
C1	0.01μF
VC1	350pF variable
VC2	See text
Tr1	2N2926
D1	OA91
L1, L2	See text
SW1	On-off switch
B1	PP3, 9V battery
Crystal earpiece	

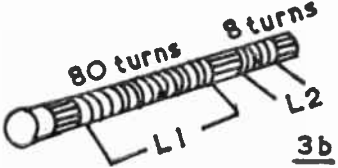
One Transistor Reflex Regenerative Receiver

With only a few modifications it is possible to improve the previous circuit even further; the selectivity will be no better, but that hardly needs improving, but the volume will be greater.

In our amplified crystal set the transistor was amplifying the audio detected by the diode, in the previous circuit it was the radio frequencies that were detected. It is quite possible to arrange for the transistor to do both jobs, that is amplify the r.f., detect it and then make it amplify the resulting audio frequencies. This technique is known as reflexing and was popular in the early days of both transistors and valves as these components were very expensive by today's standards. The problems of reflexing are in sorting out the signals at various stages in the circuit so that they go to the right places.


VC 2
See
text
L1
R1
1M
R2
2·2K
SW. 1
D1
OA 91
c
b
e
L2
VC 1
350p
80
T
8T
C1
0·01µ
Tr. 1
2N2926
B1
9V
PP3
Crystal
Earpiece

3a


80 turns
8 turns
L1
L2

3b

At first glance the circuit appears very similar to the last one, and as far as the tuned circuit and the coupling are concerned it is. The r.f. is amplified as before and a small part of it is fed back to provide a measure of regeneration as before. However the collector load here has been replaced by a magnetic earpiece of 2000Ω impedance - lower impedance ones will not generally work here.

The r.f. appearing at the collector of Tr1 finds it's way blocked by the inductance of the earpiece but finds an easy path through C2 and finds it's way to the detector diode D1 which returns the signal to C1 which smooths out the r.f.

The aerial coil here is shown slightly differently here as the secondary is wired on to the end of the main winding, this can be done by simply connecting together the windings shown in Fig. 4b.

The audio signal passes through the secondary winding to the base of Tr1 and is amplified. At the collector it can pass through the earpiece because it is at a far lower frequency than the r.f. signals. It will not easily pass through C2 which at low frequencies appears as a rather high resistance (this was not the case at r.f.) and although a little will pass, it is too little to worry about.

This time the base bias for Tr1 is passed through the diode, this will not matter and in fact helps the diode to operate at a better part of its operating characteristic. Current drain is similar to the previous circuit - that is between 1 and 2mA.

Reflex circuits can lead to a number of problems - generally speaking a transistor designed for best use at r.f. will not give it's best at a.f. and troubles with instability can result but the one shown here works very well indeed. Once again the circuit values are fairly uncritical and the same circuit can even work using a 1.5V battery, the only modification being to lower the value of R1 to 56kΩ and increasing the value of VC2 by using more twists in the wire.

As the circuit can operate using one of the very small pen-cell batteries it is highly suitable for miniaturisation.

Components List

R1	1MΩ
C1	0.05µF
C2	1000pF
VC1	350pF variable
VC2	See Text
Tr1	2N2926
D1	OA91
L1	See Text
SW1	On-off switch
B1	PP3, 9V battery
High impedance magnetic earpiece	

CIRCUIT 4 - Two Transistor Reflex Receiver

Although using two transistors, the circuit shown in Fig. 4 uses very few components indeed. Unlike the other simple receivers os far described which will work without an aerial, no regeneration is applied, yet results are still excellent.

The operation is some what more complicated than the small number of components would suggest and there is one very considerable advantage of the circuit: only one resistor is used and it's value controls the entire operation of the circuit. Nearly every circuit can be improved by selecting

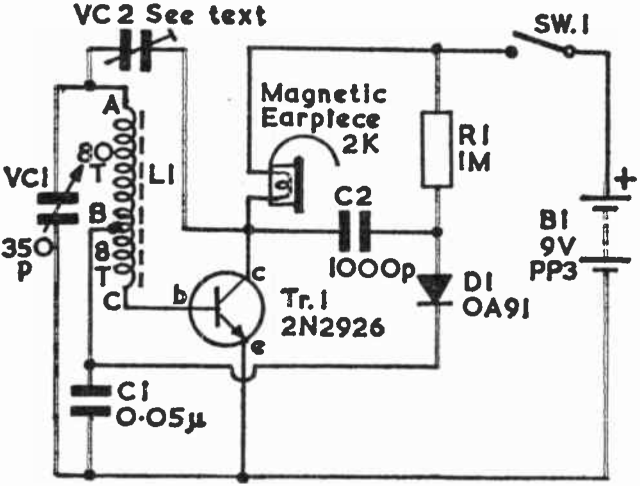

VC2 See text
SW.1
Magnetic Earpiece 2K
R1 1M
A
80 T
L1
VC1
B
350 p
8 T
C
C2
1000p
+
B1 9V PP3
b
c
Tr.1 2N2926
e
D1 OA91
C1 0·05μ

Fig. 4a

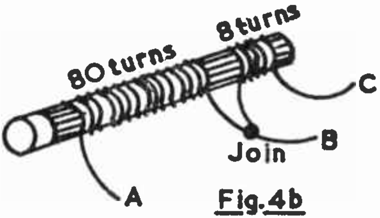

8 turns
80 turns
C
Join
B
A

Fig. 4b

exactly the right component value for the particular transistor used but this is usually impractical as one component usually has an effect on others and to find the absolute optimum value when there is more than one variable is usually not possible. The only resistor used is a 3.3kΩ and it's value may have to be changed slightly to get the best performance out of the circuit, but once found it will allow both transistors to be operated at maximum.

The first part of the circuit works in a fairly conventional way: the tuned circuit is made up from VC1 and L1 which comprises 88 turns of 32s.w.g. enamelled copper wire on a 3" length of 3/8" diameter ferrite rod, this coil being tapped at 8 turns.

The coil is connected directly to the base of Tr1 which is shown here as a 2N-2926, but many of the other transistors discussed in the introduction will function just as well.

The collector load is made up from R1, the only resistor, and part of Tr2 which is directly coupled to Tr1. Note that the collector of Tr2 goes directly to the positive supply line and the load (which is the magnetic earpiece) is in the emitter circuit. This circuit configuration is known as a "common-collector" or"emitter-follower" and although a stage so connected has no voltage amplification, it does have considerable current amplification. The input impedance to this stage is very high, being roughly equal to the value of the emitter resistor (here represented as 2000Ω) times the gain of the transistor - say 300, so this figure of 600kΩ means that very little loading is applied to the output of Tr1 which in turn has the effect of lessening the loading on the tuned circuit. We mentioned in an earlier circuit description how important it was that only a small load is applied to a parallel tuned circuit and the one shown here is an improvement on the earlier circuits in this respect. For this reason selectivity is good, even though regeneration is not applied.

The emitter load of Tr2 is the earpiece but on the first time around the signal is at r.f. and the high inductance of the magnetic earpiece acts as an r.f. choke preventing the high frequency signals passing through it.

The signals can, however, pass through the detector diode D1 and these are smoothed by C1. The signal is now at a.f. and they pass through the 8 turns on the coil with no difficulty to the base of Tr1 and are amplified in the same way as the r.f. signals were. When these audio frequency signals appear at the emitter of Tr1 they can pass through the magnetic earpiece and are heard.

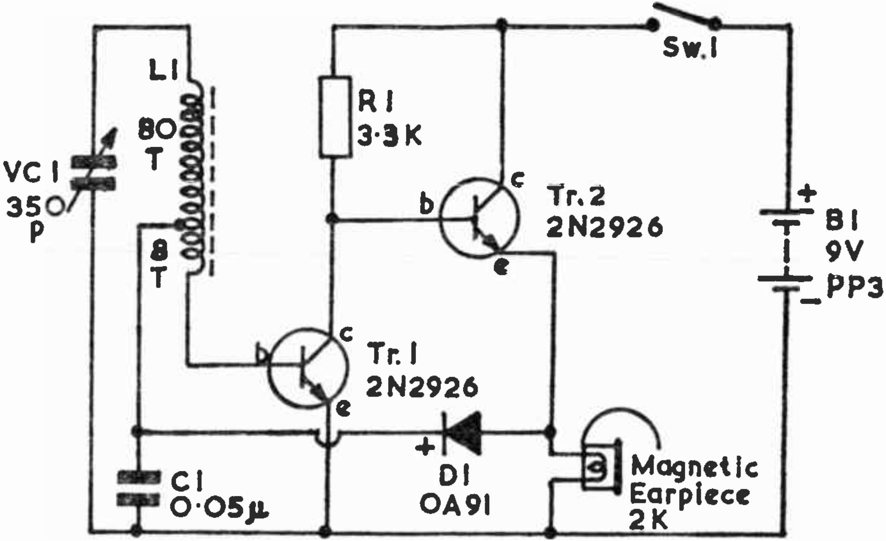
Note that only high impedance magnetic earpieces are suitable for this circuit. 2000Ω is the best, but ones as low as 250Ω are useable - nothing at all happens with low impedance types.

Where does the base bais to Tr1 come from many of you will ask? There is no resistor connecting even indirectly to the base. The emitter of Tr2 is at fairly high voltage and the bias is made through the detector diode - this of course has the added advantage of biasing the diode to its most efficient operating point.

Thus it will be seen that the value of the one resistor in the circuit controls everything about the circuit and the value shown of 3.3kΩ will be about right for most transistors but may have to be slightly changed for others.

Current drain is about the only aspect of the circuit which is not highly efficient - it runs at between 7-10mA but as this is less than normal radios operate at, normal types of batteries can be used.

The clever thing about this particular circuit is that it makes absolute maximum use of every component, many of them serving two purposes. The signal is amplified twice at r.f., detected and amplified twice again at a.f.



Sw.1
L1
80 T
8 T
VC1
350 p
R1
3·3K
b
c
e
Tr.2
2N2926
+
B1
9V
PP3
−
b
c
e
Tr.1
2N2926
+
D1
OA91
C1
0·05µ
Magnetic
Earpiece
2K

Fig. 5

Regeneration can be applied to this circuit if necessary by using the twisted wire technique described for other circuits from the collector of Tr1 to the junction of VC1 and L1 but it will not usually be necessary as the gain and selectivity of the circuit are more than sufficient for local stations.

Components List

R1	3.3kΩ - see text
C1	0.05µF
VC1	350pF variable
Tr1	2N2926
Tr2	2N2926
D1	OA91
L1	See text
SW1	On-off switch
B1	PP3, 9V battery
High impedance magnetic earpiece	

CIRCUIT 5 - THREE TRANSISTOR RADIO

The various radio circuits that have already been described all have their uses and are especially suitable for miniaturisation and portable construction but, of course, most of the time you want the radio to operate a loudspeaker - and with reasonable volume at that.

The circuit shown in Fig. 6 is that of a fairly simple three transistor radio which will operate a loudspeaker - the output level being about 300mW - or comparable to many commercial radios. The circuit given, although comples compared to those previously described, is still simple compared to a superhet circuit and although the performance does not quite equal that of a commercial radio, it very nearly achieves it. Local stations should come booming in while after dark a mass of the more powerful continental stations should be heard including Radio Luxembourg. It is especially suitable as a bedside radio and can be built into a simple hardboard cabinet. The current drain is quite high compared to the previous circuits and for this reason miniature batteries are not suitable. Of all simple loudspeaker radio circuits, this is one of the best.

The operation is slightly different from the previous radio circuits. A full length (that is 6 in.) ferrite rod should be used - wound as before with 88 turns of 32s.w.g. enamelled copper wire, tapped at eight turns.

VC1 and L1, in combination with the capacitor C1 form the tuned circuit and as before the signal is transformed and fed to the base of Tr1. The collector load of Tr1 is a 5kΩ logarithmic potentiometer - the usual value for transistor volume controls. These can be bought with a switch which can be wired as SW1 - the on/off switch.

The slider of the volume control connects to R1,390kΩ which feeds back through the coil, providing the base bias for the first transistor. At any setting of this volume control - except when it is at minimum, a degree of positive feedback is applied to the tuned circuit.

Capacitive regeneration, which we have used before, has the disadvantage that it can only be set for maximum performance at one frequency. It does have some effect at other frequencies, but it will not be doing its best.

The circuit here uses resistive feedback and the amount of regeneration applied is not dependant on the frequency, so R1 serves two purposes, applying feedback and base bias.

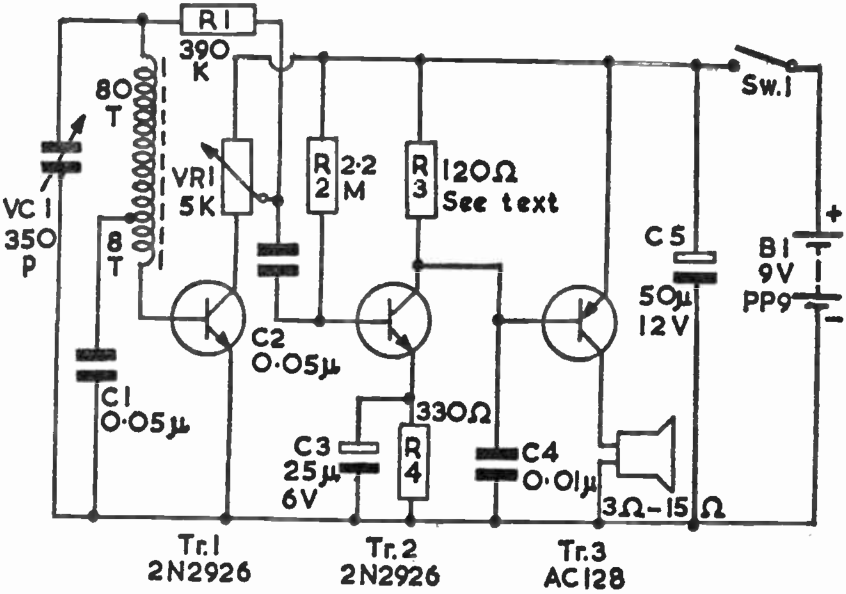

R1
390
K
80
T
VC1
350
P
8
T
VR1
5K
C2
0·05µ
R
2
2·2
M
R
3
120Ω
See text
330Ω
R
4
C3
25µ
6V
C1
0·05µ
C4
0·01µ
C5
50µ
12V
Sw.1
+
B1
9V
PP9
-
3Ω-15Ω
Tr.1
2N2926
Tr.2
2N2926
Tr.3
AC128

Fig. 6

The second connection to the slider of the volume control connects via d.c. blocking capacitor C2 to the base of Tr2, again a 2N2926 transistor. This bias resistor R2 is carefully chosen so that amplification is not linear. This means that the signal is both detected and amplified at the same time and does away with the need for a detector diode.

Previously we have not bothered to d.c. stabilise the transistors in the circuits. Silicon transistors can often do without it at low collector currents but here stabilising components R4 bypassed by C3 are necessary because of the configuration of the next stage and the fairly critical operating conditions it needs.

Stabilisation is simply a means of self limiting the current through a transistor. If the current through Tr2 rises, so will the current through R4. But the higher the current, the greater the voltage drop across it and, therefore, the lower the voltage between emitter and collector which reduces the current.

Germanium transistors, which ruled the electronics field from their introduction to about 1969, required very careful stabilisation in even low current stages but silicon transistors are less critical.

The collector load of Tr3 may at first seem low but it needs to be around this value to limit the current of Tr3 which is an inverted germanium p-n-p transistor.

In the previous radio circuits the earpieces have usually provided the smoothing capacitor after the detector but here it is necessary to include one - this being C4 - a 0.01µF capacitor.

Tr3 is directly coupled Tr2 and the loudspeaker is connected as the collector load

This amplifier arrangement works extremely well but has one disadvantage in that the value of R3 is critical. If it is removed the sound output quality is excellent but the current drain is enormous - about 500mA. If it is too low there is excessive distortion. Its value should be selected with care. There are two ways of doing this.

If you own a multimeter, connect it in the supply line and adjust R3 until the current consumption reads 20mA. Those without a meter should select R3 by choosing the minimum value at which distortion disappears. The value of R3 given, 120Ω has worked well in most versions of the circuit which have been built but it should always be selected individually and may range from 47Ω to 180Ω.

Tr3, the AC128, really requires a heat sink and one of the fin types should be fitted around this to lessen the liklihood of thermal runaway. As the quiescent current drain is 20mA, batteries of the PP9 type should be used.

The volume control at minimum settings works fairly conventionally but after a certain point the increased regeneration through R1 causes a peaking in the signal, thus increasing the volume further and at high settings of VR1 the circuit may be found to oscillate.

All in all this circuit will be found very useful in a variety of radios and it is difficult to improve on it without going over to superhet principle.

Components List

R1	390k	C5	50µF 12V
R2	2.2MΩ	VC1	350pF variable
R3	120Ω - see text	Tr1	2N2926
R4	330Ω	Tr2	2N2926
VR1	5KΩ log. pot. with switch.	Tr3	AC128
C1	0.05µF	L1	See Text, medium wave aerial coil
C2	0.05µF	B1	PP9, 9V battery
C3	25µF 6V	LS	3-15Ω loudspeaker
C4	0.01µF		

CIRCUIT 6 - Short Wave Receiver

One of the first projects that the newcomer to electronics wants to tackle is a simple short wave receiver and not surprisingly! Really excellent results can be achieved and you will rarely lose the wonder of how a mere handful of components can pick up signals from all over the world.

All simple short wave receivers have to be regenerative, there is no other way of obtaining the very high gains necessary but in this type of circuit (unlike the regenerative medium wave receivers described earlier) the regeneration cannot be set once and forgotten about - it is a control as important as the tuning capacitor and has to be set very carefully for each station to get the best results.

It will be necessary to wind your own coil for this but it is a simple matter. A ferrite rod is not used, instead a cardboard tube about ¾" in diameter is needed but wooden dowelling of the same diameter works as well.

Three windings are needed, first ten turns, next to this 25 turns and finally, another ten turns using 32s.w.g. wire. The spacing between the three coils is not critical - about ¼" is about right. Small holes can be punched in the tube and the wires pushed through to the middle and out of one end. When the winding is complete the coils should be completely covered in tape to hold them firmly in position.

A long wire aerial is needed to get any sort of results, it should be at least 20 ft. and if possible longer: the end not connected to the receiver being as high as possible.

The aerial connects to the tuned circuit via VC3, the function of which will be described later. The tuned circuit is made up from the coil of 25 turns and VC1; a 350pF capacitor although values ranging between 150pF and 500pF will be just as good.

One of the ten turn coils is connected to C1 and to the base of Tr1, much in the same way as the one Transistor Regenerative Receiver Circuit earlier.

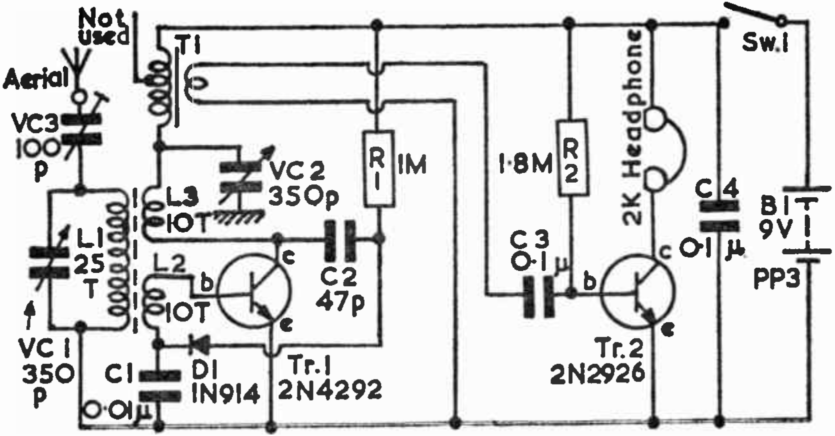
Tr1 is arranged as a common emitter amplifier and the amplified signals appear at the collector. The second ten turn coil is connected to the collector, the other end going to earth via a second 350pF capacitor. Note that a ganged capacitor (that is one with two separate capacitors on it) is not suitable as each section here has to be controlled separately.

This coil, L3, is the regeneration coil and couples some of the r.f. back to the turned circuit, the amount coupled depending on the setting of VC2. Note that the connections to this coil have to be the right way around for it to work; if it does not have any effect, reverse the connections.

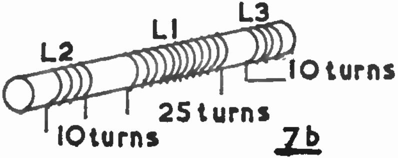
The remaining r.f. signal, that is the part not fed back, couples through C2, is detected by the diode D1, smoothed by C1 and is again amplified, this time at a.f. The detector used here is a silicon type 1N914 and has been found to be better than the OA91 types used before in this particular circuit. The bias for this diode, and the bias for Tr1, is applied by R1.

The a.f. signal appearing at the collector of Tr1 will hardly pass through C2 or VC2 but passes through L3 to the transformer T1. At r.f. the primary of T1 acted as an r.f. choke thus limiting the path of the r.f. to going through C2 but it has little effect at a.f.

T1 is a transistor output transformer. Many types of these are available but most have a centre tap connection on the primary: this is ignored for our purposes. The secondary of the transformer (which usually leads to the loudspeaker) is one side connected to earth and on the other to C3 which acts as a d.c. blocking capacitor to the base of Tr2 which is arranged as a simple a.f. amplifier, the headphones being on the collector and the base bias being provided by R2.


Not used
Aerial
VC3
100
p
T1
VC 2
350p
R
1
1M
1·8M
R
2
2K Headphone
Sw.1
L1
25
T
L3
10T
L2
10T
b
c
e
C2
47p
C4
0·1 µ
B1
9V
PP3
C 3
0·1 µ
b
c
e
VC 1
350
p
C1
0·01µ
D1
1N914
Tr.1
2N4292
Tr.2
2N2926

7a


L2
L1
L3
10 turns
25 turns
10turns

7b

C4 is a 0.1μF capacitor, this being necessary to decouple any r.f. on the supply line.

VC3 is an aerial loading capacitor and may not be necessary but if the aerial is not the right length it can often be brought to resonance by inserting a variable capacitor in it. Construction of this circuit is slightly more critical than for the others described so far but the only points to watch are to keep T1 away from the coil. Don't crowd the components together and keep the layout neat.

The coil is quickly wound and others can be constructed to cover other sections of the shortwaves. That given covers approximately 5 - 15MHz. To cover higher frequencies use fewer turns on L1, for lower frequencies more turns are needed.

Various types of transistors can be used but the 2N4292 has been found to be particulary good and it is cheap.

Once completed VC2 should be set so that the circuit is just not oscillating (this point is easily found). VC1 should then be turned until a station is heard and VC2 then reset for maximum signal. S.W. broadcasting stations can only be heard in certain sections of the band and certain bands will only be active at certain times of the day so if only poor results are achieved at first, don't worry, there may not be any thing wrong with the construction.

The results will obviously not be as good as for a complex communications receiver but over forty countries were logged in the first week on the prototype!

Components List

R1	1MΩ	Tr1	2N4292
R2	1.8MΩ	Tr2	2N2926
C1	0.01μF	D1	1N914
C2	47pF	L1	See text
C3	0.1μF	T1	Transistor output transformer.
C4	0.1μF	SW1	On-off switch
VC1	350pF variable	B1	PP3, 9V battery
VC2	350pF variable	High impedance headphones	
VC3	100pF variable - see text		

CIRCUIT 7 - Two Transistor Superhet Tuner

Newcomers to constructional radio are usually baffled by the superhet. "Why", they ask, "does one have to use this very complex principle when excellent results can be obtained with far fewer components?" This is very understandable and the author took several years to be converted.

The operation of the superhet is complex but for manufacturers to use a complex technique there has to be a good reason - and there are several.

The aerial operates in exactly the same way as for the previous circuits shown and the signal is coupled to the base of Tr1 in a similar way which amplified the signal in the common emitter mode. However, the transistor is also connected as an oscillator in the common base mode, the frequency of oscillation being determined by VC1b and a section of the oscillator coil.

The oscillator frequency is set by VC1b which is ganged to VC1a, which of course selects the r.f. signal, and is arranged so that it is always at plus 465kHz to the incoming signal. The two frequencies mix and convert the incoming r.f., whatever it's own frequency, to 465kHz. This is known as the intermediate frequency or i.f.

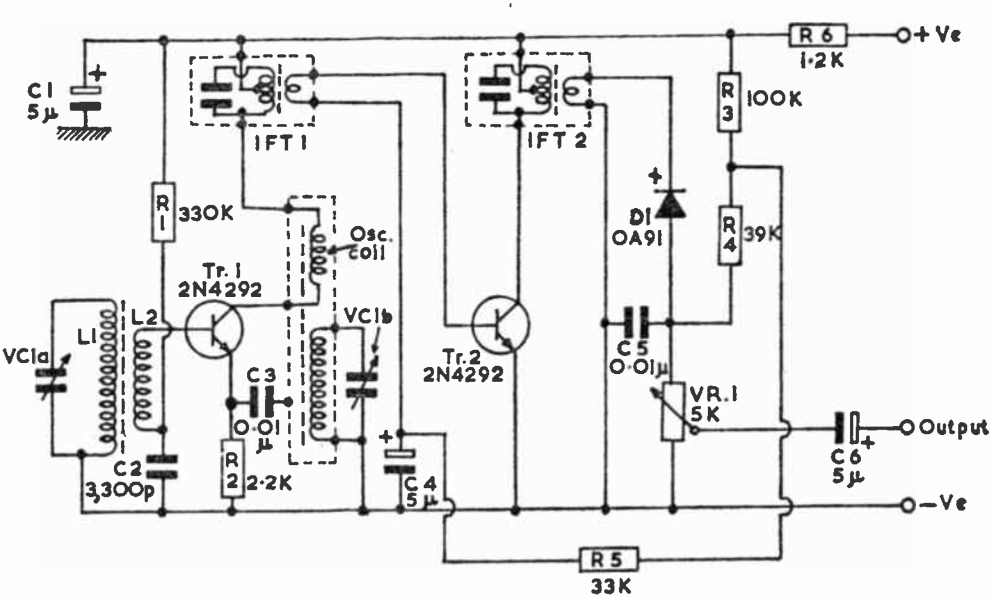

C1
5µ
+
R1
330K
IFT 1
IFT 2
Osc. coil
Tr. 1
2N4292
L2
L1
VC1a
VC1b
C3
0·01
µ
R2
2·2K
C2
3,300p
C4
5µ
+
Tr. 2
2N4292
R6
1·2K
+ Ve
R3
100K
D1
OA91
+
R4
39K
C5
0·01µ
VR.1
5K
Output
C6
5µ
+
– Ve
R5
33K

Fig. 8

The first coil above the collector of Tr1 is part of the oscillator circuit but there is also another which is a tuned circuit set at the i.f. - which is of course always 465kHz. This is transformed to low impedance by the secondary of I.F.T.1 and coupled to the base of Tr2 which amplifies and couples to IFT2 which again is set at 465kHz. The secondary winding connects to the detector D1 which feeds to the volume control and is smoothed by C5.

Automatic gain control is necessary in a superhet. This has the effect of reducing the gain on strong signals and prevents overload distortion which occurs without it - it also has the effect of producing similar outputs at the volume control whatever the input signal.

The a.g.c. is applied in the bias of Tr2 which comes from the potential divider made up of R3, R4 and VR1. The bias resistor is R5 and the raising and lowering of the bias is smoothed by C4 which produces a gradual rise and fall in the voltage bias at the base of Tr2. For those familiar with valved circuits it should be noticed that the application of a.g.c. varies considerably for transistor circuits. Here, when a strong signal is being received, Tr2 is biased towards cut-off and there is considerable distortion given to the i.f. waveform but IFT2 reforms this to a decent shape again and no distortion occurs to the a.f. component.

The circuit shown here makes use of silicon transistors and these do away with a very large number of components that were necessary with germanium types such as the OC44/OC45/AF117 types.

The far higher gains of modern transistors also mean that only one i.f. amplifier (Tr2) is needed where two stages used to be used.

A number of component kits comprising VC1, the aerial coil wound on a ferrite slab, the oscillator coil and three i.f. transformers are available and one of these is strongly recommended. The i.f. transformer not used is No. 2 and this can be used for the B.F.O. circuit given later.

The circuit as shown is simply a tuner and to get loudspeaker volume one of the amplifier circuits described elsewhere should be used. R6 drops the voltage and C1 decouples and i.f. or a.f. from the line - this allows the tuner to be coupled to any 9V amplifier.

Once the tuner has been built it is necessary to line it up - if this is not done results will be very poor indeed.

Ideally an r.f. signal generator should be used but few constructors own one or even have access to one; excellent results can be obtained simply by using broadcasts. Do the lining in the evening when continental stations are heard at a reasonable level.

First tune in the weakest station you can hear and adjust the ferrite core of IFT2 for maximum reception. Then try adjusting IFT1 in the same way but reception will probably not improve.

Then set VC1 to minimum - that is at the high frequency and where the vanes are most separated. Adjust the oscillator trimmer which is built into VC1 - this is usually identified by a small 'o' - until radio Luxembourg is heard - then back it off slightly. Next set VC1 to maximum and adjust the core of the oscillator coil until one of the low frequency stations is heard - back it off slightly.

Repeat these last two operations again, for each adjustment affects the other.

Next tune in Radio Luxembourg and adjust the aerial trimmer on VC1a - this being identified by a small 'a' for maximum reception. Tune to the other end - to your low frequency station and slide the aerial coil along the ferrite rod for maximum reception. Repeat these last two operations.

At this stage literally dozens of stations should be heard - the tuner is nearly aligned. Repeat the whole operation again and the results will probably improve yet further.

Components List

R1	330kΩ	C2	3,300pF
R2	2.2kΩ	C3	0.01μF
R3	100kΩ	C4	5μF 3V
R4	39kΩ	C5	0.01μF
R5	33kΩ	C6	5μF 6V
R6	1.2kΩ	Tr1	2N4292
VR1	5kΩ log. pot.	Tr2	2N4292
C1	5μF 12V	D1	0A91

VC1, L1, L2, Oscillator coil and IFT's - superhet Kit, see text

Amplifiers

Many electronic circuits have an amplifier connected at one end to boost a low level audio signal to loudspeaker level and three types of audio amplifier are described here. One has an output of only about 75mW, one of nearly 1W and one of 5W.

Any of these can be used with other circuits in this book such as the superhet tuner and which one is a matter of choice.

Tone controls are not included, except a simple type in the 5W amp, and to add this facility it is only necessary to add the simple tone control featured at the end of this section.

The current of all amplifiers is reasonably high - you can't get power out unless you use current! For this reason the mains power supply featured at the end of the book may be found better than battery operation.

CIRCUIT 8 - 2 Transistor Amplifier

Transistors first found their place in electronics by being used in simple amplifier circuits for radios, hearing aids, etc. because in the early days the frequency response of the available devices was limited to about 100kHz. Transistors themselves were very expensive and to make the best of them stages were usually transformer coupled. Modern transistors are so efficient compared to their earlier counterparts that even with far less efficient R-C and d.c. coupling techniques, excellent results can be obtained using only a couple of transistors.

The circuit shown here has very high gain and an output of some 75mW which, although a tiny fraction of the output of most amplifiers, is more than enough for general purposes.

Input sensitivity for full output is around 50mV which is much less than most record player pickups or radio tuners provide. The addition of a telephone pick-up coil at the input transforms the circuit into a telephone amplifier and many microphones have adequate output to drive this simple amplifier.

In these days of Hi-Fi most people are accustomed to seeing distortion figures of under 1% and will no doubt look down on the 8% or so distortion which is typical in a design of this type. However, our ears are not particularly sensitive to harmonic distortion and only a trained ear would find the quality unacceptable.

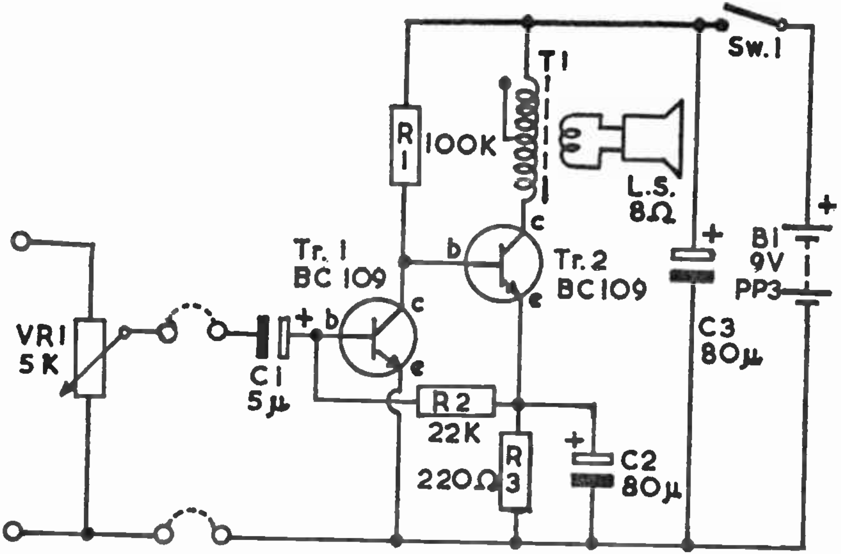

Sw.1
T1
R1
100K
L.S.
8Ω
+
B1
9V
PP3
Tr.1
BC 109
Tr.2
BC109
b
c
e
VR1
5K
C1
5µ
R2
22K
R3
220Ω
C2
80µ
C3
80µ

Fig. 9

The input is applied across the volume control, a 5kΩ pot shown in the circuit as VR2. As the output level is not very high, in many applications the volume control will not be needed, in which case the input should be connected directly to C1 and the negative supply rail.

The other side of C1 connects to the base of Tr1 and the signal is amplified and appears across the load resistor R1, 100kΩ, which also serves as the base bias for Tr2.

As the base of Tr2 is at the same potential as the collector of Tr1 (they are after all directly connected) and since the voltage at the base of Tr2 must only be about 0.7V higher than that on the emitter, it is necessary to raise the voltage at the emitter. This is done by inserting a resistor in the emitter connection, the other end going to the negative line - this is R3, 220Ω. In order to avoid high negative feedback being applied to this stage (which would reduce the output considerably), R3 is by passed by C2, a high value electrolytic. This tends to hold the voltage at the emitter of Tr2 at a fairly constant level. If it is left out the voltage at Tr2 emitter would rise and fall exactly in sympathy with the change in current through Tr2, these changes being the signal through it. This has the effect of reducing the output while improving the quality.

The base bias for Tr1 can be provided in a number of ways. One end of R2 will always be connected to the base of Tr1 but the other end could go to (a) the positive supply line(b) the collector of Tr1 or(c) the emitter of Tr2. The value would have to be altered for each of these. Each configuration has it's advantages and disadvantages. By using 'c', as we are doing, a slight amount of negative feedback is applied (that which is not smoothed by C2) but in addition the whole stage is d.c. stabilised. Thus, if there is any tendency for the amplifier to run away there will be a counter action in Tr1 preventing this.

The load of Tr2 is a small transistor output transformer - of the type usually used in transistor radios. These are not often obtainable as single ended types are more commonly sold as push-pull types - that is with a centre tap on the primary. This tap should be ignored; it is not needed for our purpose.

The loudspeaker, either an 8Ω or a 3Ω type is connected to the secondary.

C3 decouples the supply and tends to improve the quality, especially when the battery is near the end of it's life.

SW1 may be a separate switch or combined with Vr1. The current consumption of the amplifier is about 8mA in the 'no signal' condition and even the smaller batteries of the PP3 type will be perfectly adequate.

Both transistors used are BC109 types - these have gains of up to 900 each and it is the combination of two transistors with these high gains that gives a decent output from this simple circuit.

Components List

R1	100kΩ
R2	22kΩ
R3	220Ω
VR1	5kΩ log. pot with switch (SW1)
C1	5μF 6V
C2	80μF 3V
C3	80μF 12V
Tr1	BC109
Tr2	BC109
T1	Transistor ouput transformer
LS	8Ω loudspeaker
B1	PP3, 9V battery

CIRCUIT 9 - Three Transistor Amplifier

The original transistor amplifier circuits were single ended and operated in 'Class A'. These were soon replaced by a push-pull design comprising a driver transistor with a special driver transformer in the collector feeding to two matched output transistors, usually OC72's or OC81's, which in turn coupled to an output transformer. This recombined the audio signal before feeding it to the loudspeaker. Because of the standardisation of this amplifier circuit - which could provide an output of between 200mW and 1W - transformers became widely available and very cheap and this has led to the use of this circuit to the present time, even though technical advances allow for simplier and cheaper designs.

The big break through in transistor amplifier design came about with the introduction and general availability of complementary pairs of transistors. These comprise two transistors with closely matched characteristics as regards gain and other factors but one being P-N-P, the other being N-P-N. This allowed for a very different sort of amplifier and fulfilled a dream of the designs that they had held for years - a transformerless amplifier. Transformerless valve and transistor circuits has been developed but they were uneconomical or suffered from other disadvantages.

The reason for wanting to abolish the transformer was simple. It was the main factor limiting performance and they were very expensive.

At present virtually all Hi-Fi amplifiers use the configuration shown in the circuit here although they are generally much more sophisticated. This design has lowered the cost of amplifiers and resulted in tremendous improvements in quality.

This being said it should be pointed out that our circuit here is a design shorn of virtually all refinements and it doesn't compare with most commercial designs. However, the output is nearly 1W and the distortion figures are low. Frequency response is excellent as only two frequency dependant components are used, C1 and C2.

The input signal is coupled to the volume control, VR1 and the output of this is d.c. blocked by C1 which connects to the base of Tr1 which is a high gain silicon N-P-N transistor, a BC109. Although the configuration may seem confusing at first glance this has R5, 1kΩ, as it's collector load through the loudspeaker; R1 are also part of the circuit.

The collector of Tr1 will be at very nearly half the supply potential and since a 9V battery is used this will be 4.5V. Both bases of the complementary pair of transistors, Tr2 and Tr3, are connected to the collector of Tr1 (the 68Ω resistor is so small compared to the 1kΩ that it can be ignored).

The emitters of the two transistors couple via R3 and R4, low value resistors, and at that junction, because of the similarity of the two transistors, there will also be very nearly 4.5V.

When the input signal, which is first amplified by Tr1 goes negative of 4.5V, this cuts off Tr2 (as the base will be negative with respect to the emitter) but Tr3 will conduct the signal. When the input signal goes positive the reverse happens: Tr3 is cut off while Tr2 conducts.

The signals are combined at the common emitter junctions and are fed via the high value capacitor C2 to the loudspeaker. The value of C2 must be at least 250μF as shown since the load it is feeding is a low impedance and for efficient coupling of low frequencies, a high value is needed.

Negative feedback is applied in two ways. Firstly, the load resistor R5 is connected to the 'live' side of the loudspeaker and the base bias resistor of Tr1 is connected similarly.

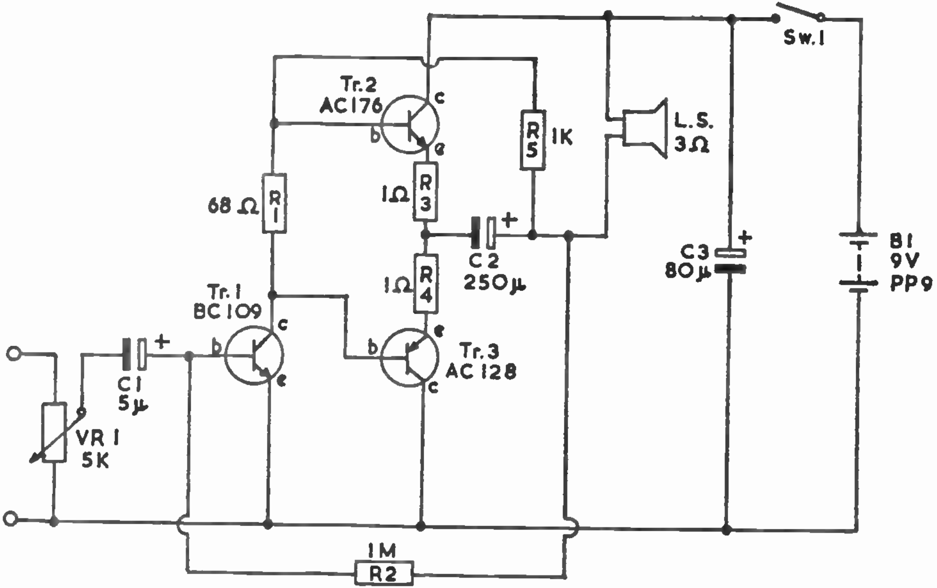

Sw.1
Tr.2
AC176
c
b
e
R5
1K
L.S.
3Ω
68 Ω
R1
1Ω
R3
C2
250μ
+
C3
80μ
+
B1
9V
PP9
Tr.1
BC109
c
b
e
1Ω
R4
e
b
c
Tr.3
AC128
C1
5μ
+
VR1
5K
1M
R2

Fig. 10

R1 is included to provide a small amount of base bias to the complementary pair. Here a resistor is being used for economy, but many designs have a thermistor or a diode here which has the advantage of preventing run-away in the output stages.

This is about the simplest arrangement of this common circuit configuration and commercial designs use up several transistors. There are disadvantages with circuits of this type. D.C. coupling throughout can lead to a lot of troubles. If one transistor alters its parameters, this reflects though the entire amplifier and complex d.c. stabilisation techniques are incorporated to overcome this. For similar reasons if one transistor blows it can cause complete and expensive failure of the complete chain.

These points are made for anyone contemplating the construction of more complicated versions of this circuit. Anyone embarking on such a venture would be well advised to build the circuit shown here first of all as failure of this circuit will not be nearly so expensive.

The AC176 and AC128 are only two of the transistors that can be used, various other types can be tried. They should always be bought as a matched pair from a reputable supplier. Individual transistors which has not been closely matched will produce poor results.

No circuit modifications are needed for introducing any other similar pair which may be available.

Components List

R1	68Ω	C2	250μF 10V	
R2	1MΩ	C3	80μF 12V	
R3	1Ω	Tr1	BC109	
R4	1Ω	Tr2	AC176)	matched pair, see text
R5	1kΩ	Tr3	AC128)	
VR1	5kΩ log. pot. with switch	B1	PP9, 9V battery	
C1	5μF 6V	LS	3 loudspeaker	

CIRCUIT 10 - 5W Amplifier

The simple complementary pair transistor amplifier previously described had an output of about 1W and although this is more than adequate for normal listening, it is still below the level of most record players, mains operated radios or T.V. sets. The average output of these is between 2W and 3W.

The circuit shown here has an output of nearly 5W and the quality is excellent. It is not Hi-Fi in the true sense of the word but it is very much better than many amplifiers claiming to fall into that category

The components used are all widely available and inexpensive and once you are happy with the interpretation of circuits and have tackled the simpler similar circuit previously described, it should prove a very useful circuit indeed.

Note the supply potential, 22V. In order to achieve this sort of output a relatively high voltage supply is necessary and for continuous operation batteries are quite unsuitable and a mains power pack is almost obligatory.

This circuit has higher quality and higher output than the previous one described and includes a tone control which has a wide range. The problems associated with this configuration, and previously discussed, have to be taken into account in this circuit. Several d.c. and a.c. feedback paths are incorporated to stabilise the circuit.

The input sensitivity is about 50mV for full output. The input signal is connected across VR1 and R1 (the function of which will be described later) and the output of the slider is coupled to Tr1 via C1, a d.c. blocking capacitor.

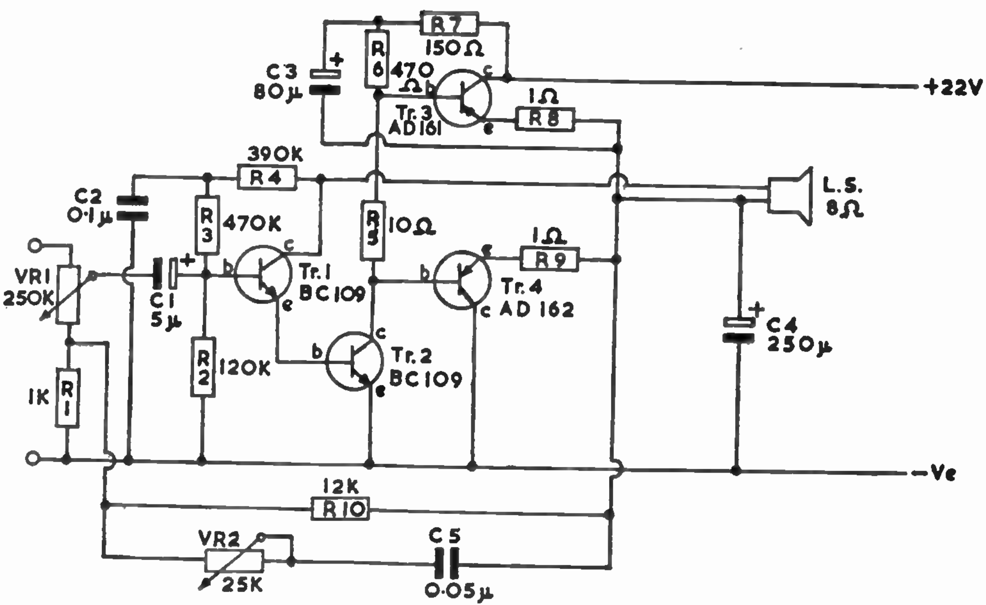

R7
150Ω
R
6
470
Ω
C3
80µ
+
c
b
Tr. 3
AD161
e
1Ω
R8
+22V
390K
R4
C2
0·1µ
R
3
470K
R
5
10Ω
1Ω
R9
L.S.
8Ω
VR1
250K
C1
5µ
+
c
b
Tr. 1
BC109
e
e
b
Tr. 4
c
AD 162
+
C4
250µ
R
2
120K
c
b
Tr. 2
BC109
e
1K
R
1
−Ve
12K
R10
VR2
25K
C5
0·05µ

Fig. 11

Because of the input circuit arrangement, the input impedance is reasonably high. It depends on the position of the slider of VR1 but is never less than 100kΩ and is thus suitable for use with ceramic pickups.

Tr1 can be regarded as a driver transistor feeding Tr2 which in turn acts as the driver to the complementary output pair, Tr3 and Tr4.

There is negative feedback from the output going back to the input via R10, VR2, C5 and R1 and the arrangement of VR2 and C5 makes this frequency sensitive and thus acting as a tone control. The negative feedback is applied with the input signal and R1 acts as the load for this.

Tr3 and Tr4 are power types transistors and must be bolted onto a heatsink but since the bodies of the transistors are the collector connections, insulating washers must be fitted when these are mounted.

An 8Ω loudspeaker is used and in this particular circuit lower impedance types are not recommended.

Component List

R1	1kΩ	VR2	25kΩ lin. pot.	
R2	120kΩ	C1	5μF 10V	
R3	470kΩ	C2	0.1μF	
R4	390kΩ	C3	80μF 15V	
R5	10Ω	C4	250μF 15V	
R6	470Ω	C5	0.05μF	
R7	150Ω	Tr1	BC109	
R8	1Ω	Tr2	BC109	
R9	1Ω	Tr3	AD161)	matched pair
R10	12kΩ	Tr4	AD162)	
VR1	250kΩ log. pot.			

CIRCUIT 11 - Tone Control

Theoretically tone controls on record players and tape recorders are not needed since the whole chain from the microphone, through the recording medium to the loudspeaker should be correct as far as frequency response is concerned. However, most people prefer to have some control over the tone that they listen to, frequently the bass notes are boosted to add depth (and to overcome the bass response of poor speakers) and treble is added to give brightness.

Simple tone controls usually only have the facility to reduce the high frequencies and the control labelled 'tone' should more properly be called 'top-cut'. These are useful as they give a certain degree of control but often the range is pitifully inadequate.

The circuit given here incorporates volume, treble and bass controls and is designed to fit between a preamplifier and the main output amplifier. It has a degree of gain, but no much, and is suitable for use between about 50mV and 500mV and can be fitted into most systems in that range.

The input signal is applied across the volume control and the output from the slider connects to the tone control network. The output from this tone control network is d.c. blocked by C5 which connects to the base of Tr1, the amplifying transistor which is biased by R3 and R4.

The collector load of the transistor is made up from two resistors, R5 and R6 and part of the signal, determined by the ratio of the two transistors, is fed back to the tone control network.

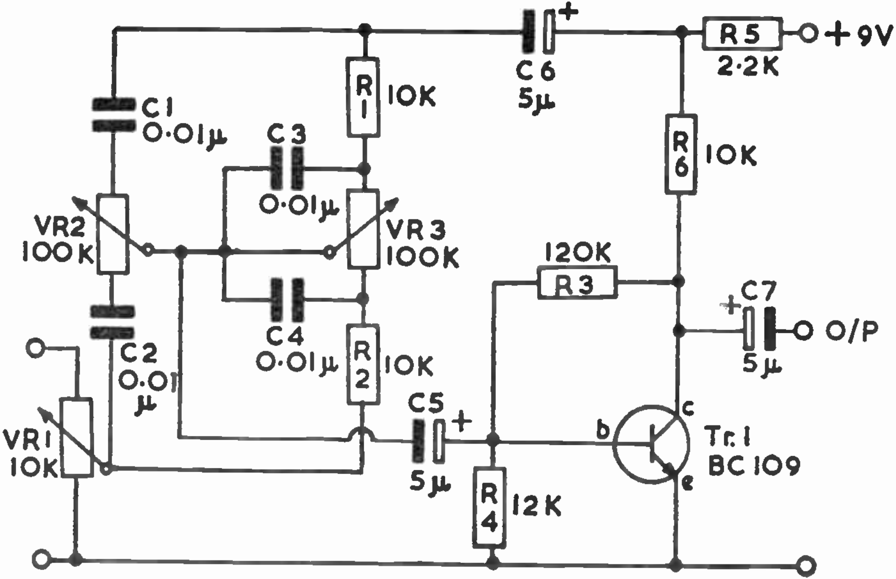

+
C6
5µ
R5
2·2K
+9V
R1
10K
C1
0·01µ
C3
0·01µ
R6
10K
VR2
100K
VR3
100K
120K
R3
C7
+
O/P
5µ
C4
0·01µ
R2
10K
C2
0·01
µ
C5
+
5µ
VR1
10K
R4
12K
b
c
e
Tr. 1
BC 109

Fig. 12

This signal will be out of phase with the incoming one and because of the arrangement of the capacitors and resistors in the network, a greater or lesser degree of negative feedback at either bass or treble can be selected. If VR2 and VR3 sliders are near C2 and R2 little negative feedback is applied but the tone is affected because of C2, R2 and C4. On the other hand if the sliders are near C1 and R1 a considerable degree of feedback is applied.

The range of control available over the tone is considerable and notes at 100Hz can be raised or attenuated by 12dB with reference to 1kHz and the same applies at 10kHz.

The gain of the stage is largely determined by the tap off point for the negative feedback signal to the network. As shown here there is a small gain of about four times but if the values of R5 and R6 are reversed the gain would be somewhat less. For greater gain, but with somewhat less range of attenuation or boosting, R5 can be lowered to 1kΩ and R6 increased to 12kΩ.

The tone control output capacitor polarisation assumes that the point to which it connects is negative with respect to the collector of Tr1. Many amplifiers will be positive at this point in which case C7 should be reversed.

A 9V supply is adequate for this control and it will normally be taken from the main amplifier via a dropping resistor and smoothing capacitor.

Components List

R1	10kΩ	C1	0.01μF
R2	10kΩ	C2	0.01μF
R3	120kΩ	C3	0.01μF
R4	12kΩ	C4	0.01μF
R5	2.2kΩ - see text	C5	5μF 6V
R6	10kΩ - see text	C6	5μF 10V
VR1	10kΩ log. pot.	C7	5μF 10V - see text
VR2	100kΩ lin pot	Tr1	BC109
VR3	100kΩ lin. pot		

TEST GEAR

The first item that any constructor should acquire is a multimeter. These need not be expensive but the one selected should have adequate voltage, current and resistance ranges. Building such a piece of equipment is usually wasteful. Commercial units cost far less than the components alone and even the worse ones are usually more accurate than even a carefully built self constructed one.

Although multimeters will cope with most problems, they have their limitations and the three simple circuits here for test equipment extend the range that you can cover.

CIRCUIT 12 - Multipurpose Tester

During the last few years literally millions of surplus, unmarked and untested transistors have appeared on the market; these are almost always sold without any form of guarentee. They are so cheap that they are usually sold in lots of 30, 50 or 100 and are very good value indeed for the home constructor. Mostly these comprise out of tolerance devices which, although unsatisfactory for commercial production lines, have wide uses for the experimenter.

We make considerable use of the 2N2926 transistor in this book because it is cheap, widely available and looks as though it may be with us for many years to come. Transistors similar to these are available in the bargain packs and even though the manufacturers marked and guarenteed versions are cheap, considerable savings can be made by buying a pack of surplus transistors and sorting out the duds - those with high leakage, low gains etc.

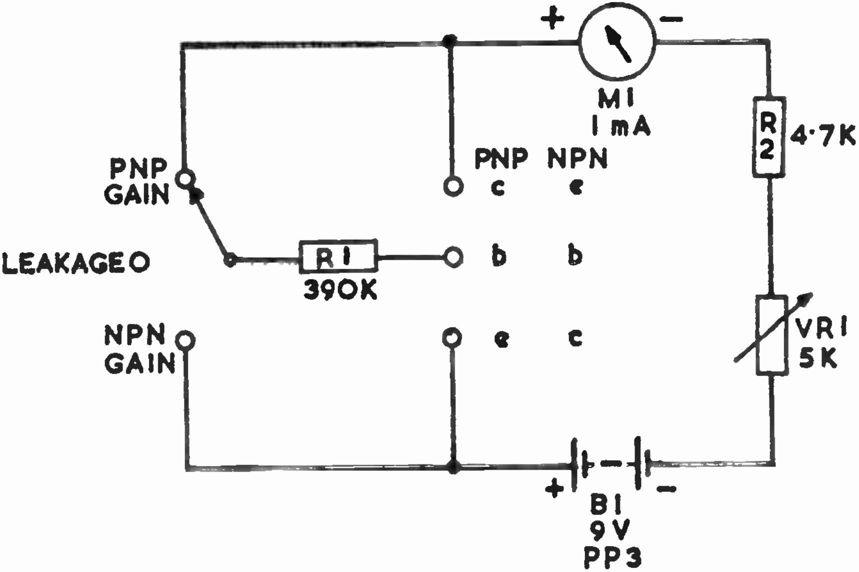

+
−
M1
1 mA
R2
4·7K
PNP
GAIN
PNP
NPN
c
e
LEAKAGE
R1
390K
b
b
NPN
GAIN
e
c
VR1
5K
+
−
B1
9V
PP3

Fig. 13

When building up a piece of equipment it is a good idea to use proper transistors, later replacing these with a surplus type which is found to work well in that particular circuit. This way of building equipment will be found to be very economical.

These very cheap packs usually contain between 10% and 30% of duds and it is essential that these are discarded.

The multi-purpose tester shown here has been designed to sort out transistors for leakage and gain - the two most important factors - and if these characteristics are found to be satisfactory the device will probably be fine for most applications. However, as well as sorting out transistors it will also fulfill a number of other functions; it will test diodes of most types; it is a sensitive ohmmeter, it will test batteries of the PP3 type and it will also electrolytic capacitors.

It is important to know that the leakage of a transistor fails below certain limits, if it is too high the device will be no good at all and many of the surplus transistors have been rejected for just this reason.

The leakage of the transistor is the current passed between the emitter and collector when no base bais is applied.

A PP3, 9V battery is used as the supply and this is connected to the emitter and collector junctions of the transistor via a 1mA meter, R1 and VR1. For ease of testing the terminals shown e, b and c are those of transistor mounting socket into which the device is plugged. To avoid complex switching only one socket is used. P-N-P devices are connected one way around, N-P-N devices the other.

With the switch in the leakage position the base is left floating and the meter registers the current passing through the device. By definition this is the leakage current. The reason for the inclusion of R1 and VR1 is so that if the device is a dead short (and this is not uncommon in these types) the meter will be limited to full scale deflection and no harm will come to it.

The gain of the transistor can be measured by connecting a known value resistor (here 390kΩ) between the collector and the base and noting the rise in current through the meter - the rise will be proportional to the gain of the device.

For gain readings it is necessary to make the switch SW1 to either N-P-N or P-N-P

By comparing the leakage and gain readings obtained with those from known quality transistors, one can assess the device. The sort of readings one can expect for a good device will quickly be learnt in this way. Germanium transistors will usually show a small leakage reading while most silicon types will register nothing, their leakages are measured as fractions of a microamp and our meter is not sensitive enough for this. If a device shows no reading on either leakage or gain, it is open-circuit and should be discarded.

Apart from acting as a transistor tester the circuit will test diodes. When connected between the collector and emitter connections, one way around they should show no, or very small, readings, while the other way around they will register a high current.

If the emitter and collector connections are shorted together and VR1 adjusted to read full scale deflection exactly, the circuit becomes an ohmmeter with a central reading of 4,500Ω which is rather more sensitive than most cheap meters. It will be necessary to calibrate the scale using high tolerance resistors but this is a simple matter.

PP3 batteries can be tested by substituting with the circuit battery. If full scale deflection cannot be achieved using VR1 the battery is very low. This test is rather better than taking a voltage reading as a higher current is being drawn than most meters take. Many low batteries register full voltage when tiny currents are drawn, but as soon as a milliamp or so is drawn the voltage falls right down.

Connecting an electrolytic capacitor correctly polarised across the circuit will show a kick towards full scale, this falling slowly as the device charges. If you use a little skill it is even possible to judge the value of capacitance by the kick you can get within very close limits using this method.

Components List

R1	390kΩ	B1	PP3, 9V battery
R2	4.7kΩ	M1	1mA meter
VR1	5kΩ lin. pot.	Transistor mounting socket	
SW1	single pole, 3-way switch		

CIRCUIT 13 - Signal Injector-Tracer

There are two extremely useful pieces of tesi gear for both the serviceman and the amateur constructor. These are a signal source and a signal tracer.

Faced with a transistor radio that doesn't work, what do you do? It is important that a logical approach is taken and although this may sound obvious, it is very, very easy to become diverted.

First check that the battery is not flat (for this accounts for about 50% of so called faults) and then check that a good contact is being made on the cut-out switch of the earpiece socket if one is fitted. Always check these first but assuming there is still no joy what do you do?

The volume control is easily located, contacts can generally be made to it quickly and it is an excellent place to start.

If you inject a signal at the slider of the volume control and it is heard at a decent level from the loudspeaker you can be fairly sure that nothing is wrong with the amplifier. If nothing is heard there is obviously something wrong and the field is immediately narrowed.

Assuming that the audio stage is working you can then inject an i.f. signal at the collector of the mixer stage - the same rules apply as before.

Alternatively you can take the 'signal detect' approach. If instead of injecting a signal at the volume control you can listen at the same point to establish that the radio is working satisfactorily up to a certain point.

The above is a super concise lesson in fault finding but it does illustrate the tremendous use that a signal injector and a signal tracer can be put to.

The project described here is for a combined device - it can inject signals at r.f. i.f and audio and can detect signals at the same frequencies assuming that they are high enough in level. The simplicity of circuit may lead you to doubt this claim but it does do all this.

The function switch, SW1, has

No. 1 Off position
No. 2 Trace Position
No. 3 Inject Position

Position 1 merely disconnects the supply and the device is of course inoperative. As shown the function switch is in position 2 and in the trace mode.

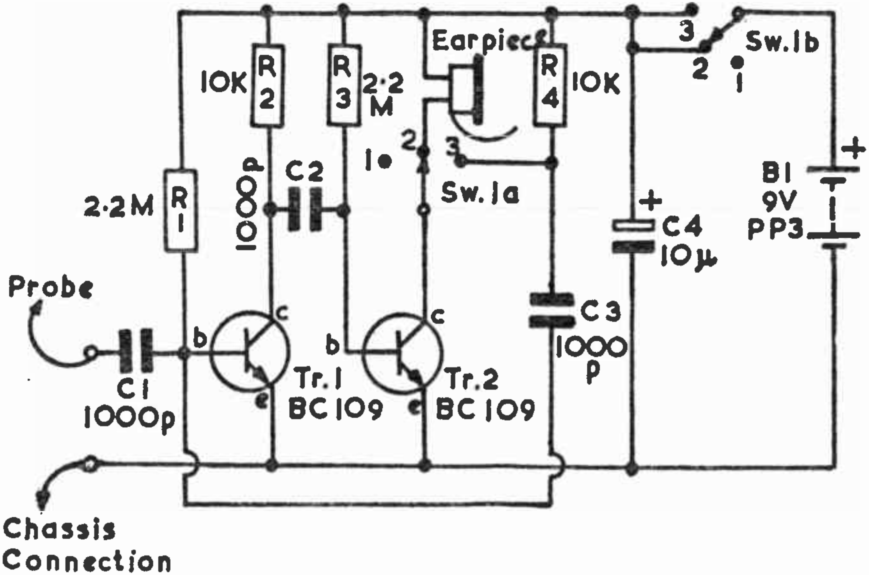

Earpiece
Sw.1b
3
2
1
10K
R2
R3
2·2 M
R4
10K
2
3
1
Sw.1a
B1
9V
PP3
+
+
C4
10µ
2·2M
R1
1000p
C2
Probe
c
b
b
c
C3
1000 p
C1
1000p
e
Tr.1
BC109
e
Tr.2
BC109
Chassis
Connection

Fig. 14

One of the contacts is the common line and should be wired using a crocodile clip to the chassis of the equipment being investigated. The other connection is the probe.

This goes via a d.c. blocking capacitor C1 whose working voltage should be high - if a 500V working component is used the circuit can be used on valved equipment working at high voltages.

The signal is fed to Tr1 which is arranged as a common emitter amplifier but which is biased nearly to cut-off which creates deliberate distortion at the same time as amplifying the signal. Distortion in such a manner leads to the detection of r.f. signals and so whatever the frequency fed in, assuming it is modulated, an audio output will be heard. The collector load of Tr1 is R2 and the output of this stage is fed to a further one of similar design, but the collector load here is represented by a high impedance magnetic earpiece in which the signals are heard.

On inject, SW1 is in position 3 and the output of Tr2 is coupled to R4, acting as the collector load and also to C3 which feeds back to the base of Tr1. The circuit, which was previously an amplifier, now becomes a multivibrator producing a square wave signal at approximately 1kHz and this is fed, again via C1, to the probe.

A square wave can be described as a fundamental frequency plus all its harmonics and so in addition to 1kHz there is an output at 2kHz, 3kHz etc., going right up into the r.f. range. In fact, these are still a useable output at 30MHz.

Holding the probe near the aerial will produce an output from a working radio as the injector is working as a very low power transmitter and an output at 1kHz will be heard from the loudspeaker.

High gain transistors are needed in order to hear really low signal sources and high frequency types are needed to handle the upper harmonics. A transistor incorporating both these qualities is the BC109 and is the one used here.

The current drain, both in the trace and inject mode is quite small and can be handled by a PP3 battery. SW1, the function switch, needs to be a 2-pole, 3-way rotary switch and these are very common.

Note that only high impedance magnetic earpieces are suitable, though 2000Ω headphones can be used instead.

Once completed and used the signal injector/tracer will be found to be almost indispensable and for this reason it is worthwhile building the circuit carefully and neatly into a small chassis.

Components List

R1	2.2MΩ	C4	10µF 12V
R2	10kΩ	Tr1	BC109
R3	2.2MΩ	Tr2	BC109
R4	10kΩ	SW1	2-pole, 3-way switch
C1	1000pF 500V	B1	PP3, 9V battery
C2	1000pF	High Impedance Magnetic Earpiece	
C3	1000pF		

CIRCUIT 14 - Capacitance Bridge

Finding the value of an unknown resistor presents few problems and all multimeters incorporate a range for measuring ohms directly off the meter.

Capacitance, however, cannot be measured using d.c. and this is unfortunate since the markings and codings on capacitors rarely have the value printed on them. Also, a method of measuring stray capacitance in a circuit is often useful.

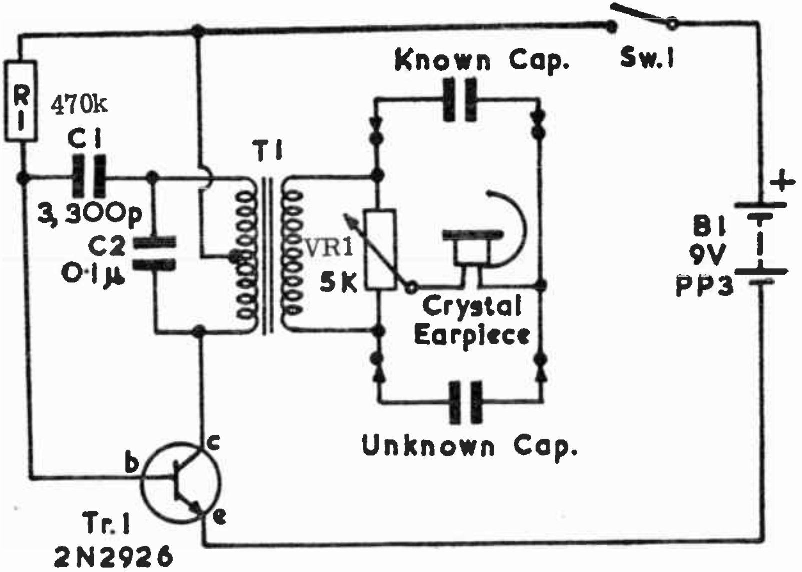

Known Cap.
Sw.1
R1
470k
C1
3,300p
C2
0·1μ
T1
VR1
5K
Crystal Earpiece
Unknown Cap.
+
B1
9V
PP3
c
b
e
Tr.1
2N2926

Fig. 15

There are a number of ways in which the value of a capacitor can be measured and the circuit shown here is one of the simplest and also one of the best - it makes use of a bridge circuit.

Tr1 is arranged as an audio oscillator, producing a fairly decent sine wave. There is a tapped transistor output transformer in the collector circuit and apart from the operating frequency is almost identical to the B.F.O. circuit described elsewhere but here the secondary of the transformer is used and it is this isolated part of the circuit that is important.

Tr1 produced a note in the audio range, the actual frequency doesn't matter and will vary with the transformer used but it should lie between 500Hz and 2kHz since the human ear is most sensitive within this frequency range.

The oscillation frequency is induced into the low impedance secondary winding and VR1, a 5kΩlinear pot is connected directly across this.

Assume, for the sake of explanation, that the known value capacitor and the unknown one are equal in value and that the slider of VR1 is at exactly the mid-position. This means that exactly half the signal in the secondary of the transformer appears at the slider of VR1 But as the signal is alternating it will also pass through both of the capacitors. Since they are both equal in value, exactly the same amount will pass through both and half the signal level will also appear at the junction of the capacitor and the other side of the crystal earpiece.
Since the signal levels across the crystal earpiece are identical nothing at all will be heard for all electronic devices depend on the electronic difference across them and if there is no difference the device is inoperative.

However, assume that the unknown capacitor is half the value of the known one. Since VR1 is still in the middle, half the signal still appears at the slider but at the other side of the earpiece the level will be different, depending on the values of the capacitors. The higher value capacitor will offer only half the reactance as the lower valued one and the tone produced by the oscillator will be heard.

If we now alter the setting of VR1 so that the top section is half the resistance of the lower section a balance will once more be achieved. When this state is achieved the bridge is referred to as being 'balanced'.

If we use a pointer knob on VR1 and mark the centre position (which should be the balance position for equal value components) and other points using known value components it is quite easy to mark ratios on it which will be good for any value of components. Accurate ratios can be marked from about 10:1 on either side giving a range of 100:1. So assume we have a known value, close tolerance 0.1μF component. When the resistance of the upper section of VR1 is 1/10th that of the other section and the bridge is balanced, the unknown capacitor will be 0.1μF x 10 or 1μF - on the other hand if the lower track is 1/10th that of the higher track the component will be 0.1μF ÷ 10 or 0.01μF. Since the range is 100:1 only a few known value components are needed and only four components are needed to measure all values between 1pF and 100μF - these are 10pF, 1000pF, 0.1μF and 10μF.

There are two points however which should be noted. With the 10pF balances will be achieved between 1pF and 100pF but there are bound to be stray capacities introduced due to the construction and, although balances will be achieved, these are unlikely to be accurate.

Another point is that electrolytic components have very wide tolerances indeed, they are frequently in the range - 50% to + 100%. Close tolerance, high value components (though not usually electrolytics) are available for the 10μF component but they are very expensive. This doesn't matter however as there are very, very few uses in electronics for close tolerance electrolytics and for this reason only a vague idea of the value is necessary and a wide tolerance electrolytic will do for the 'known value' 10µF component.

Calculations to determine the value of unknown capacitors quickly and accurately are simply made by reading off the multiplication of division factor from the pointer of VR1.

Although primarily intended for use with capacitors, the same circuit functions just as well for resistors and inductors but since resistors are virtually always clearly marked with their value in colour code and since inductors rarely need calculation in this way, these extra uses are more limited.

Components List

R1	470kΩ	T1	Transistor output transformer with tapped primary
VR1	5kΩ lin. pot.		
C1	3,300pF	SW1	On-off switch
C2	0.1µF	B1	PP3, 9V battery
Tr1	2N2926	Crystal earpiece	

MISCELLANEOUS CIRCUITS

This section includes eight circuits, some highly practical, such as the burglar alarm, others are more novel in character. There is room for experimenting with most of these circuits and considerable fun can be had from building up and using these devices.

Electronics has made inroads into many fields previously considered to be mechanical - such as the metronome and the light switch and this is probably a field in which semiconductors will encroach even further in the coming years.

An introduction to new circuit techniques for many readers is included in some of these designs and a more complete explanation is given of the operation for this reason.

The final circuit is for a general purpose power supply, suitable for all the circuits in this book if battery operation is not suitable or not desired. The cost of running equipment from the mains supply is a fraction of that of battery operation and the initial cost is soon recovered.

CIRCUIT 15 - MORSE PRACTICE OSCILLATOR

A high proportion of those interested in electronics eventually graduate to take the R.A.E. examination and a morse test and obtain a transmitting licence. Even those with considerable appreciation of electronics theory have difficulty in passing the morse test and a fair amount of practice is necessary in order to reach the required standard.

Various circuits for morse practice oscillators have been published over the years but the one shown here is about the simplest there is.

The circuit makes use of a unijunction transistor which is unlike other semiconductors devices in that there are two base connections and one emitter connection - but no collector. In fact it is really misleading to call it a transistor at all since it behaves in an entirely different way. The uses to which it can be applied are very limited - in fact it will only operate as a relaxation oscillator, but in that application it is excellent.

Although most unijunctions will operate from a 9V supply, they are more reliable and give a better output if this is increased to 18V - or even higher.

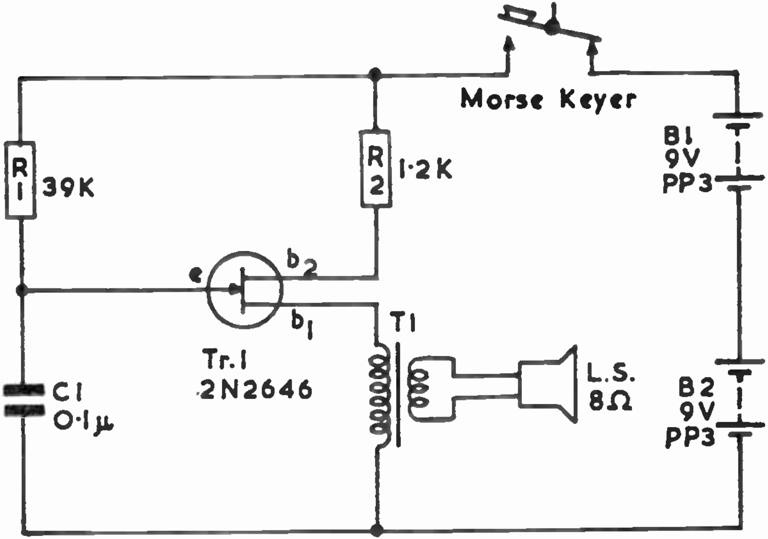

Morse Keyer
B1
9V
PP3
R
1
39K
R
2
1·2K
b2
e
b1
T1
Tr.1
2N2646
C1
0·1μ
L.S.
8Ω
B2
9V
PP3

Fig. 16

The operation of the unijunction is as follows: when there is no potential applied to the emitter, base 1 and base 2 (shown in the circuit as b1 and b2) are virtually insulated from each other but when the potential at the emitter reaches a certain level the two bases are virtually shorted together. By arranging the emitter to be coupled to a capacitor, the capacitor will also be discharged and the unijunction will revert to the non - conducting state.

In our circuit R1 and C1 form a charging circuit and thus the unijunction can be made to switch on and off at a rate determined by the time constant of these two components.

A small transistor output transformer is connected into the unijunction circuit and the current drawn by it, which will be a series of pulses, will pass through the primary and be transformed to feed the loudspeaker. If necessary the transformer can be left out, inserting the speaker directly into the main circuit - with some speakers this may even give a greater output.

R1 and C1 are chosen so that the output note is in the audio range and about 300Hz. As listening to exactly the same note rapidly becomes annoying, R1 could be replaced by a 22kΩ resistor with a 50kΩ pot in series enabling a wide range of notes to be selected.

The morse keyer is connected in the supply line to the circuit and by this means the note will sound when the keyer is depressed.

The output level is not high, though it is perfectly adequate for the purpose intended. The current consumption is low and two PP3 batteries are quite adequate.

Various types of unijunction transistors are available and they are all fairly simple. The one shown, the 2N2646 is possibly the commonest, but virtually all types will do if this is not obtainable.

Components List

R1	39kΩ - see text	T1	Transistor output transformer, see text
R2	1.2kΩ	LS	8Ω loudspeaker - see text
C1	0.1μF	B1, B2	PP3, 9V batteries
Tr1	2N2646 unijunction	Morse Keyer	

CIRCUIT 16 - Burglar Alarm

It is often said that the box mounted outside the house labelled 'Burglar Alarm' does more to put off the potential villian than the system used. There may be a lot of truth in this but a real operational burglar alarm need not be expensive or difficult to instal.

One of the most important things is for the alarm to be thoroughly reliable. It will probably never be needed or at the worst only once or twice in a lifetime but on that occasion it has to work.

There are several approaches that one can take to burglar alarm systems. The warning device can be loud, complex and frightening - making sure that the intruder is impressed and also alerting neighbours. However, such a system can cause terrible troubles for the rightful users of the house are bound to trip the alarm frequently, as it is very easy to forget to disarm the device.

The alarm system used here takes another approach, the alarm is loud but it's main aim is to frighten the intruder and wake up anyone in the house rather than warn neighbours. The low output is deliberate for although it will terrify a nervous burglar, it will not be disastrous or annoying if triggered by mistake.

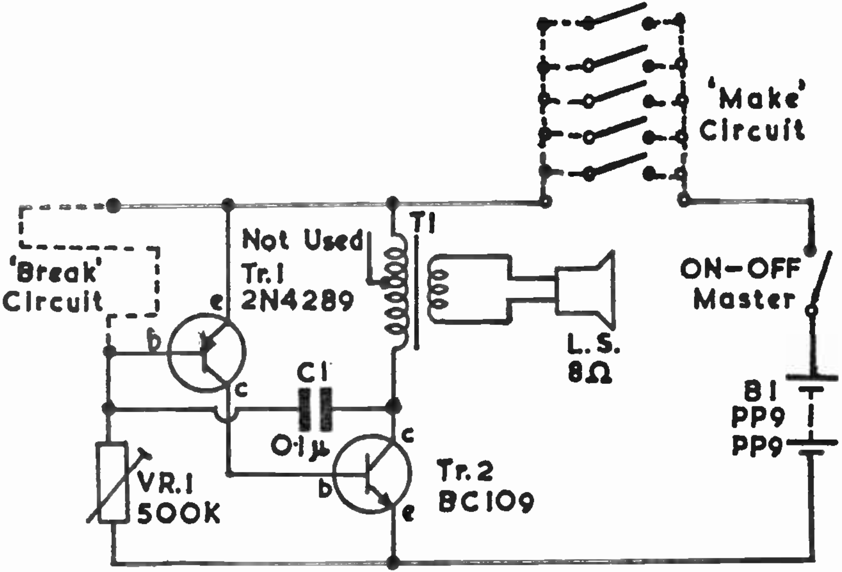

'Make'
Circuit
'Break'
Circuit
Not Used
T1
Tr.1
2N4289
e
b
c
C1
0·1μ
c
b
e
Tr.2
BC109
VR.1
500K
L.S.
8Ω
ON-OFF
Master
B1
PP9
PP9

Fig.17

The circuit of the alarm is shown in Fig. 17 and two methods of wiring are shown: one being a 'make circuit' - the other the 'break'.

A 'make' circuit would initially appear to be the easier. If the wiring goes to a whole series of contacts that are 'made' by the opening of windows or internal doors the device will operate. If this system is used a truly electronic warning device is not necessary as a battery and bell would do just as well.

There are strong disadvantages in this system; the wiring for it in this circuit is shown as a series of switches in parallel, any of which will trigger the alarm.

An awful lot of wire is needed, using this method as two wires have to run to each point, but the more serious drawback is that it is not automatically tested each time it is switched on and to ensure that all the switches are in good condition at all times would involve a considerable amount of trouble and the chore would become so great that it would not be done.

The alternative circuit is the 'break' one. For this, a single circuit wire is used, coupling to the necessary windows and doors and as opposed to the alternative system, this one triggers when the circuit is broken. This has an automatic test built into it as the alarm will trigger if a window or a door has been inadvertently left open - but unlike the previously discussed method, this will also trigger as soon as a fault occurs anywhere in the circuit.

The alarm circuit itself can be constructed in a number of ways and a considerable amount of inginuity can be used. Windows, when closed, can have phosphor-bronze contacts, built in, which complete the electrical circuit and doors may be treated in much the same way.

A more satisfactory system would be to sink small reed switches into the window frame or door and opposite this using a small bar magnet which will keep the contacts closed when the two are close together, but which will open the reed switch, and thus open the circuit when the window or door are opened.

This continuous circuit shorts out the base-emitter junction of Tr1 and thus making it non-conductive. However, as soon as this circuit is broken VR1, a skeleton preset 500kΩ pot will bias Tr1 into conduction, in turn switching on Tr2 which allows current to pass through the primary of T1. C1 is connected into the circuit in such a way that the two transistors form an oscillator circuit and so causing an audio output from the loudspeaker.

VR1 here has rather an unusual function. If the loudspeaker used is small in size - and this is recommended - the natural resonance of the cone will be quite high in frequency - perhaps up to 300Hz. Since the value of VR1 determines the output frequency, it can be set so that, when triggered, the alarm note is at the resonant frequency of the loudspeaker. At this point the actual 'loudness' of the note heard is many times higher than one would expect. Surprisingly, it is the lower quality speakers which are best at exhibiting this characteristic but although it is a strong disadvantage in most applications, here the effect can be used to advantage.

There is, of course, a constant current drain on the battery as VR1 is continuously across it but the drain is only 20 microamps and this is so small that the battery will go flat by decay before being run down because of the current drawn. Although battery operation will normally be satisfactory, a mains power pack would be better as this will never run down.

The basic circuit will be good for most uses and will serve it's purpose but it has a small disadvantage in that as soon as the window or door which has triggered the alarm is closed again, the alarm will stop. By this stage the intruder will normally be at the bottom of the garden, trying to get away as quickly as he can, but others may proceed if they know that the alarm is no longer operative.

The use of a relay, added to this circuit, with a switching transistor will overcome this disadvantage, allowing the alarm to stay on whatever the condition of the 'break' circuit, this is shown in Fig. 18.

In this a 560Ω resistor is wired into the negative line and the emitter and base of the transistor are wired across it. A 2000Ω relay is wired in the collector circuit which goes to the position line. The contacts of the relay are normally closed and are connected into the 'break' circuit.

As soon as the alarm circuit is broken, the alarm sounds and this means that current is drawn. In the standby condition the tiny current means that there is no voltage drop worth considering across R1 and Tr3 is biased off. However, when the alarm draws current there is a volts drop of nearly 1V across R1 and Tr3 is biased into conduction and the relay switches making a further break in the circuit so that whatever else happens in the 'break' wire, the alarm will continue to sound.

Components List

VR1	500kΩ preset pot.
C1	0.1μF
Tr1	2N4289
Tr2	BC109
T1	Transistor output transformer
LS	8Ω loudspeaker
SW1	On-off master switch
B1	PP9, 9V battery

Extra components for Fig. 18, holding circuit

Tr3	BC109
R1	560Ω
RL1	2000Ω relay (6V) with break contacts

CIRCUIT 17 - Light Operated Switch

You don't have to think very hard to find several uses for a light operated switch. In certain areas car owners are required by law to provide a parking light on their vehicles shortly after sunset. Automatically operated porch lights are also very useful.

The circuit shown here has two uses. Firstly it can be used to light up a bulb directly but the power that can be handled is somewhat limited and the brilliance of the bulb is too low for uses as a porch light for instance. Alternatively, the circuit operates a relay which applies the current to the bulb.

Apart from these choices the circuit can be arranged to switch either on or off in dark conditions and the same applies.

Those wishing to get up at daybreak can take advantage of this circuit by using the 'dark-off' circuit with the relay which is arranged to complete the battery supply to a radio or to some other alarm device: the metronome circuit described elsewhere and set at a fast rate would do here.

The controlling factor for the whole circuit is the light dependant resistor ORP12. Instead of having a constant resistance like normal carbon types, these components use cadmium sulphide as the resistance and this has the property of having a very high resistance in complete darkness (over 1MΩ) but in the brightest light this falls to nearly 50Ω (although individual devices vary greatly).

At first sight it would seem possible to use only the ORP12 to control the circuit but this has several disadvantages including the fact that the current passed through the device must be kept below a certain figure. The Mullard ORP12 is fairly

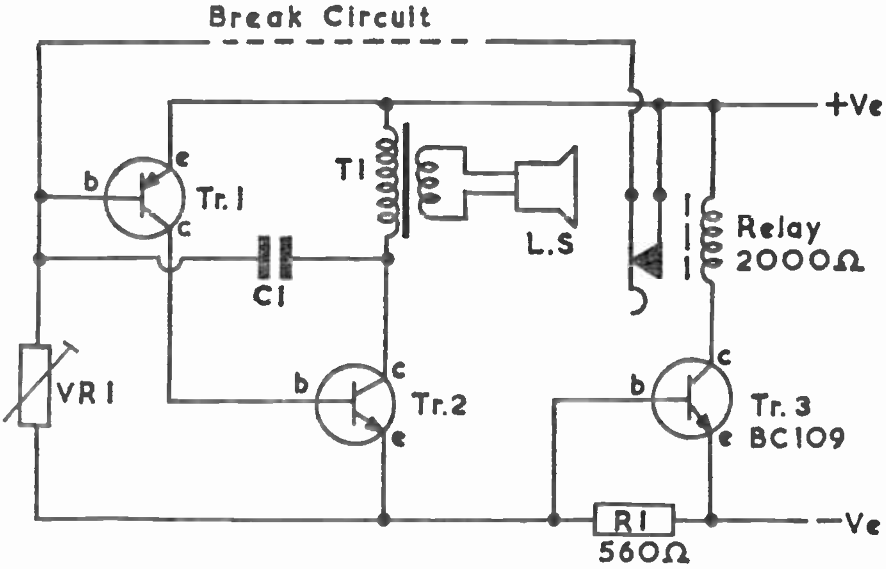

Break Circuit
+Ve
b
e
c
Tr. 1
T1
L.S
C1
Relay
2000Ω
VR1
b
c
e
Tr. 2
b
c
e
Tr. 3
BC109
R1
560Ω
—Ve

Fig. 18

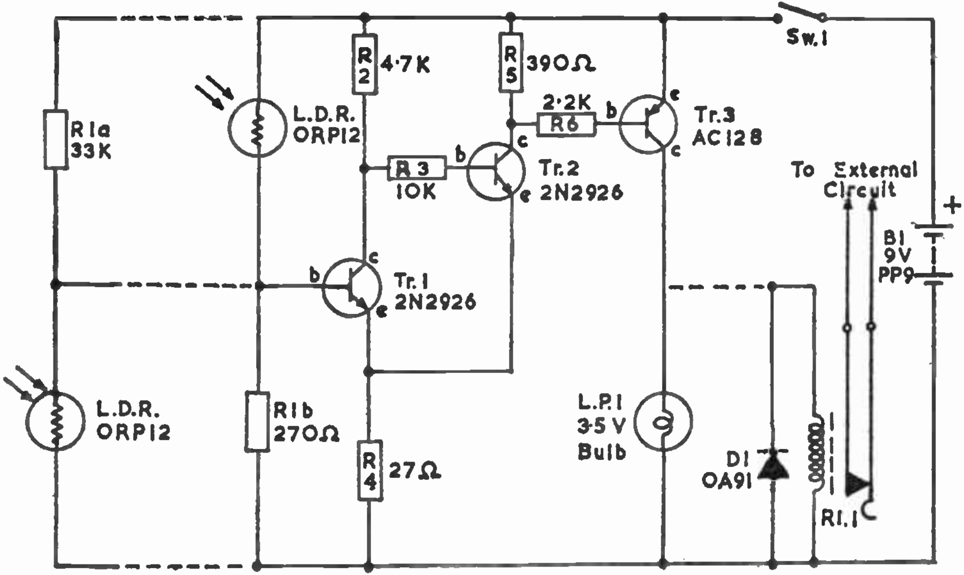

Sw.1
R 2
4·7K
R 5
390Ω
2·2K
R6
b
e
c
Tr.3
AC128
L.D.R.
ORP12
R1a
33K
R 3
10K
b
c
e
Tr.2
2N2926
To External Circuit
+
B1
9V
PP9
b
c
e
Tr.1
2N2926
L.D.R.
ORP12
R1b
270Ω
R 4
27Ω
L.P.1
3·5 V
Bulb
D1
OA91
Rl.1

Fig.19

expensive, especially when compared to the current price of transistors but cheaper imported devices are rarely as good. Many of these have been used but the minimum resistance varies from 100Ω to 1000Ω and although they will operate in this circuit they are not so versatile for others.

For simplicity the circuit will be described for the 'dark on' position using a directly lighted bulb.

When daylight is falling on the ORP12 the resistance is fairly low - the actual value is not important but it will probably be in the range of 300Ω to 3kΩ. With R1b the two components form a potential divider with the base of Tr1 connected to the junction. If the resistance of the ORP12 was high the voltage at the junction would be low but since we are discussing the circuit with the voltage at a reasonable level Tr1 is biased on- that is, it is in a conducting state. In this condition the voltage across the transistor is small and since Tr2's bias depends upon this voltage, it is therefore held off and following the chain of R5 and R6 it will be seen that the base of Tr3 is connected to the positive supply and is therefore non-conducting.

As the light level falling on the ORP12 gets less and less, so does the voltage at Tr1 base until it reaches such a level that Tr1 tends to conduct less. As the current through Tr1 falls, the voltage drop across it increases and this starts to bias Tr2 into conduction.

As Tr1 and Tr2 share the same emitter resistor there is a regenerative action. Tr2, by becoming conductive, raises the voltage on the transistor side of R4 and since the base voltage on Tr1 is still at the same level this biases Tr1 even more into non-conduction.

The switching action is extremely rapid once it has started and the overall effect is that although the voltage at the base of Tr1 is only changing gradually and slowly, Tr2 is switched completely on at a certain point and Tr1 is switched off.

The circuit configuration just described is known as a Schmitt trigger and has a number of applications in several fields of electronic switches.

When Tr2 is switched on, the voltage at the collector falls and Tr3 is biased into full condition through R6. With Tr3 on, current is passed through the bulb, which of course lights up.

A relay can be used in place of the bulb - its coil resistance hardly matters and does not upset circuit conditions. However, relay coils, when used with transistors, should always be by-passed with a diode as shown. The reason for this is that when the relay is switched off a back voltage of very high level is created which can destroy the controlling transistor. The diode however safely shunts this to the negative line and so protects Tr3.

The 'dark off' (or 'light on') circuit can be made by reversing the ORP12 and R1 - which now becomes 33kΩ and is shown as R1a. In this condition Tr1 is on but as the light level increases the voltage at the base of Tr1 falls and the same action applies as before.

R1 in both versions of the circuit can be replaced by variable components and this enables the light levels at which the circuit triggers to be varied.

Note that Tr1 and Tr2 are silicon N-P-N types whereas Tr3 is a germanium P-N-P type. Tr3 passes nearly 200mA using the bulb shown when it is conducting and will be destroyed unless a heat sink is used - one of the fin types which clip over the body should be adequate

Note that Tr1 and Tr2 are silicon N-P-N types whereas Tr3 is a germanium P-N-P type. Tr3 passes nearly 200mA using the bulb shown when it is conducting and will be destroyed unless a heat sink is used - one of the fin types which clip over the body should be adequate.

When Tr3 is off the current consumption is very low - about 4mA and this will be little drain on a battery.

Layer batteries of the PP9 will work but they will not be able to supply the sort of current needed for the bulb for long periods and cell types such as the U2 would be far better. Better still would be the power supply described elsewhere as running costs using this will be a fraction that of using batteries.

Components List

R1a	33kΩ	Tr1	2N2926
R1b	270Ω	Tr2	2N2926
R2	4.7kΩ	Tr3	AC128
R3	10kΩ	LP1	5V torch bulb
R4	27Ω	D1	OA91
R5	390Ω	RL1	2000Ω relay (6V)
R6	2.2kΩ	SW1	On-off switch
LDR	ORP12	B1	PP9, 9V battery

CIRCUIT 18 - Metronome.

Before the advent of electronics a metronome comprised of an inverted pendulum, usually clockwork operated. At each swing of the pendulum a click was made and the regularity of beat helped to induce a sense of rhythm into the person listening to it. Even though it is our aim to champion the cause of electronics unfortunately our device can hardly replace those beautifully polished wooden and brass metronomes that top many pianos; on the other hand ours is cheap, easily constructed and just as reliable. The potential range of an electronic metronome is also far far greater than for the more traditional types.

The circuit of the electronic metronome is shown in Fig. 20 and consists simply of two transistors, a 15Ω loudspeaker, a capacitor, together with one fixed and one variable resistor.

Note that one of the transistors is N-P-N, while the other is P-N-P. The circuit is simply a modified multivibrator though those familiar with the more common arrangement of this circuit may find the similarities difficult to grasp at first.

When a voltage is applied to the circuit the voltage across the capacitor is small, since it is charging up and therefore the base of Tr1 is effectively at negative supply potential. However, as the capacitor charges up through R1 and VR1 the base of Tr1 is gradually made more and more positive until it reaches a point where Tr1 is biased into conduction. As Tr1 is in the collector-base circuit of Tr2, this means that Tr2 is also biased into conduction and a heavy current is passed through the speech coil of the loudspeaker. The voltage at the collector becomes more positive and so changes the conditions across the capacitor. As the voltage across it changes, it discharges and so the process starts all over again. The rate of the current pulses depends on the combined values of VR1 and R1 and the value of the capacitor.

With the values of the resistors shown (1MΩ and 100KΩ), C1 should be about 5μF to cover the normal beats required for music but for fast frequencies which reach up into the high audio range - up to 10kHz, the capacitor can be 250pF, while for pulses of up to 10 seconds apart a value of 10μF should be used. The range covered by VR1 is quite considerable.

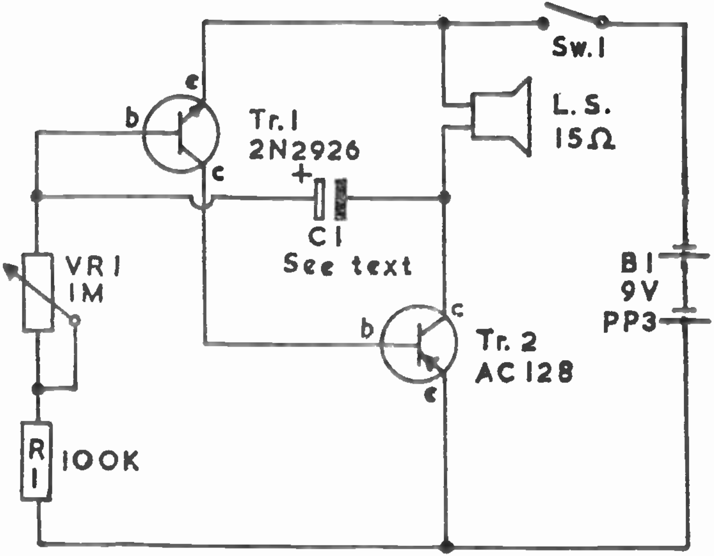

Sw.1
L.S.
15Ω
e
b
c
Tr.1
2N2926
+
C1
See text
VR1
1M
B1
9V
PP3
c
b
e
Tr.2
AC128
R1
100K

Fig. 20

The pulses passed through the loudspeaker are very healthy indeed and even a small speaker will provide more than enough output for even a group of musicians. The high level of output is due to almost the complete battery supply being switched on and off across the speech coil.

Guitarists and other musicians can make use of a modified circuit which instead of a loudspeaker operates a small earpiece.

Small 8Ω impedance earpieces, exactly like those sold with most transistor radios, are widely available and inexpensive. These can be used as a direct replacement for the loudspeaker, and because of the lower output needed, successful operation can be achieved using a 1.5V battery.

Using a single cell battery and earpiece the complete metronome can be built small enough to fit into the breast pocket of a jacket for portable operation.

Components List

R1	100kΩ
VR1	1MΩ lin. pot.
C1	See text
Tr1	2N2926
Tr2	AC128
LS	15Ω loudspeaker - see text
SW1	On-off switch
B1	PP3, 9V battery

CIRCUIT 19 - BEAT FREQUENCY OSCILLATOR

Those trying out a short wave receiver for the first time may not appreciate the need for a B.F.O. After all, any short wave receiver worthy of the name will be able to pick up literally hundreds of broadcast transmissions and no extra facilities are needed to hear these.

However, in the large gaps between the broadcast bands there are tens of thousands of other stations performing a variety of functions. Many of them use some form of coded transmission, not to make the signals hard to be heard, but to use a narrower bandwidth and obtain better results using a given aerial and transmitter power. Two of the most commonly used codings (although many will dispute the label 'coding') are morse on continuous wave (c.w.) and single sideband (s.s.b.)

Morse code is generally transmitted by interrupting the carrier wave - that is, when a dot is sent the transmitter will only be on for the short period denoting a dot. Similarly for a dash. As receivers are designed only to translate modulated signals into audio, you should not be able to hear c.w. signals. In practise these can be heard for a number of reasons and usually appear as noise bursts in sympathy with the signals. This however is very inefficient and weak morse cannot be heard. A B.F.O. converts the incoming signal to a series of tone bursts and these will be far, far stronger and much easier to read.

S.S.B. transmissions cannot be missed. They sound a bit like Donald Duck. You can recognise them as a human voice but it is almost impossible to understand what is being said. The reason that such signals can't be heard is not that they are single sideband but the fact that there is no reference carrier signal for the receiver to lock on. This explanation is greatly simplified but it is not necessary to understand the theory in order to hear such signal.

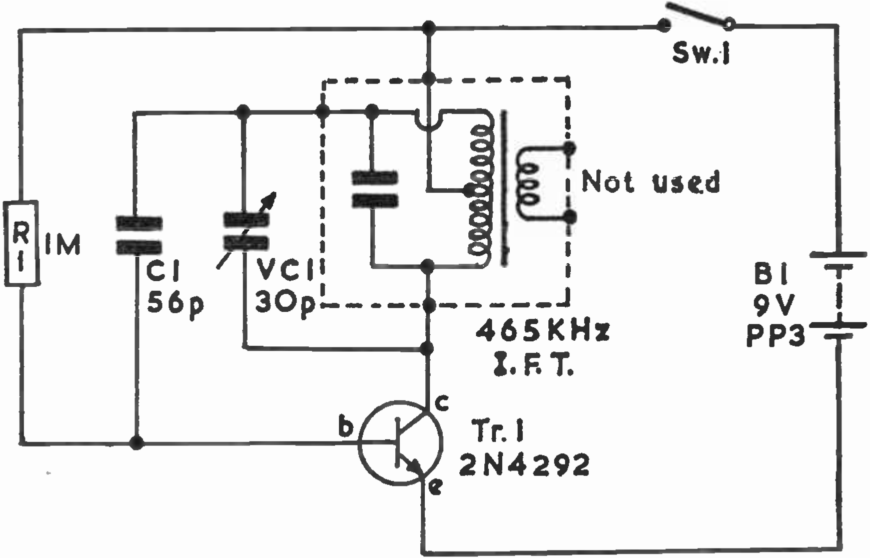

Sw.1
R1
1M
C1
56p
VC1
30p
Not used
465KHz
I.F.T.
B1
9V
PP3
c
b
e
Tr.1
2N4292

Fig. 21

When an r.f. signal at the carrier frequency is added to the S.S.B. transmissions, the signal can be clearly understood, though an absolutely correct frequency must be used otherwise the voice will be higher or lower in the audio spectrum - and this can be nearly as difficult to understand as the normal signal.

It would be quite possible and almost as efficient to reinsert the carrier at the aerial socket of the receiver. However, this would mean that the generator would have to cover a huge range. In practise the carrier is almost always reinserted at the i.f. stage as this enables the use of a signal generator which has only to be tuned over a very narrow frequency range.

Such a signal generator is known as a B.F.O. as it's main function is to enable c.w. signals to be heard and it does this by producing a frequency a few hundred, or a few thousand, cycles different from that of the i.f. The two frequencies beat together and produce an audio note which depends on the difference in frequency - thus the name - Beat Frequency Oscillator.

The same circuit is used for the addition of carrier to s.s.b. signals but the name B.F.O. bears no relationship to it.

The Circuit

A mere handful of components are required to build a B.F.O., the circuit is shown in Fig. 21.

The easiest method of obtaining a signal at i.f. frequencies is to arrange an i.f. transformer into the oscillator circuit. The B.F.O. must of course work at the i.f. of the receiver with which it is being used and there is no one standard frequency. Nearly all commercial sets use 465kHz or thereabouts, though for receivers intended primarily for the short wave band 1.6MHz is not uncommon. However, although the circuit is shown for a 465kHz i.f. receiver, the only modification for other frequencies is to use an i.f. transformer for that particular frequency.

There are a number of ways in which the i.f transformer could be coupled to oscillate, but the method used here. the Hartley Oscillator, is one of the simplest.

The transistor used is a 2N4292, an inexpensive plastic encapsulated silicon type. The tuned circuit which determines the oscillator frequency is the primary of the i.f. transformer which has VC1, 30pF in parallel with it. This allows for the small adjustments to the frequency to be made.

Oscillation is set up and maintained by C1, the feedback capacitor and the necessary base bias is provided by R1.

If no details are provided with the i.f. transformer it is quite easy to identify the connections and mate these up with those in the circuit. Five pins are normal. It will be found, using an ohmeter, that there are two conducting circuits, one which is found on two pins, the other on three pins. Ignore the pins associated with the 'two-pin circuit' - these are not used in this circuit.

Of the remaining three pins, actual resistance measurements must be used to identify them. All resistance readings will be low but it is quite easy to read them. The highest reading obtained will be across the pins representing that connecting to the collector and that which feeds to the feedback capacitor, the remaining connection goes to the positive supply line.

Connection to the receiver is not usually necessary as inductive coupling by strays is often sufficient but this means that the B.F.O. has to be physically quite near the i.f. amplifier stages. If this proves inadequate, an insulated wire can be connected to the collector of Tr1 and the other end 'dangled' near the i.f. transformers in the receiver. Direct capacitive coupling is rarely needed.

A switch and battery are shown in the circuit but of course the complete stage can be mounted inside the existing receiver and make use of the internal power supply. It will still be necessary to incorporate a switch.

Once completed and switched on, noting the above conditions for satisfactory operation, the variable capacitor VC1 should be set at mid-position and the iron dust core adjusted until the beat note is heard when a station is tuned in - even if the i.f. has been pre-aligned this is necessary as it is done to off-set the effect of VC1.

Components List

R1	1MΩ
C1	56pF
VC1	30pF variable
Tr1	2N4292
IFT	465kHz i.f. transformer
SW1	On-off switch
B1	PP3, 9V battery

CIRCUIT 20 - LIE DETECTOR

Most of us have seen films or TV programmes where someone is coupled up to a fiercesome looking piece of electronic equipment which will indicate whether the answers given are true or false. Most of this is fiction though there are such things as lie detectors and they do work, though their accuracy is much too marginal to allow them to be used very seriously. (Some countries, though not Britain do allow the use of these devices but I do not believe that the findings are ever allowable as evidence in court but only to assist enquiries).

Lie detectors make use of a peculiarity of the human body - that is, when a person is mentally disturbed they begin to sweat - not enough to cause perspiration but enough to moisten the skin slightly. The function of the detector is to measure the changing resistance of the skin which, when dry, is quite high, but when moist due to perspiration it falls markedly. No doubt there are far more scientific ways of describing the above but for our purpose it is sufficient to know that when a person is emotionally disturbed, such as when they lie, the skin resistance falls. The effect is remarkly rapid and the falling in resistance can be detected within a second or two.

One can notice the effect simply by holding two probes of a multimeter - set onto a high ohms range - but unless it is a very sensitive one, the deflection is so low as to be almost useless.

The circuit in Fig. 13 enables small changes in a high resistance - which is what we want to be shown - simply and at small cost.

A high gain silicon transistor - a 2N2926 - is used with a 250 microamp meter in the collector with a 1kΩ variable in parallel. A 1.5V battery acts as the supply.

The probes connect to the battery side of the meter and to the base and of course as soon as a resistance is connected across these, the transistor is biased on and the current starts to flow through the meter, this being shown as a deflection. Since the skin resistance even in the 'dry' state, varies considerably from person to person, it is necessary to adjust VR1 so that the current passing through the meter shows a sensible deflection - half scale is about right. Without VR1 acting

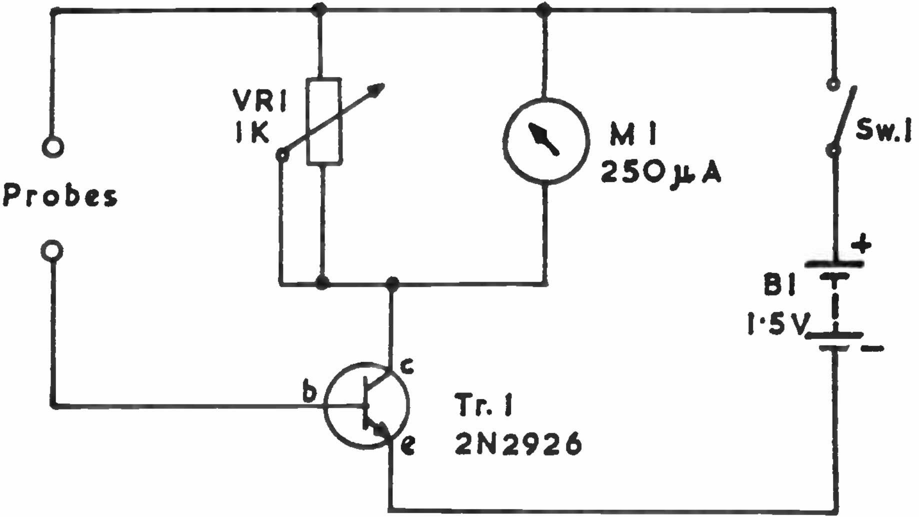


Fig.22

as a shunt, with some people who normally have moist skin, the meter would be hard against the back stop (i.e. the transistor will be drawing far more than 250 microamps).

The two probes can be made from 4in lengths of ½in diameter copper tubing - such as used by plumbers and wires can be soldered to these.

With only a small modification the circuit can be made to operate using a 9V battery, such as a PP3 as this is far easier to mount than a single 1.5V cell. For 9V operation the 1kohm potentiometer should be reduced to 47Ω (or 50Ω).

The meter used can be quite a cheap one - there is no point in spending a lot on one. Tape recorder level meters are not calibrated and rarely cost more than about 75p - often less - and these usually have a sensitivity of 250μA or thereabouts.

A lot of fun can be obtained using this little toy but be careful. Don't be too impressed by the results - deflections are often shown even when the 'victim' is telling the truth. But sure to tell people that there is no danger of any form of electric shock - many people may be frightened unless you assure them that there is no danger and lastly think carefully about what questions you put. With an instrument of this sort - and especially with it's name - you can cause some people deep offence if you ask very personal or embarrassing questions.

If these points are noted, and within its obvious limitations, the Lie Detector should provide quite a bit of fun at parties.

Components List

VR1	1kΩ lin. pot. See text
Tr1	2N2926
M1	250μA meter - See text
SW1	On-off switch
B1	1.5V pen cell battery

CIRCUIT 21 - ONE TRANSISTOR ELECTRONIC ORGAN

Electronics has led to major changes in the music field and not surprisingly! A small console electronic organ can have the range and power which a few years ago would have been impossible except in a cathedral or concert hall. Notes of any type can be simulated electronically by using filter networks.

Although for this reason electronic organs are far, far cheaper than traditional types, they are still very expensive and even kits cost over £100.

Toy electronic organs can provide great fun and retail for between £8 and £20 but even this sort of money is a lot to pay if you aren't sure of your capabilities.

The circuit here is a true electronic organ although the simplicity does mean that certain refinements have to be omitted. Nevertheless, with a little skill in setting up, the circuit can provide endless fun.

It is not a simple matter to build a keyboard as the mechanics are formidable, however, there is a very attractive alternative way of selecting the notes. This is done by having a probe - such as those supplied and used with test meters - with the other end of the wire connected to the circuit. This probe is then touched at various resistors in a circuit and completes the electrical connection. The note produced by the electronic organ depends on the resistor selected.

Looking at the circuit, assume the probe, which is connected to the base of Tr1, is touched at the floating end of R_E. The transistor is biased on via R1 and R_E and is able to conduct. In the collector circuit there is an audio transformer with a tapped primary. The loudspeaker is connected to the secondary.

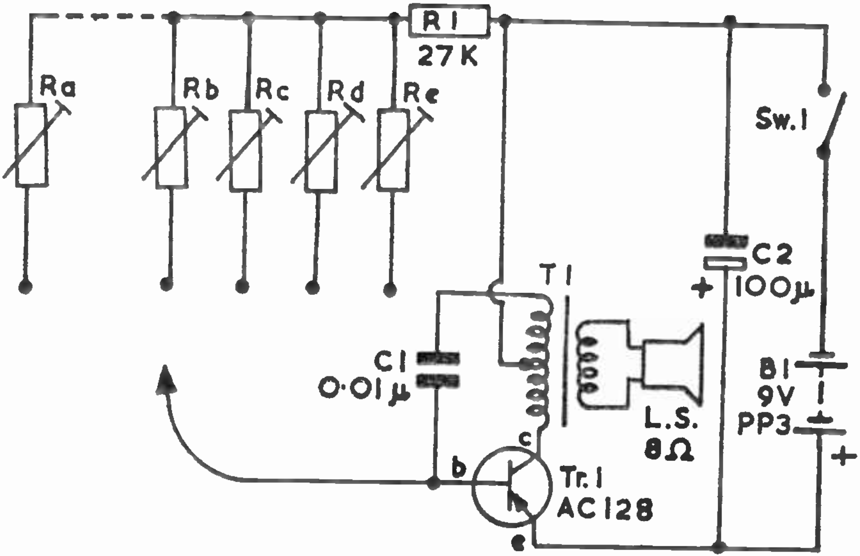

R1
27K
Ra
Rb
Rc
Rd
Re
Sw.1
C2
100µ
+
T1
C1
0·01µ
L.S.
8Ω
B1
9V
PP3
+
c
b
e
Tr.1
AC128

Fig. 23

Because of the way in which the transformer primary is connected, the transistor will oscillate in the audio range and the frequency of oscillation depends on the value of the bias resistor.

Here we are converting the circuit into an electronic organ by providing a whole range of bias resistors, in fact, one for each note and these are shown as R_A, R_B, R_C etc. It is necessary to choose the note very accurately and for this reason fixed resistors would be no good and small presets have to be used, one for each note. If these are 500kΩ, any note between about 150Hz and 10kHz can be tuned. If the range is well outside this and found to be unuseable, the value of C1 can be changed. Raising it's value will lower the range, reducing it will raise it.

Ideally the resistors used for the notes would all be in series rather than in parallel as shown here as this would allow for small value components and thus make tuning easier. On the other hand it becomes almost impossible to tune the instrument up originally.

About 18 notes will enable most tunes to be played and with these, tuning is done as follows.

Tune one of the middle notes to about 'middle C' which can be found on most instruments. Notes on one side should then follow the scale up, on the other side going down. It is possible to tune the notes by ear but it is far easier to do it with an instrument.

Considerable care should be taken in this process and although it will take quite a while, once tuned correctly no further adjustments are necessary.

The inclusion of R1 means that whatever the settings of the presets no harm can befall the transistor.

The circuit itself is very simple and skill in this case depends largely on the construction method used. The preset pots can be arranged on Veroboard in such a way that the copper strips represent the notes, or a simple keyboard can be built.

Only one note can be played at a time for if two notes are touched at the same time the presets will be in parallel and form a completely different note.

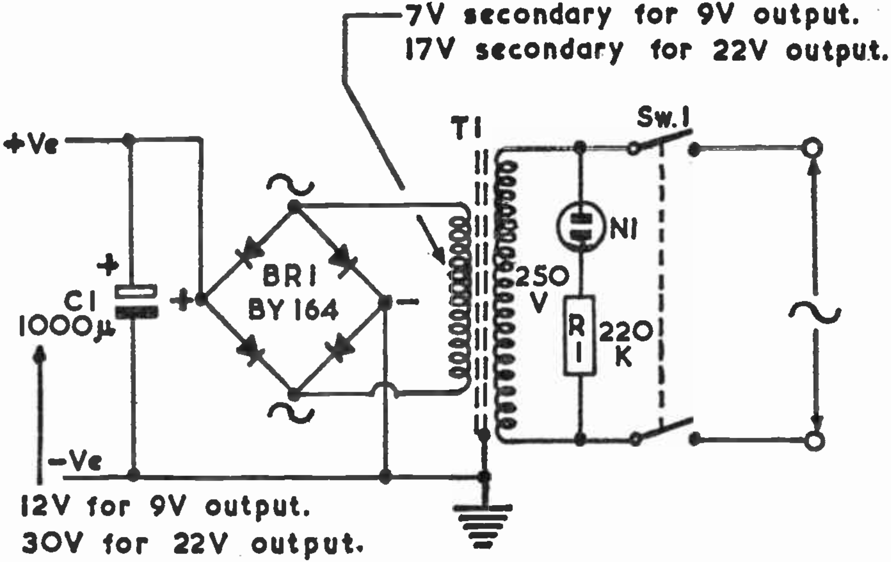
The current consumption is not all that high and a PP3 battery is quite sufficient.

It is not easy to incorporate a volume control into this design - the very simplicity precludes it - but it is hardly necessary as the output level is only 50mW or so.

A simple on/off switch and C2, a 100μF capacitor to decouple the supply are the only additional components.

Components List

R1	27kΩ
R_A etc.	500kΩ skeleton preset pots
C1	0.01μF See Text
C2	100μF 12V
Tr1	AC128
T1	Transistor output transformer with tapped primary.
LS	8Ω loudspeaker
SW1	On-off switch
B1	PP3, 9V battery



7V secondary for 9V output.
17V secondary for 22V output.

12V for 9V output.
30V for 22V output.

Fig. 24

CIRCUIT 22 - POWER SUPPLY

With the exception of the multipurpose tester, which should be portable, and the lie detector, which has to be super safe because of the way it is used, all the circuits previously described can be operated from a mains power supply.

Only four supply voltages have been suggested, 9V (for the majority) 1.5V (for the lie detector which is not applicable) 18V for the morse practice oscillator and 22V for the 5W amplifier.

One general circuit can supply all of these but as the 18V is not far off 22V and this will operate the practice oscillator, the circuit for the power supply is designed for 9V and 22V.

This circuit should not be attempted by anyone who is not sure of what they are doing - the mains supply is used and this can be lethal.

The supply is connected via a double pola on-off switch and is connected across the primary of the mains transformer. If desired an indicator neon can also be wired across the circuit. Most of these have the necessary resistor R1 built into them so this will not usually be necessary, but if other neons are used this should be included.

Many transformers have several connections on the primary to match the local supply voltage and the correct connections should be made.

The secondary voltage of the mains transformer will depend on the voltage required and should be about 7V for a final 9V supply, and 17V for 22V.

The secondary connects directly onto a silicon bridge rectifier type BY164 made by Mullard. However, many types are suitable. If necessary four silicon divides can be used as long as they have the necessary voltage and current ratings.

The output from the power supply connects to a high value capacitor whose working voltage must be at least as high as that shown in the circuit.

The body of the transformer and the negative line should be connected to the earthing pin on the mains plug.

Components List

T1 Mains transformer. 250V primary and either 7V or 17V secondary at 500mA.
BR Silicon bridge rectifier, BY164 or simiiar.
C1 1000μF 12V or 30V
SW1 Double pole on-off switch
Mains neon

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.

First Published December 1971

Printed by
V. Cooper & Partners Ltd., Flitcroft Street, London, W.C.2
for Babani Press, The Publishing division of Babani Trading
and Finance Co. Ltd., The Grampians, Western Gate,
London, W.6

BERNARD'S AND BABANI PRESS RADIO BOOKS

No.		Price
BP1	Handbook of Transistor Equivalents and Substitutes	40p
BP2	Handbook of Radio, T.V. and Industrial Tube & Valve Equivalents	40p
BP3	Handbook of Tested Transistor Circuits	40p
BP4	International Handbook of the Worlds Short Wave, Med. and Long Wave Radio Stations & F.M. & T.V. Listings	35p
BP5	Boys Book of Simple Transistor Circuits	30p
BP6	Engineers & Machinists Reference Tables	20p
BP7	Radio & Electronic Colour Codes & Data Chart	15p
BP8	Sound and Loudspeaker Manual	50p
96	Crystal Set Construction	8p
100	A Comprehensive Radio Valve Guide, Book 1	30p
104	Three Valve Receivers	10p
121	A Comprehensive Radio Valve Guide, Book 2	30p
126	Boys' Book of Crystal Sets and Simple Circuits	18p
129	Universal Gram-Motor Speed Indicator	8p
138	How to Make F.M. and T.V. Aerials, Bands 1, 2 and 3	18p
141	Radio Servicing for Amateurs	20p
143	A Comprehensive Radio Valve Guide, Book 3	30p
146	High Fidelity Loudspeaker Enclosures	37½p
147	Practical Tape Recording Handbook	30p
149	Practical Stereo Recording Handbook	20p
150	Practical Radio Inside Out	25p
156	Transistor Circuits Manual, No. 1	15p
157	A Comprehensive Radio Valve Guide, Book 4	30p
160	Coil Design and Construction Manual	30p
161	Radio, T.V. and Electronics Data Book	25p
163	Transistor Circuits Manual, No. 2	15p
165	Hartley on Hi-Fi Book 1 — Radio Tuners	30p
168	Transistor Circuits Manual, No. 4	15p
170	Transistor Circuits for Radio Controlled Models	40p
171	Super Sensitive Transistor Pocket Radio	20p
173	Practical Transistor Audio Amplifiers, Book 1	20p
174	Transistor Subminiature Receivers	32½p
175	Transistor Test Equipment and Servicing Manual	25p
176	Manual Transistor Audio Amplifiers	40p
177	Modern Transistor Circuits for Beginners	40p
178	A Comprehensive Radio Valve Guide, Book 5	30p
179	Transistor Circuits Manual, No. 5	30p
181	22 Tested Circuits using Micro Alloy Transistors	25p
183	How to Receive Foreign TV Programmes on your set by Simple Modifications	32½p
184	Tested Transistor Circuits using Professional Printed Circuit Modules, Transistor Circuits Manual No. 3	20p
185	Tested Shortwave Receiver Circuits using MAT'S	30p
186	Tested Superhet Circuits for Shortwave and Communications Receivers using MAT'S	30p
187	The TSL Mark "4" Valved FM Tuner and its Construction	20p
188	Construction of the B.H. High Fidelity "14" watt Audio Amplifier	10p
191	Practical Car Radio Handbook	30p
501	ABC's of Magnetism	30p
502	ABC's of Missile Guidance	30p
	Resistor Colour Code Disc Calculator	10p