MODERN TRANSISTOR CIRCUITS FOR BEGINNERS

by
Clive Sinclair

35 practical construction circuits.

Complete assembly drawings, circuit diagrams and parts lists.

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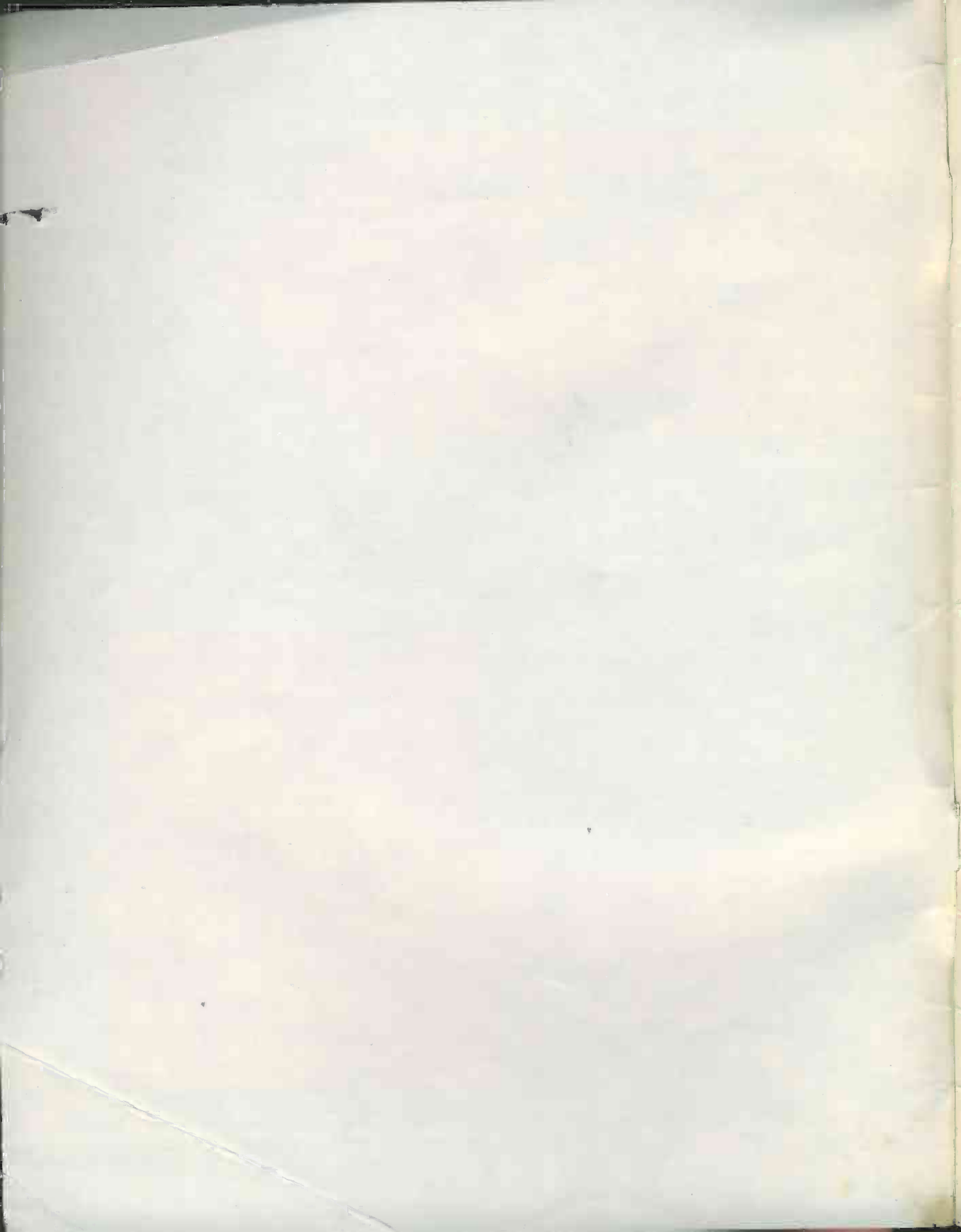Full colour codes used in transistor circuits.

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Modern Transistor Circuits for Beginners

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CLIVE SINCLAIR

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CONTENTS

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CHAPTER 1

The Components Used in Transistor Circuits

About a dozen different types of component are used in the circuits contained in this book and in other transistor circuits. Each type of component has its own symbol and the meaning of these symbols must be understood before a circuit diagram can be properly interpreted. Circuit diagrams are merely intended to show what components are used in a piece of electronic equipment and the way in which they are connected. They do not show what physical position each component has in the equipment. It would be possible to use drawings of the individual components in such a diagram and this is sometimes done but it becomes far too clumsy a method where complex circuits are concerned. Some of the earlier circuits in this book have both circuit diagrams (those using symbols) and wiring diagrams (those using actual illustrations of the components). These should enable the constructor to gain a knowledge of the circuit as a whole. One important point to remember is that specification of a component does not necessarily indicate the size or shape of that component. For example, if a 500 pF tuning capacitor is specified and no other details are given any 500 pF tuning capacitor may be used. The size and shape of 500 pF tuning capacitors made by different manufacturers vary enormously, as do the prices and in this case the choice is up to the constructor. If, however, a particular make of 500 pF tuning capacitor is specified, this make should, if possible, be used since its size has probably been chosen by the designer to fit in well with the set.

It is not always necessary to adhere precisely to the specification given for a component but it is difficult for a beginner to know when deviation is possible and to what degree. In this chapter some indication of generally permissible deviation is given and throughout the book the possibilities for deviation in a given circuit are outlined. The constructor should take note of these indications since they will help to provide the experience he needs.

Resistors.

The degree of resistance in a simple circuit determines the amount of current that flows in the circuit for a given voltage. The greater the resistance the smaller the flow of current. Resistors are two terminal components having a fixed and known degree of resistance. The resistance is measured in ohms and may be anything from less than 1 ohm to many millions of ohms. For the sake of convenience 1 thousand ohms is known as 1 Kilohm and 1 million ohms is known as one megohm. These are often further abbreviated to 1K ohm and 1M ohm respectively. The Greek letter omega is often used as an abbreviation of the word ohm on circuit diagrams.

Any value of resistance is possible but normally only certain " preferred " values are used — these are : — 1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2 ohms and repeating in the next decade 10, 12, 15 ohms, etc. Thus a circuit may specify a resistor of 2.7K ohms (2.7 thousand ohms) but not one of 2.5K ohms since this is not a standard value.

Another piece of information normally given when a resistor is specified is the power rating, i.e. the amount of power a resistor can handle. Resistors are normally rated at one of the following $\frac{1}{8}$ watt, $\frac{1}{4}$ watt, $\frac{1}{2}$ watt, 1 watt and 5 watts. With transistor circuits, however, resistors very rarely need handle more than $\frac{1}{8}$ watt so that any of these may be used. $\frac{1}{4}$ watt and $\frac{1}{2}$ watt resistors are most common. If a $\frac{1}{8}$ watt resistor is specified there is no reason why a resistor of higher rating should not be used, $\frac{1}{2}$ watt or 1 watt for example, so long as there is sufficient room to accommodate it, the higher rating being larger.

Also normally specified is the tolerance of the resistor. Resistors can not be made with precisely the resistance specified and they always deviate from it slightly one way or the other. The tolerance is the measure of accuracy of the resistor and is expressed in terms of a percentage deviation, thus $\pm$ 5%, $\pm$ 10%, or $\pm$ 20%. For example, a 100K ohm resistor which has a tolerance of $\pm$ 10% may in fact have any value between 90K ohms and 110K ohms. The designer of a circuit knows what deviation is permissible for each resistor he specifies thus if he specifies that a certain resistor should be $\pm$ 10% then a $\pm$ 20% resistor should not be used. A $\pm$ 5% type could be used however because this would be even nearer the ideal value than necessary. The wider the tolerance the cheaper the resistors, $\pm$ 20% being the cheapest. When no tolerance is specified, as is often the case, a $\pm$ 20% type may be used.

The value of a resistor may be printed on it but more usually a colour code is used. This is illustrated in Fig. 1 and should be interpreted as follows : — The colour of the body (1) or of the first band (2) gives the first figure. The tip (1) or second band (2) gives the second figure. The band or dot in the centre (1) or the third band gives the number of noughts following the first two figures. The fourth band (2) or the gold or silver tip (1) indicates the tolerance. The absence of a third band or gold or silver tip means that the tolerance is $\pm$ 20%. Typical examples are given opposite : —

a	b	c	d	Value
Brown	Black	Black	Silver	10 ohms ± 10%
Red	Red	Yellow	Gold	22,000 ohms ± 5%
Yellow	Violet	Red	None	4.7K ohms ± 20% i.e.
				4,700 ohms ± 20%
Red	Black	Blue	Silver	20 megohms ± 10% i.e.
				20,000,000 ohms ± 10%

Volume Controls

Volume controls are resistors that can be varied between zero ohms and a specified maximum value by the rotation of a spindle to which a knob is connected (spindle control type) or by rotation of the body of the control itself (rim control type). Many types include a single pole switch which is used as the on/off switch for the equipment in which the control is used.

In a volume control, rotation of the spindle causes a metal wiper to move from one end to the other of a carbon or wire track. Three external contacts are provided. One for each end of the track and one for the metal wiper. Two extra contacts are provided for the switch when one is included.

The most commonly used values of volume control for transistor circuits are 2K ohms, 5K ohms, 10K ohms and 50K ohms. (The value referring to the total resistance of the track) but volume controls are made with values ranging from about 5 ohms to about 5 meg ohms.

Three different types of track are used :— linear, logarithmic and semi-logarithmic (log. and semi-log.). These definitions refer to the rate at which the resistance changes as the spindle is rotated. With the linear type the resistance changes at the same rate all along the track but in the log. and semi-log. types the resistance change for a given degree of rotation is much greater at one end of the track than at the other, the rapid change end corresponding to the position of maximum volume. If one of these three types is specified either of the other may be used instead without altering the performance of the circuit but most of the change in volume may then occur at one of the other ends of the track making delicate setting of the volume less easy. In most cases this will not matter greatly.

Fixed Capacitors

A capacitor consists essentially of two metal plates separated from one another by an air gap or layer of insulating material. A capacitor offers a complete block to d.c. but permits an A.C. signal to pass. The larger the value of the capacitance the lower its resistance or impedance to an A.C. signal. A high frequency A.C. signal is impeded less by a capacitor of a given value than is an A.C. signal of low frequency. Thus the higher the frequency the lower the value of capacitor required to pass a signal with a given degree of loss. Whatever the value of the capacitor no d.c. should be passed at all.

The unit of capacitance is the farad but since this is an extremely large unit it is normal to talk in terms of microfarads (mfd. — millionths of a farad) and picofarad (pf — millionths of a microfarad). Even a microfarad is a very large value for a capacitor.

Capacitors are divided into two main types, electrolytic and non-electrolytic. The latter range in value from about 1 pf to 1 mfd. and the former from about 1 mfd. to about 1,000 mfd. Electrolytic capacitors are normally confined to A.F. circuitry and they are polarised. That is to say one end is positive and the other end is negative and they must always be connected the right way round. The negative side of an electrolytic is almost always visibly connected to the outer casing and this provides a convenient means of identification. Sometimes the positive end is indicated by a red band or splash of paint or by a positive sign. In the circuit diagram a positive sign is used to show which side is which. Non-electrolytic capacitors are not polarised and may be connected either way round.

Non-electrolytic capacitors are made in various types which differ in the dielectric or insulating material used. The most common types are paper, ceramic and plastic (polystyrene, melinex, etc.). In many applications these are interchangeable, that is to say, it does not matter which type is used. Where a particular type is specified, however, it should be used if possible.

As well as the value of a capacitor required for a particular position in a circuit the working voltage is normally specified. This is an indication of the maximum voltage applied to the capacitor in the working of the circuit. With non-electrolytics the lowest voltage types are more than able to cope with the highest voltages encountered in ordinary transistor circuitry and the working voltage rating need not, therefore, be taken into consideration. With electrolytics, however, more care must be taken. A typical component called for might be 4 mfd. 6 v.w. (volts working). In this case a 4 mfd. 12 v.w. capacitor may be used or one of higher voltage still if it is small enough, but a 3 v.w. capacitor must not be used as it would probably be destroyed.

When a capacitor of a required value is not available it is normally quite permissible to use one of higher value. One of much lower value should not be used however.

It is worthwhile remembering that the value of an electrolytic capacitor is never very critical. Where a 6 mfd. type is specified the use of 8 mfd

BRITISH AND RMA–JAN [USA] RESISTOR AND CAPACITOR COLOUR CODES

INSTRUCTIONS – IDENTIFY COMPONENT BY REFERENCE TO ILLUSTRATIONS IN LOWER COLUMNS, THEN USE THE TABLE IMMEDIATELY BELOW TO DETERMINE THE VALUES REPRESENTED BY THE COLOURS.

COLOUR	DIGITS OR Nº OF ZEROS	RESISTORS BRITISH, RMA/JAN		CAPACITORS, MOULDED MICA, BRITISH, RMA & JAN.			CAPACITORS, MOULDED PAPER		CAPACITORS, CERAMIC, BRITISH, RMA/JAN			
		MULTIPLIER	TOLERANCE	MULTIPLIER	TOLERANCE	CLASS OR CHARACTERISTIC	MULTIPLIER	TOLERANCE	MULTIPLIER	TOLERANCE OVER 10pF	TOLERANCE 10pF & UNDER	TEMP. COEFF. PTS/MIL / °C.
BLACK	O	1		1.	20%	A	1	20%	1	20%	2pF	O
BROWN	1	10		10		B	10		10	1%		− 30
RED	2	100		100	2%	C	100		100	2%		− 80
ORANGE	3	1000		1000	3% (RMA)	D	1000		1000	2½% (RMA)		− 150
YELLOW	4	10,000		10,000		E	10,000	5%	10,000 (RMA)			− 220
GREEN	5	100,000			5% (RMA)	F (JAN)				5%	0·5pF	− 330
BLUE	6	1,000,000				G (JAN)						− 470
VIOLET	7	10,000,000										− 750
GREY	8	100,000,000				I (RMA)			÷ 100		0·25pF	+ 30
WHITE	9	1,000,000,000				J (RMA)		10%	÷ 10	10%	1pF	−330+500 JAN +120−750 RMA
GOLD		÷ 10	5%		5% (JAN)		÷ 10	5%				
SILVER		÷ 100	10%		10%			10%				
NO COLOUR			20%					20%				

RESISTORS
BRITISH, RMA/JAN

COLOUR CODE GIVES RESISTANCE IN OHMS

COLOUR BAND SYSTEM

1ST. DIGIT 2ND. DIGIT

No. OF ZEROS OR MULTIPLIER TOLERANCE

BODY, TIP, DOT, OR NARROW-BAND SYSTEM

BODY COLOUR–1ST. DIGIT

TIP–2ND. DIGIT MULTIPLIER TOLERANCE

2ND. DIGIT BODY COLOUR 1ST. DIGIT

MULTIPLIER TOLERANCE BODY COLOUR 1ST. DIGIT

MULTIPLIER 2ND. DIGIT

EXAMPLE: YEL/VIOLET/RED/SILVER
4700 Ω ± 10%

CAPACITORS
MOULDED MICA

COLOUR CODE GIVES CAPACITY IN pF

6-DOT SYSTEM

WHITE 1ST. DIGIT 2ND. DIGIT

CLASS MULTIPLIER TOLERANCE

BUTTON SILVER–MICA

CHARACTERISTIC READ CLOCKWISE
TOLERANCE
MULTIPLIER 1ST. DIGIT
3RD. DIGIT 2ND. DIGIT

JAN 6-DOT SYSTEM

BLACK 1ST. DIGIT 2ND. DIGIT

CHARACTERISTIC MULTIPLIER TOLERANCE

EXAMPLE, 6-DOT SYSTEM:
WHITE–BROWN–GREEN } 150 pF 10%
WHITE–SILVER–BROWN   CLASS J.

CAPACITORS
MOULDED PAPER

COLOUR CODE GIVES CAPACITY IN pF

VOLTAGE RATINGS IN HUNDREDS OF VOLTS. ONE COLOUR BAND FOR VOLTAGES BELOW 1000V.

BAND SYSTEM

2ND. DIGIT MULTIPLIER
1ST. DIGIT OUTER FOIL

VOLTAGE RATING

TOLERANCE OUTER FOIL

DOT SYSTEM

2ND. DIGIT MULTIPLIER
1ST. DIGIT VOLTAGE RATING

ARROW POINTS TO OUTER FOIL END

SILVER 1ST. DIGIT 2ND. DIGIT

CHARACTERISTIC MULTIPLIER TOLERANCE

EXAMPLE, BAND SYSTEM:
RED–VIOLET–RED–YELLOW–BROWN–RED
2700pF 5% 1200 V.

CAPACITORS
CERAMIC

COLOUR CODE GIVES CAPACITY IN pF

MOULDED INSULATED TYPE

TEMP. COEFF. 1ST. DIGIT 2ND. DIGIT

MULTIPLIER TOLERANCE

TO AVOID CONFUSION WITH A RESISTOR, NOTE THAT FIVE COLOUR BANDS ARE USED. ONE BROAD, FOUR NARROW.

STAND-OFF CERAMIC

TEMP. COEFF. 1ST. DIGIT 2ND. DIGIT

MULTIPLIER TOLERANCE

DIPPED PHENOLIC TYPE OR NON-INSULATED

1ST. DIGIT, 2ND. DIGIT
TEMP. COEFF.
MULTIPLIER TOLERANCE

1ST. DIGIT MULTIPLIER
2ND. DIGIT

HIGH CAPACITY CERAMIC NOT TEMPERATURE COMPENSATED
LIGHT BLUE BODY DC WORKING VOLTS
BROWN-150
ORANGE-350
1ST. DIGIT GREEN-500
2ND. DIGIT
MULTIPLIER TOLERANCE

EXAMPLE, MOULDED INSULATED TYPE:
RED–BLUE–GREY–BROWN–GREEN
680pF 5% TEMP. COEFF −80 °C

Fig. 1. Colour code for Resistors and Capacitors.

Spindle type
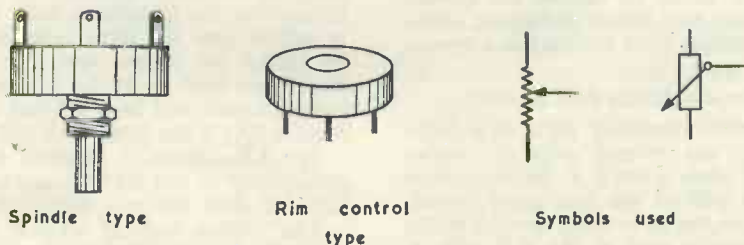
Rim control type

Symbols used

Fig. 2. Volume control symbols.

or even a 10 mfd. type will not alter performance. It is not wise, however, to use a value which is noticeably less than that specified, particularly where de-coupling capacitors are concerned.

Some extremely small electrolytics called tantalum capacitors have recently been put on the market. These have no special properties other than their small size and they may be used wherever an electrolytic is specified.

Variable Capacitors.

Tuning is normally performed in a radio set by means of a variable capacitor (often called a tuning capacitor). In simple receivers a single gang type is normally used but in more complex sets a twin gang capacitor, which is, in effect, two tuning capacitors mechanically coupled, is needed.

Until recently the majority of tuning capacitors used an air gap as the dielectric but the need for miniaturisation has now made types with a solid dielectric more popular where use with transistors is concerned. The smallest airgap types are about $1\frac{1}{2}''$ square by $1''$ deep whereas a solid dielectric capacitor has recently been introduced which is only three fifths of an inch square by three eighths of an inch deep.

The maximum capacitance of tuning capacitors designed for the broadcast band ranges from about 100pf. to 500pf. depending on the design. In a circuit which uses only a single gang capacitor the use of a type having a value other than that specified will alter the tuning range slightly but will not affect the performance. Circuits which use two gang capacitors are more critical, however, and the type specified should always be used. A solid dielectric capacitor can always be used in place of an air dielectric type of the same value.

As well as variable capacitors used for tuning purposes there are semi-variable types known as trimmers which are used for making small adjustments to some part of the circuit. Once set these are normally not varied. Twin gang tuning capacitors normally have two trimmers built-in; one for each gang. These are provided for alignment purposes.

The very small types of solid dielectric tuning capacitor should be treated with a certain amount of care. They are remarkable for their size but can be damaged quite easily by turning the spindle beyond the end stop. As a matter of interest, something over 100 separate parts are used in a typical capacitor of this type.

Coils, R.F. Chokes and Ferrite Rod Aerials.

The R.F. or radio frequency parts of a radio receiver normally use several coils of various types. The first of these is the R.F. transformer or coil which forms part of the first tuned circuit. In sets which do not use an external aerial a ferrite rod aerial is normally used as the R.F. coil. A ferrite rod aerial is an R.F. transformer wound on a rod or slab made of a material known as ferrite. The length of the rod may be anything from $1\frac{1}{2}''$ to a foot. The longer the rod the greater the signal it will pick up. The symbol for an R.F. coil is shown in Fig. 6. Sometimes, when the coil is adjustable as is usually the case, an arrow is drawn through the coil.

An I.F. transformer is merely an R.F. transformer which is tuned and designed to operate at a single fixed frequency. This type of coil is normally enclosed in a can which also includes a fixed capacitor across the primary.

An R.F. choke is a single coil of wire wound on a dust iron core or ferrite core. The name is normally abbreviated to R.F.C. It operates in the opposite way to a capacitor. That is to say it passes d.c. without any restriction but offers an impedance (or resistance) to A.C. which increases with frequency.

R.F. transformers and chokes are specified by means of their inductance. The unit of inductance is the Henry but for R.F. this is rather large and it is more normal to talk in terms of milli-Henries (thousandths of a Henry) or mH and microHenries (millionths of a Henry). A typical R.F. choke might have an inductance of 2.5mH and a typical Medium Wave aerial coil might have an inductance of 400 microHenries.

In many circuits for the home constructor some or all of the R.F. coils are home made in which case full constructional details, including the number of turns of wire, are normally given.

A.F. Transformers.

A.F. transformers are structurally similar to R.F. types but consist of a great many more turns often of very thin wire. Their inductance is often of the order of several Henries.

Two main types are used in transistor circuitry. The first is the interstage transformer which is designed to match the output impedance of one transistor to the input impedance of the next. The second is the output transformer which matches the output impedance of the last transistor to the impedance of the loudspeaker. A.F. transformer normally consist of two windings; a primary and a secondary. In some cases one or the other of these is centre tapped. The turns ratio, that is, the ratio between the number of turns in the primary and the number in the secondary, is normally included in the specification. Sometimes, the impedance ratio is quoted instead in which case the turns ratio can be calculated by taking the square root. For example, if the impedance ratio is 16 to 1 (often written 16:1) the turns ratio will be 4 : 1 and if the impedance ratio is 50 : 1 the turns ratio will be about 7 : 1.

An A.F. choke is identical to a transformer except that it has no secondary. The symbol is also the same but with the secondary omitted.

The various leads of an A.F. transformer can normally be identified by a colour code. Each manufacturer tends to have his own colour code unfortunately but details are normally included with the transformer itself.

R.F. coil symbol.

R.F. choke symbol.

Primary. Secondary.

Untapped

Tapped primary.

Fig. 5. R.F. coils and chokes.

Fig. 6. A.F. transformer and symbols.

Typical R.F. coil.

R.F. coil wound on ferrite rod.

R.F. choke.

Typical A.F. transformer

Tapped secondary.

Symbol

Symbols used.

Symbol

Symbol

Fig. 3. Fixed capacitors.

Fig. 4. Variable capacitors.

Non-electrolytic capacitor.

Electrolytic capacitor.

Single capacitor.

Trimmer.

Twin gang type with trimmer.

9

Loudspeakers, Headphones and Earpieces

Loudspeakers suitable for use with transistors are made in a large variety of sizes, shapes and impedances. Circular types are available with diameters of 1¾", 2", 2¼", 2½", 3", 3½", 4", 5", 6" and 7" and elliptical types are available in the following sizes 2 x 3", 3 x 5", 4 x 7" and 5 x 7". Larger sizes are also available. Contrary to popular belief, the smaller the speaker the more power required to drive it to a satisfactory volume level.

The first specification given for a loudspeaker is its impedance. The most common impedances are 3 and 10 ohms and these values are normally used with an output transformer. A great many other impedances are possible however and many circuits use a high impedance speaker to avoid the need for an output transformer. When a speaker of a particular impedance is specified in a circuit, that impedance should be used since the use of a speaker having a different impedance will normally result in a considerable loss of power or in distortion occurring at a low volume level.

Another important factor that controls the performance of a loudspeaker is the strength of the magnet. This is normally expressed as so many Gauss: the Gauss being the unit of magnet strength. The lowest strength normally used is 5,000 gauss and a loudspeaker with a magnet of this strength would not be very sensitive. For the very smallest loudspeakers used with transistors, 10,000 gauss is about the strongest magnet used. Naturally, the stronger the magnet is the more expensive is the speaker. Within the limitation of cost, then, a speaker with a high gauss magnet should always be used in preference to one with a low gauss magnet.

With headphones, manufacturers do not normally quote figures for magnet strength and the only information given is the impedance. The specific impedance is not normally as important as it is with loudspeakers because most circuits deliver very much more power than is actually required to drive a pair of headphones so maximum efficiency is not necessary. Many circuits just call for either low or high impedance 'phones without giving a specific figure. In this case low impedance may be taken as meaning up to 250 ohms and high impedance as above this figure..

There are two different types of earpiece, crystal and magnetic. Crystal earpieces always have very high impedances and are extremely sensitive although their quality is sometimes poor. They do not pass or conduct d.c., however, and are only suitable for certain types of circuit. Magnetic earpieces may be high impedance or low impedance and they vary a great deal in quality of reproduction and sensitivity. For most simple transistor circuits, high impedance, high sensitivity earpieces are required; the best types being those designed for use with hearing aids. For more complicated radios, designed to operate loudspeakers, low sensitivity earpieces are quite satisfactory.

Batteries.

The word battery really means several cells joined together but it is often used to describe a single cell as well, and so, for the sake of convenience, this slight misuse will be adopted here.

Two different types of battery are now made which are suitable for use with transistors. The most common and the cheapest is the zinc-carbon type such as those used in torches. Zinc carbon batteries are available in a great variety of shapes and sizes and special types designed for transistor equipment and made on the layer principle can be obtained easily. The other type is the Mallory mercury cell which is available in a wide variety of single cell sizes but in very few multi-cell units. They are most useful when a very small single cell is required (the smallest, the RM 312, is smaller than an aspirin) or where constant voltage with life is required. When a circuit specifies a mercury battery then one should be used since it has probably been specified because of it's special properties. A mercury battery may always be used in place of a zinc-carbon one, however, and will give a longer life if the two are the same size.

Diodes.

A diode is a two terminal device which conducts electricity in one direction but not in the other. There are many types made but those used in transistor circuits such as those described in this book are known as germanium point contact diodes.

Diodes are rather prone to damage due to overheating so special care should be taken when soldering them into a circuit.

One end of a diode is normally coloured red or has a red or white band round it. This is known as the positive end and is usually indicated as such on a circuit diagram.

Transistors.

A transistor has three terminals named the collector, base and emitter. On the left in fig. 10 are shown connections on the three different types normally used viewed from the wire end.

Nothing will be said about the properties of the transistor here because these will be discussed throughout the book. It should be remembered, however, that the transistor is even more prone to damage through overheating than the diode and great care must, therefore, be taken when soldering. The best plan is to hold the lead with a pair of pliers above the point being soldered.

Speaker

Earpiece.

Headphones.

Fig. 7. Symbols for loudspeaker, headphones and earpiece.

Single cell battery.

Two cell battery.

Multiple cell battery.

Fig. 8. Battery symbols.

Red tip.

Fig. 9. Diode symbols.

Spot

E B C

E B C

E B C

Lead connections.

E = emitter.

B = base.

C = collector.

Fig. 10. Transistor connections and symbols.

Headphones.

Battery

Sw. 1

Tr. 1

D1

Rd.

Grn.

C1

Ylw.

Ble.

C2

L1

Fig. 11. Circuit No 1. with wiring diagram.

Headphones.

Battery

Sw. 1

Tr. 1

Red tip

D1

Rd.

Grn.

Aerial coil

Ylw.

Ble.

C1

C2

To Aerial

To earth

Earpiece or headphones.

Battery

Sw. 1

Tr. 1

Rd.

Grn.

C1

Ylw.
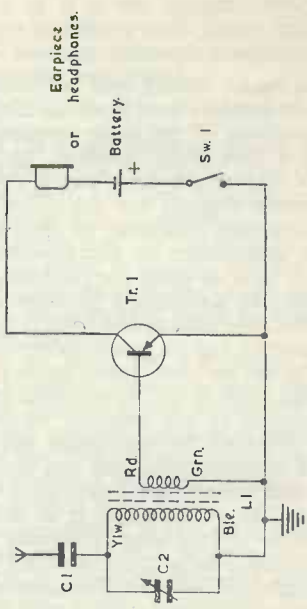
Ble.

C2

L1

Fig. 12. Circuit No 2

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CHAPTER TWO

Simple Transistor Radio Circuits.

The reader should now be reasonably familiar with the symbols used in circuit diagrams and with the functions of the basic components. To make things a little easier, however, two of the circuits in this chapter also have wiring diagrams. Neither the wiring diagram nor the circuit diagram gives any particular indication of the relative positions of the components in the receiver but in simple circuits such as these the positions do not matter and may be determined by convenience.

Many constructors will wish to build up circuits temporarily just to gain experience and they will want to use the components again in other circuits. For this reason, the same basic components are common to all the receivers in this chapter and may, therefore, be used again and again. As this entails continual soldering and unsoldering of the leads and contacts great care must be taken not to damage the components. If it is desired to use transistors several times, transistor sockets should be used since these avoid the need to solder to the transistor leads directly. The transistors should not be plugged into their sockets until the circuitry has been checked carefully and until one is sure that the battery is connected the right way round. Never plug the transistors into their sockets with the set switched on.

The point about the battery being the right way round is an important one, because in some circuits, a wrongly connected battery can destroy one or more of the transistors.

None of the circuits in this chapter use any R.F. amplification. That is to say, the signal obtained from the tuned circuit is demodulated or detected immediately and then amplified by a transistor A.F. amplifier. This means that the sensitivity of these receivers is strictly limited and an aerial and possibly an earth connection must be used to pick up a signal. With the two and three transistor circuits, however, the aerial may not have to be very long. The quality obtainable from all these circuits is excellent since, because of their very simplicity, there is little that can introduce distortion.

If a circuit is to be built up temporarily just for practice and to see how well it works, one of the best and simplest ways is to use tag strips. These are strips of paxolin with solder tags fixed along both edges. It is fairly easy to work out a simple method of constructing a particular circuit on them and the receiver will be readily demolished again later.

When a set fails to work one always tends to suspect one of the transistors being at fault. Unless they are mistreated, however, transistors very rarely fail. Components such as the tuning capacitor or the A.F. transformers are probably the most likely to be faulty but nowadays, fortunately, very few components bought turn out to be duds except perhaps in the surplus component field where one can obtain components very cheaply but with less confidence in their perfection.

Since the transistors are the most expensive components one normally has to buy there is always a strong temptation to economise on them as much as possible. The transistors specified in the circuits here are all made by reputable manufacturers and can be trusted to work perfectly. There are very much cheaper transistors on the market, however, which are normally manufacturers rejects. These are normally perfectly satisfactory for most applications but they tend to be rather noisy and to give less gain than the more expensive ones. Occasionally, they might not work at all in a particularly stringent circuit. In general, if you intend to buy only a few transistors and to use them in several circuits then it is worthwhile buying the best available. If, however, you intend to buy more than say five, the cheaper types may well be worthwhile since one or two bad ones will not matter so much.

Some of the most peculiarly tricky faults to find often turn out to be due just to a battery which is too old or worn so always try changing the battery for a new one in a faulty set before changing any of the other components.

Circuit No. 1

The first circuit is shown in Fig. 11 together with a wiring diagram. The signal is picked up by the aerial and passed to the tuned circuit via C_1. The tuned circuit is intended to select the required signal and consists of C_2, the tuning capacitor and L_1 the aerial coil. L_1 and C_2 offer a high impedance to the signal to which C_2 is tuned but a very much lower impedance to all other signals which are passed to earth. The signal selected is coupled to the diode by means of the secondary which matches the fairly high impedance of the tuned circuit to the much lower impedance of the detector.

The diode, D_1, which may be any make of germanium point contact diode such as the Mullard OA70, demodulates the R.F. signal. That is to say, it extracts the A.F. signal by removing the R.F. carrier wave. The output from the diode goes to the base of the transistors which then amplifies it and the amplified signal appears in the headphones. The amount of gain provided by the transistor in this type of circuit is about 100 times. That is to say, the signal heard in the headphones is 100 times stronger than that put out by the diode.

The battery may be either 1.5 or 3 volts, the latter giving slightly more gain. Higher voltages may be used but there is very little, if any, advantage in this. Voltages of more than 9 volts should not be used as they may cause damage to the transistor.

This circuit consumes so little power that the battery may be soldered into the circuit. Even one of the tiny slim penlight cells will give a life of about one year.

The On/Off switch may be omitted if the headphone automatically switches off the set.

C_1 is used to prevent the aerial from damping the tuned circuit too severely. When a short aerial is used it may be omitted. Damping of the tuned circuit by the aerial causes the tuning to be broad making it impossible to separate the stations satisfactorily. Other values may be used for C_1 and it may be best to use something in the region of 5 to 10 pf when a very long aerial is necessary. The earth connection may be to a water pipe, tap or radiator.

C_2, the tuning capacitor, may be any make of the 250 pf, single gang type. The type specified is the TSL which is particularly robust and small in size. This make is not supplied with fixing screws but the size needed is 10 B.A. If you already have a tuning capacitor with a value of other than 250 pf this may be used but the band coverage will be different. A value of less than 250 pf will not enable you to cover the whole of the medium wave band but a larger value will be satisfactory because the coil is adjustable.

L_1, the aerial coil, is, in fact, a very small ferrite rod aerial which is also supplied by TSL. In the circuits given in this chapter it does not act as an aerial as well as being a tuning coil but it is preferable to an ordinary tuning coil because of its much higher "Q" factor. The "Q" factor is a measure of quality and in this type of circuit a high "Q" factor increases the sensitivity and improves the selectivity. Since this ferrite rod aerial is no more expensive than an ordinary aerial coil its use is well worthwhile particularly since it will be required for many of the circuits given in this book. The coil can be moved along the rod to adjust the coverage. If you find that you cannot tune in the higher frequency stations, such as the Light programme, just slide the coil nearer to the end of the rod. If, on the other hand, the lower frequency stations, such as the Third programme, are unobtainable, then the coil should be moved nearer to the centre of its rod.

D_1, the diode, is not a particularly critical component. The Mullard type OA70 will give excellent results but there are surplus types on the market which are much cheaper and which work perfectly well.

Tr_1, the transistor, is specified as a Mullard OC71 and this type is recommended because it can be relied upon to give good results. A Mullard OC75 would be even better because of its high gain but this type is rather more expensive. In general, any make or type of small signal A.F. transistor may be used in this type of circuit.

The headphones must be good quality high impedance types if satisfactory results are to be obtained. A high impedance earpiece may be used instead, so long as it is the magnetic type, but it must be a high sensitivity unit. Those made by Fortiphone and Ardente, although expensive, will give far and away the best results.

Circuit No. 2

Fig. 12 shows the circuit diagram of a set which is even simpler than that of Fig. 11. The results are not quite so good, however, and the type of transistor required is more expensive.

All the components used are the same as in the last circuit but the diode is omitted and the transistor is an R.F. type, such as the OC44, instead of an A.F. type. An A.F. type could be used but would give much less gain.

Since there is no diode the R.F. signal is fed directly to the transistor. Detection takes place in the base-emitter junction which is really a type of diode itself. An amplified version of the signal then appears in the collector load which may be either a high impedance magnetic earpiece or a pair of high impedance headphones.

The current consumption of this set is even less than that of the last and may be only about 20 microamps. This is incredibly little and even the smallest battery cell made, the minute RM312, would last $2\frac{1}{2}$ months if left switched on all the time or about a year if used for five hours a day. A single slim pen light cell will last as long as it would on the shelf not being used even if left switched on all the time and, for this reason, the switch shown is not really necessary even if the headphones are left connected. The current consumption is so low that the set can be operated perfectly well by a simple home made battery. A simple cell can be made by sandwiching a piece of absorbent paper, which has been dipped in salt water, between two different metals. For example, the metals used could be a shilling and a halfpenny or a sixpence and a threepenny bit. Care must be taken to ensure that the two metals do not touch one another. A battery of this type may give as much as 100 microamps, particularly if it is warmed up a bit. In any case it will provide quite sufficient power to drive this set.

The actual amount of current drawn by this circuit depends on the signal strength. In the absence of a signal the current consumption may fall to as little as 5 microamps. When a signal is tuned in the current consumption will rise quite sharply and will then rise and fall continuously in proportion to the signal being broadcast. This may be watched by connecting a 100 microamp meter in series with the headphones. If a programme of music is tuned it will then be possible to follow the changing level of volume by watching the meter needle. On a powerful note, the current reading may more than double. The meter may also be used as a tuning indicator in much the same way as a magic eye is used on some domestic radios and radiograms. All that is necessary is to tune the set for maximum meter reading.

Components List

C₁—20 pf fixed capacitor.
C₂—250 pf variable capacitor—
L₁—Aerial coil— 1¾″, ferrite rod aerial.
Tr1—R.F. transistor Mullard OC44 or OC45.
High Impedance magnetic earpiece or headphones.
Battery—1½ to 6 volts.

Circuit No. 3

None of the circuits so far described have incorporated any means for varying the volume. This is not normally necessary because of the low output of the circuits. In areas of strong signal strength, however, where a good aerial is used a volume control may be necessary or at least desirable.

The volume controls used in radio sets normally have carbon composition resistive tracks and often incorporate an on/off switch. This circuit requires such a unit with a single pole switch (the most common type) and a value of 5K ohms although any value from 2.5K ohms to 10K ohms may be used. The make or type does not matter and the constructor may choose one according to the size which best suits his requirements. Some very small rim control types are now available and these will suit best those who wish to miniaturise their equipment.

There are normally five contacts on a volume control of the type required; three for the control section and two for the switch. The centre one of the group of three should go to the base of the transistor, the left hand one to the diode and the right hand one to earth. This normally results in a clockwise rotation of the spindle producing an increase in volume. If it does not, merely change over the two outside contacts. The two switch contacts may be connected either way round.

In the absence of a signal, the collector current of the transistor will vary between 20 and 100 microamps as the volume control is turned from its minimum to maximum position. (These figures will vary slightly from transistor to transistor.) When a signal is tuned in, the collector current will increase in proportion to the strength of the signal as with the last set.

With these simple sets it is usually necessary to solder the battery into the circuit because there are no suitable battery clips on the market. Soldering to batteries is not always easy but can be simplified considerably by rubbing the area to be soldered with coarse sandpaper before applying the solder. An old nailfile may be used in place of the sandpaper to good effect.

Components.

C₁—30 pf trimming capacitor (anything from 25 to 50 pf may be used)
C₂—250 pf tuning capacitor
L₁—Medium wave band aerial coil — 1¾″ ferrite rod aerial.

D₁—Germanium point contact diode — Mullard OA70.
R₁—5K ohm volume control with on/off switch — any type.
Tr₁—Small signal A.F. transistor — Mullard OC71

High Impedance magnetic earpiece or headphones.
Battery between 1.5 and 6 volts.

Circuit No. 4.

In the circuits so far described the collector current of the transistor has depended upon the strength of the signal received; the stronger the signal the greater the collector current. This is excellent from the point of view of battery economy but it does not obtain the maximum gain from the transistor.

The amount of gain a transistor provides depends upon several factors and one of the most important is the collector current. Below a certain point the gain begins to drop rapidly with decreasing collector current. With every transistor there is a particular level of collector current which gives optimum current gain. Beyond this level the gain remains reasonably high for a while and then begins to fall again as much larger current levels are reached. For small signal transistors the optimum current level lies somewhere between ½ and 3 mA and anywhere in this region good gain will be achieved.

In the circuit of Fig. 14 the transistor base is isolated from the diode and the volume control by a 2 microfarad electrolytic capacitor. The base bias is supplied by a 100K ohm resistor R₂. This means that the collector current remains reasonably constant and is independent of the signal strength. The precise level of the collector current will depend on the characteristics of the transistor, which vary quite a lot from one unit to another, and on the battery voltage. With a battery voltage of 3V. and an average OC71 the collector current should be about 1½ mA. The collector current will also be dependent on room temperature and will rise slightly if the transistor gets hotter.

In this circuit and the last the fixed capacitor used to couple the aerial to the tuned circuit has been replaced by a trimmer which is shown on the circuit diagram as having a value of 30 pf. In fact, any value between about 25 pf and 50 pf will be satisfactory. The advantage of using the trimmer is that the coupling between the aerial and the coil can be adjusted to suit conditions and the length of the aerial in use. In strong signal areas and with a long aerial it may be necessary to open the capacitor almost right out in order to separate the stations satisfactorily.

The value of R₂ may be varied experimentally to achieve maximum gain. Lowering the value will increase the collector current and vice-versa. R₂ should not be reduced to less than about 20K ohms to avoid any possibility of damaging the battery

Fig. 15. Circuit No 5.

Fig. 16. Circuit No 6. Similar to circuit No 5 but using interstage A.F. transformer.
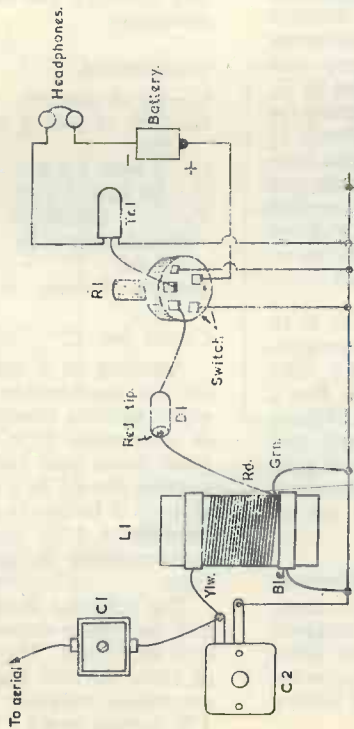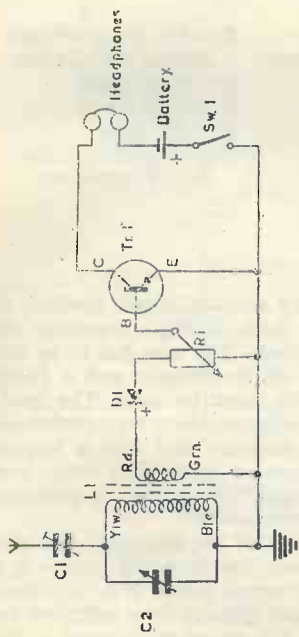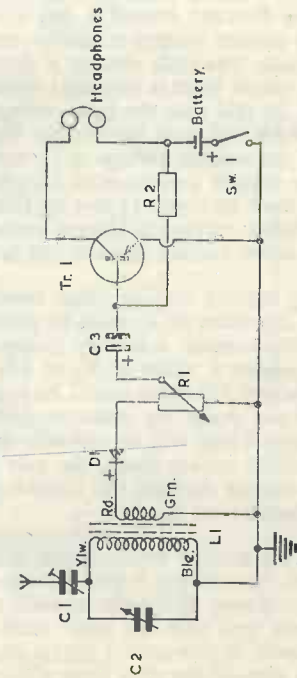
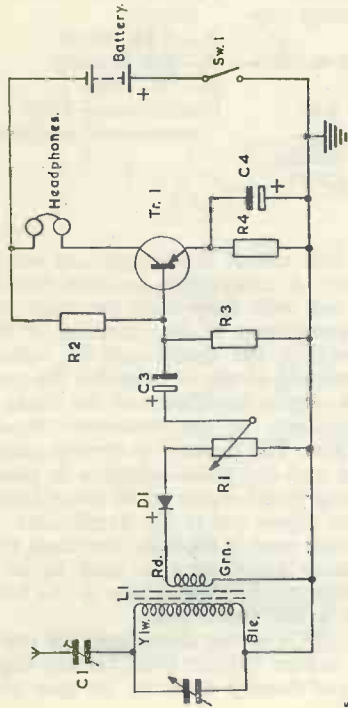Fig. 13. Circuit No 3 with wiring diagram.

Fig. 14. Circuit No 4.

Components.

C_1—30 pf trimmer.
C_2—250 pf tuning capacitor —
L_1—TSL 1¾″ ferrite rod aerial.
D_1—Germanium point contact diode — Mullard OA70.
R_1—5K ohms volume control with on/off switch.
R_2—100K ohm ¼ watt resistor 20% tolerance (lower wattage types may be used if available).
C_3—2 mfd. 3 v.w. electrolytic capacitor.
Tr_1—Small signal A.F. transistor — Mullard OC71

High impedance magnetic headphones or earpiece. Battery 1.5 or 3 volts.

Circuit No. 5

Although the collector current of the transistor in the last circuit was not altered by the strength of the signal received it was dependent on the properties of the transistor itself and on its temperature. This dependence can be overcome by using the special stabilising circuitry used in this circuit. With this type of circuit it does not matter what transistor is used or what the temperature is: the collector current remains relatively constant. In this particular circuit the collector current is 1½ mA.

Stabilisation is achieved by means of resistors R_2, R_3 and R_4. Because the base-emitter function of Tr_1 is forward biased it has a low resistance and the emitter voltage is always very nearly that of the base. The base voltage is determined by R_2 and R_3 which form a potential divider across the battery. In this case the base voltage is about 1½ volts which will also be roughly the emitter voltage. If the emitter voltage is 1½ volts though and with the emitter resistance of 1K ohm the emitter current must be about 1½ mA by Ohm's law. Since the collector current is always virtually the same as the emitter current this too will be 1½ mA.

If any battery voltage other than 9 volts is to be used the value of R_4 must be altered in proportion. For example, a battery voltage of 4.5 volts would require a value of R_4 of 470 ohms. For a 3 volt battery 330 ohms would be required. If these changes are made the collector current will still be 1½ mA. There will be virtually no loss of gain since, within certain limits, the gain is determined by the current through the transistor and not by the voltage across it.

Since the current consumption is comparatively low even the smallest 9 volt battery may be used. The Ever Ready PP5 is the smallest made and will fit in very well with the small scale of the other components. If you cannot obtain battery clips for the PP5 remove the clips from a worn out battery of the same type and use these.

Components.

C_1—30 pf trimmer.
C_2—250 pf tuning capacitor.
C_3—2 mfd. 3 v.w. electrolytic.
C_4—10 mfd. 3 v.w. electrolytic.
D_1—OA70 or similar.
Tr_1—Mullard OC71

R_1—5K ohm volume control.
R_2—6.8K ohms.
R_3—2.2 K ohms.
R_4—1K ohm.
Headphones—High impedance magnetic.

Circuit No. 6.

This is the first circuit in this book to use an A.F. transformer. A comparison between this circuit and the last will show that the only real difference between them is the insertion of this transformer between the diode and the volume control. The purpose of this is to match the comparatively high output impedance of the diode to the lower impedance of the transistor thereby increasing the gain. The increase in current gain is about 4½ times and the actual increase in power gain is something in the region of 10 times taking into account the power lost in the transformer.

The transformer used is the TSL interstage type LT-44. This same transformer is used again in many of the other circuits given later in the book so its purchase is well worthwhile.

The purpose of C4 in this circuit and the last is to prevent the emitter resistor from causing negative feedback and thereby reducing the gain considerably.

Components.

C_1—40 pf trimmer.
C_2—250 pf tuning capacitor
C_3—2 mfd. 3 v.w.
C_4—10 mfd. 3 v.w.
T_1— interstage transformer type LT-44.
Battery—9 volts.

R_1—5K ohms volume control with switch.
R_2—6.8K ohms.
R_3—2.2K ohms.
R_4—1K ohm.
High impedance magnetic headphones.

Circuit No. 7.

Amazing as it may seem it is just possible to drive a loudspeaker from a single transistor set under suitable conditions. The area has to be one of reasonably high signal strength and a really good aerial and earth must be used. The loudspeaker should be a large sensitive type preferably at least 5 inches in diameter and with a magnet strength of 8,500 gauss or more. The larger and more sensitive the speaker the better the performance.

The collector current of the transistor is 6 mA and the power consumption from the battery is a total of 63 mA. The output power is a maximum of about 20 mW which is more than sufficient for reasonable volume. The transformer used is the TSL output type LT700.
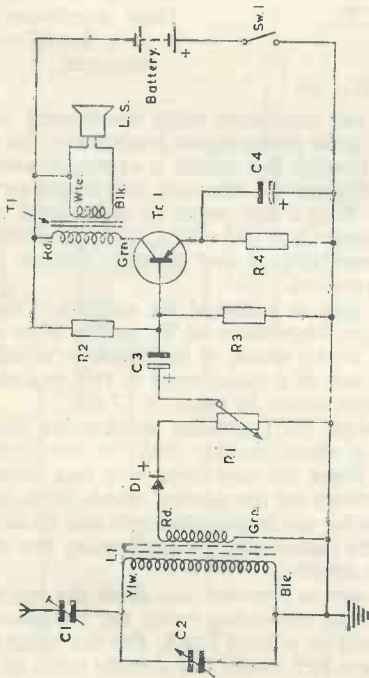
Fig. 19. Circuit No. 9.

Fig. 20. Circuit No. 10.
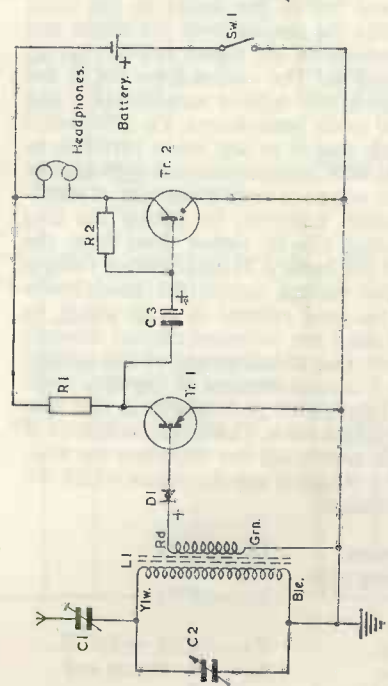

Fig. 17. Circuit No. 7. Single transistor loudspeaker receiver.

Fig. 18. Circuit No. 8. Simple 2-transistor receiver.
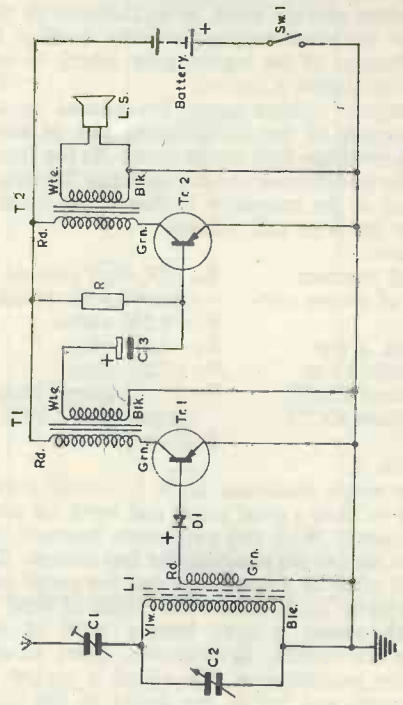
Tr$_1$, a Mullard OC75, is not really intended to be used as an output transistor but in this circuit it will work very well indeed because of the relatively low collector current level. It was chosen in preference to the usual output transistor, such as the OC72, because of its higher gain which is very useful in so simple a circuit.

The battery voltage cannot be altered in this circuit because of the considerable loss of maximum output power that would result. As the circuit stands, the transformer exactly matches the output impedance of the transistor to that of the speaker when the set is at full volume.

Components.

C$_1$—40 pf trimmer.	R$_1$—5K ohm volume control with switch.
C$_2$—250 pf tuning capacitor	R$_2$—6.8K ohms.
C$_3$—2 mfd. 3 v.w.	R$_3$—2.2K ohms.
C$_4$—25 mfd. 3 v.w.	R$_4$—220 ohms.
D$_1$—Mullard OA70.	T$_1$— output transformer type LT700.
Tr$_1$—Mullard OC75.	Battery—9 volts.

Circuit No. 8.

With a single transistor set it is almost always necessary to have a good aerial and earth for satisfactory volume. With two transistors, however, the extra gain makes the situation far less critical. The earth will often be unnecessary and the aerial may not need to be more than a few yards of wire.

Fig. 18 shows a very simple type of two transistor set which, nevertheless, gives a very satisfactory performance. The signal is picked up by the aerial and fed to the diode in the usual way. Tr$_1$ amplifies the output from the diode and the amplified version of the signal appears across the collector load R$_1$. The output from Tr$_1$ is fed to Tr$_2$ which gives still further amplification and passes the signal to the headphones. Tr$_2$ is not completely stabilised, that is to say, some variation in collector current with temperature and with change of transistor will occur. A certain amount of stabilisation is supplied, however, by taking the bias from the collector via R$_2$ rather than from the negative side of the battery. If the collector current tends to rise the voltage across the headphones drops causing the base current to drop which, in turn, tends to return the collector current towards its original value. One disadvantage of this system is that there is a certain amount of negative feedback at audio frequencies particularly in this case where the load is inductive. This negative feedback reduces the gain somewhat but improves the fidelity or quality by reducing any distortion which Tr$_2$ may have introduced.

Components.

C$_1$—40 pf trimmer.	D$_1$—OA70
C$_2$—250 pf tuning capacitor.	
C$_3$—2 mfd. 3 v.w.	Tr$_1$—OC71
R$_1$—2.2K ohms.	
R$_2$—56K ohms.	Tr$_2$—OC71 or OC75.
High impedance headphones or earpiece.	L$_1$— ferrite rod aerial.
	Battery—1.5 or 3 volts.

Circuit No. 9.

This is a much more sophisticated version of the last circuit. Both transistors are well stabilised and a volume control has been included.

The collector current of each transistor is about 1 mA and the overall power gain from the diode to the headphones is about 40 dB or 10,000 times.

All the circuits described so far, including this one but excluding circuit No. 7, can be built into a little plastic box sold by TSL for one shilling. This box is 2$\frac{1}{4}$" x 1$\frac{1}{2}$" x $\frac{7}{8}$" and will comfortably house the ferrite rod aerial, tuning capacitor, battery and other components if the smallest types are used. The box is made of clear plastic and may be painted on the inside to give a durable finish that will not rub off. Holes to take the tuning capacitor and volume control (where used) can easily be drilled in the sides where required. Assembling a set in such a box as this will give it an excellent finish and make it suitable as a present.

Components.

C$_1$—40 pf trimmer.	R$_1$—5K ohm volume control with switch.
C$_2$—250 pf tuning capacitor.	R$_2$—22K ohms.
C$_3$—2 mfd. 3 v.w.	R$_3$—2.2K ohms.
C$_4$—2 mfd. 3 v.w.	R$_4$ 1K ohm.
C$_5$—10 mfd. 3 v.w.	R$_5$—22K ohms.
C$_6$—10 mfd. 3 v.w.	R$_6$—2.2K ohms.
D$_1$—OA70.	R$_7$—220 ohms.
Tr$_1$—OC71	R$_8$—220 ohms.
	Battery—3 volts.
Tr$_2$—OC75.	High impedance magnetic headphones or earpieces.

Circuit No. 10.

With two transistors using transformer coupling a really good performance loudspeaker set can be built. Although this circuit is extremely simple the results that can be obtained with it are very satisfactory. With a few yards of aerial local stations are perfectly clear and with a really good aerial and earth more distant and possibly foreign stations can be received.

High gain is achieved by accurately matching the output impedance of Tr$_1$ to the input impedance of Tr$_2$ by means of an interstage transformer, T$_1$. The use of a transformer in this way increases the gain by about 50 times or 17 dB.

Although the larger the speaker the better the results a small speaker may be used with this circuit. There are now some very nice little 2 inch loudspeakers on the market which were specially designed for use in transistor sets and an extremely neat little radio could be built using one of these and this circuit.

The current consumption from the battery will vary a little depending upon the transistors used but should be around 7 mA. For the battery either a PP5 or a PP3 would suit a really small set or one of the larger 9 volt batteries may be used if a large speaker is to be employed.
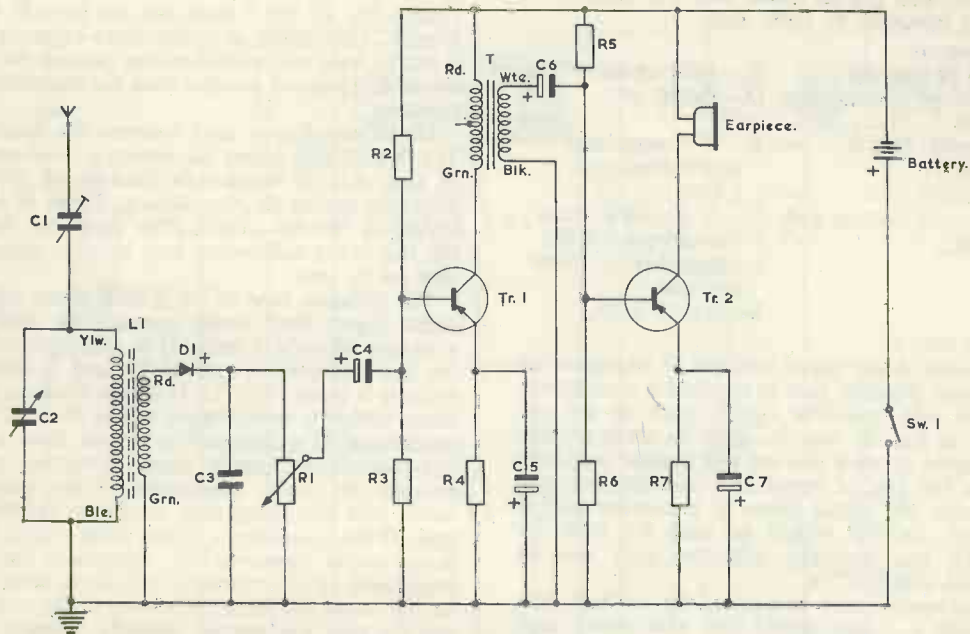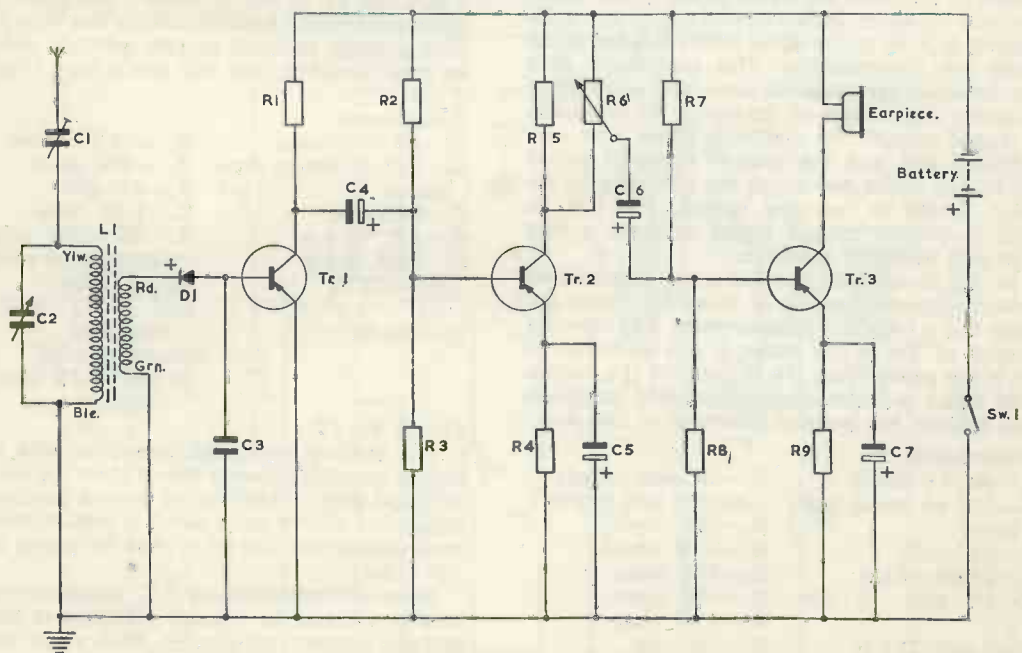
Fig. 21. Circuit No. 11.

Fig. 22. Circuit No. 12.

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If extra gain is required OC75's may be used for both Tr_1 and Tr_2. In which case the value of R_1 may be increased to 120K ohms.

Components.

C_1—40 pf trimmer	R_1—100K ohms.
C_2—250 pf tuning cap-acitor	D_1—OA70 or
C_3—2 mfd. 12 v.w.	T_1— interstage transformer type LT44.
Tr_1—OC71	
Tr_2—OC72	
L_1— $1\frac{3}{4}''$ ferrite rod aerial.	T_2— output transformer type LT700.
	Loudspeaker—3 ohms any size.
	Battery—9 volts.

Circuit No. 11.

In areas of low signal strength or whenever the maximum possible gain is required a transformer coupled two transistor circuit, such as the one shown in Fig. 21 may be used. In areas of very high signal strength this set will operate well with only a few feet of aerial and possibly just with the ferrite rod aerial alone. If maximum gain is required, OC75's should be used for both Tr_1 and Tr_2 but normally sufficient gain will be obtained with OC71's.

Some readers may be puzzled by the fact that, even with a comparatively high gain circuit such as this one, it is unlikely that the ferrite rod aerial would be adequate for signal pickup. The reason lies with the diode. In this type of circuit no amplification is given to the signal before it is fed to the diode for demodulation. This component does not, however, operate at the same level of efficiency whatever the strength of the signal. At low levels of signal strength the sensitivity drops very considerably and with the amount of signal picked up by the ferrite rod aerial the efficiency of the diode would be very low indeed. Too low, in fact, to provide enough signal for even a very high gain transistor amplifier.

In this circuit both transistors are stabilised by the conventional method of using an emitter resistor and a base bias potentiometer. The collector current of Tr_1 is just under $\frac{1}{2}$ mA and that of Tr_2 is just under 1 mA. Tr_1 is operated at a current level which provides slightly less than maximum gain because less noise is generated in this way.

Components.

C_1—40 pf trimmer.	R_1—5K ohm volume control with switch
C_2—250 pf tuning capacitor.	R_2—10K ohms.
C_3—0.01 mfd.	R_3—4.7K ohms.
C_4—2 mfd. 12 v.w.	R_4—470 ohms.
C_5—10 mfd. 12 v.w.	R_5—10K ohms.
	R_6—4.7K ohms.
C_6—2 mfd. 12 v.w.	R_7—1K ohm.
C_7—50 mfd. 3 v.w.	D_1—OA70
Tr_1—OC71	
Tr_2—OC71	High impedance magnetic earpiece.

Circuit No. 12.

This circuit has a similar overall gain to that of Circuit No. 11 but it does not use an A.F. transformer. This makes it rather more expensive but it can be built into a smaller case because the transistor is very much smaller than the transformer it replaces.

Direct coupling is used between the diode and Tr1. Whilst this means sacrificing a small amount of gain this is worthwhile because of the considerable saving in components. There is also a saving in current consumption from the battery but this is not sufficiently high to be a consideration on its own.

The collector load of Tr_1 is 4.7K ohms which is rather higher than would normally be used with a battery of only 3 volts. It is made possible by the low collector current of Tr_1 and is desirable because it means that Tr_2 is driven from an impedance which is considerably higher than its input impedance. If a transistor is driven from a very low impedance source some distortion occurs because the input impedance of the transistor varies with frequency thus causing a variation in gain. If the transistor is driven from a high impedance source however, any changes in the input impedance of the transistor will have little effect on the power fed from the source to the transistor and the gain will remain virtually constant.

Tr_2 is biased to a collector current level of about $\frac{1}{2}$ mA and Tr_3 to one of about 1 mA making the total consumption from the battery less than 2 mA. Slim penlight batteries or two mercury cells can be used, therefore, and will give a very long life.

Components.

C_1—40 pf trimmer.	$R_{1\,3\,8}$—4.7K ohms.
C_2—250 pf tuning capacitor	$R_{2\,7}$—10K ohms.
	R_4—470 ohms.
C_3—0.01 mfd.	R_5—1.5K ohms.
C_4—2 μf. 12 v.w.	R_6—5K ohms volume control with switch.
C_5—50 μf. 3 v.w.	
$Tr_{1\,2\,3}$—OC71	R_9—1K ohm.
	L_1— $1\frac{3}{4}''$ ferrite rod aerial.
D_1—OA70	
	Battery—3 volts.
	Earpiece—1K ohm magnetic type.

Circuit No. 13.

This receiver uses three transistors with transformer coupling between two of them. In this way sufficient gain is achieved to drive a loudspeaker even when only a short aerial is used without an earth connection. The set is ideal for use as a bedside radio.

When several stages of A.F. amplification are used in a circuit the internal resistance of the battery can become troublesome. With a new battery this resistance is usually low enough to be ignored but as the battery ages the resistance rises. The trouble arises because the resistance of the battery forms part of the load of each transistor.
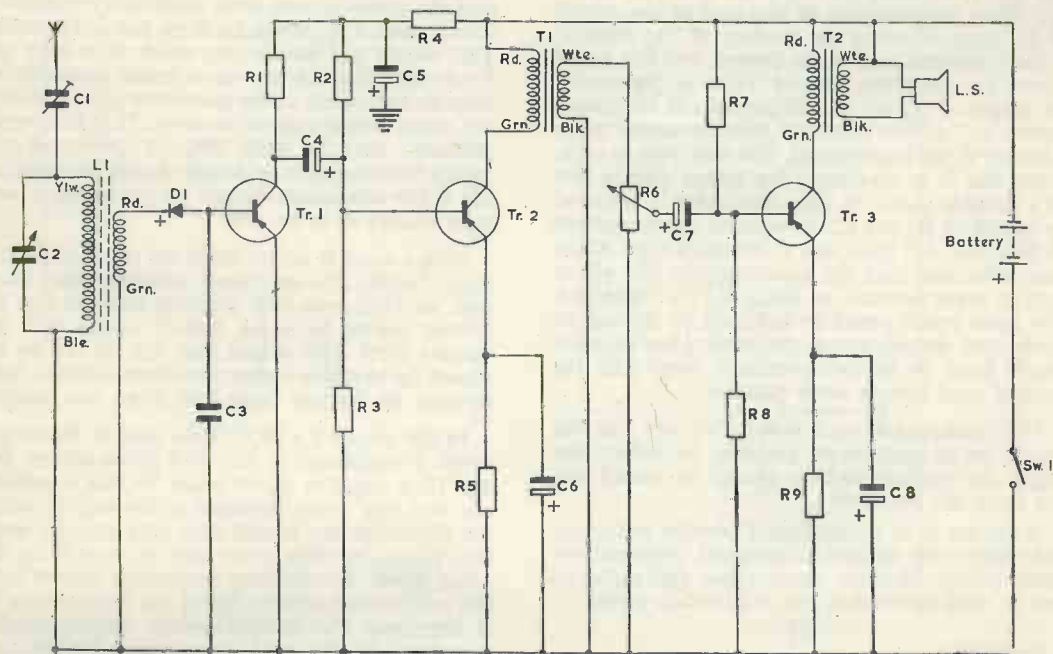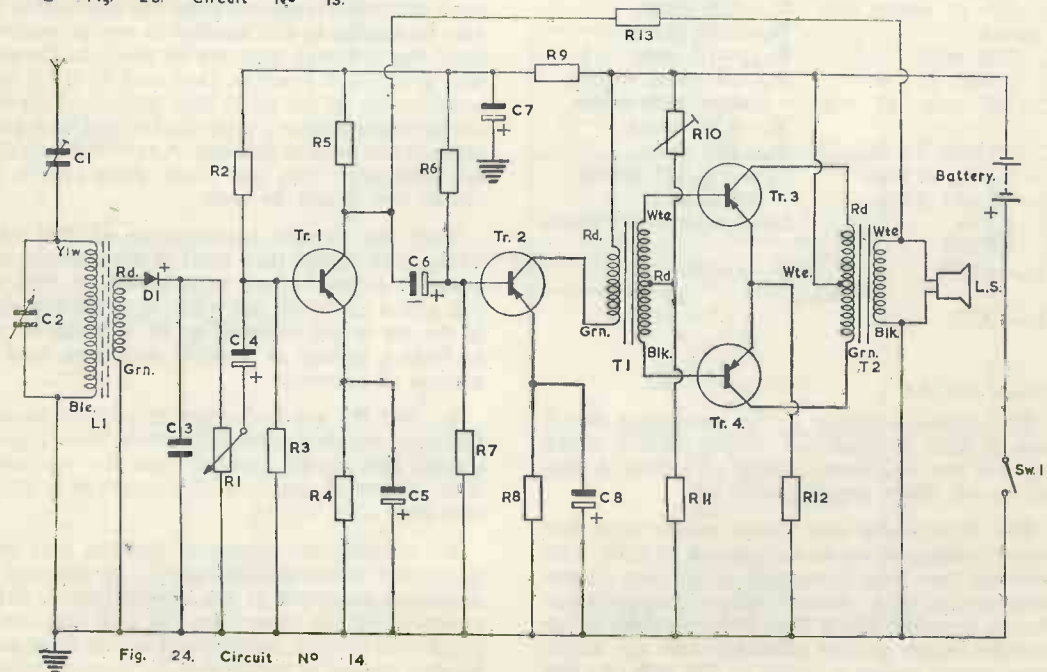
Fig. 23. Circuit N⁰ 13.

Fig. 24. Circuit N⁰ 14.

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Since the load of Tr_1 is part of the input of Tr_2 any signal imposed on the load of Tr_1 is fed to Tr_2. What happens then is that part of the output of Tr_3 appears across the loading of Tr_1, because of their common load in the battery, and this signal drives Tr_2. Since the base of Tr_2 is in place with the output of Tr_3 this normally results in oscillation known as " motor-boating " because of the noise it makes in the loudspeaker. The only way to overcome this is to de-couple the power supply line at a suitable point. In this circuit this is achieved by means of R_4 and C_5. R_4 reduces the magnitude of the signal fed back and C_5 removes most of the remainder and puts the power supply line effectively at earth potential as far as A.F. is concerned. The same result could be achieved by putting an electrolytic directly across the battery but its value would have to be inconveniently large and the method used here is more practical.

The loudspeaker used may be of any size but should be as sensitive as possible. As before, the bigger the speaker used the greater the sound output from the receiver.

If the set is to be used as a bedside radio, the bed springs may be used as the aerial. Alternatively metal window frames, water pipes and radiators can be very effective as can a television aerial.

Components.

C_1—40 pf trimmer.	R_1—4.7K ohms.
C_2—250 pf tuning cap-	R_2—12K ohms.
acitor	R_3—2.2K ohms.
C_3—0.01 mfd.	$R_{4\ 5\ 8}$—1K ohm.
C_4—2 mfd. 12 v.w.	R_6—5K ohms volume
C_5—100 mfd. 12 v.w.	control with switch.
	R_7—8.2K ohms.
C_6—50 mfd. 3 v.w.	R_9—100 ohms.
C_7—2 mfd. 12 v.w.	L_1— 1¾" ferrite
C_8—50 mfd. 3 v.w.	rod aerial.
T_1—LT44.	Loudspeaker — 3 ohms
T_2—LT700.	
$Tr_{1\ 2}$—OC71	D_1—OA70
Tr_3—OC72	

Circuit No. 14.

This circuit is similar to the last except that it uses a class B push-pull output circuit which requires two transistors instead of a class A output circuit which requires only one.

The loudspeaker sets shown so far have had power outputs of up to only about 30 mW. This limit has been kept to because of the high current consumption of a class A output stage. Circuit No. 14, however, uses a class B output stage which provides much greater efficiency and the maximum output power is raised to 200 mW. At this level, even a relatively inefficient loudspeaker will give a good volume.

With a class A output stage the maximum possible efficiency is only 50%. That is to say, only half the power drawn from the battery is actually turned into A.F. power to drive the loudspeaker. This would not matter too much if it were not for the fact that the current or power consumption remains constantly at the maximum level whatever the actual output volume in use is. Thus the overall efficiency may be only 20% or 15% and this makes it undesirable to design the set for anything but a low maximum output power unless a very large battery is to be used.

With a class B output stage the situation is very much better. The maximum efficiency may be as high as 75% even in a practical receiver and the current drawn from the battery varies with the volume level. This means that the set can be designed for a much higher maximum volume level without the battery being run down too quickly.

In this circuit 2 x OC72's are used in the output stage. Transformer T_1 acts as a phase splitter giving Tr_3 a negative signal when Tr_4 has a positive one and vice versa. Because of the way in which the transistors are biased they only amplify negative signals so that when one is amplifying the other is not. T_2 combines the output signals from the two transistors and drives the loudspeaker. It is important that each transistor should amplify the signal by the same amount and for this reason what is known as a matched pair of transistors must be used. Transistors from any production line may be similar to one another in overall performance, but although they are all made in the same way as far as is possible, they tend to differ quite considerably in the gains they provide. This does not normally matter a great deal except with push-pull circuits such as this one. A matched pair does not cost more than two single units and in this circuit one should be used.

Since the current consumption of this set is likely to be higher than most of the previous ones a rather larger battery is desirable. A PP3 will still give a useful life but a PP5 is rather too small. If the set is not intended to be a miniature one as large a battery as possible should be used for reasons of economy.

R_{12} and R_{13} are both used to provide negative feedback and thus reduce distortion. They result in a small loss of gain, however, and may be omitted if the degree of distortion this results in is acceptable as it often will be.

R_{10} controls the degree of forward bias given to the two transistors and should be adjusted for minimum distortion at low volume levels. Before switching on the battery for the first time set R_{10} roughly to its mid position and adjust from there. Be very careful to ensure that R_{10} is never reduced to its minimum resistance position as this may cause damage to the transistors.
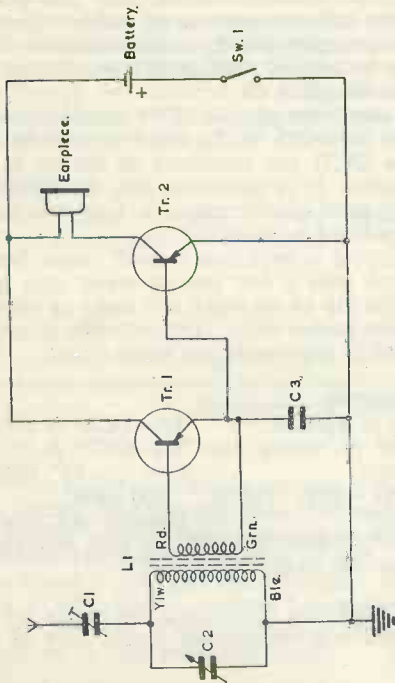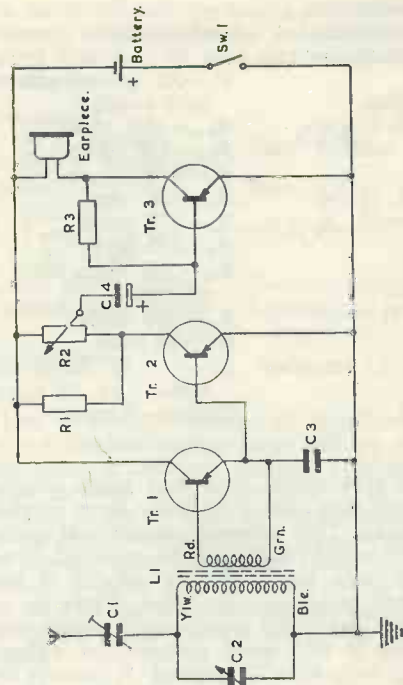
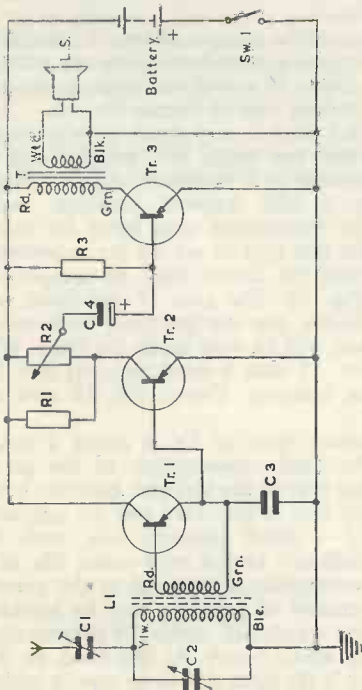Fig. 25. Circuit Nº 15.
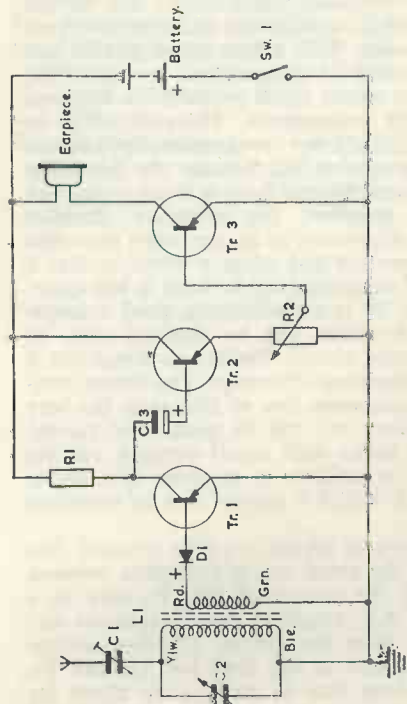

Fig. 26. Circuit Nº 16.

Fig. 27. Circuit Nº 17.

Fig. 28. Circuit Nº 18.

Components.

C_1—40 pf trimmer. Loudspeaker

C_3—250 pf tuning cap-
  acitor R_1—5K volume control
C_3—0.01 muf. with switch.
C_4—2 mfd. 12 v.w. $R_{2\,13}$—68K ohms.
$C_{5\,8}$—100 mfd. 3 v.w. $R_{3\,7}$—10K ohms.
  R_8—3.9K ohms.
C_6—2 mfd. 12 v.w. $R_{4\,8}$—1K ohm.
C_7—100 mfd. 9 v.w. R_6—27K ohms.
  R_9—470 ohms.
T_1—LT44. R_{10}—20K ohms semi
T_3—LT700. variable.
$Tr_{1\,2}$—OC71 R_{11}—100 ohms.
  R_{12}—10 ohms.
$Tr_{3\,4}$—OC72's (matched L_1— $1\frac{3}{4}''$ ferrite rod
  pair). aerial.
D_1—OA71 Battery—9 volts.

Circuit No. 15.

The last few circuits have been fairly compli-
cated in that they used a relatively large number
of components. They followed conventional design
practice. Excellent results can be achieved, how-
ever, with very much simpler circuits if less
conventional techniques are used. There is no
virtue in complexity but unfortunately people tend
to associate it with good performance without
considering fully what is involved. A receiver for
any given performance requirements can always
be designed using conventional techniques without
too much trouble. With a little more trouble and
a certain amount of imagination, however, the
same or better results could probably be achieved
with far fewer components. There is virtue in
simplicity, not only nor even primarily because
of the saving in cost but because the fewer the
components used the less there is to go wrong and
the greater, therefore, the reliability. Another
advantage of simplicity, in an age when miniatur-
isation is important and often a creed, is that a
given piece of equipment can be built in less space.

Circuit No. 15 is a particularly good example
of what good results can be obtained with an
extremely simple circuit. Besides its simplicity it
has another important advantage. The current con-
sumption is extremely low so that even the very
smallest mercury cell can be used. The current
consumption varies with signal strength but the
average level is unlikely to be more than about
1/5th of a mA, which is minute even by transistor
standards.

The operation of the set is a little unusual. The
secondary of the aerial coil is connected between
the base and the emitter of Tr_1. Tr_1 acts as a
detector and A.F. amplifier and C_3 removes any
residual R.F. from the output. The base-emitter
circuit of Tr_2 acts as the load for Tr_1 and Tr_1
supplies the base bias as well as the signal for
Tr_2. In this way no resistors are required and
coupling and de-coupling capacitors are avoided.
Whilst no provision is made for stabilisation none

is necessary because even at fairly high tempera-
tures the collector currents of the two transistors
will be extremely low by normal standards. C_3 can
usually be omitted without affecting the perform-
ance of the set at all.

For maximum gain an OC44 should be used for
Tr_1 and an OC75 for Tr_2 but even with an OC45
and an OC71 the sensitivity of the set is quite
remarkable. It is important that the earpiece be
a really good quality magnetic type with as high
an impedance as possible.

If this set is built into a small plastic box and
provided with a few feet of aerial wire with a
crocodile clip on the end it will make an extremely
attractive pocket radio. The crocodile clip can be
attached to any convenient metal object.

Components.

C_1—40 pf trimmer. Tr_1—OC45 & OC44.
C_2—250 pf. tuning cap- Tr_2—OC71 & OC75.
  acitor L_1— $1\frac{3}{4}''$ ferrite
C_3—0.01 mfd. (when rod aerial.
  used). Mercury cell (any type)
High impedance ear- or slim penlight cell.
  piece—1K ohm.

The total cost of building the above set, even
using the best components should only be about
30s. 0d.

Circuit No. 16.

The gain of the receiver shown in Circuit No. 15
can be increased considerably by the addition of
another stage. If a volume control is included
the set becomes that of Circuit No. 16.

The third stage is very much more conventional
than the first two being R-C coupled and stabil-
ised by means of a feedback resistor. The basic
simplicity is still retained, however, with the
number of components used being far below the
average for this type of set. As far as performance
is concerned the circuit may be compared with
that of Fig. 22. The gain of the latter will be
slightly higher but the practical performance of
the two sets will be very much the same. Whereas
Circuit No. 12 uses 8 fixed resistors and 5 fixed
capacitors, however, Circuit No. 16 uses only 2
of each.

The current level of Tr_3 is about 1 mA. This
makes the total consumption of the set much
higher than that of the last one, bringing it to over
1 mA, but this is still very low by normal stan-
dards and a small mercury cell, such as the
RM400, will still have a very useful life. If a still
lower consumption is required at the expense of
a small amount of gain, R_3 may be increased to
120K ohms which will make the current drain on
the battery about $\frac{1}{2}$ mA. At this level, an RM400
cell, which is the same size as an aspirin tablet, will
give a life of 140 hours. (The RM400 is made
by Mallory and may be bought or ordered from
Boots the Chemists).

As with the last circuit, C_3 can normally be omitted. The higher gain transistors can also be used but this is unlikely to be necessary since the gain is already very high. If an OC75 is used for Tr_3, R_3 should be increased to 68K ohms. The earpiece must be a sensitive high impedance type with an impedance between 250 and 1,000 ohms.

Components.

C_1—40 pf trimmer.	L_1— $1\frac{3}{4}''$ ferrite rod aerial.
C_2—250 pf tuning cap- acitor	
	Tr_1—OC45
C_3—0.01 mfd.	
C_4—2 mfd. 12 v.w.	Tr_2—OC71
R_1—1.5K ohms.	
R_2—5K ohms volume control with switch.	Tr_3—OC71
R_3—56K ohms.	Earpiece—1K ohm.

Circuit No. 17.

This receiver follows a similar pattern to the last but the battery potential has been increased to 9 volts and the set has been designed to drive a loudspeaker. The collector current of the output stage is about 9 mA and the maximum output power is 30 mW. With a sensitive 2 inch diameter 3 ohm loudspeaker, a pocket radio of good performance can be built using this circuit.

The total current consumption is no longer low enough to be ignored. The drain on the battery will be about 10 mA and whilst a PP5 could be used its life would not be very long. Unless absolute minimum size is required a PP3 would be preferable.

The circuit lends itself very well to miniaturisation because of the small number of components.

The aerial coil and the tuning capacitor are both extremely small and for the volume control a rim control type may be used to minimise the space consumed.

Components.

C_1—40 pf trimmer.	Tr_1—OC45
C_2—250 pf tuning cap- acitor	
	Tr_2—OC71
C_3—0.01 mfd.	
C_4—2 mfd. 12 v.w.	Tr_3—OC72
R_1—2.2K ohms.	
R_2—5K ohms volume control with switch.	T_1— type LT700. Loudspeaker—3 ohms impedance
L_1— $1\frac{3}{4}''$ ferrite rod aerial.	

Circuit No. 18.

This is another example of simplified design. Tr_1 is a common emitter stage with an extremely high value of collector resistor. This is used to match the high input impedance of Tr_2 which is operated in the common collector mode. Despite the use of a common collector stage, which normally has low gain, the overall power gain of the receiver is very high because of the accurate matching of the impedances. The collector current of Tr_3 varies with the setting of the volume control.

Components.

C_1—40 pf.	$Tr_{1, 2, 3}$—OC71
C_2—250 pf. tuning cap- acitor	
	D_1—OA70
C_3—2 mfd. 12 v,w.	
R_1—22K ohms.	L_1— $1\frac{3}{4}''$ ferrite rod aerial.
R_2—5K ohms volume control.	High impedance mag- netic earpiece.

CHAPTER THREE

Regenerative and Reflex Receivers.

None of the radios so far described include any R.F. amplification before the detector. As has been explained this makes them insensitive, so that they require external aerials and unselective which makes it difficult to separate the stations satisfactorily. Nor are these sets suitable for receiving foreign stations except under very good conditions and with a very long aerial.

The above faults can be overcome, at least to a certain degree, by the use of a regenerative detector instead of a crystal diode. The regenerative detector, which in this book is, of course, a transistor but which could also be a valve, provides a reasonable amount of R.F. gain. The transistor functions in the normal way as a detector which provides A.F. gain but, because the transistor used is an R.F. type, it also amplifies the R.F. signal and the R.F. output is fed back to the input to increase it. If more than a certain amount is fed back the transistor will oscillate so the degree of feedback has to be carefully controlled.

Detection occurs in a transistor at very low levels of collector current: with certain restrictions, the lower the better. For maximum R.F. gain, however, a very much higher collector current is required. This means that a compromise must be made between detection efficiency and R.F. gain. Nevertheless, the circuit is extremely useful because of the simplicity with which R.F. gain is obtained and because a single transistor is persuaded to perform three functions; namely detection, R.F. amplification and A.F. amplification The economy of this is obvious.

The optimum collector current for a transistor performing these functions is usually about 0.25 mA for an R.F. germanium junction transistor such as the OC44 and about 0.1 mA for a surface barrier transistor. S.B.T.'s, (surface barrier transistors) make particularly good regenerative detectors and they are used in several of the circuits in this chapter.

Circuit No. 19.

The circuit shown in Fig. 29 is that of a very simple single transistor receiver. The signal is picked up by the aerial and selected by the tuned circuit in the normal way. It is coupled to the transistor via the secondary of the aerial coil. Since the transistor is biased to a low level of collector current the input is fairly non linear, that is to say, a negative signal is amplified more than a positive one, and a certain amount of detection takes place and gives rise to an amplified A.F. signal in the collector. A certain amount of R.F. amplification also takes place, however, and this is coupled back to the tuned circuit by means of L_2. It is then added with the input signal and contributes to the output. If it were not for this regeneration the set

would operate simply as a detector plus A.F. amplifier receiver as in the last Chapter. The inclusion of the regeneration effectively increases the input signal by as much as 100 times or even more, the actual level depends very much on the degree of regeneration that can be applied before oscillation starts. This means, in theory, that an aerial which picks up only one hundredth of the signal is required to obtain the same results as are obtained without any regeneration at all.

In this circuit the regeneration is controlled by sliding L_2 along the ferrite rod. This alters the coupling with L_1 and thus controls the amount of feedback. L_2 consists of between 3 and 5 turns of thin enamelled wire (the gauge is not important) wound onto a single layer of paper. The layer of paper should be sufficiently loose to enable it to be slid up and down on the rod. The coil is put onto the end of L_1 nearest to the yellow lead.

When the set is completed, slide L_2 up and down the rod to obtain oscillation in the headphones. If no oscillation occurs reverse the connections to L_2 or take it off the rod and put it on the other way round. If you still fail to obtain oscillation increase the number of turns on L_2 and repeat the operation above.

When oscillation has been achieved, move L_2 towards the end of the coil a little way past the point at which oscillation stops and connect up a small aerial. It should now be possible to tune in one or more stations. To achieve maximum sensitivity, the coil should now be moved towards L_1 to the point just before oscillation begins. Each time a station is tuned in, L_2 will have to be readjusted for maximum sensitivity. A strip of cardboard or thin plastic may be glued to L_2 to make this easier. The end of the strip should then pass through a slot in the case so that it can be conveniently adjusted without opening the back.

As has been mentioned, the collector current level is something of a compromise. The optimum level varies somewhat from one transistor to another and it is well worthwhile trying different values for R_1 which controls the collector current. In this circuit any value from 250K ohms to 4M ohms may be tried or you could try omitting R_1 altogether since this gives the best results with some transistors. The higher the battery voltage used the larger the value of R_1 is likely to be for maximum gain.

Components.

C_1—40 pf trimmer.	R_1—See text.
C_2—250 pf. tuning capacitor	Tr_1—OC44
C_3—0.01 mfd.	L_1— 1¾″ ferrite
C_4—0.001 mfd.	rod aerial.

Headphones or earpiece—high impedance magnetic type.

Circuit No. 20.

There are quite a large number of methods of controlling regeneration or feedback and this circuit shows an alternative to that of Fig. 29. Apart from the methods of feedback the two circuits are virtually identical and will give the same performance.

Instead of using a feedback coil this circuit uses a feedback capacitor with an R.F. choke to prevent the R.F. signal from going to earth via C_5. The degree of regeneration depends on the setting of C_3 which may be any type of trimmer. Particularly suitable, however, are the air gap types with quarter inch diameter spindle since a knob can be fitted for simple adjustment. The actual value used is not particularly critical but it must be large enough for oscillation to be obtainable. At least 15 pf is normally required for this but it depends very much on the transistor used and on the length of the aerial.

The value of the R.F.C. may be anything from 1 mH to 5 mH without any alteration in the performance. The only purpose of this component is to ensure that the signal is fed back to the tuned circuit. C_5 removes any R.F. signal that passes through the R.F.C. and prevents the headphones or earpiece leads from affecting the performance. In some cases it may be an advantage to increase the value of C_5 to 0.01 mfd. but this is rarely necessary.

When a regenerative detector is in oscillation it acts as a miniature transmitter and can cause bad interference to radios in the vicinity. This not only annoys the neighbours but is liable to incur the wrath of the G.P.O. so a set of this type must not be allowed to oscillate more than momentarily.

The notes referring to the value of R_1 and the battery voltage in the last circuit also apply to this one. Lower battery voltages can be used if R_1 is reduced accordingly. For a battery voltage of 1.5 the value of R_1 will need to be around 250K ohms but other values should be tried.

Components.
C_1—40 pf trimmer.
C_2—250 pf. tuning capacitor
C_3—20 pf trimmer.
C_4—0.01 mfd.
C_5—0.001 mfd.
L_1— 1¾″ ferrite rod aerial.
Tr_1—OC44 or
R.F.C.— 1.5 mH.
Headphones or earpiece—high impedance magnetic types— 1K ohm.

Circuit No. 21.

This circuit is basically that of Circuit No. 19 with a stage of A.F. amplification added. The gain is considerably increased by this and reasonable results can be expected with only the ferrite rod aerial.

Tr_2 is biased by means of an emitter resistor and base bias potentiometer to a collector current

level of 1 mA with a 9 volt battery or ½ mA with a 4.5 volt battery.

The application of regeneration to a detector not only increases the sensitivity of the receiver but also the selectivity. This may be understood by considering the properties of the tuned circuit. If both the tuning capacitor and the coil were perfect from the theoretical point of view and if there was no damping of the tuned circuit by the transistor and aerial then the " Q " of the tuned circuit would be infinite and the selectivity would be razor sharp. Too sharp, in fact, because the sidebands would be cut off. In practice, however, the coil has a certain amount of d.c. resistance and there is leakage in the capacitor. Furthermore, the tuned circuit is fairly heavily damped. These factors make the " Q " low and the tuning far too broad. When a signal is fed back from the output of the transistor in such a way as to augment the signal in the tuned circuit, however, it tends to overcome the losses in the tuned circuit and thus raises the " Q " factor and improves the selectivity. As the degree of regeneration is increased the gain becomes higher and the selectivity narrower and it is sometimes possible to make the " Q " of the tuned circuit too high to pass the 5 Kc/s band of the broadcast signal. This is unlikely to cause the constructor any trouble however.

The use of regeneration thus overcomes, to a certain degree, the two major disadvantages of the sets in Chapter 1. The only disadvantage is a slight loss of quality which increases as the point of oscillation is approached.

Components.
C_1—40 pf trimmer. R_1—1 Meg. ohm.
C_2—250 pf tuning cap- R_2—2.2K.
   acitor R_3—33K.
C_3—0.01 mfd. R_4—4.7K.
C_4—0.001 mfd. R_5—1K.
C_5—2 mfd. 12 v.w. Tr_1—OC44
C_6—25 mfd. 12 v.w.
L_1— ferrite rod Tr_2—OC71
   aerial.
L_2—as in fig. 29.

Circuit No. 22.

By using two stages of A.F. amplification with a regenerative detector really good performance can be obtained with only the ferrite rod aerial. Even in areas of fairly low signal strength this set should still be able to hold its own without an external aerial.

In any set which is to work without an external aerial certain precautions should be taken in the layout of the components. The ferrite rod aerial should be mounted away from large components such as the battery and the tuning capacitor since these tend to damp it. If space allows, separate the coil from all the other components by a minimum of a quarter of an inch. The ferrite rod aerial is highly directional and must be rotated for maximum pick up. This will occur when the rod is
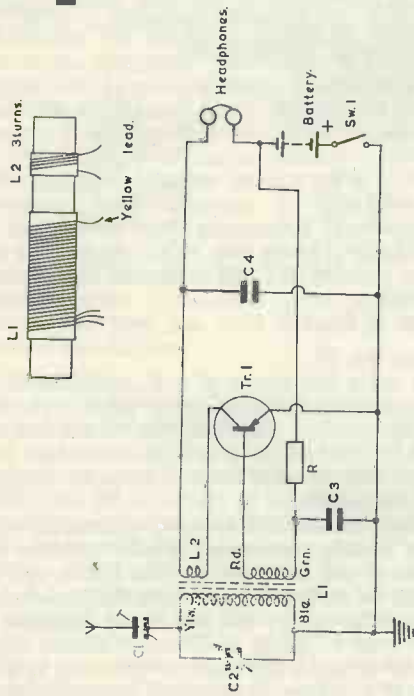
Fig. 31. Circuit No 21.

Fig. 32. Circuit No 22.

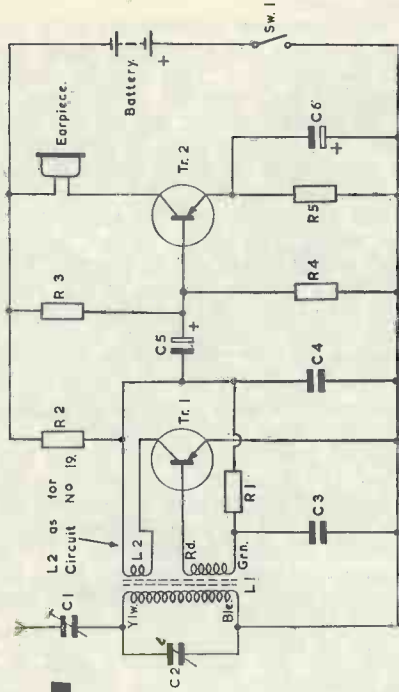L1   L2 3 turns.

Yellow lead.

Fig. 29. Circuit No 19. Single transistor regen. detector.
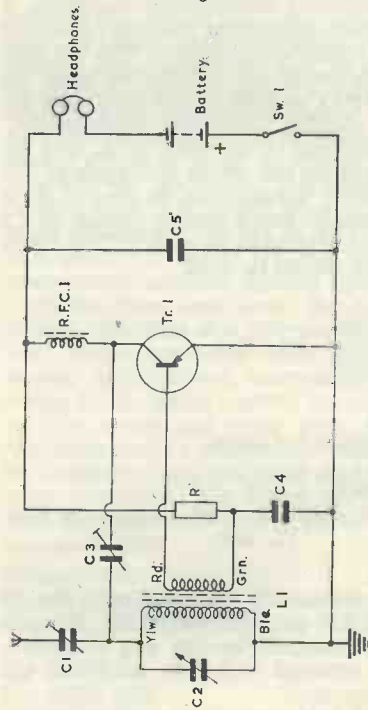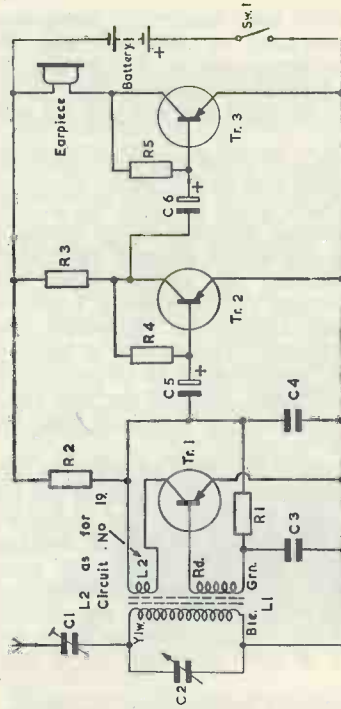

Fig. 30. Circuit No 20.

parallel with the ground and at right angles to the direction of the transmitting station.

The collector currents of the A.F. transistors depend on the gains of the transistors themselves but should be around 1 mA and 1.5 mA for Tr_2 and Tr_3 respectively when a 9 volt battery is used and half these values when a 4.5 volt battery is used. For higher gains OC75's may be used instead of OC71's.

The performance of the regenerative detector depends to a large extent on how good the R.F. qualities of the transistor are. The OC44 has a reasonably high cut-off frequency and works very well but if any other type of R.F. transistor is used it should have a cut-off frequency of at least 7 mc/s. Surplus types, such as those known as white spot transistors, perform well sometimes but vary rather a lot from one type to another. At their best they can be excellent but it is really a matter of luck since some will not oscillate at all. If several are bought the best could be used for R.F. purposes and the others should work well in A.F. circuits wherever an OC71 is specified.

Components.

C_1—40 pf trimmer.
C_2—250 pf tuning capacitor
C_3—0.01 mfd.
C_4—0.001 mfd.
C_{5,6}—2 mfd. 12 v.w.

R_1—1M ohm.
R_2—2.2K.
R_3—1K.
R_4—390K.
R_5—220K.
Tr_1—OC44

L_1— 1¾" ferrite rod aerial.
L_2—as Fig. 29.

Tr_{2,3}—OC71

Circuit No. 23.

This circuit consists of the same regenerative detector used in the previous circuits coupled to a three stage 200 mW amplifier. This amplifier will give enough gain for full output to be obtained from just a ferrite rod aerial.

By using a certain amount of ingenuity in the layout of the components the entire set can be built into a case small enough to fit into the pocket. The output power is more than adequate to give really good volume from a 2" loudspeaker but any size loudspeaker may be used.

The collector current of Tr_1 depends, as mentioned before, on the value of R_1 and various values may be tried to obtain the best results. Tr_2 has a collector current of 1 mA and Tr_3 has one of 3 mA. The collector currents of the output transistors depend upon the strength of the signal but they may vary from 3 mA to about 20 mA on peaks. Since the output stage is operated as a Class B amplifier the efficiency is high and a PP3 battery may be used.

Components.

C_1—40 pf trimmer.
C_2—250 pf tuning capacitor
C_3—0.01 mfd.
C_4—0.001 mfd.
C_5—2 mfd. 12 v.w.
C_{6,9}—100 mfd. 3 v.w.

C_7—2 mfd. 12 v.w.
C_8—100 mfd. 8 v.w.

Tr_1—OC44 or SFT 308.
Tr_2—OC71 or SFT 352.
Tr_3—OC71 or SFT 352.
Tr_{4,5}—matched pair OC72's.
T_1— type LT44.
T_2— type LT700.
Loudspeaker—3 ohms

R_1—1 meg.
R_2—5K volume control with switch.
R_3—6.8K.
R_4—10K.
R_5—3.9K.
R_6—1K.
R_7—27K.
R_8—10K.
R_9—1K.
R_{10}—470 ohms.
R_{11}—20K semi-variable.
R_{12}—100 ohms.
R_{13}—10 ohms.
L_1— 1¾" ferrite rod aerial.

Circuit No. 24.

All the transistors used in circuits so far described have been ordinary alloy junction types. Other types exist, however, and one of these is the surface barrier type. S.B.T.'s are made by Semiconductors Limited and they have several peculiarities which make them particularly suitable for use in regenerative detector circuits.

S.B.T.'s have extremely good high frequency performance, their gain being very nearly constant throughout the A.M. band. They also provide their maximum gain at very low levels of collector current, high gain being obtainable at only 0.2 mA, for example. These two features are very important in a detector because they mean that good R.F. gain can still be achieved at the level of collector current required for high detection efficiency.

S.B.T.'s can be damaged by excessive voltage or current. To be completely safe a battery of more than 4.5 volts should never be used and the collector current should be kept to a limit of 5 mA. Care must also be taken when using a soldering iron since stray voltages from one of these can ruin the S.B.T. To be on the safe side the iron should be unplugged from the mains just prior to use.

The S.B.T. oscillates very well. So well, in fact, that once started it is very hard to stop. The method of control sometimes used with alloy transistors of varying the base bias to control the gain will not work with an S.B.T. since it will often continue to oscillate when all bias is removed. In view of this another method is used in Fig. 34. A feedback coil is used as before but now it has a 5K ohm volume control wired in parallel with it. The circuit is initially set up by adjusting the control so that there is maximum resistance across L_2 and then sliding L_2 towards the centre of the rod until oscillation starts. L_2 is then pushed a bit further still to ensure that oscillation is continuous across the band. The circuit now can be brought
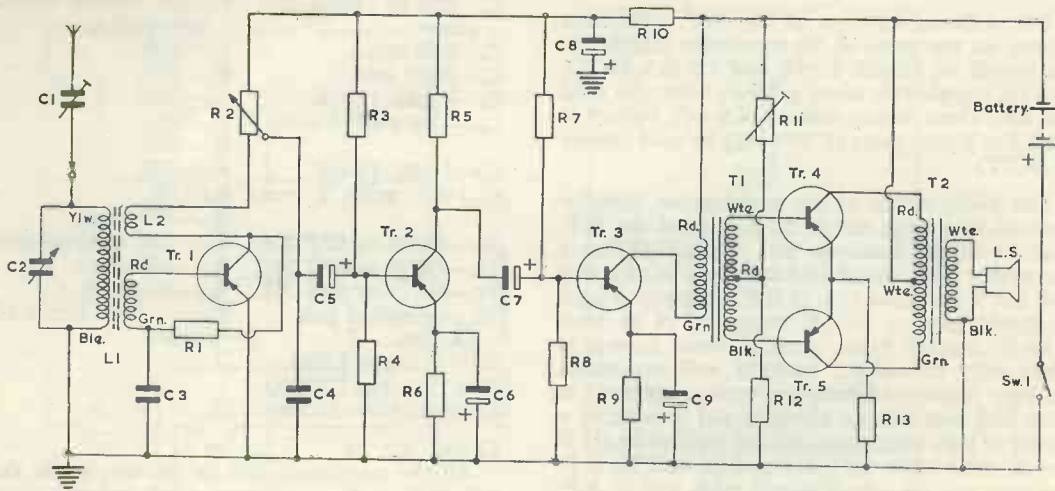
Fig. 33. Circuit No 23.
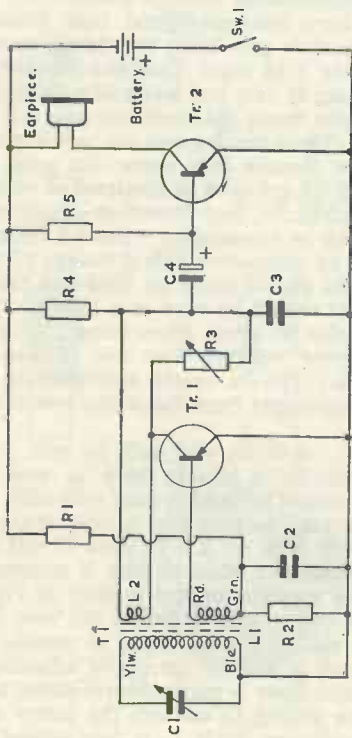
Regen. detector with 200 mW. A.F. amplifier.
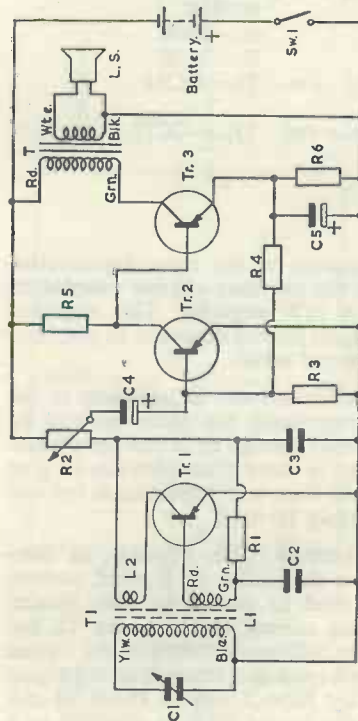

Fig. 34. Circuit No 24.

Fig. 35. Circuit No 25.

in and out of oscillation and the degree of regeneration can be controlled by varying R_3. Since this method of varying regeneration is smooth and convenient it may be used with any of the other regenerative detector circuits in this Chapter.

No particular type of S.B.T. has been specified for this circuit because any type may be used, at these frequencies, with satisfactory results. The SBO78 is usually the cheapest type available and is perfectly suitable.

Components.

C₁—250 pf tuning cap-
  acitor
C₂—0.01 mfd.
C₃—0.001 mfd.
C₄—2 mfd. 12 v.w.
Tr₁—any surface barrier
  transistor.
Tr₂—OC71
  SFT 352.
L₁—   1¾″ ferrite rod
  aerial.

R₁—100K.
R₂—470 ohm.
R₃—5K volume control
  with switch.
R₄—1K.
R₅—82K.
Earpiece—High impe-
  dance magnetic type.

Circuit No. 25.

This receiver uses an interesting and elegant output circuit which, although economical in number of components, is well stabilised against temperature changes and which can accept a wide variation in transistor parameters.

The driver and the output transistor are directly coupled, the collector of Tr₂ being connected to the base of Tr₃. Any tendency for the collector current of either transistor to change is amplified by the other and reapplied to that transistor with its phase change so as to halt or minimise the tendency. A full explanation of the way in which the circuit functions is given in " Transistor Audio Amplifier Manual ".

The output power of the set is 30 mW which is quite adequate if a good loudspeaker is used. The small number of components used makes miniaturisation simple and since the set will not normally require an external aerial it should make an excellent pocket radio. Increased gain may be obtained by using an OC75 for Tr₂.

Where a more convenient type of regenerative control is required, R₂ may be replaced by a 4.7K ohm fixed resistor and the 5K ohm volume control may be connected across the coil L₂ as in Fig. 34. There will then be no need to slide the coil up and down once it has been set.

The total current drain of the set is about 10 mA and the most suitable battery for a pocket set will be the PP3.

Components.

C₁—250 pf.
C₂—0.01 mfd.
C₃—0.001 mfd.

R₁—1 meg.
R₂—5K ohms volume
  control.

C₄—2 mfd. 12 v.w.
C₅—100 mfd. 3 v.w.

Tr₁—OC44 or SFT 308.
Tr₂—OC71 or OC75.
Tr₃—OC72 or SFT 323.
Loudspeaker—3 ohms

R₂—10K.
R₄—22K.
R₅—5.6K.
R₆—100 ohms.
T₁—   type LT700.
L₁—   1¾″ ferrite rod
  aerial.

Circuit No. 26.

This receiver has the same output power as that of Fig. 35 but has much more gain. The increased gain is obtained by transformer coupling Tr₂ to Tr₃ and it makes the set more suitable than the last one for difficult reception areas. The added gain is achieved at the expense of simplicity, however, since far more components are required. Unless the extra gain is really needed the last circuit will be preferable.

Just for the sake of variety a different form of regeneration has been used. L₂ consists of 10 turns wound next to the yellow wire end of L₁ and it does not need to move. Feedback is controlled by means of C₄, a 40 pf trimmer capacitor. If oscillation cannot be achieved reverse the connections to L₂. Conventional stabilisation is used for Tr₁ to provide a collector current of about ¼ mA. The regeneration systems used in Figs. 34 and 35 may be used instead of the one shown.

Components.

C₁—250 pf tuning cap-
  acitor
C₂—0.01 mfd.
C₃—100 mfd. 3 v.w.

C₄—40 pf trimmer.
C₅—2 mfd. 12 v.w.
C₆—100 mfd. 3 v.w.

C₇—100 mfd. 12 v.w.

C₈—2 mfd. 12 v.w. TSL.
C₉—100 mfd. 3 v.w.

Loudspeaker—3 ohm

R₁—2.2K.
R₂—68K.
R₃—10K.

R₄—1K.
R₅—47K.
R₆—4.7K.
R₇—1K.
R₈—5K volume control.
R₉—470 ohms.
R₁₀—8.2K.
R₁₁—2.2K.
R₁₂—220 ohms.
Tr₁—OC44

Tr₂—OC71

Tr₃—OC72

L₁—   1¾″ ferrite rod.
T₁—   type LT44.
T₂—   type LT700.
R.F.C.—1.5 mH.

This completes the series of regenerative detector receivers circuits given in this book. They are a little more difficult to build than the sets in Chapter 2 but they are also more rewarding. One point should be remembered, these sets are not suitable for use by someone unfamiliar with this type of set so they make poor presents. Anyone who has no knowledge of them is unlikely to be able to set the regeneration level correctly so that they may cause oscillation and hence interference. They are best suited, therefore, for use by the constructor himself.
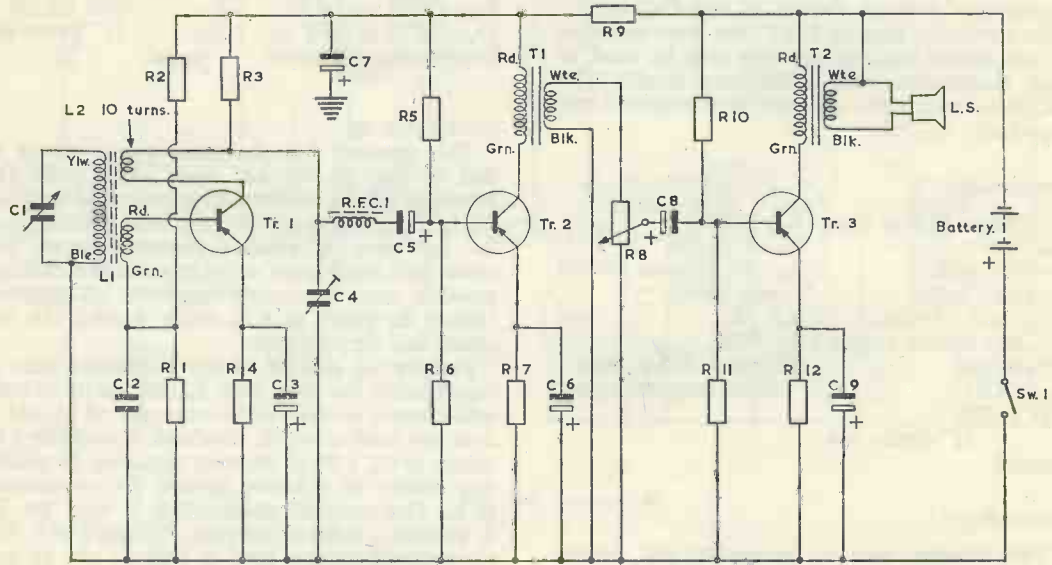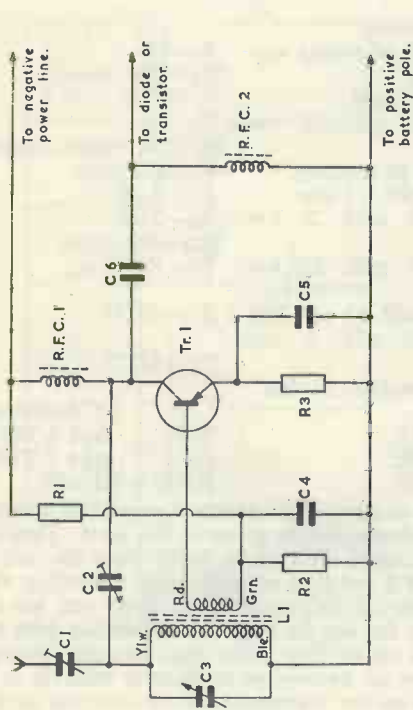
Fig. 36. Circuit Nº 26.

Fig. 37. Circuit Nº 27. R.F add on unit for circuits In chapter 2.
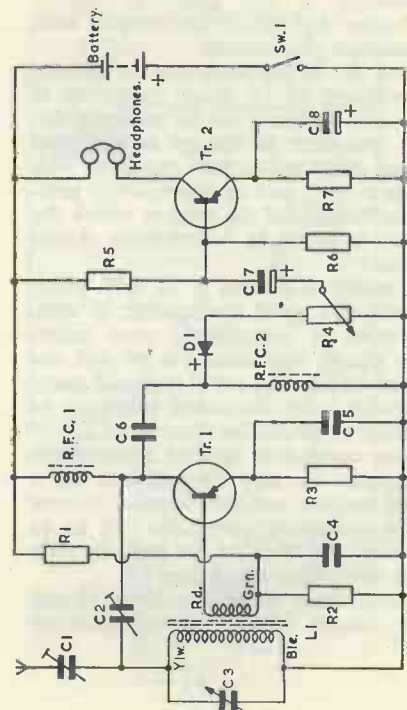

Fig. 38. Circuit Nº 28. Circuit Nº 27 combined with that of circuit Nº 5.

32

Circuit No. 27.   R.F. Add-on Unit.

The reasons for the shortcomings of the simple sets in Chapter Two have already been given and it may be remembered that they are primarily due to a lack of R.F. gain before the detector. Fig. 37 shows the circuit diagram of an R.F. amplifier that may be added to any of the circuits in Chapter Two and which will considerably boost their performance. In many cases it will make it possible to use the set without an external aerial of any sort. The selectivity will also be improved considerably.

Tr_1 acts as an R.F. amplifier and this is its only function. The signal is picked up by the ferrite rod aerial, or by an external aerial when one is used, and fed to the transistor. The output load for the transistor is the R.F. choke R.F.C.1. The output from the unit as a whole is taken from across R.F.C.2. When this unit is connected to any of the circuits in Chapter Two, the aerial coil and tuning capacitor of that circuit are omitted and R.F.C.2 of Fig. 37 is connected in place of the secondary of the aerial coil. The only other connections to be made are those connecting the negative and positive lines of the R.F. amplifier to those of the receiver.

The R.F. gain of the amplifier is considerably increased by the regeneration which also improves the selectivity. The gain is not entirely dependent on regeneration, however, as it is in regenerative detectors. The unit will work without regeneration and this is only used to improve the performance. The degree of regeneration is controlled by C_2, but, once set, it need not be altered each time a new station is tuned in. It can be adjusted and forgotten in fact.

C_2 should be set to as high a position as possible without oscillation occurring at any setting of the tuning capacitor. This is best done by setting C_2 so that the set is oscillating and then bringing it back slowly until oscillation just stops. C_2 should now be tuned across the band and it will probably be found that oscillation still occurs at one or two frequencies. C_2 should then be reduced slightly again until oscillation does not occur at all. Once set, C_2 should not need to be altered again unless the set is operated in somewhere where the temperature is considerably different from that when the adjustment was made.

When the add-on unit is to be used with a low voltage set, 4.5 volts or less, the use of an S.B.T. instead of an OC44 is possible. If the voltage is only 1.5 volts an S.B.T. will, in fact, give a much better performance.

In some cases it may be necessary to remove the connections to the secondary of the aerial coil before oscillation can be obtained. It may also be necessary to use a larger value for C_2 if the supply voltage is very low but this is unlikely.

Components.

C_1—40 pf trimmer	R.F.C. 1 and 2—1.5 mH
C_2—20 pf trimmer.	—2.5 mH (not critical).
C_3—250 pf tuning capacitor	L_1— 1¾″ ferrite rod aerial.
C_4—0.01 mfd.	Tr_1—OC44 or SFT 308.
C_5—0.1 mfd.	R_1—4.7K.
C_6—0.1 mfd.	R_2—2.2K.
	R_3—1K.

Circuit No. 28.

This circuit is included to give an example of how the circuit of Fig. 37 can be coupled to those in Chapter Two. The circuit it is couple to is that of Fig. 15.

As may be seen, the circuit of Fig. 15 remains completely unchanged except for the input. In a sense, the R.F. amplifier has been interposed between the aerial coil and the diode with a resulting increase in both gain and sensitivity. Since this type of set does not need any special adjustment each time it is tuned it is perfectly suitable for use by someone unfamiliar with its methods of functioning. It is so simple to use, in fact, that it can be given as a present to anyone without any special operating instructions.

Reflex Receivers.

The regenerative detector type of receiver overcame, to a certain extent, the disadvantages of the circuits in Chapter Two, but they do have disadvantages themselves. The main one is the need to readjust the regeneration level frequency but they also suffer from insufficient sensitivity for many purposes. Circuits as simple as these cannot, of course, be expected to compete with commercial sets which are very much more complicated but better results can be obtained by using the reflex principle. A well designed reflex set can be almost as good as a manufactured 6 transistor superhet. It will not have quite the sensitivity but for the Home, Light and Third and possibly Luxembourg it may be just as good particularly from the quality point of view where it may well outstrip the superhet.

A reflex amplifier is one that amplifies two different frequencies in a receiver at the same time. Unlike a regenerative detector, however, it does not demodulate the signal. Nor does it depend on its R.F. amplification purely on regeneration. Since the transistor does not have to act as a detector, this function being performed by a diode, there is no need for a compromise as far as the collector current is concerned, this may be set for maximum gain. Since maximum R.F. gain and maximum A.F. gain must occur at very much the same collector current levels there is no confliction of interests as far as these are concerned.

A reflex radio works then, in the following way: the required signal is amplified at R.F. by the first transistor and is then demodulated by a germanium diode as in Fig. 38. From the diode, however, the A.F. signal is returned to the first
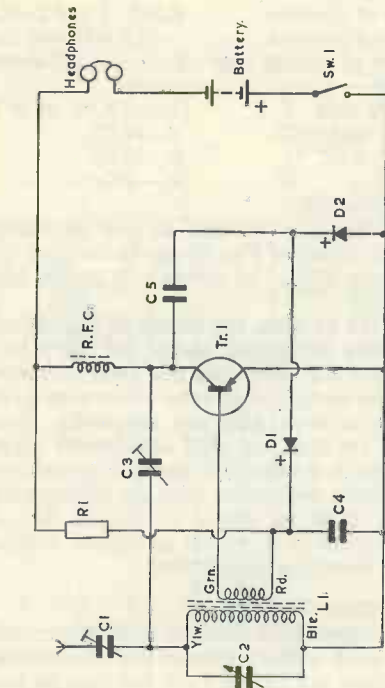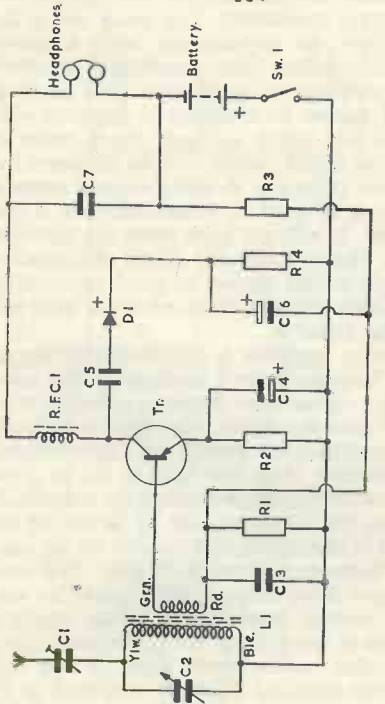
Fig. 41. Circuit No 31.

Fig. 42 Circuit No 32.

Fig. 39. Circuit No 29. Simple reflex receiver.
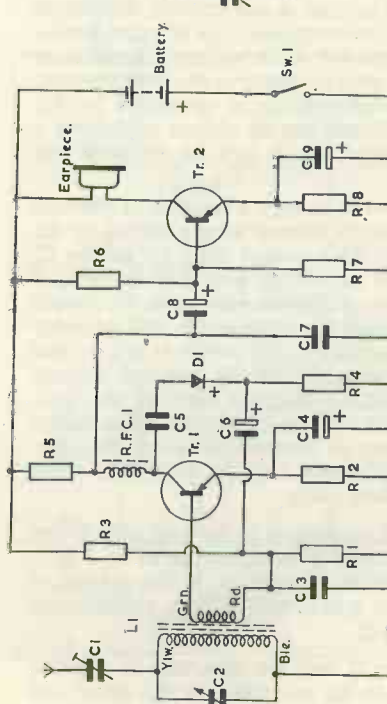
Fig. 40. Circuit No 30.

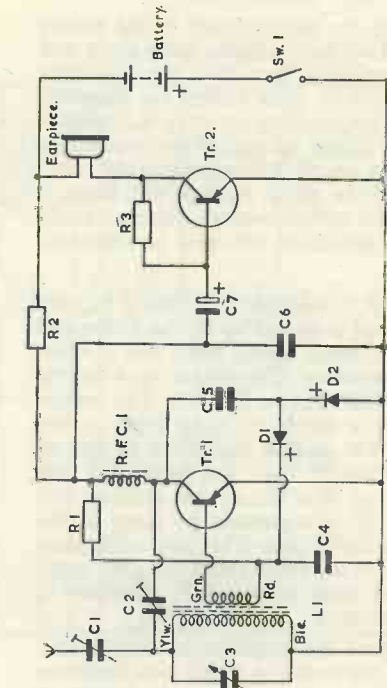transistor to be amplified again. Any further stages there may be will simply provide more A.F. amplification. Regeneration may be used to maximise the R.F. gain and improve selectivity but it need not be continuously adjusted.

Circuit No. 29.

The first reflex receiver is shown in Fig. 39. It may be compared with that of Fig. 38. Both circuits give the same performance but Fig. 39 achieves it with one less transistor because Tr_1 amplifies at R.F. and A.F. thereby performing the functions of Tr_1 and Tr_2 in Fig 38.

After the required signal has been selected by the tuned circuit it is amplified by the transistor. The R.F. output of Tr_1 is prevented from reaching the headphones by the R.F. choke and is passed to the diode via C_5. The A.F. output from the diode is developed across R_4 and fed back to Tr_1 via C_6. Any R.F. that may have crept through is earthed by C_3 which has too low a value to noticeably attenuate the A.F. signal. The A.F. signal is then amplified by the transistor and fed to the headphones via the R.F.C. which has much too low a value to block it at all. C_5 has a low enough value to prevent the A.F. signal from reaching the diode.

The transistor is biased to a collector current of 1 mA at which level it will give a high gain at both R.F. and A.F. As a matter of interest the transistor gives a total power gain of something like 60 dB or 1,000,000 times.

Regeneration may be applied by connecting a 20 pf trimmer between the collector of Tr_1 and the yellow terminal of the ferrite rod aerial. It may then be adjusted as in Fig. 38.

With regeneration used this set will work in some areas without an external aerial, a remarkable achievement for a single transistor radio. Under these circumstances the volume will, of course, be very low but the fact that it is possible at all is amazing.

Components.

C₁—40 pf trimmer.
C₂—250 pf tuning capacitor
C₃—0.01 mfd.
C₄—25 mfd. 12 v.w.

C₅—200 pf.
C₆—2 mfd. 12 v.w.
C₇—0.01 mfd.
Tr₁—OC44 or SFT 308.

R₁—2.2K.
R₂—1K.
R₃—18K.
R₄—5K.
D₁—OA70

L₁—   1¾″ ferrite rod aerial.
Headphones or earpiece —high impedance magnetic type.
R.F.C.—1.5 mH.

Circuit No. 30.

Fig. 40 shows the circuit of a receiver similar to that of Circuit No. 29 but with an additional state of A.F. amplification. With the extra gain provided by Tr_2 the set will give really good volume without an external aerial.

Both Tr_1 and Tr_2 are biased so as to have col-

lector currents of 1 mA making the total consumption of the set 2mA. This is low enough for a PP5 battery to be used so the set may be built very compactly. If the smallest components available are used the set may be built into one of the TSL 1/-d. plastic boxes.

As the quality of this type of set is normally very good it may be used as a jack for recording radio programmes on tape. For this purpose the earpiece should be replaced by a 4.7K ohm resistor and the output taken from across this resistor via a 1 mfd. isolating capacitor. For best quality regeneration should not be used although a small amount will do no harm. This may mean that an aerial is necessary in which case it should be kept as short as possible consistent with an adequate recording level. If it is necessary to use a long cable between the receiver and the tape recorder the value of the resistor should be reduced to 1K ohm. The output from the set should be sufficient to drive virtually any tape recorder on the market.

Components.

C₁—40 pf trimmer.
C₂—250 pf tuning capacitor
C₃—0.01 mfd.
C₄—25 mfd. 12 v.w. TSL.
C₅—200 pf.
C₆—2 mfd. 12 v.w.
C₇—0.01 mfd.
C₈—2 mfd. 12 v.w.
C₉—50 mfd. 3 v.w.
Tr₁—OC44 or SFT 308.
Tr₂—OC71 or SFT 352.
9 volt battery.

R₁—2.7K.
R₂—1K.
R₃—18K.
R₄—5K.
R₅—1K.
R₆—33K.
R₇—4.7K.
R₈—1K.
D₁—OA70

R.F.C.1.—1 mH — 2.5 mH.
High impedance magnetic earpiece 1K ohm.

Circuit No. 31.

Simpler reflex circuits than those just described are possible. The one shown in Fig. 41 is a typical example. It uses two diodes instead of one but far fewer resistors and capacitors because stabilisation is by means of a feedback resistor instead of an emitter resistor and base bias potentiometer. The performance of the set is very much the same as that of Fig. 39.

Regeneration is included in the circuit, feedback being by means of a 20 pf trimmer. In some cases, it may be better to use a 10 pf type to achieve a smoother and finer control. Once set to the optimum position the regeneration control need not be altered.

Components.

C₁—40 pf trimmer.
C₂—250 pf tuning capacitor
C₃—20 pf trimmer.
C₄—0.01 mfd.
C₅—200 pf.
R₁—100K.
R.F.C.—1—2.5 mH.

Tr₁—OC44 or SFT 308.
D₁ ₂—OA70's

L₁—   1¾″ ferrite rod aerial.
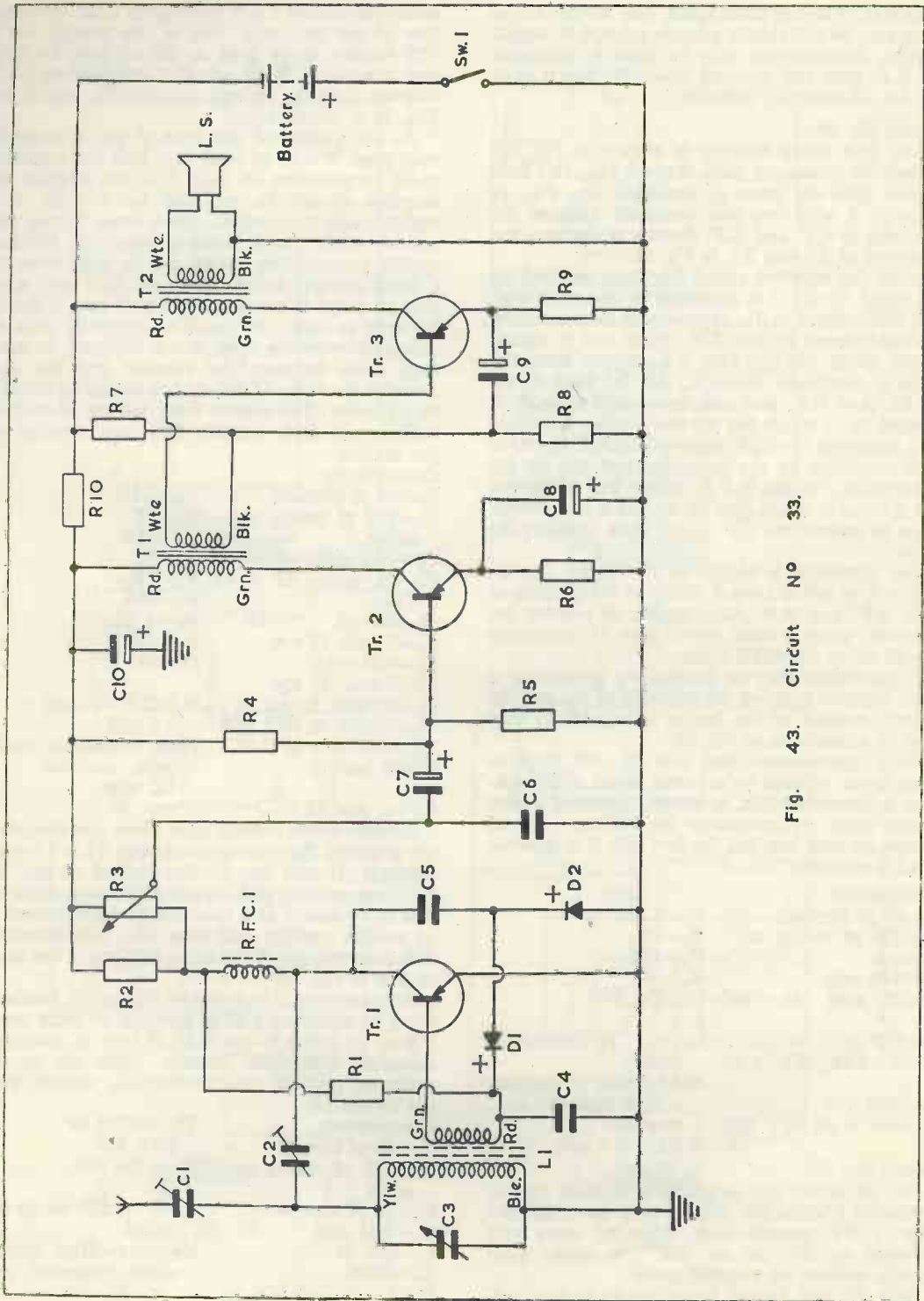Earpiece—High impedance magnetic type 1K ohm.
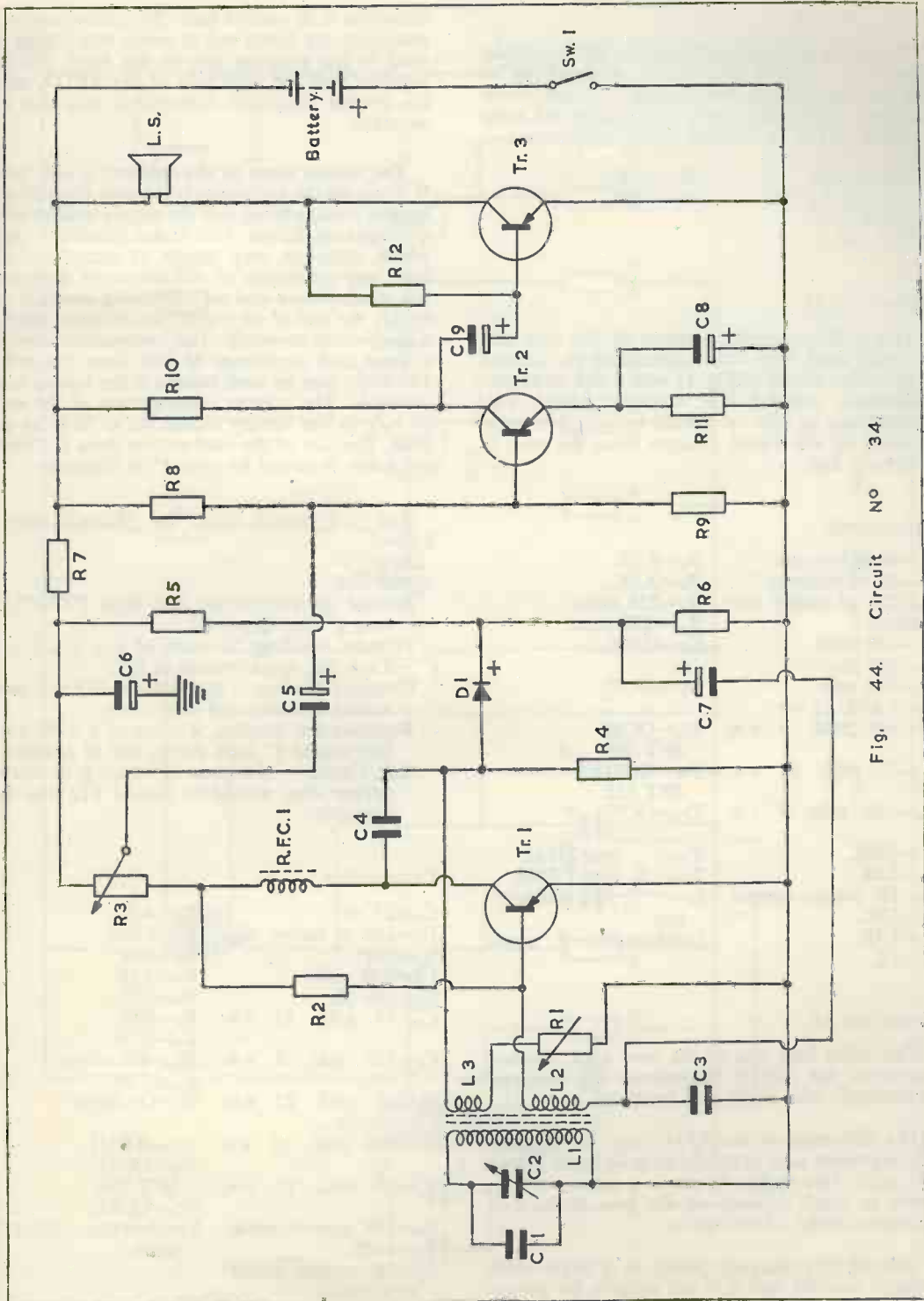
Fig. 43. Circuit No. 33.

Fig. 44.   Circuit No 34.

Circuit No. 32.

By adding a simple A.F. stage to the last circuit a receiver of similar performance to that of Fig. 40 can be built whilst maintaining the component economy. The components required are the same as those for Fig. 41 with the following additions:—

C_6—0.01 mfd.	R_2—2.2K.
C_7—2 mfd. 12 v.w.	R_3—510K.
Tr_2—OC71 or	
SFT 352.	

Circuit No. 33.

This is the last reflex receiver of this type and it should need very little explanation. It consists of the reflex circuit of Fig. 41 with a two transistor transformer coupled A.F. amplifier added. The performance of this set should be adequate even in areas of low signal strength since the gain is extremely high.

Components.

C_1—40 pf trimmer.	R_7—8.2K.
C_2—10 pf trimmer.	R_8—2.2K.
C_3—250 pf tuning cap-	R_9—220 ohms.
acitor	R_{10}—470 ohms.
C_4—0.01 mfd.	D_1—OA70,
C_5—200 pf.	
C_6—0.01 mfd.	D_2—OA70,
C_7—2 mfd. 12 v.w.	
C_8—100 mfd. 3 v.w.	Tr_1—OC44
	SFT 308.
C_9—25 mfd. 12 v.w.	Tr_2—OC71
	SFT 352.
C_{10}—100 mfd. 8 v.w.	Tr_3—OC72
R_1—100K.	T_1— type LT44.
R_2—2.2K.	T_2— S1 type LT700.
R_3—5K volume control.	L_1— 1¾" ferrite
R_4—33K.	rod.
R_5—4.7K.	Loudspeaker—3 ohms
R_6—1K.	

Circuit No. 34.

This radio uses one of the new alloy diffused transistors, the AF117. The circuit was designed by Mullards who make this transistor.

The advantage of the AF117 over an ordinary R.F. transistor such as the OC44 is its much higher R.F. gain. This makes its use in a reflex receiver, where so much depends on the gain of the first transistor, really advantageous.

This set was designed purely as a larger sized portable receiver and it is not suitable for minia-turisation in its present form. To achieve maximum sensitivity the aerial rod is much larger than that used in the previous sets in this book and this, together with the high gain of the AF117, makes the overall sensitivity comparable with that of a superhet.

The output stage of the receiver is also novel. It works on the half-supply principle, the collector-emitter voltage being half the supply voltage under quiescent conditions. This makes possible a circuit which, although very simple, is completely free from any possibility of the transistor dissipating too much power and so destroying itself. It also avoids the use of an output transformer which is a worthwhile economy. The loudspeaker used has a voice coil impedance of 130 ohms but one of 140 ohms may be used instead if the former is not available. The current consumption of the set is 40 mA so the battery should be as large as possible. The size of the loudspeaker does not matter much but it should be over 4" in diameter.

The coil details given by Mullards are as follows:—

Aerial Coil.

Wound on Ferroxcube rod type FX1057, 6" long ½" dia. Grade B2.

Primary winding, 50 turns of 3 x 3 x 3 x 46 s.w.g. litz, spreadwound to 2½".

Coupling winding, 3 turns of 3 x 46 s.w.g. inter-wound at earthy end of primary.

Regenerative winding, 4 turns of 3 x 46 s.w.g. interwound ¾" from earthy end of primary.

R.F. Choke — 600 turns of 40 s.w.g. enamelled copper wire, wound on Neosid T12 iron dust assembly.

Components.

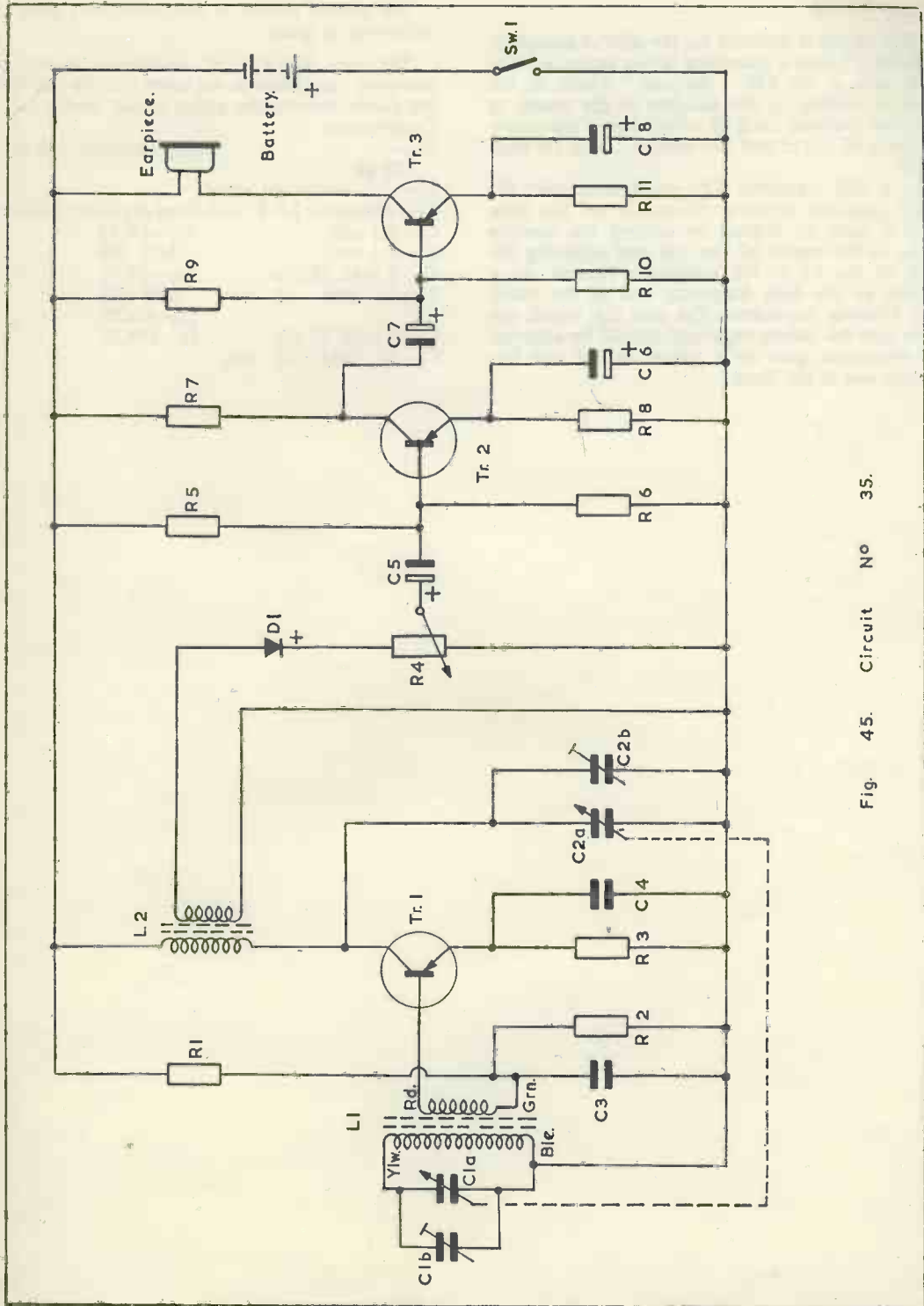|	
C_1—27 pf.	R_4—4.7K.
C_2—365 pf tuning cap-	R_5—150K.
acitor	R_6—10K.
C_3—0.02 mfd.	R_7—2.2K.
C_4—330 pf.	R_8—33K.
C_5—10 mfd. 12 v.w.	R_9—10K.
	R_{10}—1.5K.
C_6—100 mfd. 8 v.w.	R_{11}—470 ohms.
	R_{12}—5.6K.
C_7—10 mfd. 12 v.w.	D_1—OA70 or
C_8—100 mfd. 12 v.w.	Tr_1—AF117.
	Tr_2—OC71
C_9—10 mfd. 12 v.w.	SFT 352.
	Tr_3—OC81
R_1—50K semi-variable.	Loudspeaker—130-150
R_2—500K.	ohms.
R_3—5K volume control with switch.	

Fig. 45. Circuit No 35.

Circuit No. 35.

This circuit is included for the sake of completeness since it uses a twin-gang tuning capacitor. The type used is the TSL " Babyvar " which, at the time of writing, is the smallest in the world. It has two sections each of which has a maximum capacity of 120 pf and two trimmers; one for each gang.

L_2 is any transistor I.F. transformer with the fixed capacitor removed. When the set has been built it must be aligned by moving the winding of L_1 to the centre of the rod and adjusting the slug of the I.F.T. for maximum volume on a station at the high frequency end of the band. The trimmer capacitors, C_1a and C_2b which are built into the tuning capacitor, should be adjusted for maximum gain on a station at the low frequency end of the band.

The gain of this set is not particularly good but selectivity is good.

The vast majority of commercial radios use two-gang capacitors in superhet circuits but these are rather outside the scope of this book.

Components.

$C_{1\,2}$—   tuning capacitor 120 pf + 120 **pf.**

L_1—   ferrite rod aerial.

L_2—Transistor I.F.T. with fixed capacitor removed.

C_3—0.1 mfd. Tr_1—OC44

C_4—0.1 mfd.   SFT 308.

C_5—2 mfd. 12 v.w. Tr_2—OC71

C_6—10 mfd. 12 v.w.   SFT 352.

.. Tr_3—OC75.

C_7—2 mfd. 12 v.w. D_1—OA70

C_8—10 mfd. 12 v.w.

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