RADIO SERVICING POCKET BOOK

EDITED BY J.P. HAWKER

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POCKET BOOK

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J. P. HAWKER

The fully-revised second edition of this popular pocket manual and data book contains much new information. Of particular interest will be the practical guidance on the servicing of transistor receivers and the repair of printed wiring panels.

The sections on servicing and aligning V.H.F./F.M. receivers have been expanded; car radio receivers, the suppression of car electrical interference, and record reproducers (including stereo reproduction) are all dealt with in greater detail.

Apart from the basic sections on modern radio circuits, much useful information is given on servicing instruments, fault-finding and alignment, aerials and electrical interference suppression, gramophone mechanisms and pick-ups. In addition, some 35 pages of tabulated reference data includes valve base connections and equivalents, transistors and crystal diodes, B.B.C. and European broadcasting stations, battery equivalents, wavelength-frequency conversion, etc.

In short, this book provides the essential information and data needed in the day-to-day work of servicing the whole range of modern A.M. and V.H.F./F.M., valve and transistor radios.

Experienced engineers, trainees and newcomers to servicing work will all find that this book shows an understanding of their real needs, and will repay its cost time and time again.

Second Edition

A companion volume to
"Television Engineers' Pocket Book"

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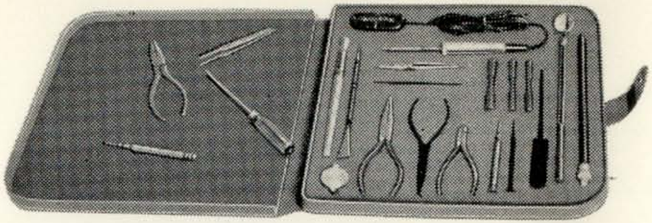

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J. P. HAWKER

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PREFACE

Radio servicing has advanced a long way since the days when a voltmeter, an accumulator-charger and a stock of replacement valves comprised the " Service Department " of many shops. Today, it is widely recognised that first-class, after-sales service, organised on sound economic lines, is a prime requisite of the industry.

This change in outlook has brought great opportunities to all those engaged in radio and television servicing. But modern radio receivers—*particularly those for frequency-modulation or using transistors*—call for considerably greater technical knowledge and skill on the part of the service engineer; and present also an ever-increasing need for a handy source of technical information and data available for instant reference in the workshop, or when carrying out repairs in the field.

This book—a companion volume to *Television Engineers' Pocket Book*—contains basic information on modern radio circuitry, including special sections on F.M. and transistor receivers, alignment, fault-finding, servicing equipment and workshop practice, aerials and earths and the cure of electrical interference. In addition, much useful reference material is given, including valve-base connections, valve equivalents, transistors, colour codes, basic formulae with worked examples, wavelengths and frequencies of B.B.C. and European stations, together with wavelength/frequency conversion tables.

J. P. Hawker.

CONTENTS

[SECTION 1]

MODERN A.M. VALVE RECEIVERS

THE majority of the low- and medium-priced A.M. receivers manufactured in the post-war period employ basically similar chassis, though with considerable variation in detail and in presentation. By far the most popular arrangement is a four-valve (plus power supply) superheterodyne circuit comprising :

A triode-hexode or heptode frequency changer.
A variable-mu pentode amplifier operating at an I.F. of the order of 470 kc/s.
A double-diode-triode (or diode-triode) as demodulator, A.G.C. rectifier and A.F. amplifier.
A beam-tetrode or pentode A.F. output valve.

Three-valve circuits which dispense with the first stage of A.F. amplication and in which the demodulator and A.G.C. diode(s) are combined with the I.F. or output valves are also fairly common. Recently, the introduction of new combination valves, such as the triode-pentode, is noticeably affecting the layout of the "standard" type of circuit: for example, a popular arrangement is to use a frequency-changer, a diode-pentode as I.F. amplifier and combined demodulator/A.G.C. diode, followed by a triode-pentode as A.F. amplifier and output stage. This provides a three-valve chassis having substantially the same performance as the "standard" four-valve arrangement. A few models use reflex amplifiers in which a single pentode valve is used first for I.F. amplification and subsequently, by filtering circuits, for A.F. amplification.

Straight (tuned-R.F.) circuits have completely disappeared from the ranges of many manufacturers, but are still occasionally found in the small transportable receivers intended for local-station reception.

Band-pass aerial tuning and tuned R.F. amplifiers, both of which involve the added complication of a three-gang tuning capacitor, are seldom found in standard models, though tuned R.F. stages are featured in some of the more expensive models and in car radios.

The use of push-pull output stages to provide a greater output, to reduce even harmonic distortion and to prevent core saturation of the output transformer, is general in the higher price ranges. To drive such stages a phase-reversing stage is fitted to provide oppositely phased signals to feed to the control grids of the two output valves.

Miniature valves and components, and the introduction of the layer-built H.T. battery made the all-dry battery receiver and the combined mains/battery receiver popular for a time, but such designs have now been largely superseded by transistor models (see Section 3). The earlier 2-volt wet accumulator for low-tension supplies has also gradually disappeared, though still occasionally found in country districts.

The Aerial-input Circuit

Good selectivity before the frequency changer is essential with the crowded broadcasting situation on the medium and long waves in Europe. Unless care is taken to achieve sufficient selectivity in the aerial-input circuit, heterodynes will occur due to break-through of stations operating on the image frequency or other frequencies giving rise to spurious responses.

For example, with a receiver having an I.F. of 470 kc/s tuned to 650 kc/s, the local oscillator will usually be on $650 + 470 = 1{,}120$ kc/s. Now a station operating on $1{,}120 + 470 = 1{,}590$ kc/s would also beat with the oscillator to give an output on 470 kc/s. To eliminate completely such spurious signals, an efficient—*i.e.*, high Q-factor—tuned circuit must be used. On the other hand, if this selectivity is too great, there will be a loss of the higher A.F.s, due to side-band cutting, particularly on the lower frequencies. It is also desirable that the tuned circuit should give a fairly uniform performance over the entire tuning range, and should have a reasonably efficient impedance match with the type of aerial for which the receiver is intended. For all these reasons, the design of the aerial-

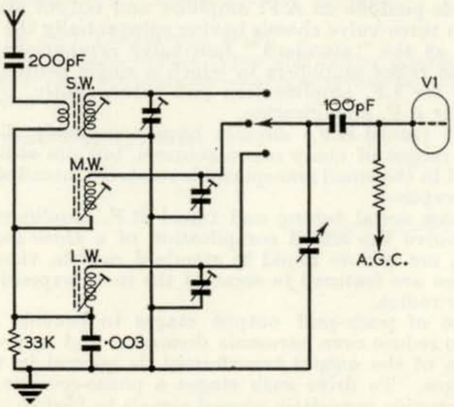


FIG. 1.—A THREE-WAVEBAND AERIAL COUPLING CIRCUIT POPULAR IN MODELS WITH EARTHED CHASSIS.

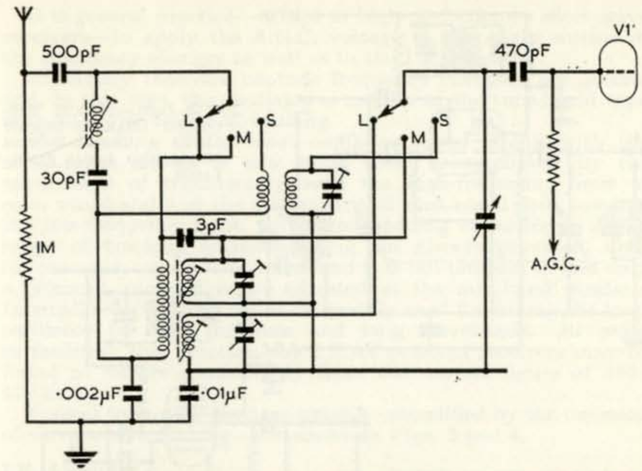


FIG. 2.—A MORE ELABORATE AERIAL-INPUT CIRCUIT USED WITH LIVE CHASSIS. THIS IS DISCUSSED IN THE TEXT.

input circuit affects markedly the ultimate performance of the receiver and tends to be somewhat more complicated than might be expected—although the increasing use of ferrite-rod aerials as the tuning inductance has tended to simplify this part of the circuit in recent years.

For standard models, probably the most used system is mutual inductance coupling with a high-impedance primary, which also operates—possibly with added shunt capacitance—on the long waves. To obtain greater uniformity of performance, a " top-capacitance " of about 3 pF may be added between the aerial socket and the grid end of the tuned winding. Alternatively, separate aerial coupling coils may be switched in for each band.

To avoid interference from stations operating on or near the I.F. (of especial importance in coastal areas where shipping or coast stations on the 600-metre band are active), an I.F. rejector circuit is often included. This may take the form of a capacitor of about 30 pF in series with a coil wound on an iron-dust core connected across the primary winding of the aerial coil, the dust core being adjusted to bring the circuit into resonance at the I.F. Less commonly, the rejector may be a parallel resonance trap between the aerial socket and the aerial coil.

Better image rejection than is possible with a single-tuned circuit, and at the same time freedom from serious side-band cutting, can be obtained with a band-pass input circuit. This method, however, is little used at present owing to the extra coils and the three-gang capacitor required.

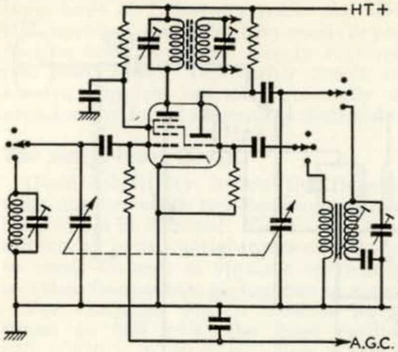


FIG. 3 (*left*).—TYPICAL FREQUENCY CHANGER CIRCUIT USING A TRIODE-HEXODE MIXER AND LOCAL OSCILLATOR.

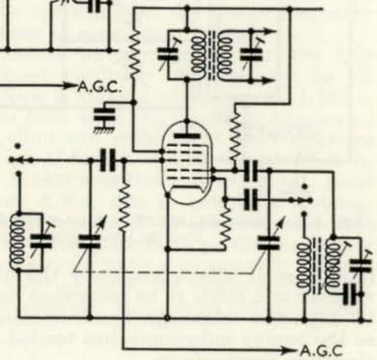


FIG. 4 (*right*).—TYPICAL CIRCUIT FOR A PENTAGRID FREQUENCY CHANGER.

On chassis which are connected directly to one side of the mains supply, an isolating capacitor should be connected in both the aerial and earth leads, and a resistor should be connected between the aerial and earth sockets to provide a D.C. continuity as a static discharge path.

These points are illustrated in Fig. 2.

Frequency Changer

The design of frequency-changing circuits in mains-operated receivers has remained basically similar for many years. The valve is almost always either a triode-hexode, triode-heptode or heptode (pentagrid). The variations that do occur are mainly in the type of feedback used in the oscillator circuit.

An economy measure that is now widely adopted is the omission of the cathode biasing resistor and by-pass capacitor, the cathode current being kept within its limits by lowering the screen voltage. To overcome the wide variation of oscillator output at various settings of the tuning capacitor and on different wavebands, resistors are often included in the grid-lead of the oscillator, particularly on the short-wave band.

It is general practice—except in high-performance short-wave receivers—to apply the A.G.C. voltage to the mixer section of the frequency changer as well as to the I.F. amplifier.

In battery receivers heptode frequency changers are general and, in this case, the oscillator is usually of the tuned-grid type with an anode feedback winding.

The tracking of the local oscillator tuned circuit with the aerial-input circuit is now most often accomplished by the adjustment of trimmers towards the high-frequency limit of each waveband and the adjustment of dust-cored coils towards the low-frequency limit, with fixed padding capacitors. A full range of tracking adjustments is not always provided, and, for example, on the long waveband it is not unusual to find only a trimmer intended to be adjusted at the mid-band position. In small receivers one coil is frequently used for tuning the local oscillator for both medium and long wavebands. In order to facilitate this practice, the I.F. of personal receivers may be found to depart considerably from the normal figure of 460–470 kc/s.

Typical frequency-changer circuits—simplified by the omission of waveband-switching—are shown in Figs. 3 and 4.

I.F. Amplifier

The main improvements relating to the I.F. amplifier have taken place in the design of the I.F. transformers rather than in changes in circuitry, which has remained basically similar for many years. Few receivers have more than one stage of I.F. amplification, though some battery models include an extra stage operating usually into a resistive (untuned) load.

The overall band-width of the receiver is largely determined in the I.F. section of a superheterodyne receiver. Fig. 6 shows the effect of: (*a*) too sharply-peaked; (*b*) insufficiently selective; and (*c*) almost ideal band-pass response curves. Curve (*c*) may be obtained by means of stagger-tuning the I.F. tuned circuits (see "Alignment"); in practice, however, relatively few standard models are adjusted in this manner. Fig. 7 shows a typical I.F. response curve achieved with two transformers. Since this curve departs appreciably from the ideal vertically sided response,

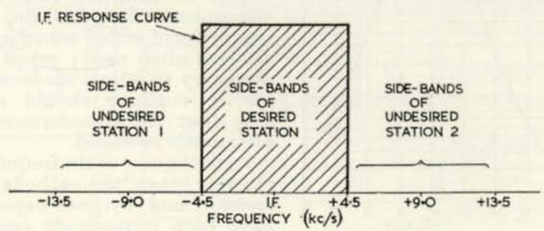


FIG. 5.—IDEAL I.F. RESPONSE CURVE.

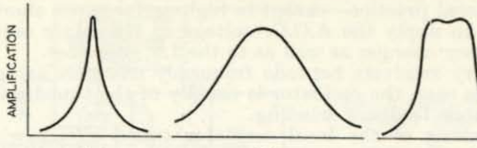


FIG. 6.—PRACTICAL I.F. RESPONSE CURVES.

considerable side-band cutting of the higher frequencies results, even from the moderate degree of selectivity represented by this curve. The fall-off in treble response has to be made good as far as possible by tone correction (treble rise) in the A.F. circuits of the receiver.

In order to reduce valve damping, the secondary of the second I.F. transformer may be tapped; this reduces the gain but improves selectivity. Alternatively, the inductance of this final winding may be considerably less than that of the other I.F. transformer windings, the circuit being brought to resonance by increasing the value of the capacitor.

The sense of connection of the I.F. transformer windings affects the band-width of the receiver owing to the capacitance coupling that exists between the windings: the connections should generally be such that the stray capacitance coupling assists rather than opposes the magnetic coupling. When replacing I.F. transformers, care should therefore be taken to ensure that the sense of connection has not been changed.

The gain of I.F. stages may be much reduced by the effects of moisture in the transformers, and this is especially the case with battery receivers in humid atmospheres. Mains-operated receivers are less affected, provided they are in regular operation, since the heat produced in the receiver tends to dry out the windings. To overcome the effects of moisture and other atmospheric deterioration, various types of sealed transformers are now often used; when it is necessary to adjust the cores the service engineer should make sure that the transformers are afterwards re-sealed.

As in the case of the frequency-changer stage, the cathode bias resistor and by-pass capacitor have been increasingly omitted from the I.F. valve.

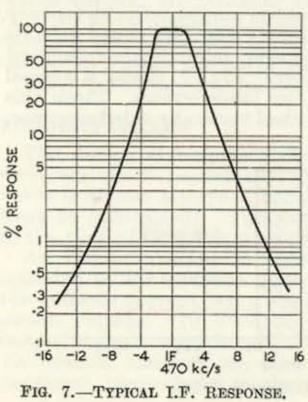


FIG. 7.—TYPICAL I.F. RESPONSE.

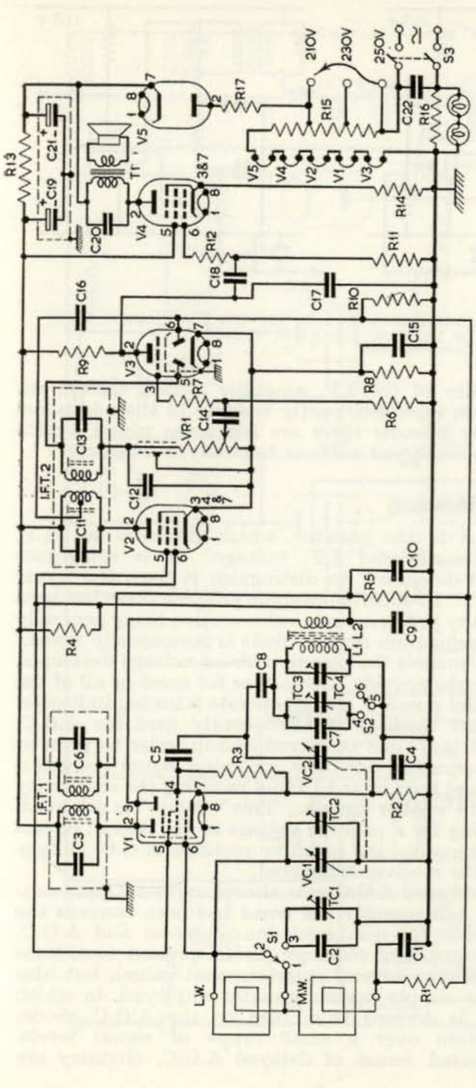


FIG. 8.—A REPRESENTATIVE COMPACT TRANSPORTABLE A.C./D.C. RECEIVER CIRCUIT.

Valves.		*Capacitors.*						*Resistors.*			
V1	UCH42	C1	0·05	C10	0·05	C19	16	R1	1M	R10	1M
V2	UF41	C2	130 pF	C11	110 pF	C20	0·01	R2	220	R11	470k
V3	UBC41	C3	110 pF	C12	100 pF	C21	32	R3	47k	R12	47k
V4	UL41	C4	0·05	C13	110 pF	C22	0·1	R4	12k	R13	10k
V5	UY41	C5	50 pF	C14	0·01	TC1—TC4	4–40 pF	R5	2·2M	R14	150
		C6	110 pF	C15	0·05	VC1 } VC2 }	2 × 528 pF Ganged	R6	2·2M	R15	950 + 150 + 150
		C7	515 pF	C16	50 pF			R7	100k	R16	250
		C8	605 pF	C17	0·003			R8	330	R17	150
		C9	0·05	C18	0·01			R9	150k	VR1	500k

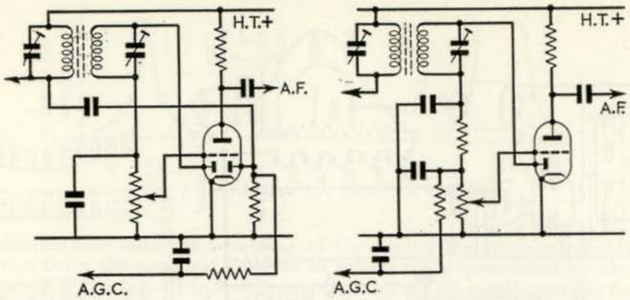


FIG. 9.—TYPICAL DEMODULATOR CIRCUITS SHOWING TWO COMMON WAYS OF DERIVING THE A.G.C. VOLTAGE.

Variable selectivity of the I.F. amplifier is now seldom encountered in modern receivers, partly because of the additional expense, and partly because there are few areas where a wide band-width can be employed without heterodyne whistles.

The Demodulator (Detector)

The demodulator is the rectifier which produces an A.F. voltage from the modulated I.F. voltage. It is sometimes called the "second detector" to distinguish it from the mixer or "first detector". In superheterodyne practice there has been little change for many years, a diode valve section being generally used, although a germanium crystal diode is occasionally fitted.

In many current models the negative direct voltage developed by the diode is used to provide A.G.C. bias for some or all of the preceding valves, and possibly also to operate a tuning indicator. However, a separate diode is still frequently used for A.G.C. in order that a "delay" can be introduced in order to prevent the A.G.C. from operating until the incoming signal reaches a certain predetermined level so as to avoid reducing the sensitivity of the receiver on the weaker signals. This "delay" is achieved, usually, by arranging for a positive voltage in the A.G.C. circuit having to be overcome by the negative rectified A.G.C. voltage before the gain of the receiver is affected.

A few years ago delayed A.G.C. was almost universal on mains-operated receivers, but recently the trend has been towards the use of a single diode for combined demodulation and A.G.C. This is partly on grounds of economy (under present conditions weak signals are seldom of real entertainment value), but also partly because the simple system usually employed, in which the delay voltage is derived from bias on the A.G.C. diode, may cause distortion over a small range of signal levels. The more complicated forms of delayed A.G.C. circuitry are

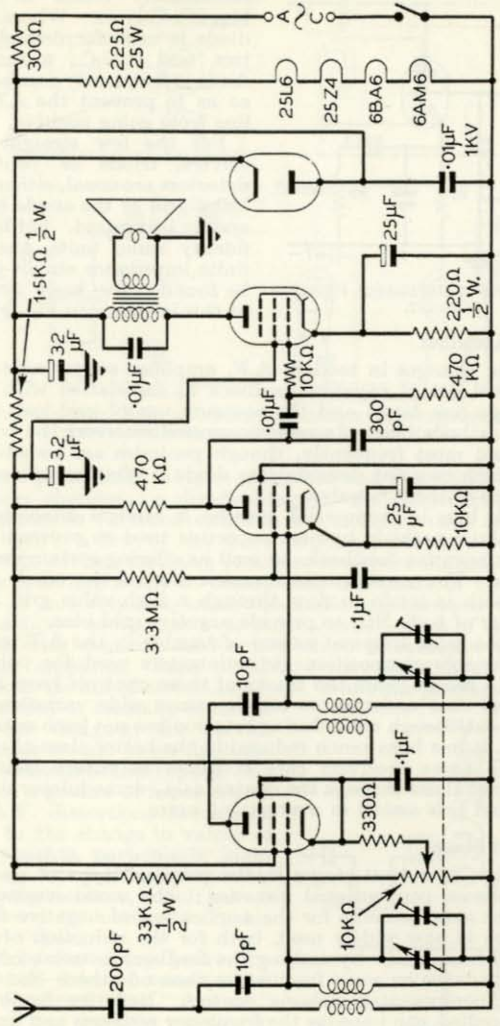


FIG. 10.—REPRESENTATIVE CIRCUIT OF A MINIATURE T.R.F. (STRAIGHT) RECEIVER FOR LOCAL STATION RECEPTION, USING THE FOLLOWING VALVES: 6BA6 6AM6, 25L6 AND 25Z4.

occasionally found in the bigger receivers. Where one diode is used for demodulation and A.G.C., a second diode is frequently connected so as to prevent the A.G.C. line from going positive.

For the few straight receivers, triode or pentode detectors are usual, either the leaky-grid or the anode-bend system being used. For high-fidelity radio units, the infinite impedance circuit may be found: the basic circuit of this is shown in Fig. 11.

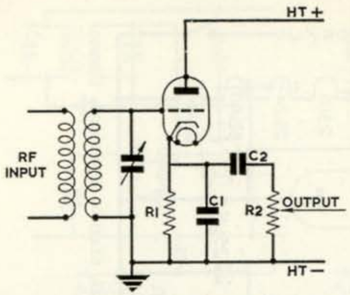


FIG. 11.—INFINITE IMPEDANCE DETECTOR CIRCUIT.

The A.F. Amplifier

The main changes in modern A.F. amplifier stages relate to the increased use of negative feedback in association with the output stage (see later) and the common use of grid-leak bias instead of cathode bias. In mains-operated receivers the triode is still found most frequently, though pentodes are sometimes used, in which case the demodulator diode is often contained in the envelope of the I.F. valve.

Grid-leak bias is economical because it renders unnecessary the electrolytic cathode by-pass capacitor used to prevent loss of gain by negative feedback, as well as offering certain design advantages. The usual method makes use of the small grid current which is made to flow through a high-value grid leak (of the order of 5–20 MΩ) to provide negative grid bias.

One of the most frequent causes of trouble in the A.F. stage are the variable composition potentiometers used for volume control. In recent years the tracks of these controls have been improved so that moisture no longer causes wide variations in resistance. Although noise during rotation has not been entirely eliminated, it has been much reduced in the better class of component. In some receivers care is taken to ensure that no direct current flows through the control (*e.g.*, demodulator diode current), and this assists in overcoming noise.

The Output Stage

The design of output stages in the standard type of models usually follows conventional practice: the main variations being in the arrangements for the application of negative feedback, which is now widely used, both for the reduction of distortion and hum, and—by making the feedback network offer a greater impedance on some frequencies than on others—for tone control or compensated volume control. Negative feedback, correctly applied, can improve the frequency response and linearity of the amplifying stages and of the output transformer, and

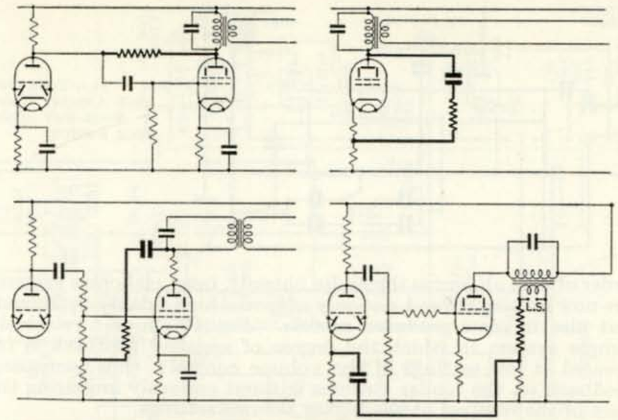


FIG. 12.—FOUR POPULAR NEGATIVE FEEDBACK CIRCUITS—THE NEGATIVE FEEDBACK LOOPS ARE SHOWN IN HEAVIER LINES.

reduce phase-shift, output resistance and the effect of random voltage changes: a disadvantage is the reduction in output. Considerable variation exists in the circuitry used for negative feedback: a few of the more popular methods are shown in Fig. 12. When servicing receivers incorporating negative feedback it is important to ensure that the phase of the feedback loop is not reversed, otherwise audio regeneration will occur. Instability—sometimes over only a small range of A.F.s—may occur with negative feedback if there is excessive phase-shift in the amplifier. Such instability may be difficult to detect without the aid of an oscilloscope. While the prevention of such instability is basically a matter for the designer, the service engineer should be on the look-out for faults of this type (giving rise to a greater or lesser degree of A.F. distortion) developing due to the change in values of components, particularly high-value, low-wattage, current-carrying resistors, which have a tendency to increase in value after a time.

While for many years the standard form of tone control has consisted of a " top-cut " circuit (a variable resistor in series with a capacitor of the

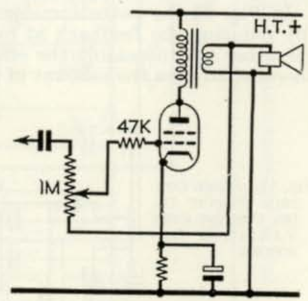


FIG. 13.—SIMPLE COMPENSATED VOLUME CONTROL CIRCUIT.

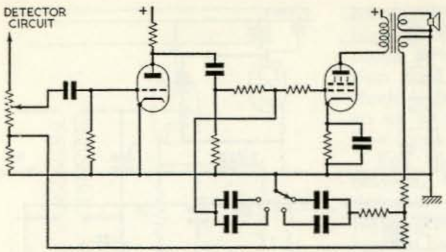


FIG. 14.—TONE-CONTROL CIRCUIT USING A FOUR-WAY ONE-POLE SWITCH.

order of $0{\cdot}05\ \mu F$ across the audio output), more elaborate systems are now gaining ground, not only in special high-fidelity equipment but also in mass-produced models. Fig. 13 shows a relatively simple system in which the degree of negative feedback is increased at low settings of the volume control; thus increasing feedback on the louder stations without seriously impairing the gain of the receiver at the higher volume settings.

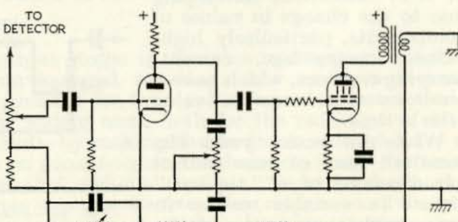
This system of tone control is often termed "compensated volume control", and represents an attempt to overcome the difficulties arising from the difference between the level of music when reproduced and when heard under natural conditions. Compensated volume control is worth while chiefly in avoiding "thinness" in the reproduction at low volume levels and "boom" at the higher levels.

Two more elaborate tone-volume-control circuits are shown in Figs. 14 and 15.

The circuit of Fig. 14 uses negative feedback to give two positions of treble rise, and capacitance shunting to give two positions of treble cut. The effectiveness of the treble cut diminishes as the volume control is turned down, because here the feedback is at its maximum and tends to level the frequency response at high frequencies.

In Fig. 15 the potentiometer gives treble rise in one direction (by reducing the feedback at high frequencies) and treble cut in the other (by increasing the effect of a capacitance short). The rheostat adjusts the amount of bass rise.

FIG. 15.—TONE CONTROL CIRCUIT USING CONTINUOUSLY VARIABLE RESISTORS



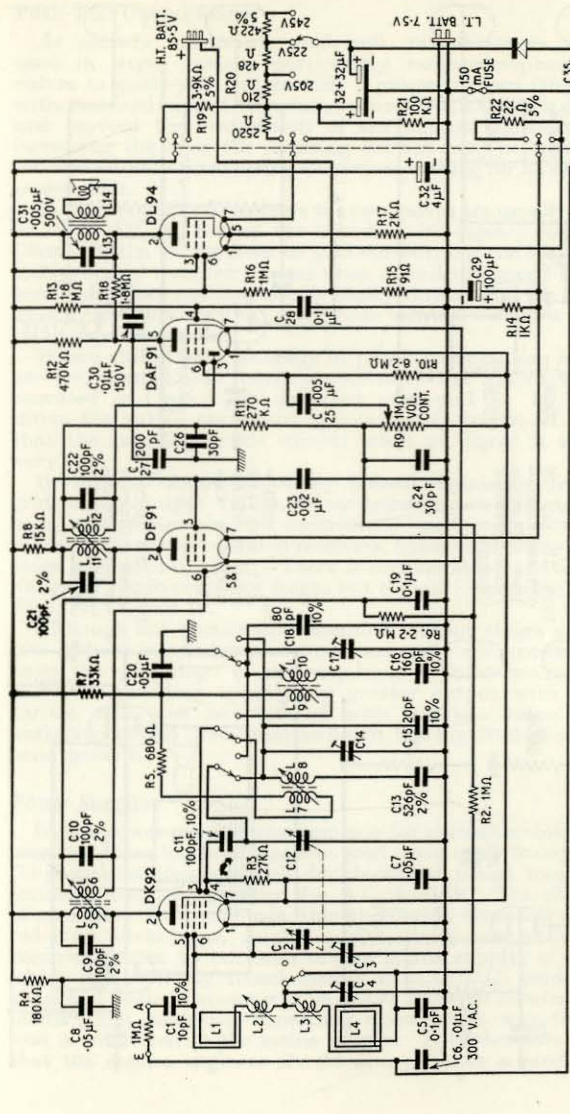
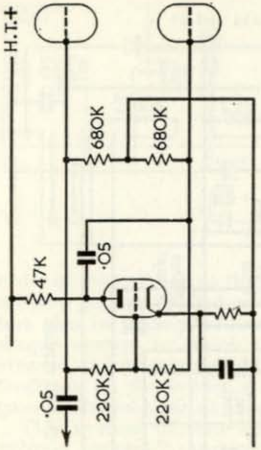
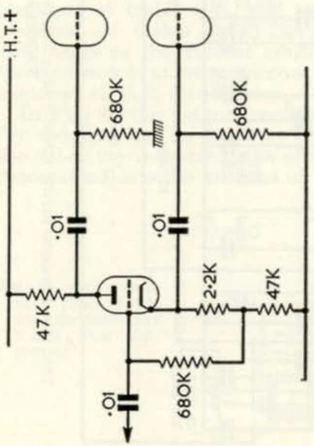


FIG. 16.—REPRESENTATIVE CIRCUIT OF A COMPACT A.C./D.C./BATTERY TWO-WAVEBAND RECEIVER.





FIGS. 17 AND 18 (*left and right*).—TWO POPULAR PHASE-REVERSING CIRCUITS.

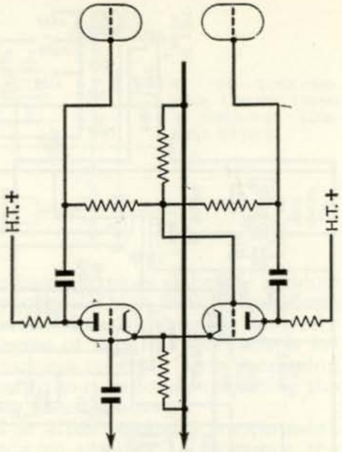


FIG. 19 (*right*).—ALTERNATIVE FORM OF PHASE-REVERSING CIRCUIT.

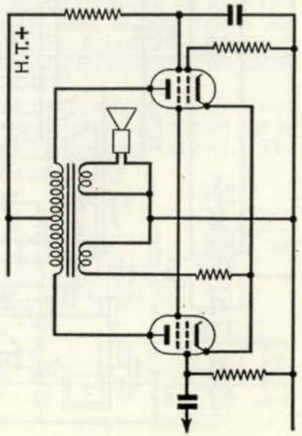


FIG. 20 (*left*).—BASIC CIRCUIT OF THE CATHODE-COUPLED OUTPUT STAGE.

Push–Pull Output Stages

As already mentioned push–pull output stages are often used in larger models, particularly radiogramophones. Two valves in push–pull will provide a greater output (10–15 watts with standard output tetrodes), reduce even harmonic distortion and prevent core saturation of the output transformer. By increasing the bias, the standing current may be substantially reduced without introducing distortion, making for an economical power pack.

In mains-operated receivers the two valves are usually operated in Class AB_1 to reduce the standing (no-signal) current. In Class AB_1 the valves draw no grid current, but the bias is appreciably higher than for normal Class A and the anode current in each valve does not flow continuously throughout the full input cycle: the effect is that the anode current increases when an input signal is applied.

Where still greater economy of power consumption is desired, as—for example—in battery receivers, the valves are often operated in Class B_1 ("quiescent push–pull"). In this condition the valves are biased approximately to cut-off value, so that the standing anode current when no signal is applied is very low.

In order to obtain oppositely phased signals for driving the grids of the output valves, driver transformers with tapped, or split, secondaries are still occasionally used, mainly in battery models; for mains-operated receivers, however, a phase-reversing stage is commonly used. There is considerable variation in the design of phase-reversing stages but typical circuits are shown in Figs. 17, 18, and 19.

Although not particularly common, output stages employing two cathode-coupled valves are occasionally encountered; these have the advantage of not requiring a phase-reversing stage and yet providing appreciably greater output with less distortion than can be obtained with a single valve. Several variations of this circuit may be found, but Fig. 20 shows the basic arrangement.

Power Supplies

In the power-supply arrangements for normal mains-operated receivers there has been a pronounced trend away from full-wave (bi-phase) rectification with double-wound mains transformers, formerly standard practice for A.C. models. The elimination of secondary H.T. windings, though offering economic and heat-reducing advantages, results in the direct connection of the receiver chassis to one side of the mains supply, a condition which was formerly found mainly in A.C./D.C. models. The chassis of such receivers will be either at earth (neutral) or full mains (line) potential, depending upon which way the power lead is connected to the mains supply. It is therefore essential that the service engineer should always make a careful check

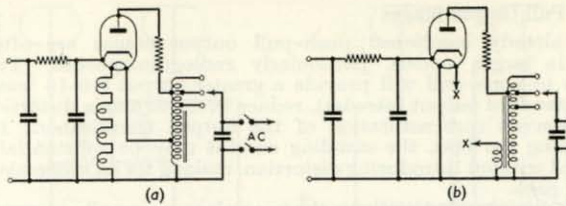


FIG. 21.—TYPICAL MAINS-INPUT CIRCUITS FOR A.C. MODELS WITH "LIVE" CHASSIS.

before making any tests which might bring him—or his servicing instruments—into contact with the chassis, unless he is certain that a double-wound isolating transformer is being used. The two most common circuit arrangements in this class of receiver are shown in Fig. 21. In (*a*) the heaters are series-connected, in (*b*) parallel-connected and fed from a low-voltage secondary winding.

In order to protect the public from the dangers of mains-connected chassis, a number of recommendations have been drawn up by the British Standards Institution (B.S. 415). The radio servicing engineer should ensure that during servicing no alterations are made to a receiver that might invalidate the manufacturer's safety precautions, and should bring to the notice of the owner any deficiencies in receivers which do not comply with good practice. Precautions which need to be taken to prevent the user from having access to live parts include such points as the following :

1. *The Chassis.* The ventilation holes in the back-plate should be small enough to prevent access, and the back-plate should be removable only by the use of a tool such as a screw-driver.
2. *Control Spindles.* Live spindles are considered to be acceptable only if the fixing holes for grub-screws are subsequently filled with wax or other insulating material.
3. *Fixing Screws.* All screws securing such parts as the

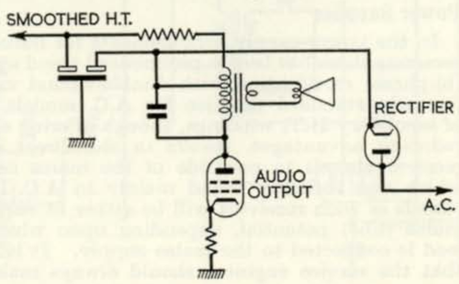


FIG. 22.—HUM CANCELLATION WINDINGS ON AN OUTPUT TRANSFORMER.

This system, in which hum voltages in the primary winding cancel out, permits the use of a simpler smoothing system.

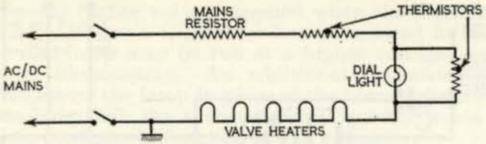


FIG. 23.—THE USE OF THERMISTORS TO REDUCE THE INITIAL CURRENT SURGE AND PROTECT DIAL LAMPS.

chassis, loudspeaker, etc., should be isolated from the chassis. It is good practice to earth all large metal parts, including metal ornaments on the cabinet.

4. *Chassis Outlets.* All outlets from the chassis, such as the aerial and earth sockets, should be isolated from the chassis. It should not be possible to touch a live part with a plug or wire when trying to insert or connect it.
5. *Aerial- and Earth-leakage Current.* The leakage current which could flow to earth from any sockets accessible to the user should be so small that no more than small, harmless shocks occur if the sockets are touched or wires connected to them are held. Since even a small shock might unbalance someone standing on a ladder, a particularly low limit should be set to the aerial-leakage current. In practice, the leakage current will be determined largely by the value of the isolating capacitors. A D.C. leakage path should be provided from the aerial socket to earth to prevent static charges from being built up on the aerial.
6. *Insulating Materials.* Insulating materials should be of good quality. It is important, for example, that isolating capacitors should be easily capable of withstanding alternating voltages over a long period.

Thermistors

The resistance of an unenergised valve-heater or dial lamp is considerably lower than at its normal operating temperature, and, if several heaters are connected in series, the initial current surge when the receiver is switched on may shorten the life of the valves and lamps. To prevent this destructive surge, either a barretter (ballast tube) or a thermistor (temperature-sensitive resistive element with a large negative temperature coefficient of resistance) may be wired in series with the heater chain. In appearance, thermistors usually resemble low-wattage resistors. The resistance offered depends upon the operating temperature and may, for example, drop from over 5,000 ohms at 20° C. to under 40 ohms at maximum operating temperature. They are usually soldered directly into the circuit, but as the body temperature may reach 250° C., they should be carefully positioned in order to prevent damage to or effect on neighbouring components.

When a dial lamp is connected in a heater chain it is normally considerably under-run to allow for its short heating time and

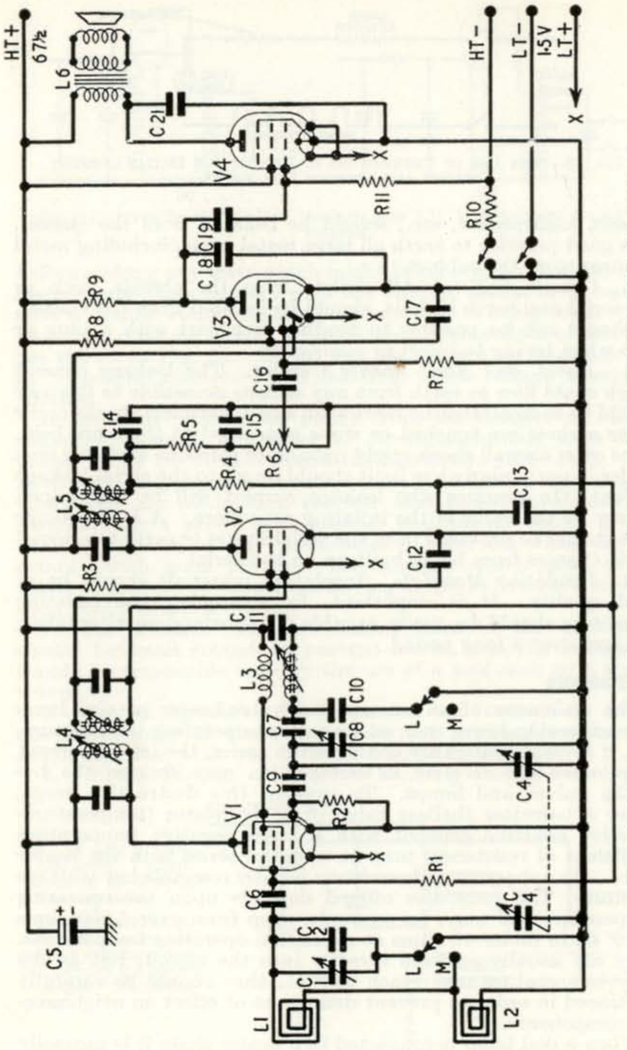


FIG. 24.—REPRESENTATIVE CIRCUIT OF A TWO-WAVEBAND BATTERY PORTABLE RECEIVER.
Component values are given opposite.

the consequent higher voltage applied when the receiver is first switched on. Where a thermistor has been fitted in the heater chain the dial lamp may be run at a higher voltage, and hence give greater illumination. An additional thermistor is sometimes wired across the lamp in place of the normal shunt resistor: should the lamp fail, the thermistor will quickly warm up and the set then continue to function at full efficiency.

Fuses

To reduce the risk of outbreaks of fire in radio receivers, and to afford protection to the receiver, greater attention is now being given to the provision of fuses. A major difficulty that has always existed with the normal cartridge-type fuses is that one which will blow on a moderate overload—such as may result from the breakdown of a smoothing capacitor and which could easily cause an excessive rise in temperature of the mains transformer, etc.—is prone to open during the normal switching-on surge. If the rating is increased to eliminate surge blowing, then the protection afforded by the fuse may be seriously reduced. One means of overcoming this difficulty is the use of a Mag-Nickel delay fuse; fuses of this material will carry up to about twenty times the rated current for a hundredth of a second.

Another approach, used by a number of manufacturers, is the temperature fuse. These are generally fitted to mains transformers, and often consist of a well-insulated copper strip placed between the H.T. and heater windings; the order of windings being primary, screen, H.T., heater and rectifier heater. The copper strip projects at both ends of the coil, having a lug at one end to which the start of the primary winding is soldered. The other end is joined to a phosphor-bronze spring by a fusible alloy of low melting point. The other end of the spring is secured to the insulated tag jacket of the transformer by a tag which serves also as a connection to one lead of the mains input. Then, should the temperature of the copper strip rise above the melting point of the alloy, the spring separates from the strip, and thus breaks the mains-input circuit.

The fusible alloy may be a mixture of bismuth, lead and tin in certain definite proportions, which produce what is known as a "eutectic" alloy—that is one which melts rapidly at a single fixed temperature. Since other proportions would produce a

Capacitors.				*Valves.*		*Resistors.*	
C1	3–30 pF	C12	0·1	V1	1R5	R1	470k
C2	90 pF	C13	0·1	V2	1T4	R2	100k
C4	305 pF Swing	C14	100 pF	V3	1S5	R3	47k
C5	2 (200 V)	C15	100 pF	V4	3S4	R4	2·2M
C6	100 pF	C16	0·01			R5	47k
C7	100 pF	C17	0·1			R6	1M
C8	3–30 pF	C18	50 pF			R7	4·7M
C9	360 pF	C19	0·01			R8	4·7M
C10	315 pF	C21	0·005			R9	1M
C11	0·1					R10	820
						R11	4·7M

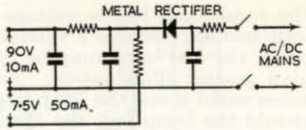


FIG. 27.—POPULAR MAINS INPUT CIRCUIT FOR PERSONAL RECEIVERS.

less well-defined melting point, it is important that the service engineer, when dealing with a fuse which has opened, should take care not to upset the proportions of the alloy, by, for example, adding solder. For this reason always thoroughly clean the soldering-iron before attempting to repair the fuse. Normally, the quantity of the alloy used in the original joint will be found sufficient to enable the joint to be repaired by the application of heat alone. Should any flux be used during repair, it is absolutely essential that this should be non-corrosive, since the slightest trace of corrosive flux near the fine-wire windings of the mains transformer may easily lead to trouble later.

Portable Receivers

Portable and " personal " receivers intended for either battery or mains operation (often termed " A.B.C. receivers ") were popular in the pre-transistor period. Some of these models employed orthodox valve-rectifying circuits, but a common arrangement is that shown in Fig. 27, in which a half-wave selenium rectifier is used to supply D.C. filament power as well as the normal H.T. power. With low-consumption filaments connected in series, individual shunt resistors will usually be necessary in order to keep the filament voltages within the permitted limits, since the H.T. currents of the valves will flow through part of the heater chain and must be taken into account. The tolerance of the resistors used as shunts or for voltage dropping in the chain should be carefully observed when making replacements. Difficulty may also occur due to the wide tolerances of many electrolytic reservoir capacitors. Replacement of the reservoir capacitor by one of nominally the same—but actually different—value may appreciably affect the voltage across the heater chain, and careful checks of the voltage should be made when carrying out this operation.

Series-connected pairs of 125-volt R.M.S. input, 100 mA, selenium rectifiers are commonly employed in small portable receivers. As with all metal rectifiers, the ventilation is of great importance, since the working life of metal rectifiers is determined almost entirely by the operating temperature of the elements, rather than by the electrical loading. Metal rectifiers operate at a much lower surface temperature than valve rectifiers, and therefore must

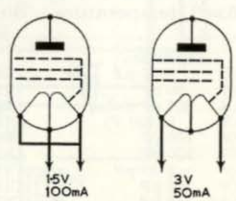


FIG. 28.—USE OF CENTRE-TAPPED FILAMENTS.

dissipate their heat by convection and conduction rather than by radiation. With convection-cooled units, it is essential to ensure an unrestricted flow of cool air through the unit, and service engineers should take care that no changes are made in a receiver that could impair the ventilation.

A popular development has been the contact-cooled rectifier, used in receivers and record players. This type of metal rectifier is very much more compact than the normal convection-cooled types, and is dependent for its cooling on contact with the receiver chassis, there being no cooling fins. The lower end of each stack of rectifying elements is insulated from the bottom of the case by a thin sheet of insulating material having good conductivity of heat. The case is constructed with a flat under-surface which is bolted down in good thermal contact with the chassis, and is usually provided with raised lugs on the upper surface to ensure that it cannot be incorrectly mounted. The heat in the elements thus flows into the chassis.

A more recent development has been the silicon rectifier, which has an extremely low forward resistance, and thus generates very little heat. It is, however, important to avoid excessive surge voltages, and also the peak inverse voltage ratings of some of these rectifiers are rather low. They are likely to be used to an increasing extent.

The output valve in battery-operated receivers usually has a centre-tapped filament to enable it to be wired either in series or in parallel with the remaining valves, which generally require only half as much filament power. How this is done is shown in Fig. 28. At one time, the basic current consumption of 1·4-volt battery valves was 50 mA. but 25-mA types were later introduced, and were widely used until the growth in popularity of transistors (see Section 3).

[SECTION 2]

PRINCIPLES AND PRACTICE OF F.M. RECEIVERS

THE advantages of a V.H.F. frequency-modulated broadcasting service when compared with normal medium- and long-wave A.M. transmissions are:

(1) There is room for many more new stations in the V.H.F. band allotted to broadcasting than could possibly be accommodated in the already overcrowded medium- and long-wave bands.

(2) The local nature of the V.H.F. service gives improved signal-to-noise ratios in many areas, providing a quiet background and reduction of interference.

(3) F.M. receivers are relatively insensitive to ignition and other impulsive forms of electrical interference.

(4) With more frequency space available, there is no need for the severe side-band cutting (resulting in poor reproduction of the higher audio-frequencies) employed in M.W. practice.

(5) Owing to the comparatively restricted range of V.H.F. transmitters and the absence—except under freak propagation conditions—of signals reflected from the ionosphere, the reception is unlikely to be marred by interference from unwanted stations. Even where two signals on the same channel are received, the so-called "capture effect" of F.M. receivers will usually completely eliminate the weaker signal.

(6) Noise reduction can be further improved by the use of pre-emphasis at the transmitter and de-emphasis at the receiver.

The disadvantages of an F.M. system are the added complexity of the circuits where combined A.M./F.M. reception is required, leading to higher prices, the impracticability of receiving distant or foreign stations, the lower stage gains, greater circuit losses on V.H.F. and the need for valves and components specially designed for use at V.H.F., and—perhaps most important for the service engineer—the servicing techniques and test equipment required for the maintenance and repair of F.M. receivers.

In practice, further disadvantages with F.M. systems are the need for accurate tuning of the receiver and the tendency for V.H.F. oscillators to drift, though much can be done to overcome these problems by careful receiver design and by the provision of an efficient tuning indicator.

Although the frequency-modulation service was not intro-

duced primarily to provide high-fidelity reproduction—the higher A.F.s are still limited in many cases by the connecting links between the studios and the transmitters—nevertheless, the range of A.F.s transmitted is considerably greater than on M.W. and L.W., where overcrowding gives rise to limitation of the higher frequencies at both the transmitter and the receiver. From the viewpoint of high-quality, probably the most important components are the loudspeaker and output transformer, and the elimination of cabinet resonances; the use of push-pull output valves also assists in reducing harmonic distortion.

Basic Principles

With normal amplitude modulation, the mean voltage of the R.F. carrier is varied in accordance with the volume of the sound, whereas with frequency modulation the voltage of the carrier remains the same but the frequency varies in proportion to the loudness of the sound being transmitted. In other words, the frequency of a frequency-modulation station is constantly fluctuating around the nominal frequency. The maximum extent of this frequency swing is known as the *deviation*. The standard

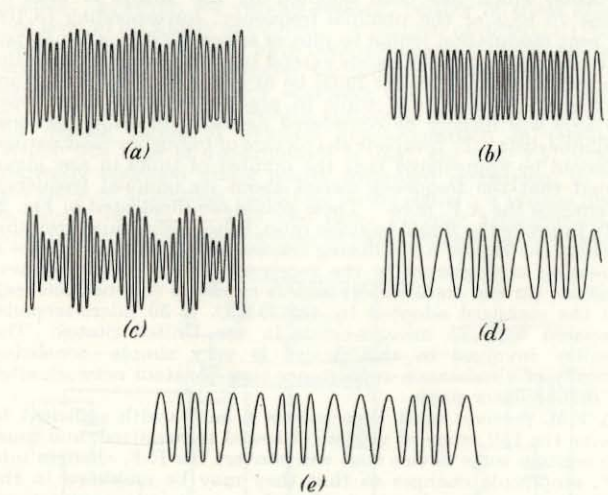


FIG. 2.—SYSTEMS OF MODULATION.

(*a*) Amplitude-modulated carrier. Low depth of modulation (weak A.F. note). c) Amplitude-modulated carrier. Large depth of modulation (strong A.F. note). (*b*) Frequency-modulated carrier. Small deviation from mean frequency (weak A.F. note). (*d*) Frequency-modulated carrier. Large deviation from mean frequency (strong A.F. note). The A.F. component is of the same frequency in all these cases. (*e*) Frequency-modulated carrier in which the A.F. component is of lower frequency than in (*d*).

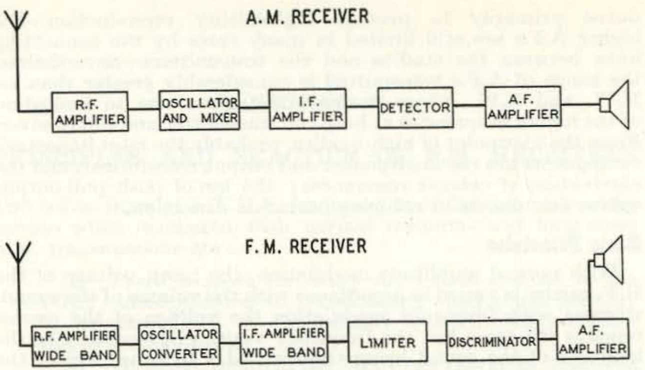


FIG. 3.—BLOCK SCHEMATIC COMPARISON BETWEEN A.M. AND F.M. RECEIVERS.

deviation which has been adopted by the B.B.C. is plus or minus 75 kc/s of the nominal frequency, corresponding to 100 per cent modulation (equal to plus or minus 22·5 kc/s for 30 per cent modulation). Sidebands extend beyond these limits, so the band-width of the receiver must be at least twice the maximum deviation, *i.e.*, 150 kc/s, while in practice a figure of at least 200 kc/s will usually be considered desirable to allow for local oscillator drift. To complete the picture of frequency modulation, it should be appreciated that the number of times in any given second that the frequency varies about its nominal frequency determines the A.F. note. These points are illustrated in Fig. 2.

To improve the signal-to-noise ratio, it has been found desirable to boost the higher A.F.s during transmission and to introduce a correcting arrangement in the receiver : this is known as *pre-emphasis* (in the transmitter) and *de-emphasis* (in the receiver), and the standard adopted by the B.B.C. is 50 micro-seconds, compared with 75 micro-seconds in the United States. The circuitry involved in this device is very simple—consisting basically of a resistance–capacitance time-constant network after the demodulator stage.

A F.M. receiver must thus possess a band-width sufficient to receive the full range of volume of sound transmitted, and must also contain some device that will convert the R.F. changes into A.F. amplitude changes so that they may be amplified in the normal way. An important, though less obvious, requirement is that some means must be found of preventing the unavoidable amplitude variations of the incoming signal—such as those that result from fading—from being passed on to the A.F. section of the receiver : such a device is termed a *limiter*. The basic outline of a F.M. receiver, compared with an A.M. receiver, is shown in Fig. 3.

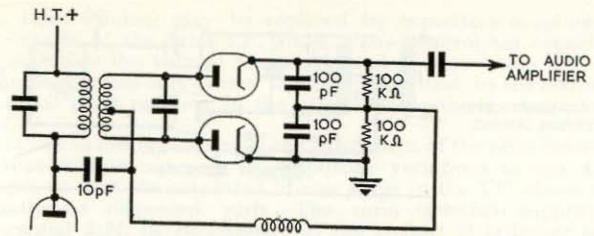


FIG. 4.—FOSTER-SEELEY TYPE F.M. DISCRIMINATOR.

Detectors for F.M.

The type of detectors or demodulators found in normal receivers are amplitude rather than frequency sensitive devices, and so cannot be employed for the reception of F.M. signals. Exceptions to this statement are the super-regenerative arrangement and what is known as the " slope detector ", both of which can be used with moderate efficiency for both types of signals ; however, for various reasons, neither of these systems has been at all widely employed. A number of different types of detector or discriminator have been developed for F.M. reception, and one of the most popular for communications work is that shown in Fig. 4. Service engineers will recognise this circuit as being basically that used for automatic frequency control and for certain forms of flywheel synchronisation in television. Where this type of discriminator is used, the final I.F. valve is generally operated under nearly saturated conditions, to limit the effect of amplitude variations of the signal ; a typical limiter is shown in Fig 5. But the more popular arrangement for broadcasting reception is a type of phase discriminator known as

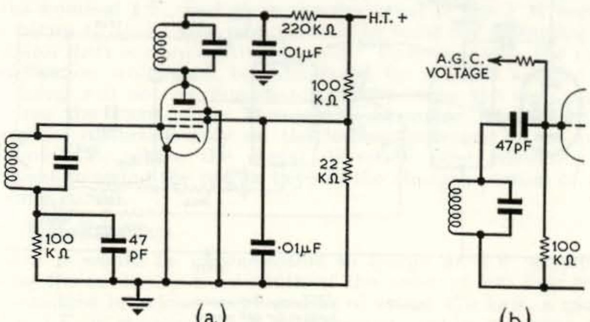


FIG. 5.—(*a*) TYPICAL LIMITER CIRCUIT. (*b*) ALTERNATIVE BIASING ARRANGEMENT.

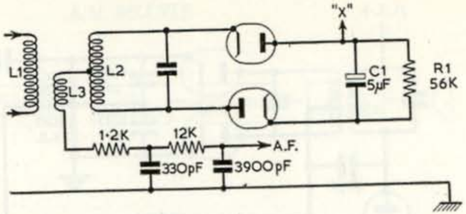


FIG. 6.—BASIC RATIO DETECTOR CIRCUIT.

the "ratio detector". This requires two well-matched diodes, which may be either germanium-crystal diodes or valve diodes with independent cathode connection. One reason for the popularity of this circuit is that it is relatively insensitive to amplitude changes, and thus provides a considerable degree of self-limiting, so that normal variations in the incoming signal can be disregarded. Valves, such as the EABC80 and 6AK8, have been specially developed for this application in combination F.M./A.M. receivers. These are triple-diode-triode arrangements permitting the use of two diodes for a F.M. ratio detector, one diode for A.M. detection and possibly A.G.C., and a triode section which can be used for A.F. amplification for both systems.

The circuit of Fig. 6 shows a typical ratio detector, although a number of variations are possible. The primary winding (L1) of the ratio filter forms the anode lead of the final I.F. stage. The secondary coil (L2) is adjusted to the I.F., while the tertiary winding (L3) is wound closely over the anode end of the primary and forms a matching transformer between the anode circuit of the preceding I.F. stage and the diode circuit; in some instances

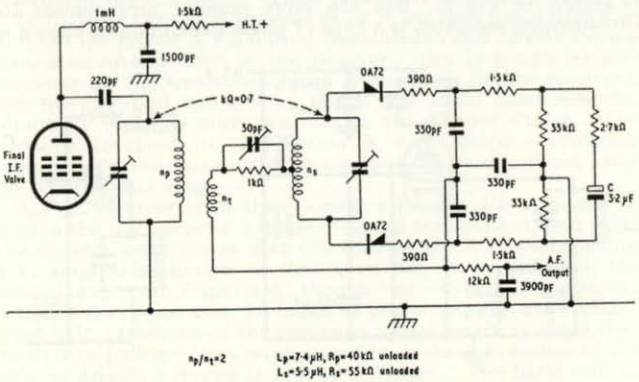


FIG. 7—RATIO DETECTOR CIRCUIT USING OA72 CRYSTAL DIODES

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the third winding may be replaced by capacitive coupling to the anode of the final I.F. stage. The electrolytic capacitor C1 stabilises the voltage across R1, and in some cases may be connected across only part of the total diode load, by the addition of equal fixed resistors in the anode and cathode connections to C1.

As mentioned above, one of the chief assets of the ratio detector is that it does not pass on amplitude variations to the A.F. stages, so that the saturated limiter stage in the I.F. chain can usually be dispensed with. The ratio detector suppresses unwanted A.M. by smoothing out the peaks: it is better able to do this when the signal presented to it is reasonably strong.

Owing to the smoothing out of signal-amplitude variations in a ratio detector, there is less need for A.G.C. when receiving F.M. signals, and this is often omitted. However, when required, an A.G.C. line may be taken from point *X* in Fig. 6, and this point may also be used for the operation of a tuning indicator.

F.M. Tuning

One of the main difficulties in the operation of an F.M. receiver is that, unlike an A.M. receiver, there is no immediate change in "tone" as the tuning control is moved through its correct setting. It might therefore be supposed that accurate tuning of an F.M. receiver is less important than with an A.M. model, but this is far from being the case.

In the first place, the efficiency of the noise suppression (*i.e.*, A.M. peak suppression) falls off rapidly when the set is more than about 50 kc/s out of tune (this figure may seem high when compared with M.W. practice, but represents quite sharp tuning at 90 Mc/s). Secondly, distortion will be introduced unless the detector is operating on the straight section of its response curve up to the full deviation. In practice, this section of the response curve will seldom exceed about 100 kc/s on either side of the nominal I.F., and since the deviation of the F.M. signal will be up to $\pm$ 75 kc/s, the amount in hand for mistuning or oscillator drift is comparatively small. Unfortunately, the type of distortion which will be introduced by a small amount of mistuning will not be immediately apparent to the user, since it takes the form of an increase in harmonic (mainly third harmonic) distortion only on the loudest passages of the programme (*i.e.*, where the signal deviation plus mistuning is sufficient to swing the carrier beyond the straight portion of the response curve).

A.M./F.M. Receivers

Since it would be impracticable to design an I.F. amplifier having the necessary band-width of the order of 200 kc/s with the standard broadcast receiver I.F. of about 470 kc/s, a much higher I.F. is required for F.M. reception; while retaining the standard I.F. for normal M.W. and L.W. A.M. transmissions. To avoid the additional cost of two separate I.F. chains, this

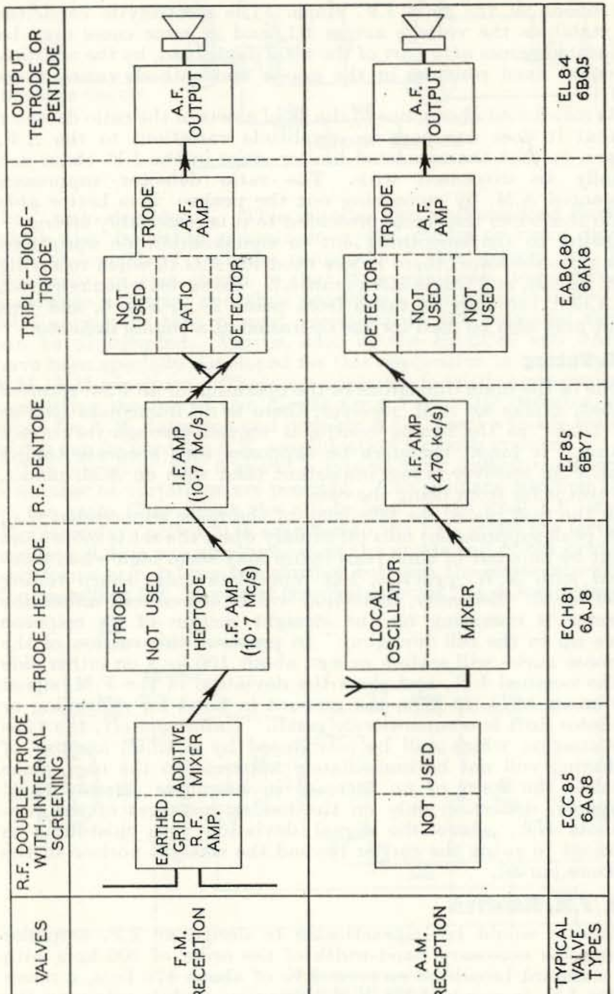


FIG. 8.—SCHEMATIC DIAGRAM SHOWING THE VALVE FUNCTIONS OF A COMBINED A.M./F.M. RECEIVER.

requirement is generally met by employing a dual I.F. strip, in which two series-connected I.F. transformers replace the normal transformer: one set of the I.F. transformers are tuned to about 470 kc/s; the others to a much higher frequency (generally about 10·7 Mc/s). Switching arrangements to enable either set of the series-connected transformers to be taken out of circuit may be included, but often both sections remain in circuit. The higher-frequency transformers are aligned to provide a band-width of about 200 kc/s, while the 470-kc/s transformers are peaked to give the usual band-width of the order of 9 kc/s. Since the amplification per stage for the broad-band condition will be appreciably lower than with the sharply peaked A.M. circuits, it is often desirable to include an extra stage for F.M. reception: one method is to use the hexode section of the A.M. frequency changer for this purpose, using a separate frequency changer for F.M. reception and feeding the 10·7-Mc/s signal to the signal grid of the M.W./L.W. frequency-changer valve.

Frequency Changer.—The frequency changer for F.M. reception may follow similar practice to those found in television receivers, though the self-mixing (additive) oscillator is also popular. There are two main difficulties in the design of local oscillators for F.M. reception, and it is essential that the service engineer should be fully aware of these problems. The first is that of achieving the necessary order of stability at frequencies of the order of 100 Mc/s, since, unless the signal as presented to the detector stage remains centred around roughly the same nominal frequency, considerable distortion may occur, calling for frequent re-tuning of the oscillator. Stability of a local oscillator on these frequencies can be improved in a number of ways, most of which are currently found in television-receiver technique; in particular, the use of a relatively large capacitance across the frequency-determining tuned circuit to swamp the effects of changes of valve capacitance, etc., the use of compensating negative-temperature-coefficient capacitors and the careful placing of this stage in regard to the main sources of heat in the receiver.

Oscillator Radiation.—The second main problem concerning the local oscillator is that of reducing the radiation of signals outside the receiver which would otherwise cause interference with local F.M. receivers and television receivers. This problem can at times be fairly acute, due to the relationship between the frequency allocations for Band II broadcasting and Band III television. Since a F.M. I.F. of 10·7 Mc/s is widely adopted, the local oscillator will at times be running within the limits of Band II, whilst the second harmonic (*i.e.*, double the fundamental frequency), which is usually a strong signal at such frequencies, will fall at times within the Band III television allocations. For these reasons, some manufacturers occasionally use a considerably higher I.F. for F.M. reception, possibly of the order of 20 Mc/s. Whatever I.F. is used, however, there is need for careful screening of the local oscillator, with good isolation

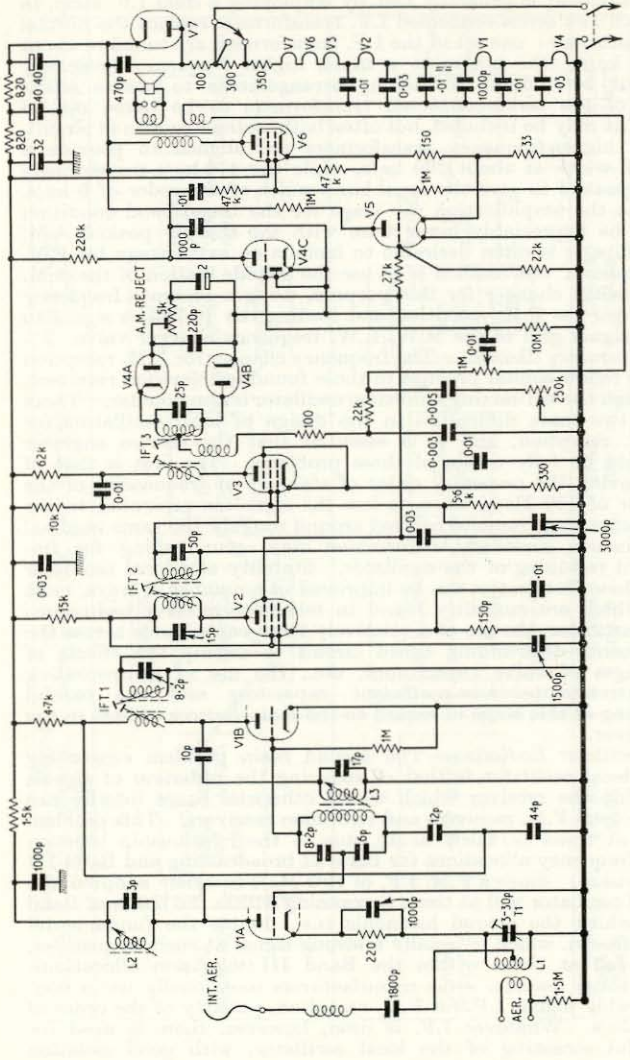
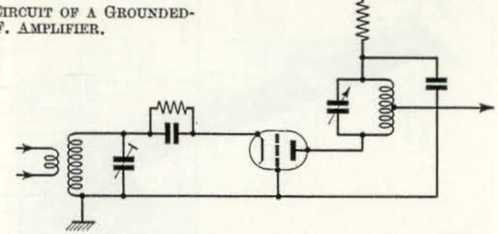


FIG. 9.—REPRESENTATIVE CIRCUIT OF V.H.F./F.M. ONLY RECEIVER.
V1 UCC85; V2 UF80; V3 UF80; V4 UABC80; V5 DM70 (tuning indicator); V6 UL84; V7 UY85.

FIG. 10A.—BASIC CIRCUIT OF A GROUNDED-GRID R.F. AMPLIFIER.



between the aerial-input circuits and the local-oscillator circuits. It is mainly on this account that most British F.M. receivers include an R.F. stage whose main purpose is to act as an isolating buffer stage between the frequency changer and the aerial circuits rather than to provide appreciable gain.

In continental practice the R.F. stage is often omitted and a bridge-circuit arrangement of the self-oscillating triode mixer (additive mixer) balances out stray radiation. One method, with a self-oscillating triode mixer, is to feed the signal voltage to a bridge-balanced null point on the oscillator coupling coil, and

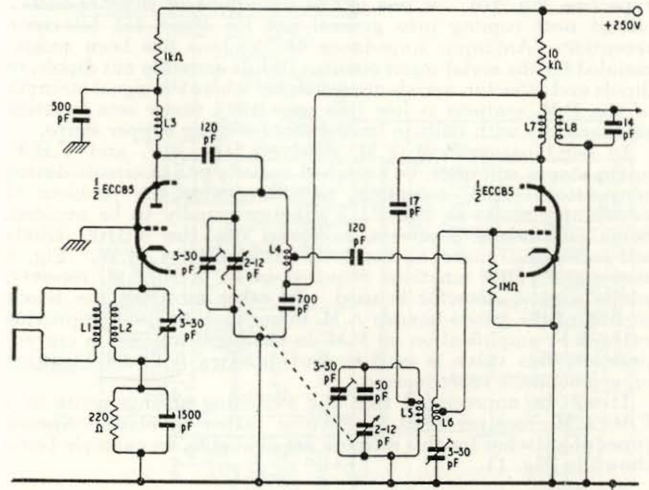


FIG. 10B.—PRACTICAL GROUNDED-GRID R.F. AMPLIFIER AND ADDITIVE MIXER CIRCUIT.

(*Mullard Ltd.*)

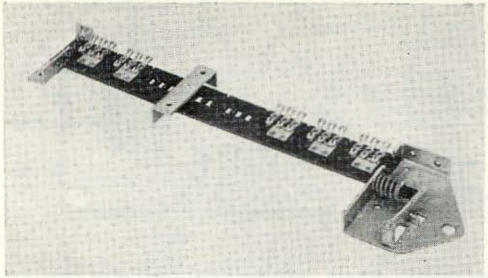


FIG. 11.—PLESSEY A.M./F.M. SLIDE SWITCH.

with positive feedback to remove the damping of the triode or the I.F. transformer. The degree of suppression provided by these methods is not likely to prove adequate when the receiver is operated in close proximity to other F.M. or television receivers unless combined with other measures such as good screening. Radiation may also be reduced by careful design of a balanced-input circuit where a dipole aerial is used.

R.F. Amplifiers.—R.F. amplifiers may be of conventional V.H.F. design, as used in television practice; or of earthed-grid type (see Fig. 10); or one of the variations of the "cascode" circuit now coming into general use for Band III television reception. An input impedance of 75 ohms has been recommended for the aerial-input circuit. While correctly cut dipole, or dipole and reflector, aerials are necessary where the signal strength of the F.M. stations is low (see page 132), many sets function satisfactorily with built-in loaded dipoles using copper strips.

In combination A.M./F.M. receivers, the R.F. and V.H.F. mixer stages will often be switched entirely out of circuit during conventional A.M. reception, as this avoids the problem of switching circuits at V.H.F., a practice usually to be avoided. Some continental receivers, however, use the V.H.F. triode self-oscillating mixer as the local oscillator on M.W. Fig. 8 shows the valve functions required in an A.M./F.M. receiver, where a ratio detector is used. In other receivers the triode section of the triode-hexode A.M. mixer may be used to provide extra A.F. amplification on F.M. in the same way as, in current practice, this valve is used to provide extra A.F. amplification on gramophone reproduction.

It will be appreciated that the switching arrangements in a F.M./A.M. receiver tend to become rather involved. Special types of switches for this purpose are available, an example being shown in Fig. 11.

Representative Circuit

Fig. 12 shows the complete circuit of a representative British combination A.M./F.M. receiver. The receiver provides cover-

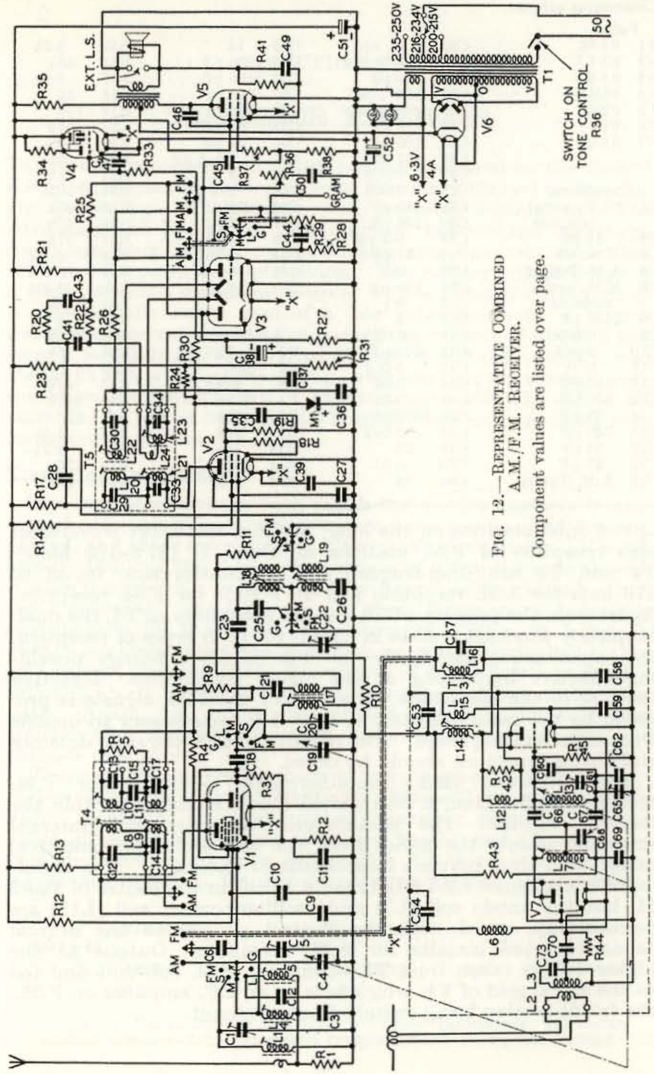


FIG. 12.—REPRESENTATIVE COMBINED A.M./F.M. RECEIVER.
Component values are listed over page.

Component values:

Valves.

V1	6AJ6
V2	6BY7
V3	6AK8
V4	65ME
V5	6BQ5
V6	6V4
V7	6AQ8

Capacitors.

C1	S.W. aerial trimmer
C2	75 pF
C3	0·005
C4	A.M. Tuning
C5	M.W. aerial trimmer
C6	1000 pF
C9	0·003
C10	0·003
C11	0·01
C12	150 pF
C13	500 pF
C14	22 pF
C15	220 pF
C17	22 pF
C18	47 pF
C19	A.M. Tuning
C20	S.W. osc. trimmer
C21	100 pF
C22	M.W. osc. trimmer
C23	440 pF
C25	100 pF
C26	492 pF
C27	0·003
C28	0·003
C29	150 pF
C30	150 pF
C33	8·2 pF
C34	51 pF
C35	0·1
C36	100 pF
C37	0·1
C38	5
C39	0·01
C41	500 pF
C43	0·002
C44	0·01
C45	0·01
C46	1000 pF
C47	0·003
C49	25
C50	0·01
C51	32
C52	16
C53	1000 pF
C54	1000 pF.
C57	22 pF
C58	33 pF
C59	82 pF
C60	22 pF.
C61	1·5–8 pF
C62	4 pF
C65	3–9 pF
C66	22 pF
C67	22 pF
C68	18 pF
C69	0·003
C70	0·003
C73	24 pF

Resistors.

R1	1k
R2	220
R3	47k
R4	470k
R5	470k
R9	33k
R10	15k
R11	100
R12	33k
R13	2·2k
R14	68k
R17	2·2k
R18	33
R19	120
R20	56k
R21	680k
R22	56k
R23	1M
R24	10M
R25	560k
R26	47k
R27	27k
R28	6·8M
R29	0·5M
R30	2·2M
R31	150k
R33	4·7M
R34	470k
R35	2k
R36	0·5M
R37	47k
R38	470k
R41	180
R42	1·2k
R43	2·2k
R44	100
R45	56k

age of A.M. stations on the long, medium and short wavebands plus reception of F.M. stations on Band II (87·5–100 Mc/s). T4 and T5 are dual-frequency I.F. transformers, tuned to 470 kc/s for A.M. reception and 10·7 Mc/s for F.M. reception. Apart from the primary of T4 and the secondary of T5, the dual-frequency windings remain in circuit for both types of reception, the capacitances across the lower-frequency windings providing effective by-passing at the higher frequencies. Effective limiting of the amplitude variations of the F.M. signals is provided by the ratio detector, so that it is unnecessary to include a separate limiting stage. The polarity of C38, the ratio detector stabilising capacitor, should be noted.

The front-end (R.F. amplifier-mixer) sub-unit for F.M. reception is fed from a compressed dipole contained within the receiver cabinet. The earthed-grid amplifier and internal screening isolate the aerial from the self-oscillating (additive) mixer, and thus prevent local-oscillator radiation. The aerial-input transformer L2-L3 is broadly tuned to the centre of Band II, but the anode coil (L7) and oscillator-mixer coil (L13) are permeability tuned with the control ganged to the normal capacitor-tuned circuits for A.M. reception. Output at the higher I.F. is taken from T3 within the F.M. sub-unit and fed to the signal grid of V1, which acts as an I.F. amplifier on F.M., the triode section being switched out of circuit.

[SECTION 3]

TRANSISTOR RECEIVERS

TRANSISTOR receivers and record players appeared on the United Kingdom market in 1956, and since then have formed an increasing percentage of domestic and portable equipment. The advantages of low power consumption, low-voltage operation, small size, long life and robust construction have almost ousted the valve for portable applications. The battery consumption of a small portable transistor receiver with a Class B output stage is substantially below that of a four-valve receiver: a typical transistor receiver would have a standing current of about 8 mA from a 9-volt battery, rising to 55 mA at 300 mW output, and about 25 mA average for music; representing an average consumption of about 225 mW. This compares with 125 mA at 1·4 volts and 10 mA at 90 volts (1,115 mW) for a receiver using low-consumption valves.

Transistor Amplification

The transistor circuits with which the service engineer is concerned are mainly ones where valves have previously been employed, and there are naturally many basic similarities. We can usually think of the " base " electrode of a transistor as though it were the grid of a valve; the " emitter " as the cathode; and the " collector " as an anode. In these terms many transistor circuits resemble the familiar valve circuits. We must, however, always remember that whereas valve current is controlled by the grid *voltage,* in a transistor the control of the collector current is brought about by variations in the *current* in the emitter–base path. Again, the impedance offered between the base and emitter of a transistor is much lower than between grid and cathode of a valve.

There are three basic methods of using a transistor to amplify, corresponding roughly to: (1) the conventional grounded-cathode valve amplifier (common-emitter transistor circuit); (2) the valve grounded-grid circuit (common base); and (3) the valve cathode-follower (common collector). All three basic arrangements are found in transistor receivers, though the transistor

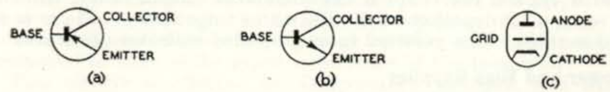


FIG. 1.—(*a*) USUAL SYMBOL FOR P–N–P JUNCTION TRANSISTOR. (*b*) USUAL SYMBOL FOR N–P–N TRANSISTOR. (*c*) CORRESPONDING VALVE ELECTRODES.

arrangement (common emitter) corresponding most closely to the conventional grounded-cathode valve system is the most widely used. The three basic arrangements are compared in Fig. 2 and considered briefly below.

Common Emitter Operation.—Although this arrangement corresponds with grounded-cathode valve operation, the impedances differ appreciably. The input impedance is very much lower, of the order of 500–1,000 ohms, while the collector impedance is roughly 50,000 ohms. As with the corresponding valve circuit, there is a 180° phase shift between input and output voltages. Also referred to as grounded-emitter operation.

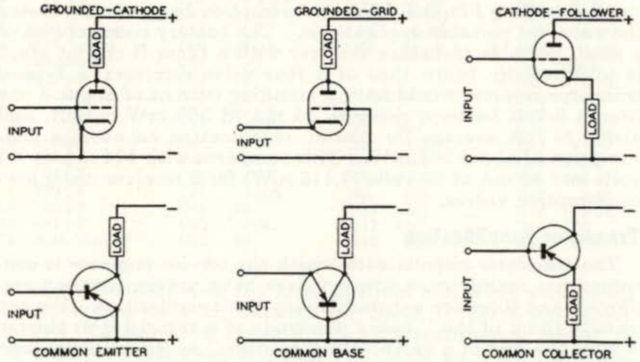


FIG. 2.—THE THREE MAIN FORMS OF TRANSISTOR AMPLIFIERS SHOWN BENEATH THE CORRESPONDING VALVE CIRCUITS.

Common Base Operation.—This circuit has a higher maximum frequency of operation for a given transistor, and thus may be used for R.F. amplifiers and oscillators. The collector impedance is very high (often above a megohm) while the input impedance is very low (about 25 ohms). There is no phase shift between input and output voltages. Also referred to as grounded-base operation.

Common Collector Operation.—Here the signal is fed in between base and collector, and taken out between emitter and collector. It gives less gain than the other two arrangements, but can be made to have high input impedance and low output impedance, and a typical use is for a low-distortion output stage, directly driving a loudspeaker of 50–100 ohms impedance. There is no phase-shift. Also referred to as grounded-collector operation.

Power and Bias Supplies

The provision of power supplies for transistors differs in several respects from those in valve sets. In the first place no heater or

filament supply is required. Secondly, the full " H.T. " supply rarely exceeds 18 volts and is more often only 6 or 9 volts. This voltage must be applied with the correct polarity or the transistor will be damaged. For the conventional pnp transistor, the correct polarity is with *collector negative*. The much less common npn transistor has collector connected to the positive battery terminal.

Particular importance attaches to the bias supplies, as to a marked extent these determine the stability of the circuit for changes in temperature (germanium transistors are very susceptible to changes in working temperature). Bias of a Class B output stage also affects the standing current consumption and the cross-over distortion, and this point will be considered later.

As temperature goes up there will be an increase in the current flowing in a transistor. Since this current increase will generate additional internal heat, and this will cause even more current to

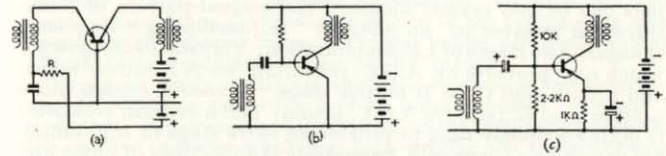


FIG. 3.—TRANSISTOR BIASING CIRCUITS.

(*a*) Bias circuit for common-base transistor amplifier. (*b*) Simple bias circuit for common-emitter amplifier. (*c*) Bias circuit for common-emitter amplifier with stabilisation against thermal run-away.

flow, there is the danger that the process may get out of hand—termed " thermal runaway "—leading ultimately to the overheating of the junction and permanent damage to the transistor. Fortunately there are fairly simple circuit methods of reducing the likelihood of this happening, and these are known as " D.C. or bias stabilisation ".

A simple bias circuit for a common-base amplifying stage is shown in Fig. 3 (*a*). This uses a separate bias battery, and the bias current is determined by the battery voltage divided by the sum of the input resistance of the transistor and the feed resistor *R*. Because of the need for a separate battery, this system is seldom found in practice.

A much more common bias arrangement is shown in Fig. 3 (*b*). Here the negative current is derived from the negative " H.T." line through a resistor, while the capacitor prevents it from passing direct to earth through the transformer winding. The value of this capacitance must be high enough to have an impedance low compared to that of the input impedance of the transistor.

This circuit is affected by temperature changes, and some elaboration is often desirable to give greater thermal stability. One method is to add a resistor in the emitter lead, shunting it with a capacitor to prevent reduction of gain (in a circuit diagram this looks like the conventional valve cathode biasing system, but it should be remembered that its purpose is primarily that of increasing thermal stability); this is effective, but results in some loss of output. Further stabilisation may be added, at the cost of some extra battery drain, by connecting a resistor between base and earth: a circuit showing this combined arrangement is shown in Fig. 3 (*c*). To give good thermal stability without undue sacrifice of power, circuits have been devised with thermistors or metal rectifiers in the bias network. Bias stabilisation is particularly important in output stages: portable receivers may be used in the blazing sun, in a steamy kitchen or in an unheated bedroom in winter.

TRANSISTOR RECEIVER CIRCUITS

Most A.M. transistor receivers use six or seven pnp transistors plus one or two crystal diodes. The general pattern of a six-transistor receiver is: an additive " self-oscillating " frequency changer; two stages of I.F. amplification; a crystal diode detector which also provides an A.G.C. potential; an A.F. driver stage; and a push–pull Class B output stage. A second crystal diode is often used to improve A.G.C. action; and a seventh transistor is quite commonly used to provide an extra stage of A.F. amplification or, less commonly, to separate the functions of mixer and local oscillator. F.M. transistor receivers will be considered separately.

Input Circuits

Ferrite-rod aerials with a tapped or matching winding provide a convenient means of obtaining a low-impedance input for the frequency changer. Since the only connection from the rod aerial at high impedance is that to the wave-change switch or, in single-band models, to the tuning capacitor, the stray capacitances can be kept to a very low figure, making possible a much lower tuning swing than found in valve models: as low as 110 pF compared with about 520 pF in valve receivers.

Although a few models have used two transistors for mixing

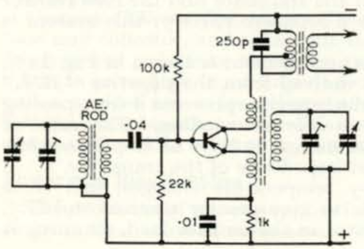


FIG. 4.—TYPICAL TRANSISTOR FREQUENCY-CHANGER.

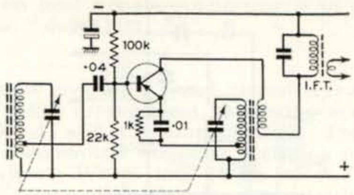


FIG. 5.—ALTERNATIVE FORM OF FREQUENCY CIRCUIT USING TAPPED COILS.

with one acting solely as a local oscillator, by far the more popular arrangement is a single transistor used as a self-oscillating additive mixer. Figs. 4 and 5 show two typical circuits, simplified by the omission of wave-change switching. These circuits use a common-emitter mixer combined, in the same transistor, with a common-base oscillator in which positive feedback is obtained from the collector circuit. To provide satisfactory tracking without padding capacitors, the oscillator section of the tuning gang may have specially shaped vanes. Typical values are aerial tuning 175 pF swing; oscillator tuning 120 pF swing.

To permit ready oscillation when the receiver is first switched on, the oscillator transistor may be initially biased for Class A operation; subsequently, rectification of the oscillator voltage at the emitter provides additional bias, driving the transistor into Class B operation. This stabilises the amplitude of oscillation and also tends to reduce the falling off in the performance towards the higher-frequency limit of the transistor. Coupling between aerial and oscillator circuits must be kept low to prevent spurious oscillation; for this reason a screen may be placed between the two sections of the tuning gang.

I.F. Amplifiers

Two I.F. stages are generally included, although a few of the smaller receivers have used one stage with controlled regeneration. I.F. transformers usually comprise a single tuned circuit with a step-down output winding to match into the succeeding transistor input circuit, but there are a number of receivers using double-tuned transformers to increase adjacent-channel selectivity.

Because of the base-collector capacitance of alloy junction transistors—corresponding to the grid–anode capacitance of a triode valve—it is necessary to include components to neutralise the effect of positive feedback via this capacitance. Neutralisation can be achieved by balancing out this feedback by introducing external feedback paths of opposite effect. Where this external path is purely capacitive, it may be found necessary to change the value of this neutralising capacitor if the transistor is changed. However, it is common practice to introduce resistance into the external feedback path to give what is termed a " unilateralised " stage, and in these designs it is usually unnecessary to change the capacitor when replacing the transistor. With the improved

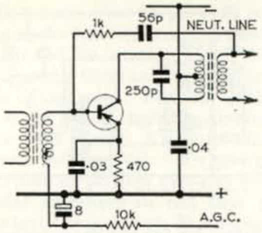


FIG. 6.—TYPICAL I.F. AMPLIFIER.

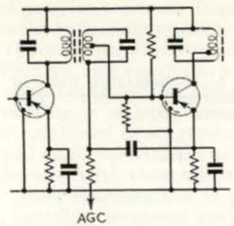


FIG. 7.—I.F. STAGE WITH ALLOY-DIFFUSED TRANSISTOR.

alloy diffusion H.F. transistors, such as OC170 or AF117, the base-collector capacitance is sufficiently low to permit stable operation at high gain without neutralisation.

A germanium diode is almost invariably used for detection, with the D.C. voltage developed across the load resistance fed back to the first I.F. stage to provide A.G.C. For pnp transistors, the A.G.C. line will be positive in respect of the chassis (the greater the positive voltage, the less will be the stage gain). Apart from controlling the gain, the A.G.C. line may be used to provide a small forward bias for the detector diode.

Since a relatively high circulating current may exist in the diode circuit, the position of the diode by-pass capacitor and the associated wiring needs careful attention in order to minimise radiation of the harmonics present in this circuit; excessive harmonic radiation is likely to produce spurious whistles and instability, particularly the second harmonic on about 940 kc/s. When servicing, take care not to change the position of these components or leave unduly long leads. Owing to the dual detector/A.G.C. function, it is important when replacing this diode to observe correct polarity.

The simplest A.G.C. systems may provide insufficient range of control, and various circuits incorporating additional diodes have been used to improve A.G.C. One fairly common method is to connect a germanium crystal diode across the first I.F. trans-

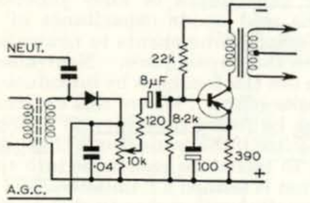


FIG. 8.—TYPICAL CRYSTAL DIODE DETECTOR AND A.F. DRIVER STAGE.

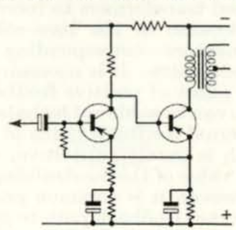


FIG. 9.—DIRECT-COUPLED TWO-STAGE A.F. DRIVER.

former to provide damping on loud signals, connecting it to a suitable potential to introduce " delay ".

A.F. Stages

An A.F. driver stage is almost invariably found, though a few small receivers have used a reflex arrangement permitting one transistor to be used for both I.F. and A.F. amplification. The A.F. driver is usually a common-emitter amplifier operating in Class A with bias stabilisation. Where two stages of A.F. amplification are used, the collector of the first is often directly coupled to the driver stage.

A high-value miniature electrolytic capacitor and resistor are generally used to decouple the " H.T." line so as to prevent dis-

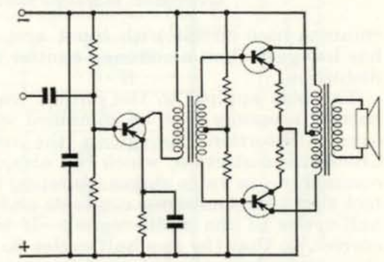


FIG. 10.—A.F. DRIVER AND CLASS B OUTPUT STAGES USING CENTRE-TAPPED INPUT AND OUTPUT TRANSFORMERS.

tortion or instability as the internal resistance of the battery increases with age. Negative feedback, derived from the output stage, is commonly applied via the emitter circuit of the driver stage.

While the early stages of A.M. transistor sets tend to follow roughly parallel lines, there has been more noticeable variation in the circuits used for the output stage. One popular arrangement is to use two matched transistors in a Class B push–pull common-emitter stage, with transformers for impedance matching and phase reversal in both input and output circuits; see Fig. 10. The output transformer may be omitted if the loudspeaker speech coil has an impedance of about 100 ohms.

Also widely employed have been two variations of what is usually termed the " single-ended push-pull circuit "; see Fig. 11. These arrangements have an output impedance of about 30–80 ohms, and thus make it easier to eliminate the output transformer. Since in small portable receivers the output transformer may have an efficiency of only about 50 per cent, the omission of this component can result in an appreciable saving of battery power, since the same acoustic output can be obtained for lower electrical output from the transistors. The single-ended circuit is also a little easier to stabilise against thermal runaway, although it has the disadvantage of being more prone to distortion on loud signals.

Another arrangement occasionally found is two transistors in a

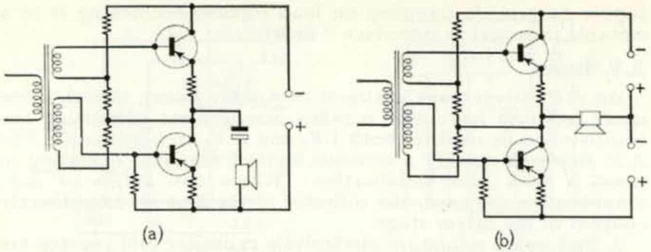


FIG. 11.—"SINGLE-ENDED" PUSH-PULL OUTPUT STAGES.
Loudspeaker impedance about 30–80 ohms.

common-base circuit with input and output transformers; this has less gain than a common-emitter circuit, but introduces less distortion.

The bias applied to the output transistors is critical if good battery economy is to be combined with a minimum of "cross-over" distortion throughout the useful life of the battery. Cross-over distortion, which can also occur—although much less commonly—in valve stages operating in Class B, arises from the fact that each transistor conducts and amplifies during alternate half-cycles of the audio signal. If the bias conditions are incorrect, so that the two half cycles do not exactly fit together at the point where the signal changes over from one to the other transistor, it will cause distortion which can be most noticeable. Since the battery voltage will gradually diminish throughout its life, this means that bias and operating conditions change and it is difficult to avoid some degree of cross-over distortion towards the end of the useful life of a battery. Negative feedback can help to reduce this form of distortion, and in practice there will usually be standing current above that of the "cut-off" condition (which for transistors represents minimum, but not zero, collector current). It is usual to fit five per cent tolerance bias resistors, and a common emitter resistor helps to compensate for slight differences in transistor characteristics and to guard against thermal runaway. Some makers have developed fairly elaborate bias networks, containing thermistors or metal rectifiers, to reduce cross-over distortion at low battery voltages.

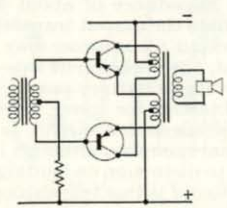


FIG. 12.—SPLIT-LOAD OUTPUT STAGE FOR REDUCTION OF CROSS-OVER DISTORTION.

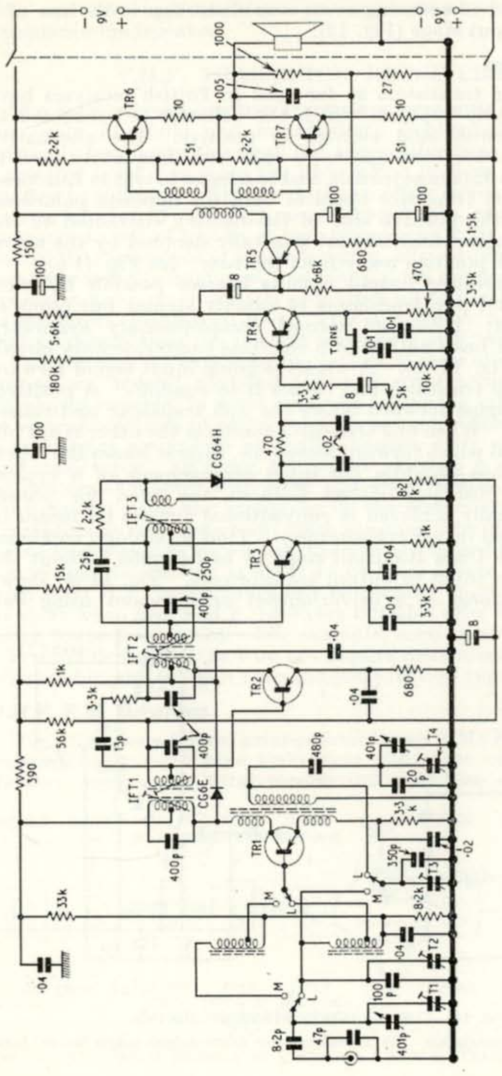


FIG. 13.—REPRESENTATIVE CIRCUIT OF SEVEN-TRANSISTOR PORTABLE RECEIVER.

In addition to the internal ferrite-rod aerial, a socket is commonly provided for the connection of an external car aerial. An A.G.C. damping diode (CG6E) improves the A.G.C. characteristic and prevents overloading on strong signals. In this model there are five I.F. tuned circuits, but it is not uncommon for each I.F.T. to have only one tuned winding. In six-transistor models a single A.F. driver stage is generally used.

One method of reducing cross-over distortion is the use of a split load output stage (Fig. 12).

npn Transistors

Most of the transistors so far used in British receivers have been of the pnp type, in which the collector is connected to negative potential and emitter to positive. The alternative form of transistor—the npn type—has been frequently used in American and Japanese models, and to a lesser extent in European sets. The npn transistor operates with the opposite polarities, that is with the positive side of the battery connected to the collector. These transistors are generally denoted by the arrow on the emitter pointing away from the base: see Fig. (1 *b*).

Several interesting output circuits become possible by combining npn and pnp transistors of exactly similar but opposite characteristics; these are termed complementary symmetry circuits. The basic outline of a zero-bias complementary circuit is shown in Fig. 14 (*a*). A negative-going input signal forward biases the pnp transistor and causes it to conduct. A positive-going input signal forward biases the npn transistor and causes it to conduct. When one transistor conducts the other is cut off, since the signal which forward biases one, reverse biases the other. The circuit thus provides the input arrangement of a typical single-ended push–pull circuit without the need for phase-inversion (usually achieved in conventional circuits by means of a centre-tapped driver transformer). Thus a pnp/npn combination permits a Class B output stage to be designed without the need for either input or output transformers. Fig. 14 (*b*) shows the main features of a driver/output arrangement using two

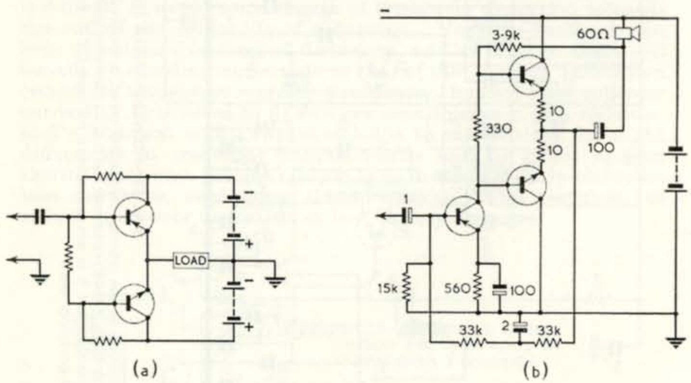


Fig. 14.—Complementary Symmetry Circuits.

(*a*) Basic zero bias circuit. (*b*) Transformerless driver/output stages derived from a Mullard design.

pnp and one npn transistor in conjunction with a 60-ohm impedance loudspeaker.

V.H.F. TRANSISTOR RECEIVERS

The early alloyed-junction transistors were suitable for operation only at audio and intermediate frequencies. This was primarily because of the small but appreciable time taken for the " positive holes " to cross the base region in their passage from emitter to collector. This produces an effect similar to the early valves, which had very high input capacitance, causing the performance to fall off rapidly at high frequencies. By skilful reduction of the dimensions of the base region, alloyed-junction transistors were steadily improved, and many types are now suitable for operation as common-emitter amplifiers up to about 3 Mc/s and as oscillators to above 10 Mc/s. This is, however, not sufficiently high to permit their use in short-wave or V.H.F. receivers.

To overcome the frequency limitations of these alloyed-junction transistors, several modified forms of construction have been developed capable, in some instances, of giving good results up to several hundreds of megacycles per second. These transistors include what are known as surface barrier, drift, alloy diffusion and mesa types. Of these, the service engineer is most likely to be concerned mainly with drift and alloy diffusion transistors. Fortunately, from the viewpoint of the service engineer, these transistors do not present any fresh handling difficulties, although as the base region is very small, the damage caused by incorrectly connecting the battery is likely to be more severe. Transistors with good H.F. performance can be usefully employed not only in short-wave and V.H.F. receivers but also offer advantages at much lower frequencies. For example, such transistors used as I.F. amplifiers at 470 kc/s do not require neutralisation and offer appreciably greater gain than alloyed-junction types.

V.H.F./F.M. Receivers

Fig. 15 shows a typical arrangement for an A.M./F.M. transistor receiver using some nine transistors and three or four crystal diodes: some continental models use only one stage of A.F.

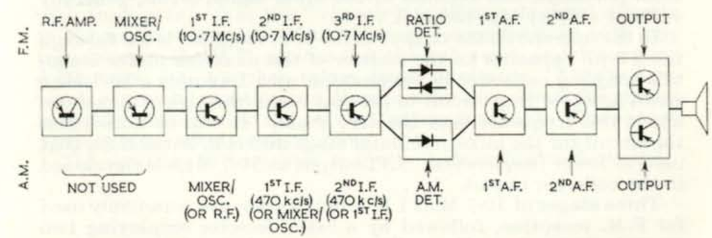


Fig. 15.—Functional Diagram of a Typical A.M./F.M. Transistor Portable.

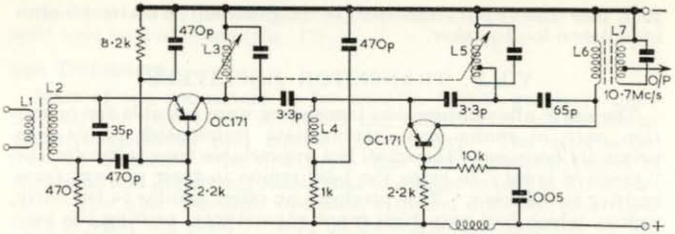


FIG. 16.—SIMPLIFIED CIRCUIT OF A V.H.F. TUNER UNIT FOR F.M. AND A.M./F.M. SETS.

amplification apart from the output stage, and thus have eight transistors. As in valve receiver practice, the two V.H.F. tuner unit transistors are not normally used for A.M. reception in order to avoid the difficulties of switching V.H.F. tuning circuits.

Transistorised V.H.F. units differ in several respects from circuits found in medium-wave receivers. Fig. 16 shows a typical design using two OC171 alloy diffusion transistors, simplified by the omission of the stabilising and temperature-compensating capacitors usually connected across the tuned circuits. The first transistor operates as a common-base R.F. amplifier with fixed tuned input circuit and permeability or capacitive tuning of the collector output circuit. With this type of transistor, slightly greater gain can be obtained at Band II frequencies in this mode of operation, instead of the common-emitter type amplifiers used at lower frequencies.

In some designs A.G.C. may be applied to the R.F. stage so as to reduce signal fluctuations at the input to the mixer/oscillator stage, as such variations may cause the oscillator frequency to vary. The problem of oscillator stability with widely varying input levels is a difficult one for designers: one method of reducing signal fluctuations is to connect a crystal diode across the output circuit of the R.F. amplifier to provide damping on strong signals (similar in principle to the A.G.C. damping diodes used in some A.M. portables, but because of the lower signal levels, generally without a delay bias network).

In the unit shown the output of the R.F. amplifier is fed through the 3·3-pF capacitor to the emitter of the mixer/oscillator stage; this coupling capacitor in conjunction with L4 forms a 10·7-Mc/s series acceptor trap circuit to prevent break-through of signals on about this frequency into the I.F. chain. It will be noted that the circuit for the mixer/oscillator stage differs in detail from that used at lower frequencies. I.F. output at 17·7 Mc/s is developed in the collector circuit.

Three stages of 10·7 Mc/s I.F. amplification are commonly used for F.M. reception, followed by a ratio detector employing two crystal diodes, sometimes fitted with a balancing control to

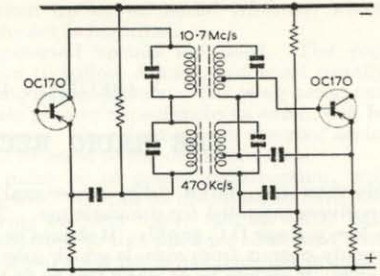


FIG. 17.—EXAMPLE OF DUAL-CHANNEL I.F. AMPLIFIER FOR A.M./F.M. RECEIVERS.

permit adjustment for maximum A.M. rejection. On A.M./F.M. receivers the final I.F. stage is generally a dual-frequency arrangement with series-connected 10·7-Mc/s and 470-kc/s I.F. transformers. The second of the three I.F. stages is also generally used in this manner, with the first 10·7-Mc/s I.F. stage switching to become the A.M. mixer/oscillator. In some designs, however, the second 10·7-Mc/s stage is used for this purpose, with the earlier stage becoming an R.F. amplifier on A.M reception. A.G.C. is often—but not always—omitted from the I.F. stages, and in some designs the bias for these stages is stabilised by means of small metal rectifiers. By using H.F. transistors in the I.F. stages, neutralization can be omitted at both 470 kc/s and 10·7 Mc/s. The I.F. transformers have to provide a step-down low-impedance output for feeding to the subsequent stage, this can be done by means of inductive or capacitive tappings. A separate crystal diode is generally fitted as an A.M. detector.

The A.F. stages of these receivers follow normal transistor practice, though where advantage is to be taken of the good quality of F.M. signals, the standing current in the push–pull output stage may be increased a little compared with A.M. practice, to give greater freedom from cross-over distortion; the additional stage of A.F. amplification also permits a greater degree of negative feedback to be applied.

A point of particular importance to service engineers dealing with these sets is that the " chassis " is often connected directly to the *negative* terminal of the battery (corresponding with *pnp* transistors to the *H.T. positive line* of a valve set), and decoupling condensers, etc., are then taken direct to chassis. This is a reversal of normal practice in A.M. transistor sets, where the chassis is usually connected to the *positive* battery terminal. The change permits more effective decoupling.

The servicing of transistor receivers is described in Section 8.

[SECTION 4]

CAR RADIO RECEIVERS

MODERN car radios differ in several important respects from receivers intended for domestic use. The set must operate from a low-voltage D.C. supply; it should be capable of providing good, steady output from signals which may vary rapidly over a wide range; it should be of small size to fit the limited space available in the average car; it should be built to withstand constant vibration and wide variations of temperature and humidity; it should draw a minimum of power from the vehicle's electrical system; and the controls should be readily accessible to the driver and capable of rapid adjustment without diverting his attention from the road.

To make best use of available space, it is common practice to divide the receiver into two or three separate units: one containing all controls and the early receiver stages; another containing the output stage and power pack; and often a separately mounted loudspeaker positioned so that it may perform most efficiently.

Transistors have had considerable influence on car-radio design, reducing the size and—more important—substantially lowering the load on the car battery. There are at present three main types of receivers: (1) sets using valves in conjunction with a vibrator power unit; (2) sets using special valves needing only 12-volt "H.T." in conjunction with a transistor output stage; and (3) fully transistorised sets intended either solely as a car radio or, alternatively, as combined portable/car radios.

When a car radio is installed it is necessary to take such measures as may be needed to suppress interference from the ignition system, from electrical accessories and sometimes from brakes. This is discussed later in this section. Most of the interference generated within a car can be successfully overcome, but it may not prove possible to eliminate entirely interference from trolley-bus lines, power lines, neon signs and from some passing vehicles.

Car Aerials

Car aerials are rather poor collectors of signal due to their positioning and low effective height. Consequently, a car radio needs greater sensitivity than a domestic set. To satisfy this requirement, a tuned R.F. amplifier stage is often fitted; this not only improves sensitivity but also makes possible better automatic gain control, an important consideration in a car radio.

Car aerials are coupled more tightly to the first R.F. circuit than is practicable in a domestic radio. Variations in aerial and

feeder capacitance are taken up by an aerial trimmer, which should be adjusted after the set is installed.

Mostly wing- or roof-mounted aerials are used. The roof aerial is in a better position to collect signals, but must usually be short to prevent it fouling garage lintels. The wing aerial can be longer and, because of its greater capacitance to earth, can be more closely coupled to the set. An advantage of the roof aerial is that it is less susceptible to some forms of interference.

Wing-mounted aerials must be of sound construction, well sealed against ingress of water. Owing to the speed of cars, the water pressures under a wing are very high; and an aerial base mounted on the wing is subjected to this pressure combined with a bombardment of dirt. When a car radio has poor performance the earth leakage of the aerial should be checked, especially where the fault develops after a spell of wet weather.

Since the aerial is capacitive, closest coupling to the set is possible where a permeability tuner is used, and this is now general practice. Tracking on such a tuner is effected by the shaping of the tuning coils or by mechanical linkages, and the only adjustment necessary is to the external trimmers. Unless in possession of the detailed alignment procedure, it is most inadvisable to change the relative positions of the movable dust cores in a permeability tuner.

Vibrator Power Units

In car radios the H.T. power is usually obtained from the 6- or 12-volt car battery by means of vibrator power packs. The vibrator interrupts the direct current from the car accumulator at a rate roughly equivalent to 100 c/s. The interrupted current is then passed through the primary of a step-up transformer, which results in a peaky A.C. waveform of high voltage appearing across the secondary winding of the transformer. This alternating voltage can then be rectified by a valve in the normal manner or, in the case of synchronous vibrator units, by the action of a second set of contacts on the vibrating arm. Typical circuits are shown in Fig. 2. Complete failure of the power pack can often be traced to the filter capacitors usually fitted across the secondary winding; these must be capable of withstanding the high peaky alternating voltages.

Gas-filled, "cold-cathode" rectifier valves are sometimes found in vibrator power packs. Such valves consist of two anodes and a cathode coated with electron-emitting material, the envelope being filled with an inert gas at very low pressure. The name "cold-cathode" is to some extent a misnomer, since the cathode is heated, not by a heater, but by ionic bombardment. Circuit arrangements must be such that sufficient current is drawn at all times to maintain the cathode at working temperature. A faulty cold-cathode rectifier may sometimes give rise to a form of electrical interference resembling hash.

When servicing, it is important to treat as one unit the vibrator, the transformer and the filter or buffer capacitor fitted across the

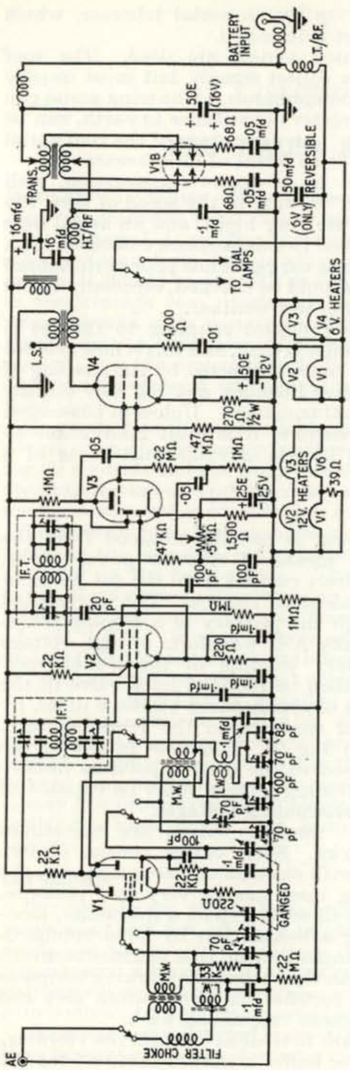


FIG. 1.—REPRESENTATIVE CAR RADIO CIRCUIT USING A SYNCHRONOUS VIBRATOR.
Valves: V1, 6K8GT; V2, 6K7GT; V3, 6Q7GT; V4, 6V6GT.

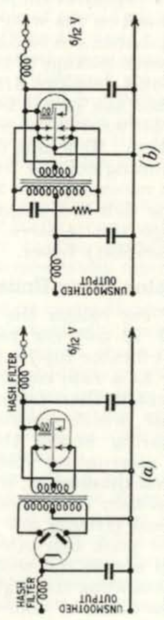


FIG. 2.—(*a*) NON-SYNCHRONOUS AND (*b*) SYNCHRONOUS VIBRATOR POWER UNITS.

transformer secondary: each of these components, if they fail, should be replaced by exact equivalents; otherwise vibrator life may be reduced and excessive sparking may cause interference.

Vibrator units are subject to deterioration and have a limited life; the contact points, in time, wear or become pitted and stick, or the springs lose their tension. Repairs are possible by filing the points and adjusting the spring tension and gap, but these measures are likely to afford only a temporary relief. Towards the end of the useful life of a vibrator it may be found that when the receiver is switched on the vibrator fails to function but can be induced to start by sharply striking the case; this usually indicates worn points, but may denote that battery voltage reaching the vibrator is too low. In this type of receiver the main on/off switch has to carry a relatively high current at low voltage; any resistance due to dirt or oxidation caused by arcing will seriously affect receiver performance.

Transistor Converters

It is now possible to use a transistor converter instead of a vibrator unit to provide H.T., although only a few sets using this principle have been marketed in the United Kingdom. In this arrangement the transistor is used as a switch to interrupt direct current in place of the vibrating reed. Transistor converters can be very efficient and are used for larger installations, such as two-way mobile radio. A few receivers have used a small transistor converter to provide H.T. for the valves in the early stages in conjunction with a transistor output stage, but this practice fell into disfavour with the introduction of valves operating directly from a 12-volt H.T. line.

Hybrid Receivers

A popular type of car radio is the " hybrid " receiver using the special 12-volt " H.T." valves designed for this purpose, in conjunction with a power transistor in the output stage. Since the maximum voltage required in this type of receiver is only 12–14 volts, it can be operated directly from the car battery without any form of voltage conversion. These low-voltage valves are capable of giving useful voltage amplification and frequency conversion, but cannot provide more than a few milliwatts of output power. The early valve stages in these receivers thus follow fairly conventional lines except that component values tend to differ and a small *positive* standing bias is often applied. An R.F. stage is often used not only to provide gain but also to reduce spurious responses, which could otherwise easily occur because of non-linearity. Since transistors are current-operated devices, the valve section of the receiver must provide at least a few milliwatts of audio power, and there is often an A.F. amplifier followed by an A.F. driver. In some models a driver transistor is fitted.

While power economy and miniaturisation is not so pronounced with these sets as with all-transistor models, nevertheless they represent a worthwhile advance on the all-valve receiver. Typical power consumption at 13·6 volts is about 1·2 amp.

Power Transistor Output Stages

Unlike the domestic and portable sets, transistor car radio output stages often use a single power transistor in a Class A stage with a high standing current. Power transistors differ from the conventional small transistors mainly in their size and in the relatively high currents they will handle. The transistor is designed to have as large an area of junction as possible to keep current density to a minimum and to provide the optimum heat transfer from the junction to the metal casing. The semi-conductor wafer is bonded on to a block of metal, such as copper, having high thermal conductivity: the metal block is then bolted firmly to the heat sink, which may comprise a finned plate or box, part of the receiver casing or the main chassis. Since the metal is bonded to the wafer, it is electrically part of one of the electrodes—usually the collector. In some circuits the collector cannot be electrically connected to chassis, and it is necessary either to insulate the heat sink from chassis or to insulate the body of the transistor electrically (but not thermally) from its heat sink; this can be done with extremely thin washers of mica sheet. Mica although a good electrical insulator offers relatively low resistance to heat transfer. Improved thermal conductivity may be achieved by coating all touching surfaces, including the mica washers, with silicone grease. When servicing, take care not to do anything which could reduce the heat transfer. Ensure that the heat sink is not covered when a receiver is installed, and that a reasonable degree of air circulation is possible. A transistor unit should not be mounted directly in the air stream of a car heater.

Although the power transistor has three electrodes—emitter, base and collector—its characteristics are in many ways similar to those of a pentode valve. A Class A common-emitter circuit using a single transistor is the most frequent arrangement. The difference from a valve amplifier lies mainly in the amplication of the input *current*; both signal and bias are supplied as current. Owing to the high spread of the current amplification factor and input resistance in different transistors of the same nominal type, the value of the bias current is usually adjusted by means of a

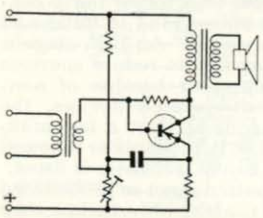


FIG. 3.—CLASS A POWER TRANSISTOR OUTPUT STAGE.

Collector current is adjusted to required figure by means of variable resistor.

pre-set resistor. This current must be checked and if necessary adjusted when the transistor is replaced or circuit changes are made. This bias control provides a simple means of checking a suspect transistor: the collector current should change with any adjustment of this control.

The peak output power of a transistor can be appreciably increased without unduly raising battery consumption by a circuit technique known as "sliding bias", and this circuit has been used in a few receivers. A small proportion of the audio output of the stage is rectified, usually by a crystal diode, and applied as bias. This means that the working point of the transistor is changed during audio peaks to cope with the extra power. Since the peaks of output for speech and music are relatively widely spaced, it is possible to almost double the peak output of the transistor without exceeding permissible ratings, though at the cost of some slight increase in distortion.

With any power transistor stage it is important always to have a loudspeaker or other form of matched load connected into circuit; otherwise high voltages may be developed across the primary of the output transformer and damage the transistor. Special care should be taken when installing a transistor car radio to ensure that the unit is suited to the type of electrical system fitted (positive or negative chassis system). Most modern cars have positive chassis, but receivers can usually be adapted for either system.

Fully Transistorised Car Radios

A further saving in battery consumption can be obtained by using transistors for all stages, the early stages employing circuits similar to those described for transistor portable receivers. It seems likely that transistors will eventually largely replace the 12-volt valve for this application, as they have the advantage that no heater power is required.

Some motorists use conventional portable receivers in their cars, and provision is made on a number of portables for a co-ax connection to be made to a permanently installed car aerial. A good car aerial will overcome the screening effects of the car body and—to a great extent—the directional effects of the built-in ferrite-rod aerial. The average portable receiver, however, has a performance specification below that desirable for good reception during actual travel. This has encouraged a few firms to develop dual-purpose receivers which can be used as a normal portable or plugged into a special container which automatically connects it to the car electrical system via interference-suppression components (permitting a larger power output), and to a car aerial and sometimes to a larger loudspeaker.

INTERFERENCE SUPPRESSION

Modern car-radio receivers, when correctly installed, should be capable of receiving even weak stations without the reception being marred by interference generated in the vehicle. However, cars vary widely in this respect, and just occasionally interference will continue to be troublesome even when routine installation instructions have been correctly carried out. It is believed that this very wide variation, which may occur even between cars of similar make and model, is due to differences in the electrical wiring of the car and the varying quality of spot welds on which bonding depends.

Ignition interference originates mainly at the sparking-plugs, though a certain amount can be traced to the gaps between the rotor arm and the fixed contacts in the distributor, and also to the operation of the contact-breaker in the H.T. circuit of the ignition coil. The lay-out of the ignition system, the length of the H.T. leads and the condition of the sparking-plugs have an important bearing on the amount of interference likely to be radiated.

Adequate suppression of ignition interference can often be obtained by fitting one of the high-temperature resistors (5,000–15,000 ohms) made for this purpose in the main lead from the ignition coil to the distributor. By law, modern cars should already have ignition suppression of this type, though sometimes it is worth replacing the fitted resistor with one of higher ohmage. In more difficult cases resistors are sometimes fitted in the sparking-plug leads as close as possible to each plug.

Additional methods of reducing ignition interference include: checking that the sparking-plugs are in first-class condition and that the gaps are correctly adjusted; eliminating any tendency for small sparks to occur at the " pinch fit " terminals on H.T. leads by soldering each H.T. wire to its terminating lug; increasing the distance between L.T. and H.T. wires, if unshielded, to at least 6 in. Ignition interference often reaches the receiver via the L.T. wires and other wires and controls that pass through the bulkhead. The L.T. wire from the ignition coil to the dashboard switch is a frequent carrier of interference; this can be reduced by fitting a 0·25-μF capacitor between the switch and the chassis. Any other leads suspected of forming similar interference paths should be by-passed in a similar manner, the capacitors being connected with leads not more than 1 in. in length.

Normally, the power for a car radio is obtained from the A2 accessory terminal on the junction box, but, with difficult cases of battery-borne interference, it may prove more effective to connect the battery lead to the A1 or A terminals; or sometimes even to make a direct connection to the battery. An alternative method is to retain the A2 connection, but to fit an additional 1-μF suppressor capacitor between the terminal and the bulkhead or adjacent part of the body or chassis. Battery-borne interference can usually be identified on valve models by disconnecting the battery supply and noting whether the interference ceases during the short period for which the set will continue to function.

In difficult cases it is advisable first to check carefully all earth connections, making quite sure that the earthing of the aerial base and the braid of the screen aerial feed is effective. The

aerial braiding must be connected to the body of the car through the aerial base, as well as via the casing of the receiver. Where an earth connection has to be made to the bodywork of the car it is essential to clean the metalwork carefully, and often to protect the connection against corrosion. Earthing leads should preferably be in the form of braiding and as short as possible.

If interference persists it will be advisable, before taking further measures on the car, to check that the receiver itself is functioning correctly; check all covers and connections for good earthing, and the effectiveness of the various filter components.

If ignition interference—which can be distinguished from other forms of interference by its frequency increasing with the speed of the engine—ceases when the aerial is removed from the receiver the bonding of the car bonnet, which screens the aerial from the ignition system, should be suspected. This can be checked by connecting braiding, effectively connected to both body and bonnet, across the hinges.

Cars with fibre-glass bodies present special difficulties. Generally, the aerial should be placed as far as possible from the engine; all metal parts bonded together and the aerial base connected by braiding to the nearest metal point. In some cases the ignition system may need shielding, which may take the form of a sheet of aluminium bolted on to the engine block and covering the ignition wiring. Rarely, where such a shield is impossible, it may even be necessary to form a shield by sticking aluminium foil inside the bodywork, taking care that there is good electrical continuity between the various sheets.

Many cars include an electrical system of indicating water temperature, including a " thermal temperature transmitter ", which is mounted on the engine and which can cause interference; this can be suppressed with a standard type of 1-μF metal-cased suppressor capacitor.

Tyre and wheel static are uncommon in the United Kingdom, although sometimes troublesome overseas. A similar and fairly common form of interference is " brake static ". This causes a rhythmic rushing noise related to the speed of rotation of the wheels, heard only when the brakes are applied; sometimes this interference builds up rapidly from a low level into a continuous roaring noise.

[SECTION 5]

MONO AND STEREO RECORD REPRODUCTION

RECENT years have seen a great increase in the reproduction of gramophone records on equipment ranging from small transportable record reproducers up to elaborate high-fidelity sound systems. The stereo disc record, introduced in 1958, has created a demand for dual-channel equipment and imposed new requirements on pick-ups. Battery-operated transistor record reproducers are also available, incorporating low-consumption, battery-driven motors.

Pick-ups

Where the pick-up is suspect, it may be tested most satisfactorily with the aid of frequency test records such as E.M.I. No. JG449 and Decca No. LXT2695. In the case of crystal cartridges a test by direct substitution is usually effective. When a faulty crystal cartridge or other type of high-fidelity pick-up is discovered it should be returned unopened to the manufacturers, as otherwise no responsibility will be accepted by them.

It should also be noted that with most turn-over-type heads, it is not necessary to unsolder the leads from the crystal cartridge in the event of this proving faulty and requiring replacement. The leads are usually inserted into the cartridge by means of two small contact " plugs ", which can easily be removed from their sockets either with the fingers or a pair of pointed-nose pliers. Any attempt to unsolder the leads will almost certainly result in irreparable damage to the cartridge in such cases.

Magnetic-type pick-ups may be carefully examined after removal of the cover, usually a simple matter. The position of the armature, which should be exactly in the centre of the gap between the pole pieces, should be checked : in some models, adjustment screws are provided to facilitate re-centring the

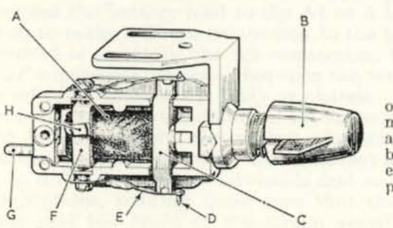
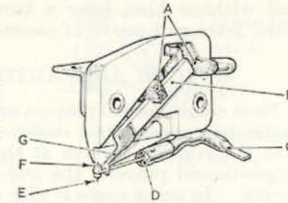


FIG. 1.—TYPICAL TURNOVER CRYSTAL PICK-UP.

A, crystal bimorph; B, turnover knob; C, plastic driving member; D, stylus; E, stylus arm; F, plastic "clamping block"; G, contact pin; H, foil electrode from crystal to contact pin.

FIG. 2.—CERAMIC CRYSTAL CARTRIDGE.

A, plastic clamping and supporting blocks; B, ceramic crystal bimorph; C, styli turn-under lever; D, rubber-styli support and damper; E, standard stylus; F, L.P. stylus; G, reed.



armature where it is found to be out of alignment. The armature should be attached firmly to the reed plate and, where distortion is experienced, should be examined for signs of damage or bending. The rubber damping pads should also be carefully examined, as these occasionally perish and cause needle stiffness. Dust, grit and iron filings may also find their way into the air gap and cause distortion. Iron filings, which adhere to the pole magnets, may be removed with the aid of a piece of plasticine. The coil windings of magnetic-type pick-ups can be tested for continuity by means of an ohm-meter : crystal types cannot be so tested.

When investigating the causes of weak or distorted output, the possibility of dirty switch contacts, and plug and socket connections should not be overlooked. Where screened leads are used to connect the pick-up to the receiver, short-circuits may develop between the shielding and the internal wires.

Styli

The stylus pressure on the record is important : if too light, the stylus will not track heavily modulated grooves ; and if too heavy, excessive record and stylus wear will occur.

For modern, three-speed mono units the stylus pressure usually recommended is 8–10 gm. Pick-up arm counterbalance adjustment is provided on most units to facilitate this setting. It is recommended that the stylus pressure be checked on installation and that periodic checks be made, as the tension of the pick-up-arm counterbalance spring may alter slightly with use.

If difficulty is found in setting the correct stylus pressure, it may be due to excessive friction in the cross-pivot, which should be examined : clean and lubricate, if necessary.

Should the stylus occasionally jump a groove, first check the stylus point to see that it is not excessively worn or broken. If found to be in order, see that the screened lead from the pick-up arm is not strained or twisted in such a way that it can bias the free movement of the pick-up arm. This lead should not be disconnected from the tag strip but left as supplied by the manufacturers.

Mono microgroove stylus tips should have a radius of 0·001in., and the pick-up arm should have the freest possible vertical and horizontal movement. To avoid any tendency for the pick-up arm to slide, it is essential that the arm should swing accurately, and without bias, over a turn-table that is perfectly level : a spirit level will prove of assistance in checking this.

MOTORS AND AUTO-CHANGE MECHANISMS

Most single-record players and all record changers have an automatic trip mechanism designed to operate as the pick-up runs into the run-out groove at the end of a record. In the case of single-record players, the trip operates a switch which stops the motor. In some cases it also causes a brake to be applied to the turn-table. On record changers the trip releases the operating cam to commence the changing cycle.

The mechanism for an automatic trip usually falls into one of two categories, viz., the velocity type or the ratchet type. The velocity principle is almost exclusively used on modern three-speed units, and it operates as follows : as the pick-up advances towards the centre of the record it moves at a slow, even speed and the trip does not operate, but when it runs into the record run-out groove the speed of the pick-up arm is accelerated and the trip operates.

Single-speed units playing only 78-r.p.m. records often use the ratchet type of trip mechanism ; this is operated by the reversal of the inward movement of the pick-up as it runs into the eccentric run-out groove of the record. A lever attached to the pick-up arm carries a very light pawl which moves along a ratchet connected to the switch or change mechanism, the pawl riding over the ratchet teeth as the pick-up moves inward, but engaging with a tooth and moving the ratchet, which trips the mechanism, as the pick-up-arm movement reverses.

Since there is no eccentric groove on the 45-r.p.m. microgroove records, any unit intended for playing these records should have some form of velocity trip.

Velocity Trips

Fig. 3 illustrates the principle of the velocity trip mechanism. A quadrant is moved by the pick-up arm ; this carries the trip lever, which is moved with it by the friction of a felt pad on the polished face of the quadrant. When the pick-up nears the centre of the record, the quadrant commences to move with it, transmitting its inward movement to the trip lever. As the end of the trip lever moves towards the turn-table spindle, a felt pad, located in the end, contacts a projection—usually referred to as a striker—on the revolving turn-table spindle. Each revolution of the striker pushes away the trip lever as it slowly moves inward ; but when the movement of the trip lever is accelerated by the pick-up reaching the run-out groove, the trip lever moves inward too far to be pushed back by the striker, and the striker then either lifts the trip lever or moves a lever attached to it to trip the mechanism. This type of auto-trip can be made very sensitive in operation, accelerated movement of the pick-up through $\frac{3}{32}$ in. being sufficient to operate it. It should be noted

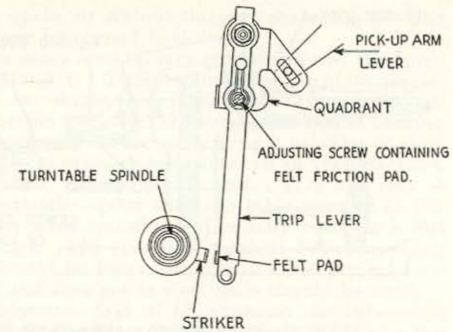


FIG. 3.—VELOCITY TRIP MECHANISM.

that the felt friction pad on the quadrant face should not be lubricated, since the oil is liable to become gummy and also collects dust ; this may increase the friction to such an extent that the action of the striker pushing the trip lever will be transmitted to the pick-up and become audible in the reproduction.

Auto-change Mechanism

A typical auto-change mechanism, using a sloping type of record spindle, is shown in Fig. 4. The records rest on the step of the spindle, and are pushed off one at a time by the platform mechanism on the left.

The distance between the face of the step on which the records rest and the underside face of the inverted step is such that only one record can pass at a time. The spindle is inclined toward a platform on which the edge of the records rest. This platform has a pawl or stud which at the correct moment engages with the edge of the lowest record and pushes it, causing the record to drop off the step ; as the record falls, the slope of the spindle causes it to pull away from the platform and drop flat on to the turn-table. When using a simple platform with this type of spindle, the platform position must be pre-set for the size of record to be played. Mixed sizes of records can, however, be handled with this type of spindle by using the special form of platform described below. The stack of records is held at the correct angle on the sloping record spindle by means of an overarm. The overarm is required to hold the records in position while the platform moves away to select the record size : Fig. 3 shows the mechanism in the platform. To drop a record, the platform first moves inward beneath the records to a position determined by the smallest-diameter record. Having reached its innermost position, the platform rises to touch the records ; if a record is present of the appropriate size, the latch on the platform is not depressed, thus allowing its lower end to engage with a stop. The platform then remains in this position, allowing its operating lever to select

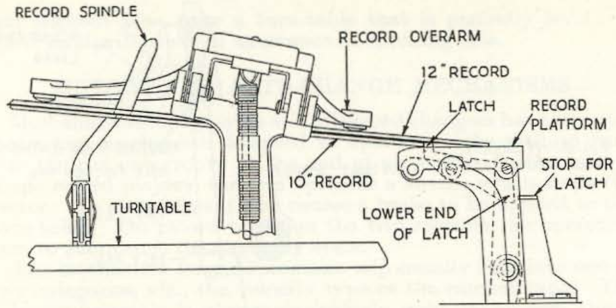


FIG. 4.—REPRESENTATIVE AUTO-CHANGE MECHANISM.

the corresponding track on the cam to push the platform forward to release the record. If, however, the platform when rising encounters a record of a larger diameter, the latch is depressed, and its lower end then fails to engage with the stop. In this case the platform falls back to the edge of the record, and the latch then rises, allowing another cam track to be selected to move the platform forward.

Installation

Radio-gramophones should, on installation, be checked by placing a spirit level on a record on the turn-table to see that the turn-table is level. Level the unit, if necessary, by adjusting its spring suspension. It should also be noted that the spring suspension serves to prevent the build-up of acoustic feed-back between the loudspeaker and pick-up : its presence is indicated by a characteristic howl from the loudspeaker when the pick-up is placed on a record. The unit should float freely on its suspension springs.

Adjustments and Servicing

Many so-called faults in the motor and auto-change mechanism often prove, on inspection, to be due to faulty adjustment of the unit. Whenever possible, these units should be set up strictly in accordance with the manufacturers' instructions. Adjustments that may be required include those affecting the pick-up dropping position and its height, the auto-trip mechanism and the setting of the record platform.

Faults that most commonly develop in the motor and auto-change mechanism are those due to the various friction drives wearing slightly or becoming distorted, or to spring tensions slackening. A fault can often be located by slowly turning the turn-table by hand and watching closely to discover at what precise point the symptom occurs. If this is done, no attempt should be made either to retard or to hurry the pick-up during

the record-changing cycle, or serious damage may result. The turn-table should never be turned backwards.

On record changers using a stationary record spindle, the turn-table must revolve around it. This precludes the use of the single-ball thrust as used on single-record players. The single-ball thrust is quiet and rumble free ; but the turn-table thrust bearing of record changers is usually a race containing a number of steel balls which, unless special precautions are taken in manufacture, can be a source of noise, rumble and flutter. This ball race is situated either immediately under the turn-table boss or at the lower end of the turn-table spindle, and usually rests on a felt or plastic buffer washer. The two steel washers between which the steel balls run should be hardened, ground and lapped to a high degree of finish and first-grade steel balls should be used.

If rumble is troublesome, first of all examine the turn-table thrust race, since dirt in the race, indented washers, due to the turn-table receiving a blow, or a hardened felt or plastics buffer washer may be the cause of the rumble. The race should be cleaned out and, if necessary, the washers and balls replaced.

Rumble, and often hum and flutter, may be caused by perished motor-mounting rubbers ; these are rubber grommets or brushes in the unit plate. The resilience of the rubber is important in preventing unavoidable vibrations of the motor from reaching the pick-up via the unit plate. The rubbers should be replaced, if necessary, by new ones obtained from the manufacturer.

Where lubrication is considered necessary, light machine oil and grease may be applied sparingly to those points at which it can be seen from careful study to have been applied previously. Lubricating the wrong points, or excessive application, may cause complete failure of the unit. In general, light oil can be applied to bearings and lever pivots, and grease to gears. Before using lubricants, it is advisable to clean the points thoroughly. Particular care should be taken to ensure that lubricants do not reach any rubber-tyred drive wheels, and it is advisable to wash such drives with carbon tetrachloride to remove any oil and grease that may have reached them accidently.

With governor-controlled motors, the felt governor pads should be saturated with oil : dry pads may cause uneven speeds. If governor rattle occurs this may often be cured by applying thick oil to the shaft along which the governor sleeve slides.

Where an " Isle-of-Man " washer is fitted, no lubricant other than loom oil should be applied to this part.

If the weak tension of a spring appears to be causing unsatisfactory action, the fault may not be due to the spring, but to excessive friction between the parts controlled by the spring. Such friction may be due to insufficient, old or unsuitable lubricants, or to bent or roughened levers.

A knock or rumble audible in the loudspeaker may be caused by excessive friction or by the deterioration of the rubber or spring mountings on which the motor and turn-table are usually floated.

On the completion of servicing, the speed of the turn-table, under load, should be carefully checked by means of a stroboscope disc and the speed regulator adjusted where necessary. The motor voltage should also be correctly adjusted to suit the mains-supply in use. If the motor appears to run hot, the consumption should be checked by inserting an A.C. meter in series with the windings; most motors consume between about 15 and 25 watts, and excessive consumption may denote shorted turns.

Speeds

The majority of turn-tables are fitted with a speed-adjustment lever, and adjustment to the correct speed is thus a simple matter. To ascertain the correct speed, a stroboscopic disc should be placed on the turn-table. These are available for different speeds, and can be distinguished by the different number of bars on the disc. The following table gives the different number of bars on stroboscopic discs for use with 50-c/s mains supplies.

Speed (r.p.m.)	*Number of Bars*
33·33	180
45·11	133
77·92	77

Stroboscopic discs are most accurate when viewed with a light directly above them: if possible a neon lamp should be used; as this provides a better source of light for this purpose than a normal filament lamp.

STEREO RECORDS

With a single-channel system (called " monaural " or " monophonic "), the only dimension that can be reproduced is depth; for example, a singer may sound in front of the orchestra, but we have to rely upon imagination to " place " the members of the orchestra. This would not be true at a live performance, where our two ears would enable us to achieve a reasonably accurate side-to-side (" azimuth ") localisation; indicate the arrive angle in the vertical plane (" zenith "); as well as telling us the approximate distance. It is believed that the human being with normal hearing locates the azimuth positioning mainly by the difference in arrival time or phase at the lower frequencies, and the difference in arrival time and intensity at the higher frequencies. The zenith localisation is done by head movements giving a series of results from which the brain automatically provides the answer. Judgment of distance is achieved by a combination of loudness and memory in places where there is no reverberation, and by the relationship between the direct and the reverberant sound in enclosed spaces.

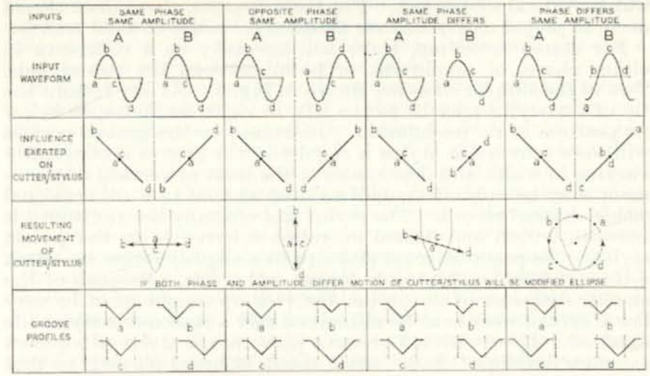


Fig. 5.—Basic Principles of Stereo " 45/45 " Disc Recording.

The two-channel system used in disc records was originally developed by A. D. Blumlein in 1929. The output of two microphones, placed close together, have their phase differences converted to amplitude differences, and the resultant signals fed to two well-spaced loudspeakers. A listener will hear a correct sound image when he is on the centre line between the two loudspeakers.

The two channels are recorded in a single groove. This can be done by displacing the recording stylus in a vertical plane for one channel, while displacing it horizontally for the other; this is termed the " L/V " (lateral/vertical) system. In practice, these displacements are turned through 45 degrees, so that the axis of each displacement is at 45 degrees to the horizontal, but remain at 90 degrees to each other: called the 45/45 system. Since the displacement angle roughly corresponds to the wall angle of the groove, the simple explanation is often given that the two channels are recorded one on each wall of the groove: a single stylus tip, supported simultaneously by both walls, could not, of course, follow two different contours at the same time. In reality, the displacements of the cutter stylus under the influence of the two channels result in a combined movement which changes the position of the stylus tip, both up-and-down and side-to-side. An idea of what happens in terms of groove profiles can be obtained from Fig. 5.

It will be seen that if exactly the same signal (in both intensity and phase) is fed to both channels the vertical movements cancel out, leaving only horizontal movement. It is this feature which *in theory* allows the use of stereo records on normal equipment. In practice, however, a finer stylus is needed for stereo records, and most single-channel pick-ups have mechanical stiffness towards vertical movement. For these reasons, *stereo discs should never be played on reproducers designed for single-channel records.*

For stereo recording, there will normally be a difference in either phase, or amplitude, or both, between the two signals. Two of the simpler cases are shown in Fig. 5. At any instant the tip of the stylus may be to the left, or right, or above, or below its position of no modulation. Reference to the groove profiles will show why a fine stylus is required; the groove is constantly varying in width and depth, and at the limit of vertical displacement may be only about half as deep as that of a conventional single-channel record. The stylus size officially recommended is between 0·0005 and 0·0006 in. (often referred to as the $\frac{1}{2}$-thou stylus). In practice, most pick-ups fit a slightly larger tip, often $\frac{3}{4}$-thou (0·00075 in.) to give longer stylus life. Because of the smaller diameter of the stylus, the pick-up weight must be very low if record wear is to be minimised and a reasonable stylus life attained. Even with a 3-gramme pick-up, the stylus of a $\frac{1}{2}$-thou sapphire develops " flats " after about 70 hours playing, so that for this stylus size a diamond stylus is highly desirable.

Stereo Pick-ups

The basic requirement for a stereo pick-up for the 45/45 system is that it should contain two transducing elements for converting the mechanical movements into electrical voltages. Each element should respond to stylus displacements in one plane, but be as unresponsive as possible to displacements at angle of 90 degrees from it.

Two representative designs for crystal stereo pick-ups are shown in Fig. 6.

In Fig. 6 (*a*): Movement of the stylus (*D*) and stylus arm (*C*) in direction x moves tension arm *F*, thus bending crystal *B*, clamped at its farther end, causing an electrical output from this crystal. This movement will not affect tension arm *E* and crystal *A*. Similarly, movement of the stylus in direction y results in

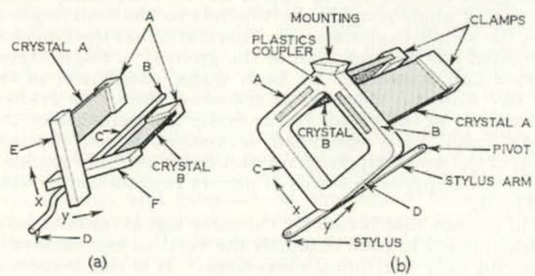


FIG. 6.—CRYSTAL STEREO PICK-UPS.

A, clamp; B, stylus arm pivot; C, stylus arm; D, stylus; E, crystal A torsion arm; F, crystal B torsion arm.

electrical output from crystal *A* but not from *B*. Thus the complex movements of the stylus in directions x and y, as it follows the complex-cut track of the stereo disc, will provide a dual-channel output from the two crystals.

In Fig. 6 (*b*): The two crystals are arranged in what is termed a " diamond structure resolver ". Movement of the stylus and stylus arm in direction x (parallel to section *C* and *B* of the coupler) will cause movement of sections *A*, *C* and *D* of the coupler; thus crystal *B* (which is clamped at its other end) produces an electrical output. During this movement, section *B* of the coupler remains stationary, so that crystal *A* is not affected. Movement of the stylus in direction y will, in the same way, provide an output from crystal *A*, section *A* of the coupler then remaining stationary.

In all stereo systems the signals in the two channels should, ideally, be kept completely separate, since mixing of these signals will impair the stereo effect. In practice, however, with most medium-priced pick-ups some degree of cross-modulation must be tolerated, particularly at the extremes of the audio range.

TONE CONTROLS

Many types of tone control are in current use, and in high-fidelity equipment it is usual to include an extra valve to make good the gain lost in the tone control. The following four basic types of tone control may often be found, either singly or in combination with one another :

(1) adjustable treble rise (or high-frequency intensification);
(2) adjustable treble cut (or high-frequency attenuation);
(3) adjustable bass rise (or low-frequency intensification);
(4) adjustable bass cut (or low-frequency attenuation).

Where negative feedback is incorporated, treble rise is often obtained by reducing the feedback at high frequencies. The usual arrangement is for the feedback to diminish as the volume control is turned up. This is effected by incorporating either a switch with fixed capacitors or a variable resistor.

Treble cut is often obtained by shunting a capacitor across a portion of the audio circuit. This may be adjusted : (1) by switching different capacitors; (2) by using a variable capacitor; or (3) by using a variable resistor in series with a capacitor. Alternatively, treble cut may be obtained with negative feedback by reducing the feedback at middle and low frequencies, using a switch or variable capacitor or resistor to vary the effect.

Bass rise is often obtained by reducing negative feedback at low frequencies. It is adjusted by incorporating a switch or variable resistor, often operating in conjunction with the volume control, to restore the low-frequency feedback in varying degrees.

Reducing the size of the coupling capacitor between the audio-amplifier and audio-output valves is a common way of providing bass cut. A variable resistor shunted across the

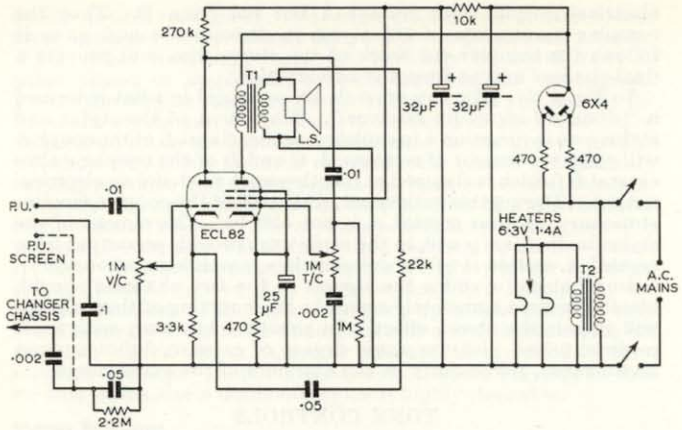


FIG. 7.—REPRESENTATIVE MODERN PORTABLE RECORD REPRODUCER.

capacitor, or a system of switched capacitors, varies the effect. Alternatively, bass cut is sometimes obtained by reducing negative feedback at middle and high frequencies, using a switch or a variable resistor to achieve variation.

CARE OF RECORDS

To avoid a static charge forming on the record and subsequently attracting dust (a frequent cause of noisiness), all records

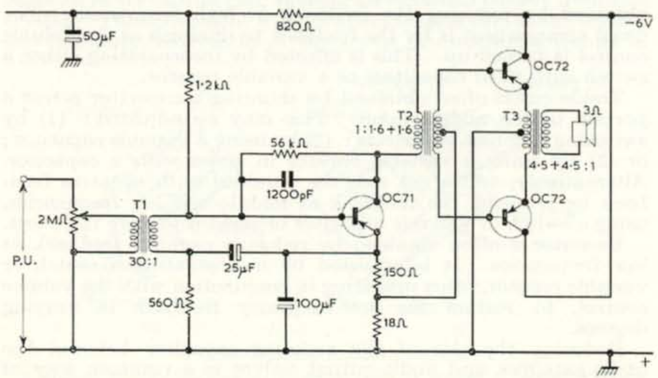


FIG. 8.—TRANSISTOR BATTERY AMPLIFIER FOR PORTABLE RECORD REPRODUCER.

should be cleaned occasionally with one of the special solutions now on the market, or alternatively with a damped non-fluffy cloth. Records should always be handled by their edges, and dust should not be allowed to settle on the turn-table.

LP records should not be stored leaning against one another, but kept in their cases, placed vertically on edge. Should they become a little warped, they should be slightly warmed on both sides and placed between two sheets of glass, also slightly warm, and left in a horizontal position under slight pressure.

Where sapphire stvli are fitted, the point should be examined regularly with the aid of a suitable magnifying glass.

EXTENSION LOUDSPEAKERS

Receivers are frequently designed with provision for an extension loudspeaker. Sometimes a switch or plug is included so that the loudspeaker can be switched off when not required. Unless some additional component is included it is clear that the optimum conditions of matching cannot be fulfilled in both cases, *i.e*, with either one or two loudspeakers in use. To prevent mismatching when the circuit is switched from one condition to the other, a resistance equal to the extension loudspeaker impedance should be inserted when the extension loudspeaker is withdrawn, so that the circuit conditions remain almost the same. Parallel connection of loudspeakers is usual.

Volume Control

Where several loudspeakers in different rooms are fed from the same set, individual volume control is desirable so that the output of one speaker can be adjusted without affecting the others. The simple arrangement of a variable series resistance which is sometimes used is not altogether satisfactory, as it affects the quality of reproduction. The impedance of the loudspeaker speech-coil is lower at low frequencies, so that in the lower notes the series resistance tends to absorb a greater proportion of the total voltage across the loudspeaker, and attenuation of bass notes is likely to occur. The alternative of potentiometer control with one terminal of the loudspeaker connected to the slider has its disadvantages also. As the potentiometer resistance is a shunt to the speech coil, it must be fairly high, otherwise it will divert too much power from the speaker. Under these conditions there will still be a high resistance in series with the speech coil when the volume is turned down, so that the same objections as in the case of the series resistance still exist. A tapped choke offers a third and better alternative, but gives only stepped degrees of volume control, and is expensive. These objections make it preferable, whenever possible, to incorporate the volume control in the amplifier circuit to adjust the overall gain rathei than to use an attachment to the loudspeaker circuit.

Phasing

If more than one loudspeaker in the same room is connected to the same power circuit, care must be taken to see that all the speech-coils are connected correctly so that the diaphragms all move in the same direction at the same instant, otherwise the vibrations from any unit whose terminal connections are reversed will be out of phase, and the total volume of sound will be reduced. Generally, the polarity of the coil is marked or indicated by coloured terminals. If not so indicated, the connections will have to be identified, though as a general rule, with loudspeakers of identical form, the position of like terminals will be the same.

However, identity of conections can be confirmed either by connecting the speech-coil to a battery to find out which way the diaphragm moves for a given polarity, or through aural detection by trial. For the second type of test, with one loudspeaker operating, the result of switching the second loudspeaker on is observed. If the sound is reduced, the phasing is incorrect, and one of the loudspeaker windings must be reversed. A further method of ensuring that several loudspeakers are correctly phased is as follows :

Disconnect the loudspeaker from the amplifier and connect a D.C. milliammeter across the loudspeaker input terminals. Gently but sharply push in the loudspeaker cone and notice which way the milliammeter needle kicks. Repeat with the other loudspeakers, and thus determine for each the way the milliammeter has to be connected in order that they all produce a kick in the same direction. A " polarity " is thus established enabling the loudspeakers to be connected in series or parallel as repuired.

[SECTION 6]

WORKSHOP ORGANISATION AND PRACTICE

WHETHER intended for the small one-man repair shop or the multi-engineer service station, care and thought expended on the layout and tooling of the workshop is time well spent. Most of the major decisions are matters of applied common sense —yet all too often are conspicuously absent in practice. The workshop should be dry, adequately heated and lighted, with plenty of bench and storage space for tools, replacement valves and components, and technical information. Tool clips should be mounted in readily accessible positions—and tools should always be replaced in their correct places immediately after use. An abundance of power points—of all likely types and sizes of sockets—should be provided, and test positions should be individually fused. Mains cables should be permanently installed with earthed, lead sheathing.

Consideration of the safety of all personnel, servicing equipment and of the equipment under repair must receive the most careful consideration. Incidentally it is as well to remember that, legally, each test position should be equipped in accordance with the Factory Acts and regulations.

Apart from dangers arising from poor mains wiring and fire hazards (a fire extinguisher should always be at hand—and receive regular attention to ensure that it retains its efficiency), undoubtedly the most likely cause of injury or damage comes from the " live " chassis—not forgetting those nominally " isolated " chassis which have been rendered " live " by breakdowns in transformer insulation or leaky capacitors.

These dangers can be minimised by ensuring that the power supplies for receivers in which any trouble-shooting is to be carried out are derived from a properly screened double-wound (1 : 1) transformer of adequate wattage and with the screen earthed. The entire load for a particular bench, for one engineer only, should come from one transformer secondary : two engineers should never share a transformer, since they could easily get two chassis not very far apart connected to opposite sides of the supply. Precautions must also be taken to avoid similar situations arising between the chassis of receivers and service equipment.

Damp concrete flooring adds greatly to danger from shock, apart from being most unpleasant to stand on for any length of time.

The bench itself should be secure and rigid, with a linoleum or other smooth, hard covering so as to avoid the cracks into

British Association Screws and Drills

No.	*Dia. (in.)*	*Clearance Drill*		*Tapping Drill*		*Threads per inch*
		Morse No.	*Nearest Fractional Size*	*Morse No.*	*Nearest Fractional Size*	
0	0·236	C	$\frac{15}{64}$	12	$\frac{3}{16}$	25·3
1	0·209	3	$\frac{7}{32}$	19	$\frac{5}{32}$	28·2
2	0·185	11	$\frac{13}{64}$	26	$\frac{9}{64}$	31·3
3	0·161	19	$\frac{11}{64}$	30	$\frac{1}{8}$	34·8
4	0·142	26	$\frac{5}{32}$	34	$\frac{7}{64}$	38·4
5	0·126	29	$\frac{9}{64}$	40	$\frac{3}{32}$	43·1
6	0·110	32	$\frac{7}{64}$	44	$\frac{5}{64}$	47·8
7	0·099	37	$\frac{7}{64}$	48	$\frac{5}{64}$	52·9
8	0·087	42	$\frac{3}{32}$	51	$\frac{1}{16}$	59·1

which nuts have a habit of falling. An aerial and earth distribution point should be located on the bench; an "isolated" earth point with a 0·02-μF, 1,000-volt capacitor connected in series with true earth is also useful. Do not carry out tests with a "live" chassis where there is the slightest possibility of touching a point at "true" earth. A loudspeaker with optional matching transformer permanently installed above the bench will save much time when dealing with chassis removed from their cabinets. A plentiful supply of single, twin and multiple-wire flexible connecting leads made up into a variety of convenient lengths and terminated with an assortment of prods, plugs and the useful crocodile clips will help to speed up repair work—provided that they are kept within reach and carefully returned to their appropriate hooks directly they are no longer needed.

Time is money in repair work, and much will be needlessly wasted in searching for odd parts, tools, connecting leads or technical information unless these are scrupulously kept in order. The time spent hunting around for a missing service sheet can easily absorb the entire profit on a particular job.

Tools

The range of tools must, to a great extent, be governed by personal choice and habit. Some engineers find that a small number of tools, kept in good condition, and made doubly

Linear Measures

1 inch	2·54 cm. or 25·4 mm.
1 foot	30·48 cm. or 304·8 mm.
1 yard	0·9144 m.
1 mile	1·6093 km.
1 millimetre	0·03937 in.
1 centimetre	0·3937 in.
1 metre	39·37 in. or 3·281 ft.
1 kilometre	0·6214 mile or 1093·6 yd.

Decimal Equivalents of Fractions

$\frac{1}{32}$	0·03125	$\frac{17}{32}$	0·53125
$\frac{1}{16}$	0·0625	$\frac{9}{16}$	0·5625
$\frac{3}{32}$	0·09375	$\frac{19}{32}$	0·59375
$\frac{1}{8}$	0·125	$\frac{5}{8}$	0·625
$\frac{5}{32}$	0·15625	$\frac{21}{32}$	0·65625
$\frac{3}{16}$	0·1875	$\frac{11}{16}$	0·6875
$\frac{7}{32}$	0·21875	$\frac{23}{32}$	0·71875
$\frac{1}{4}$	0·25	$\frac{3}{4}$	0·75
$\frac{9}{32}$	0·28125	$\frac{25}{32}$	0·78125
$\frac{5}{16}$	0·3125	$\frac{13}{16}$	0·8125
$\frac{11}{32}$	0·34375	$\frac{27}{32}$	0·84375
$\frac{3}{8}$	0·375	$\frac{7}{8}$	0·875
$\frac{13}{32}$	0·40625	$\frac{29}{32}$	0·90625
$\frac{7}{16}$	0·4375	$\frac{15}{16}$	0·9375
$\frac{15}{32}$	0·46875	$\frac{31}{32}$	0·96875
$\frac{1}{2}$	0·5	1	1·0

useful by familiarity, is better than an extensive range of tools with which they are less skilled. Another point to be considered is that most engineers undertake a certain amount of constructional work, and this requires a wider range of tools than purely repair work. Then again, in the course of their work, many servicemen light upon some unorthodox tools—whose original purposes may be far removed from radio repairing—but which soon become indispensable: secondhand medical and dental instruments, for example, solve many problems when dealing with awkward locations.

But there are at least some tools which would generally be regarded as indispensable for repair and minor constructional work. These include:

An electric soldering-iron. Also low-power (under 35 watts) iron for work on printed-circuit panels.

An assortment of screw-drivers with various lengths of shaft and widths of blade. Philips-head screw-drivers.

A pair of flat-nosed, combination pliers.

A pair of round-nosed pliers.

A pair of side cutters.

A supply of non-metallic trimming tools.

A 3-in. vice fitted with copper or other soft metal jaws.

Set of taps and dies (2, 4, 6 B.A.) with wrench and stock.

Hand drill, and twist drills, 0 B.A. clearing to 8 B.A. tapping.

Set of spanners, 2, 4, 6 B.A.

Set of box spanners, 2, 4, 6 B.A. Set of Allen keys.

Smooth file.

Hacksaw.

Tank cutter up to 3 in.

Centre punch, scriber and metal rule.

A supply of insulated prods and hooks (*e.g.*, knitting-needles, crotchet-hooks, etc.)

A supply of hooks and prongs (*e.g.*, made from brass wire) for re-stringing cord drives.

HACKSAW BLADES AND LUBRICANTS

Material	*Blade*	*Lubricant*
Brass	Normal	None
Aluminium	Normal	None
Duralumin	Normal	None
Cast iron	Normal	None
Mild steel	Fine	Thin oil
Bakelite *	Normal	Trace of vaseline on blade
Polystyrene *	Normal	Paraffin

* Saw very slowly. Use a fine blade for tubing.

In addition, a supply of solder and non-active flux (or cored solder), furniture polish and spirit stain for removing scratches, a duster and small dusting brush, switch cleaning fluid and thin lubricating oil are indispensible. For the larger repair shops, such items as a bench grinding wheel (for keeping twist drills and screw-drivers in good condition) and a small electric drill will soon repay the initial cost.

Soldering

For general repair and constructional work, the following points should be observed :

1. Only non-corrosive fluxes should be used. Cored solders with rosin-based fluxes are generally convenient. For miniaturised components and assemblies, where the lengthy application of heat may have harmful effects, a liquid flux of resin base permits joints to be made rapidly. Acid-based fluxes, such as killed spirits, should not be used.

2. All wires, tags and solder should be clean and free from oxidation. Since the cleansing action of non-corrosive fluxes is less effective than with active fluxes, such as used in non-radio applications, care is needed in pre-cleaning of wires and tags, and it may be advisable to tin these parts before final assembly.

3. The iron should be clean, adequately tinned and should be about 50° Centrigade above the liquifying point of the solder. With cored solders, " spitting " indicates too high a temperature of the bit, while " plasticising " indicates too low a temperature.

4. With cored solders, the iron should never be used to carry the solder to the joint : wherever possible apply the iron beneath the joint and then apply the solder from above.

5. Fine-gauge enamelled wires should not be scraped with a knife or with emery cloth, as this may damage the wire. A suggested method of cleaning them is to heat such wires in the flame of a spirit lamp, plunge them into methylated spirits and finally wipe them dry.

6. Dry joints, which may introduce considerable resistance into a circuit and which represent a point of mechanical weakness, are caused by layers of undiffused resin between the solder and the

COPPER WIRE TABLE

S.W.G.	*Dia. (in.)*	*Yards per Pound (Bare)*	*Ohms per Yard*	*Max. Safe Current* *	*Turns per Inch*				*Nearest American B. & S.*		*S.W.G.*
					D.S.C.	*D.C.C.*	*Enam.*	*Enam. & S.S.C.*	*Gauge*	*Dia.*	
10	0·128	6·67	0·00186	35 A	7·55	7·04	—	—	8	0·1285	10
12	0·104	10·15	0·00283	28 A	9·22	8·47	9·26	—	10	0·102	12
14	0·080	17·21	0·00478	19 A	11·8	10·6	11·9	—	12	0·081	14
16	0·064	26·90	0·00746	13 A	14·7	13·15	14·8	14·2	14	0·064	16
18	0·048	47·80	0·01327	7 A	19·6	16·9	19·7	19·0	17	0·045	18
20	0·036	73·40	0·02359	4 A	25·6	21·3	26·0	24·7	19	0·036	20
22	0·028	140·5	0·03899	2·5 A	32·2	25·6	33·3	31·2	21	0·028	22
24	0·022	227·2	0·06316	1·5 A	40·0	31·2	42·3	39·5	23	0·023	24
26	0·018	340·0	0·09435	1·0 A	48·8	35·7	51·5	48·1	25	0·018	26
28	0·0148	502·8	0·1395	700 mA	57·8	40·3	62·5	57·8	27	0·0142	28
30	0·0124	716·5	0·1988	500 mA	67·1	44·6	74·6	67·0	28	0·0126	30
32	0·0108	945·0	0·2621	400 mA	75·2	48·1	85·5	76·3	29	0·0113	32
34	0·0092	1300	0·3612	250 mA	85·5	52·0	100	87·7	31	0·0089	34
36	0·0076	1905	0·5292	150 mA	99·0	60·2	120	102	32	0·0079	36
38	0·0060	3058	0·8491	100 mA	117	66·6	151	125	34	0·0063	38
40	0·0048	4780	1·327	70 mA	137	72·5	188	151	36	0·0050	40

* Maximum safe currents listed in this table apply to single circular copper conductors only. For power-transformer windings, etc., maximum safe currents are between, approximately, $\frac{1}{4}$ (heavy duty, continuous rating) and $\frac{1}{2}$ (normal service) of the values given.

TWIST DRILLS

Drill No.	*Size (in.)*	*Drill No.*	*Size (in.)*	*Drill No.*	*Size (in.)*
1	0·2280	30	0·1285	59	0·0410
2	0·2210	31	0·1200	60	0·0400
3	0·2130	32	0·1160		
4	0·2090	33	0·1130	A	0·234
5	0·2055	34	0·1110	B	0·238
6	0·2040	35	0·1100	C	0·242
7	0·2010	36	0·1065	D	0·246
8	0·1990	37	0·1040	E	0·250
9	0·1960	38	0·1015	F	0·257
10	0·1935	39	0·0995	G	0·261
11	0·1910	40	0·0980	H	0·266
12	0·1890	41	0·0960	I	0·272
13	0·1850	42	0·0935	J	0·277
14	0·1820	43	0·0890	K	0·281
15	0·1800	44	0·0860	L	0·290
16	0·1770	45	0·0820	M	0·295
17	0·1730	46	0·0810	N	0·302
18	0·1695	47	0·0785	O	0·316
19	0·1660	48	0·0760	P	0·323
20	0·1610	49	0·0730	Q	0·332
21	0·1590	50	0·0700	R	0·339
22	0·1570	51	0·0670	S	0·348
23	0·1540	52	0·0635	T	0·358
24	0·1520	53	0·0595	U	0·368
25	0·1495	54	0·0550	V	0·377
26	0·1470	55	0·0520	W	0·386
27	0·1440	56	0·0465	X	0·397
28	0·1405	57	0·0430	Y	0·404
29	0·1360	58	0·0420	Z	0·413

wire ; this may be because of too brief an application of the soldering-iron, or by the bit being at too low a temperature.

7. With miniaturised or heat-sensitive components, such as germanium diodes or transistors, permanent damage may result from too long an application of the soldering-iron. In such circumstances an effective thermal shunt can be made by gripping the lead between the joint and main body of the component with a pair of pliers ; much of the heat is then absorbed into the pliers rather than by the body of the component.

8. For the outside soldering of aerial wires, etc., either a really large iron or a small blow-lamp should be used. An alternative method for use in an emergency is to twist the wires together, twist a little cored solder around the joint, surround this completely with some silver paper or tin foil, and then to apply the flame of a cigarette lighter to the foil : on removal of the foil a soldered joint will be found.

9. Soldering of connections to aluminium and its alloys is seldom effective with normal methods. In recent years, however, equipment has been marketed specifically for this purpose using an iron whose bit is subjected to a supersonic frequency produced by a magneto-striction oscillator. This supersonic frequency prevents oxidation by disturbing the fluxing metal. A tin/zinc-based solder is used.

[SECTION 7]

SERVICING EQUIPMENT

THE establishment of an efficient servicing workshop requires that careful thought be given to the choice of test gear. A full range of reliable servicing equipment, wisely used, will reduce to a minimum the time taken to trace and rectify faults. On the other hand, when initially equipping a workshop it is usually better, in the long run, to invest in the few essential items of test gear from a reputable maker, and to add to these later when finances permit, rather than to purchase a complete range of cheaper, but less soundly constructed equipment. It is not suggested that the most expensive equipment is necessarily the best—particularly for general servicing work—but purchasers are advised, if possible, to compare carefully the mechanical soundness and finish of the construction of, and the exact facilities provided by, a number of instruments in the same general class before choosing a particular item. The possibility of difficulties in obtaining replacement parts, at a later date, should also be considered when buying second-hand or foreign equipment.

For the routine repair of broadcast radio receivers the following list shows the test equipment most frequently required :

Absolutely Essential

1. Universal testmeter, preferably with a sensitivity of at least 1,000-ohms per volt on D.C. ranges (20,000-ohms per volt sensitivity preferred for servicing transistor receivers).
2. General coverage signal generator.

Highly Desirable

3. Resistance–capacitance bridge.
4. Insulation tester.

Well Worth While

5. Valve Tester
6. Cathode-ray oscilloscope with frequency-modulated " Wobbulator ".

In addition, although some duplication of facilities is involved, such items as circuit analyser (signal tracer), a power-output meter, an A.F. generator, a valve (electronic) voltmeter and a crystal calibrator will be found most useful, particularly for larger repair shops, or those dealing with the more specialised types of equipment. All the equipment listed above will be found desirable for television servicing, though, for this type of work,

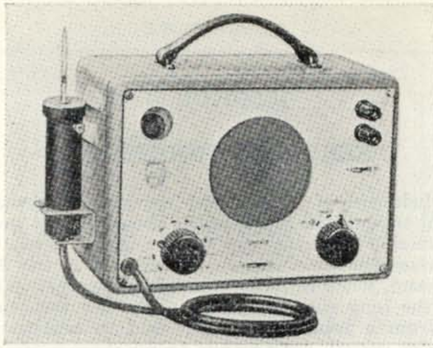


FIG. 1.—PHILIPS SIGNAL TRACER, TYPE GM7628.

This versatile and compact signal tracer, for the rapid location of faults in receivers and A.F. and R.F. amplifiers, comprises, basically, a two-stage amplifier with a built-in loudspeaker and power supply. The sensitivity and amplification of each stage can be checked, and A.G.C. and oscillator voltages are shown by means of a tuning-eye indicator. An R.F./A.F. diode probe enables signals up to 100 Mc/s to be followed through a receiver, the tuning indicator giving a perceptible deflection for inputs of about 15 mV on R.F. signals and 1 mV on A.F. signals, the probe comprising loads of 12 MΩ on A.G.C. lines, more than 1 MΩ on A.F. signals, and about 2 MΩ at 1·5 Mc/s. The unit has an eight-position input attenuator and a selector switch enables the amplifier to be used with external measuring indicators.

additional items, such as a good pattern generator and an E.H.T. testmeter, may take priority, whilst the sensitivity of the testmeter may usefully be increased to 20,000 ohms per volt. The selection of test equipment for television servicing is discussed in *Television Engineers' Pocket Book*.

Combination or "portmanteau" test equipments, with a number of separate facilities provided within the same unit, have been developed by some manufacturers, and where these are available the total number of instruments required may not be so great as the above list suggests.

In the following pages the major factors that should govern the choice and maintenance of servicing equipment are reviewed briefly, particular attention being given to the more common types of equipment.

Universal Testmeters

A general-purpose multi-testmeter capable of measuring direct and alternating currents amd voltages, and resistances, is a first essential in any repair department. By means of an internal multi-position switch (occasionally by sets of alternative-input terminals) various shunts and multipliers are brought into the circuit of a sensitive moving-coil meter. The full-scale deflection (f.s.d.) figure for the meter movement varies, in the

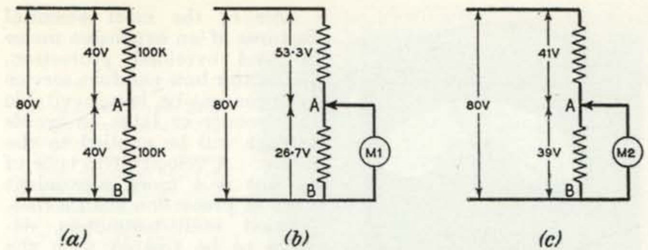


FIG. 2.—EFFECT OF THE METER RESISTANCE WHEN MEASURING VOLTAGES IN HIGH-RESISTANCE CIRCUITS.

(*a*) Shows the actual voltage conditions existing in a simple potential divider circuit, 40 volts being present between points A and B with no voltmeter connected.
(*b*) Shows that a 1,000-ohms/volt meter (M1) on a 100-volt range (total resistance 100k) would give a reading of 26·7 volts when connected between A and B.
(*c*) A 20,000-ohms/volt meter (M2) on a 100-volt range (total resistance 2MΩ) would give a reading of 39 volts between A and B.

better-class instruments, from about 50 μA to about 4 mA. On A.C. ranges, iron-cored transformers, copper oxide rectifiers and rectifier shunts are brought into circuit. The A.C. ranges are calibrated in terms of R.M.S. values, and the accuracy tends to fall when used on non-sinusoidal inputs. With any moving-coil meter, the accuracy of readings will be greater in the top- than in the bottom-half of the scale.

The limitations of a multi-testmeter for voltage measurements must always be borne in mind. For instance, it is essential, in high-resistance circuits, to take into account the power consumed by the meter and to appreciate that when a meter is connected the voltages developed in the circuit may change appreciably. This point is indicated in Fig. 2, which shows that in high-resistance circuits, a low-sensitivity meter (*i.e.*, one requiring appreciable current) will give a much less accurate reading than a high-sensitivity meter. In this connection, it is the total resistance of the meter and its shunts that is the important factor, and it may be preferable to use a testmeter on a higher voltage range than would otherwise be employed. For example, the total resistance of a meter with a 1 mA f.s.d. movement will be 100,000 ohms on its 0–100-volt range, but 1 MΩ on its 0–1,000-volt range. Thus, for instance, when measuring the voltage on the anode of, say, a first audio-amplifier stage (which usually has a high-resistance anode load) a more accurate reading will usually be obtained on the 1,000-volt range than on the 100-volt range, even though this appears to contradict the earlier statement that the accuracy of the meter itself is greater on the higher-scale readings. When measuring voltages in high-impedance circuits, it may prove more satisfactory to take current measurements, and to compute voltages from Ohm's Law.

FIG. 3.—AVOMETER MODEL 7.

One of the most essential features of an expensive meter is good overload protection. No matter how careful a service engineer may be, it is inevitable that sooner or later an excess voltage will be applied to the meter. A velocity-trip type of cut-out is a more convenient form of protection than a fuse.

Good multi-testmeters deserve to be treated with the respect due to a piece of delicate mechanism. Sudden mechanical shock or frequent overloads is likely to damage the jewelled bearings, and lead eventually to pivot stick and loss of accuracy.

It is important always to remove the internal batteries when these are expended, even if the instrument is not used as an ohmmeter. Testmeters should not be used without batteries, since, on some instruments, the battery supplies a compensating current on A.C. ranges in order to overcome the non-linearity of rectifiers. Should the test meter be stored for any length of time, the internal battery should be removed; otherwise it may deteriorate and cause corrosion.

With sensitive meters it may be advisable to short-circuit the meter when it is being transported, since this will introduce damping and stop the pointer from swinging violently. It is good practice to cultivate the habit of always leaving the testmeter switched to the highest voltage range, in order to reduce the chances of accidental overload when next connecting it into circuit.

Like all electronic apparatus, meters are susceptible to dampness, dust, fumes and extremes of temperature, and should therefore be kept in places free from bad conditions. Care should also be taken to keep all test leads in good order, and to avoid frayed or defective wires or insulation which could accidentally connect the meter across high potentials, or form a potential source of shock to the service engineer. It is as well to remember that even quite small shocks may cause the engineer to jerk the testmeter and cause damage to the meter pivots, or even to drop the meter.

Signal Generators

Since the advent of the superheterodyne receiver, an essential item to the service engineer is a tunable oscillator, which can be

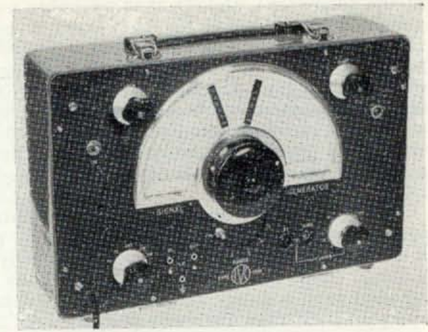


FIG. 4.—AVO TYPE TFM WIDE-BAND SIGNAL GENERATOR.
The instrument covers an F.M. frequency range of 80–100 Mc/s, and an A.M. frequency range of 5–225 Mc/s. Maximum deviation on F.M. is ±150 kc/s.

modulated with an A.F. note, and which is provided with means of adjusting the level of the R.F. output. Such an instrument is indispensable for testing, re-alignment and general performance tests.

In the past, such R.F. generators fell fairly clearly into two main classes: the test or service oscillator, intended primarily for general fault-finding and rough bench work; and high-grade standard signal generators, with a much higher standard of calibration accuracy, and with facilities enabling the output to be checked by a meter. However, the distinction between these classes has tended to disappear, and to-day most radio servicing engineers rely, at least for bench and field work, on one general-purpose signal generator. The increasing use of frequencies above about 80 Mc/s, however, may tend in the future to encourage the use of two separate generators, one for the lower and the other for the higher frequencies.

What are the most desirable features to look for when choosing a signal generator?

Tuning Range. The instrument should provide a fundamental output on all frequencies likely to be encountered. The introduction of Band II and Band III stations has made this requirement a difficult one to meet with a single instrument, though some instruments covering a very wide range are available. The lower limit, for normal practice, is about 100 kc/s, since frequencies of this order are still required for the alignment of the I.F. stages of some older receivers. The use of harmonics to provide a wider range, though useful for some purposes, is not recommended.

Stability. The instrument should be relatively immune from frequency drift once it has reached its normal operating temperature, and should provide a "clean" R.F. signal—free from all "warble" and hum, even at the highest frequencies. Extremely sound construction is required to prevent mechanical vibration of the instrument from unduly affecting the stability of the oscillator: though it is probably asking too much from a general-purpose oscillator to expect a high order of stability under vibration. Also important is the long-term stability, that is to say, the ability of the generator to retain accurate calibration over a long period. Even with a high-standard of long-term stability, however, it is important to remember that most test oscillators require periodical checking of the calibration on each waveband against known signals (high-stability broadcast stations, standard-frequency transmissions or a local crystal oscillator).

Accuracy. The accuracy of the calibration of a general-purpose oscillator is unlikely to be better than about 1 per cent, and this figure is likely to be obtained only if the instrument has a long, easily-read, tuning dial and has its full tuning range divided into a fairly large number of bands. It is important to appreciate that, for some purposes, an accuracy of even 1 per cent is rather low. This is so, for example, on short-wave broadcast ranges: on the 19-metre band, for instance, an accuracy of $\pm$ 1 per cent represents a frequency range of $\pm$ 150 kc/s, and this precludes accurate station calibration of broadcast receivers fitted with bandspread ranges without the use of a crystal oscillator or check stations.

Tuning Mechanism. A clear tuning dial and mechanism is necessary to permit accurate setting—and re-setting—of the generator, and should be free from slip or backlash.

Screening. Unless really adequate screening (preferably double-screening of the R.F. circuits), specially designed to prevent the leakage of electrostatic and electromagnetic R.F. fields, is fitted, then the minimum output from the instrument may be too high for optimum adjustment of the more sensitive receivers, and such leakage will seriously affect the efficiency of the attenuator. Normally the minimum signal increases with increasing frequency, and typical figures for popular models are of the order of 1 μV, increasing to about 3 μV on the highest frequencies.

Output. Maximum output from the attenuator is usually of the order of 50–100 mV, while a "force" (non-attenuated) output of the order 0·25–1 volt is often provided. The "force" socket must be so designed as to ensure that no appreciable R.F. leakage occurs from this point.

Modulation. Optional modulation of the R.F. output by an A.F. note is an essential feature for general servicing work. A built-in A.F. oscillator generally modulates the R.F. carrier to a depth of about 30 per cent with a 400-c/s note. Two useful features to look for here are the provision of a socket enabling the A.F. output to be obtained directly, for checking audio stages, and facilities for modulation of the R.F. output from an external source such as a wide-range A.F. generator.

Dummy Aerial. The output from a signal generator may conveniently be taken through a co-axial lead to a terminating unit, which will usually contain a built-in dummy aerial with

FIG. 5—AVO SIGNAL GENERATOR.

This A.M./C.W. signal generator covers 150 kc/s to 220 Mc/s in six ranges.

FIG. 6.—HIGH-SENSITIVITY POCKET MULTI-RANGE TEST-METER.

Servicing transistor receivers is simplified by the use of high-sensitivity testmeters. This $5\frac{3}{4} \times 3\frac{3}{4} \times 2\frac{1}{8}$-in. S.E.I. "Mini test" instrument has a sensitivity of 20,000 ohms/volt on D.C. ranges and 2,000 ohms/volt on A.C. ranges.

FIG. 7—COSSOR F.M. RECEIVER ALIGNMENT GENERATOR

provision for taking the output either direct or through the dummy aerial. The use of a dummy aerial is described in Section 9.

Power Supply. Both mains- and battery-operated generators are available. With mains equipments good ripple filtering is necessary if the note is to be free of hum. The mains output lead should be screened from the R.F. components in order to prevent R.F. leakage.

Resistance-Capacitance Bridges

Some means of checking the values—to within about 5 per cent—of resistors and capacitors, and determining the power factor and leakage of the larger-value capacitors will assist in tracing the many faults that arise from these components changing their value, due to deterioration. There are a number of good instruments available, based on variations of the Wheatstone Bridge method, in which the component to be measured is inserted in one arm of a bridge network and compared with standard values in another arm. An A.C. supply is necessary to measure capacitors and inductors. The bridge is balanced when no current flows in the connecting link between the two sides of the network, and this is usually indicated either by means of a sensitive meter or by a " magic eye " tuning indicator.

For laboratory work, where a high degree of accuracy is required, external standards are often employed, but for general servicing work extreme accuracy is seldom required.

When testing capacitors of less than about 1,000 pF it is important to use short leads between the component and the

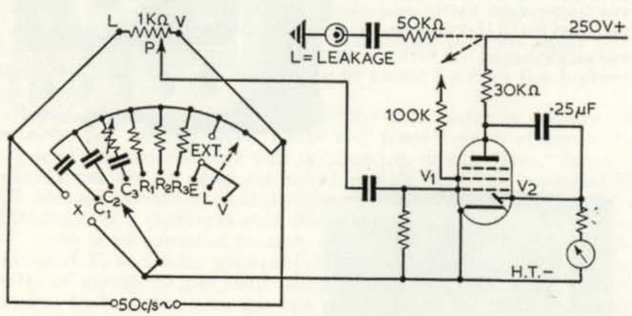
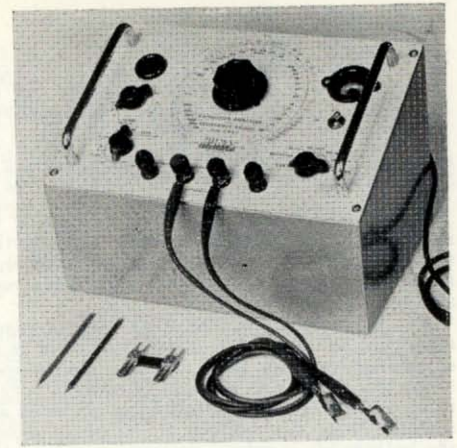


FIG. 8.—SIMPLIFIED CIRCUIT, USING A WHEATSTONE BRIDGE ARRANGEMENT, OF A TEST BRIDGE.

This instrument is capable, within certain limits, of measuring unknown resistances, capacitances, capacitor power factors, capacitor leakage-resistances (switch position L), A.C. voltages (switch position V), and, by comparison with a known component, resistors, capacitors or inductors (switch position E).

FIG. 9.—HUNT TYPE CRB3 CAPACITOR ANALYSER AND RESISTANCE BRIDGE.

The ranges covered are 20 pF to 500 µF and 50 ohms to 100 MΩ. Capacitances, resistances, capacitor leakage-resistances and insulation can all be measured directly.



bridge, otherwise inaccurate measurements may be obtained owing to the stray capacitance of the leads.

In general terms, capacitors used for filter and by-pass applications should not be less than about 66 per cent of their rated values, and between about 90 and 110 per cent where tuned filter circuits are involved; for untuned filter and by-pass applications a considerable degree of excess capacitance is usually unimportant. Tuned R.F. circuits will usually require capacitors with close tolerances (better than ± 5 per cent), and where fixed padders are used with no means of varying the inductance of the circuit a tolerance of ± 1 per cent may be required for optimum results.

The power factor of electrolytic smoothing and bias capacitors should not exceed about 40-50 per cent; where such a capacitor serves also to by-pass R.F. signals, this figure must be reduced to about 10 per cent unless additional mica or paper capacitors are wired in parallel with the electrolytic capacitor to prevent regenerative coupling between the stages.

Insulation Testers

Many component bridges include facilities for testing leakage of capacitors, indication being by means of a neon bulb which flashes with a frequency governed by the leakage. Nevertheless, a separate insulation tester, with meter readings of resistances up to about 200 MΩ and subjecting the insulation under test to a potential of about 500 volts, is extremely useful in checking not only leaky capacitors, but also testing for leakage between transformer windings, and for ensuring that the safety measures

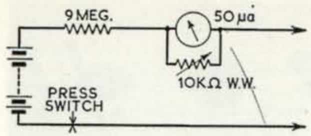


FIG. 10.—A SIMPLE INSULATION TESTER WHICH CAN EASILY BE BUILT. THE METER CALIBRATION IS SHOWN BELOW.

Current (μA) .	50	45	40·9	32·1	28·1	23·6	18·8	15·5	7·6	4·1	2·1	0
Resistance (MΩ)	0	1	2	5	7	10	15	20	50	100	200	∞

necessary with a " live " chassis are effective : an insulation test between chassis and any metal-work that can possibly be touched by the user should be made when repairs to live-chassis sets have been completed.

For portable work, the Wee Megger insulation tester with a built-in 500-volt hand-driven generator is a most useful type of instrument, but there are also mains-operated instruments available. It is also possible to make a very simple instrument using eight 67½-volt deaf-aid-type batteries and a 50 μA (f.s.d.) meter. Since the battery drain never exceeds about 50 μA, the battery life is extremely long.

Valve Testers

Valves—despite steady improvements in design and construction—remain the most frequent cause of receiver breakdown. Were it not for the ease with which valves may be tested by substitution methods (provided care is taken to ensure that new valves are not damaged by circuit faults), a valve tester would rate higher in the priority list. Nevertheless, they are most useful in the busy repair shop, or where large stocks of valve replacements are not immediately available. Though it is no reflection on commercial valve testers to admit that there are some valve faults that may not be revealed by them.

FIG. 11.—TAYLOR MODEL 45C VALVE TESTER.

The scope and range of the tests which can be carried out on valve testers vary considerably with the type—and cost—of the various instruments, but the following notes cover a number of the methods in common use.

Simple emission tests are normally restricted to rectifier and diode

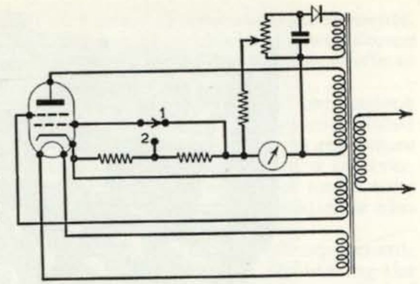


FIG. 12.—ARRANGEMENT FOR MEASURING MUTUAL CONDUCTANCE.

With the switch at 1, the meter current is neutralised by means of a variable D.C. potential provided by the metal rectifier. A direct reading of the increase in anode current when the grid bias voltage is reduced is made by switching to 2.

valves, a mutual conductance test being more satisfactory for valves containing one or more grid electrodes. The mutual conductance of a valve is the change in anode current which occurs for a unit change in grid voltage, this factor being related to the anode impedance and amplification factor of the valve. For any given valve, the mutual conductance will vary according to the condition of the valve and will show a gradual decrease throughout its useful life. For practical purposes, the life of a valve is regarded as complete when the mutual conductance drops to a figure varying, according to the class of valve, between 60 and 75 per cent of its rated value.

To reduce the bulk and cost of valve testers, unrectified alternating voltages are usually applied to the valve electrodes. To measure the mutual conductance, the valve is operated under suitable conditions and the anode current noted. The grid bias is then changed by 1 volt and the current again noted ; the difference between the readings being the mutual conductance of the valve at the particular electrode potentials employed. In practice, the taking of measurements is simplified by neutralising the original valve current. This is done by passing a reverse current of equal magnitude through the meter ; with this system—often termed " bucking the meter "—only the increase of current with the reduction of grid voltage is shown, and no mathematical calculations are necessary : a typical arrangement is shown in Fig. 12.

Full-wave rectifying valves are subjected to an emission test, in which voltages are applied in turn to each anode and the emission of each section compared.

Cathode leakage, under operating conditions, may be checked by breaking the cathode circuit while H.T. potentials are still applied between the heater and anode. Leakage current can then be directly observed on a meter in the H.T. circuit. Inter-electrode short-circuits, heater-continuity tests and the like are generally made with a small neon bulb placed in series with an H.T. winding of the analyser transformer ; a switch arrangement enabling this circuit to be connected in turn across the various

Fig. 13.—Avo Valve Characteristic Meter Mark III.

electrodes. This test, however, may not always be conclusive, since in many cases it is made with the heater cold.

The presence of gas or grid emission is usually detected by connecting the grid through a resistor to a bias network. The grid resistor is then brought in and out of the circuit by means of a press contact switch. If any appreciable grid current—either positive or negative—is flowing, the anode current will vary, since the grid resistor will add to or subtract from the standing bias voltage.

In some valve testers, the correct potentials for the various tests are selected automatically by means of punched cards or similar devices to enable testing to be carried out by non-technical personnel, in other cases the potentials are selected manually by means of switches.

Oscilloscopes

A well-designed cathode-ray oscilloscope, incorporating an efficient vertical amplifier and a linear, wide-range time-base, has many important uses in a radio repair shop, provided always that the service engineer has made himself thoroughly conversant with its application and with the interpretation of results. Unfortunately unless the instrument is used with care and understanding, its usefulness may be much diminished by spurious pick-up, and mains hum. Misleading results may be brought about by the attachment of the oscilloscope disturbing the condition of the circuit under test.

The oscilloscope is basically a voltmeter which indicates not only voltage but also waveform. Instead of laboriously

having to plot graphs based on a series of separate measurements, the service engineer is able to see at a glance the waveforms present in a receiver and observe immediately the precise effects of adjustments.

For radio and television servicing, the value of an oscilloscope is greatly enhanced when used with a frequency-modulated oscillator (" wobbulator ") which makes it possible to reproduce the response curves of the I.F. and R.F. sections of a receiver. Its usefulness is further increased where a source of audio tone (preferably variable) with good sine-wave characteristics is also available.

The main uses of the oscilloscope, and associated equipment, in radio servicing are: (1) visual I.F. alignment, facilitating the setting up of any desired band-width and the correction of asymmetrical response curves; (2) as a means of detecting the presence of, and tracing the source of A.F. distortion, parasitic oscillations and hum; (3) as an output meter and for the measurement of A.C., A.F. and R.F. peak and peak-to-peak voltages; (4) for checking the fidelity of audio amplifiers. Other, possibly less common, uses include frequency measurement, checking of harmonic content and hum content, and adjusting vibrators for automobile receivers. A 'scope can also, of course, be used for the measurement of D.C. voltage without drawing appreciable power from the circuit under test.

To the service engineer not experienced in the use of an oscilloscope, the array of control knobs may appear formidable at first sight, but their use can rapidly be mastered. " Brilliance " and " focus " have the same significance as in television practice, though it should be noted that electrostatic focusing and deflection are normally used. " X-shift " and " Y-shift " are for positioning the trace on the screen of the cathode-ray tube by altering the bias voltages applied to the deflecting plates, " X " referring to the horizontal axis, and " Y " to the vertical axis. The " coarse " and " fine " controls govern the setting of the time-base frequency, and the " amplitude " control alters the output, and hence the length of the horizontal sweep. The " sync " control is to enable the time-base to be synchronised with the wave-form under examination, so that the trace remains in a stationary position on the screen. In addition, there will generally be either a master switch or alternative input sockets, so that the signal may be connected to the " X " and " Y " plates, directly for D.C., and via isolating capacitors for A.C. (to remove any D.C. component); additional positions will normally provide for attenuation or amplification of the signal by fixed amounts.

For radio servicing the time-base should cover the range of approximately 10–100,000 c/s or more, the vertical amplifier should provide gains in known steps of up to about 500 times. The frequency response of the vertical amplifier is of considerable importance, particularly if it desired to use the oscilloscope for television work, where a good response characteristic up to about

3 Mc/s is desirable. The amplifier should also be as free as possible from phase-shift and amplitude distortion, and have a low input capacitance and high input impedance, so that the oscilloscope may be connected across high-impedance grid circuits without unduly affecting their operation. Screened, low-capacitance cable, kept as short as possible, should be used between the connection of the receiver and the oscilloscope. It is common practice to connect either a small capacitor (about 5 pF or less) or a large resistor (1 MΩ or more) in the tip of the test prod or crocodile connector, so as to reduce to a minimum the disturbance caused to the circuits under test. As with almost all test equipment, poorly designed or constructed oscilloscopes may prove more of a hindrance than a help, and when choosing a commercial model it is as well to pay more attention to the quality and facilities incorporated than to the price of the instrument.

For visual alignment of the I.F. stages, a frequency-modulated oscillator is required: when used in conjunction with a signal generator this should produce a signal varying regularly about 15–25 kc/s above and below the I.F., with the repetition rate—usually about 25 c/s—synchronised with the cathode-ray oscillator time-base. This frequency-modulated signal is injected into the grid of the frequency-changer valve, as in standard alignment practice, and either an I.F. signal taken—via a small capacitance—from a convenient point immediately prior to the demodulator valve, or more commonly, an A.F. signal tapped-off via a large coupling capacitor from the I.F. filter capacitor or across the volume control and fed to the Y-amplifier. The local oscillator of the receiver should be rendered inoperative during alignment. Where the frequency sweep of the " wobbulator " is known, the exact band-width of the I.F. stages may be directly observed and any necessary adjustments made to the I.F. transformer trimmers to obtain the desired band-pass characteristics.

[SECTION 8]

FAULT-FINDING AND REPLACEMENTS

THE normal procedure for fault-finding in broadcast receivers—as with most types of electrical apparatus—is to eliminate successively the sections of the circuit which are not affected by the fault until the source of the trouble is pin-pointed. This may require many separate tests and measurements of valve voltages, currents and resistances, but, with practice, many of the routine checks can be omitted by intelligent appreciation of the symptoms of the fault and by drawing upon past experiences of similar models. This need to reduce to a minimum the time taken to locate the exact source of a fault is of paramount importance if servicing is to be profitable, and it is with this aim that many of the special servicing instruments have been developed.

Some faults cause a complete failure of the receiver, whereas others impair its performance to only a limited extent. This second type of fault is generally considerably more difficult to trace—and this is particularly true where the fault occurs only intermittently.

In order to cut down servicing time, it is necessary to have a clear understanding of the types of faults that occur most frequently, and the effect they have on receiver performance.

Basic Faults

Purely mechanical faults, which are often self-evident, most frequently occur in the tuning circuits; cord-drives, for instance, sometimes break, and other manual controls and switches are subject to considerable mechanical wear. Loosening of the cement used to fasten the valve envelopes to their bases or the top caps is a common occurrence in old receivers. Extensive physical damage to a chassis or cabinet, caused, for example, by the accidental dropping of a receiver may also be met with.

More numerous are the faults where mechanical failures adversely affect the electrical circuits. These are frequently not self-evident, and can often be traced only with the aid of correct servicing procedure. Short-circuiting of variable capacitors, either over their entire span or in one or more positions; open-circuits in battery, power, aerial, earth and loudspeaker leads and, due to defective soldering, in the wiring; short-circuits caused by accidental bending of wires, the presence of metallic dust or other foreign bodies; physical damage to the cones or speech coils of loudspeakers; noisy potentiometers caused by wear or dirt; and deterioration or damage to valve sockets and valve pins.

Valves.—Valve troubles account for the majority of faults in radio receivers. The main causes are: heater failures; gradual loss of emission; ionisation (due to the gradual liberation of gas within the valve envelope, producing " soft " valves); breakdown of inter-electrode insulation, particularly heater/cathode leakage; fracture or disconnection of the leads between the electrodes and valve pins; microphony (sensitivity to mechanical vibration).

Unwanted negative grid current in a valve can be caused either by the presence of gas, internal leakage paths or grid emission, and may cause distortion, lack of sensitivity and output, broad tuning, etc. The effects of grid current may not become apparent until a few minutes after the receiver has been switched on: a gradual loss of sensitivity indicating that grid emission may be taking place in an R.F. or I.F. valve, while a gradual increase in distortion suggests its presence in an A.F. stage.

Accidental bending of the pins has become fairly common with miniature " all-glass " construction, and great care is needed when straightening such pins unless the special jigs now available are used.

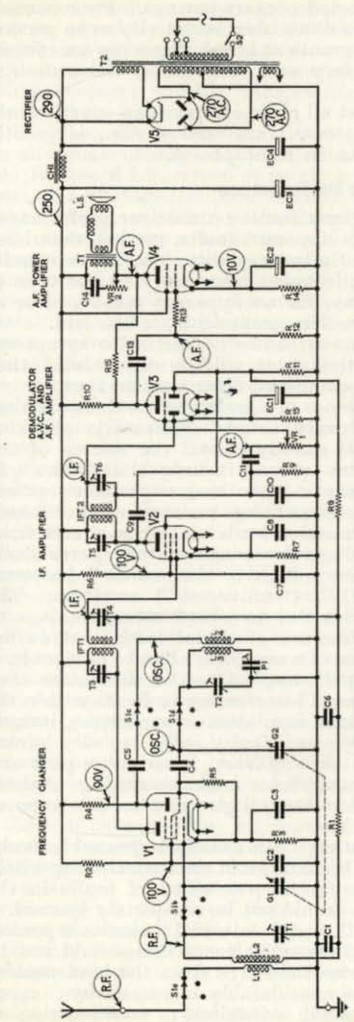
The life of a valve is governed to a considerable extent by the conditions under which it is operated, and—for example—excessive heater screen and anode currents or lack of ventilation may cause premature failure.

Resistors.—These may go " open-circuit " or develop very high resistance due mainly to excessive power dissipation or deterioration, this is particularly true of high-value, low-wattage resistors which carry a steady direct current; the development of low resistance is less common, but may be occasionally encountered due to failure of insulating materials; " noisy " resistors—the noise often disappears when the resistor is prodded—are due to intermittent failure, and such resistors may prove difficult to locate.

Capacitors.—Complete or partial or intermittent failure of the insulation, may produce short-circuits or D.C. leakage currents. It is quite common for the insulation resistance of wax-coated cardboard-cased paper capacitors to fall as low as 5 MΩ, and for certain applications (particularly inter-valve coupling) such a leakage path will affect the performance of the receiver. Other faults include fracture of internal leads, loss of insulating wax due to overheating, deterioration of electrolytic capacitors, leading to capacitances well below the rated values and to high power factors.

Coils and Transformers.—Short-circuiting of adjacent turns or sections; windings disconnected or broken due to excessive dissipation, faults in the wires, or the failure of soldered contacts; loose turns causing the inductance to vary; damage to or fracture of dust-iron or ferrite cores is of increasing importance, particularly in I.F. transformers; excessive damping across coil windings due to metallic dust or failure of insulating materials.

RADIO TROUBLE TRACING CHART



SIMPLIFIED CIRCUIT OF A.C. BROADCAST RECEIVER SHOWING TYPICAL CHECK VOLTAGES

NO RECEPTION
MAY BE DUE TO :-
FAILURE OF VALVE HEATER.
LOSS OF EMISSION V1, V5.
EC3 OR EC4 S/C.
FAILURE OF T1, CH1, OR T2.
FAILURE OF POWER LEADS, POWER PLUG OR S2.
DIRTY OR DISTORTED VALVE SOCKETS AND PINS.
C13 OR IFT1 LEAKING.
DIRTY OR DISTORTED S1A-D CONTACTS.
O/C — OPEN CIRCUITED. S/C — SHORT CIRCUITED.

FAULTY RECEPTION	
SYMPTOMS	POSSIBLE FAULTS
DISTORTION ON STRONG SIGNALS. (OVERLOADING OF VALVES)	C1 OR C6 LEAKING. AERIAL TOO LONG. INCORRECT REPLACEMENTS V1, V2.
DISTORTION ON LOUD PASSAGES.	DISTORTED OR DIRTY L.S. COIL OR CONE. LOSS OF EMISSION V4. VALVE IONIZATION. R14 OR EC2 FAULTY. DEFECTIVE INSULATION T1, C14. VALVE OR G2 MICROPHONY.
LOW SENSITIVITY WITH HIGH NOISE LEVEL.	BREAK IN AERIAL LEAD. L1 O/C. DIRTY OR DISTORTED S1A-D CONTACTS. LOSS OF EMISSION V1, V2. C9 LEAKING. MISALIGNMENT.
DISTORTION WITH LOW OR ZERO CATHODE VOLTAGE V3, V4.	EC1 EC2 S/C. LOSS OF EMISSION V3, V4.
DISTORTION WITH UNDULY LOW H.T. VOLTAGES.	R14 OR EC2 S/C. C13 LEAKING. EC3, EC4 LEAKING. WRONG MAINS VOLTAGE ADJUSTMENT. V4 "SOFT"
DISTORTION WITH UNDULY HIGH H.T. VOLTAGES.	LOSS OF EMISSION V4.
WHISTLES ON ALL SIGNALS (I.F. INSTABILITY).	V1, V2 SHIELDS OR I.F.T. CANS NOT EARTHED. LEADS TO I.F.T.'S OR V2 INCORRECTLY POSITIONED. C7 O/C.
HOWLING	A.F. INSTABILITY— LEADS TO L.S., VR1, VR2, IF2 INCORRECTLY POSITIONED. REVERSAL OF PHASE NEGATIVE FEEDBACK LOOP. MICROPHONY OR DETERIORATION V3, V4. MICROPHONY G2.
MODERATE HUM.	EC2 DETERIORATED OR O/C. VALVE HEATER/CATHODE LEAKAGE. REVERSAL OF CONNECTIONS TO L.S. HUM-BUCKING COIL. CH1 S/C.
LOUD HUM.	EC3 AND EC4 O/C. R13, R12, R9, R8, R1, IFT1, IFT2 OR L2 O/C.
VERY WEAK OUTPUT.	LOSS OF EMISSION V2, V3, V4. R2, R3, R6, R7, R15 O/C.
"BLIND SPOTS".	LOSS OF EMISSION V1. G1, G2 VANES TOUCHING. RESONANCE EFFECTS OF NEAR-BY COILS. OSCILLATOR NOT TRACKING— DETERIORATION L3, L4, P1.

Switch Contacts.—Unduly high resistance caused by dirt, oxidation, corrosion or distorted contact springs. Poor contact on R.F. switches may lead to diminished sensitivity or to general noise. Where fairly high currents at low voltages are concerned, *e.g.*, on/off switches in battery and car radios, the switch is particularly susceptible.

The deterioration of almost all radio components—particularly insulating materials, capacitors, transformers, etc., is greatly increased in humid or salt-laden atmospheres.

Effects of Faults on Receiver Performance

The effect of the above basic faults on receiver performance may take the form of clearly apparent faults, gradual deterioration in the sensitivity, selectivity or quality, intermittent faults which may occur at most infrequent intervals, and the type of intermittent fault which may, for no apparent reason, clear as soon as the chassis, or particular components, is touched.

The following list of common causes of particular symptoms is intended for guidance, though it will be appreciated that unexpected faults will be encountered from time to time.

No Output.—Complete absence of signals may be due to almost any of the basic faults already listed. Systematic checking of valves and voltages will usually reveal the source of the trouble. The more frequent causes include the failure of: one or more valves; electrolytic smoothing capacitors; power and output transformers; smoothing resistors and chokes; power supplies, power-transmission leads and open-circuit fuses (not necessarily blown); voltage-dropping resistors (particularly where the dissipation of power is high); " line-cords ", barreters and pilot lamps in A.C./D.C. (" universal ") receivers. The choking of valve-control grids due to over-biasing, damage to loudspeaker speech coils, fracture of aerial leads and switch faults are also common causes of a complete absence of signals.

Crackles, Noise, Excessive Fading.—Crackles and noise may be caused by external sources of interference or faults within the receiver. Partial breakdown of insulation in capacitors, inductances, I.F. and A.F. transformers; faulty resistors; dry joints; loose or high-resistance switch contacts; loose valve pins and sockets; faulty power transformers and smoothing chokes; dirty or faulty potentiometers can all give rise to this type of symptom.

Excessive fading or " blasting " can usually be traced to faults in the A.V.C. network. The breakdown of resistors and capacitors should be suspected, although the possibility of faults in the aerial or aerial-input circuit should not be completely ignored.

Excessive Hum.—Most A.C. and " universal " receivers possess a residual mains hum, but in a quiet room this should not be audible at approximately more than 1 ft. from the loudspeaker. The level may, however, be considerably increased by: open-circuit or " ageing " smoothing capacitors; transposition of mains-input plug (" universal " types); external pick-up of stray mains hum; absence or failure of earthing system; short-circuit of windings or leakage of power transformers; defective valves, especially where the cathode/heater insulation has completely or partially broken down; failure of grid resistors; open-circuit or resistance of switch contacts; open-circuit of grid inductors; and the transposition of connections to the loudspeaker hum-bucking coil.

Whistles, Motor-boating, Ringing, etc.—A tunable whistle on all signals usually indicates I.F. instability, which may be due to: failure of I.F. screen or anode by-pass capacitors; excessive gain of I.F. stage resulting from failure of the I.F. bias resistor or capacitor, or from a too sharply peaked alignment of the I.F. transformers; batteries which have developed a high internal resistance; poor screening; stray capacitance or inductance coupling; and poor layout of components.

Constant howling or " motor-boating " usually denotes A.F. instability, although blocking of the local oscillator, loose valve bases, valve microphony and poor voltage regulation can also cause this trouble. A.F. instability may airse from: failure of anode or screen by-pass capacitors; batteries with high internal resistance; stray coupling.

" Ringing " usually denotes valve microphony, but occasionally it may be due to vibration of the oscillator tuning capacitor or an electrolytic capacitor.

Excessive interference may be caused by: misalignment of the tuned circuits or poor tracking of the gang capacitor; incorrect adjustment of the I.F. wave-trap; faulty I.F. transformers; " spurious " responses, denoting incorrect alignment, poor screening or excessive R.F. output from the local oscillator; high resistance of switch contacts. Reception of Morse signals from ship stations operating in the 600-m. band usually denotes I.F. break-through. Reception of medium-wave stations on the long-wave band may be due to insufficient " image " rejection.

Distorted Output.—Distorted output may be due to wrong bias voltages; faulty anode and screen resistors; short- or open-circuit by-pass capacitors; loss of emission in valves; " soft " valves; leaky A.V.C. lines; misalignment of push-button and other tuning devices, misalignment of tuned circuits; parasitic oscillation, particularly in A.F. stages; and leaky inter-stage coupling capacitors causing positive biasing.

Lack of Output.—May be caused by lack of emission in one or more valves, especially in the output stage; damaged loudspeakers (distorted speech coils, loss in field strength); faulty resistors or capacitors in valve inter-coupling networks; short-circuits producing an excessive drain on the power supply; partial failure of metal rectifiers.

Lack of Sensitivity.—May result from loss of emission in one or more valves; faults in the R.F. or mixer stage; misalignment or poor tracking of tuned circuits; faulty resistors or capacitors; leaky capacitors in the A.G.C. line, for example, can cause flat tuning and general loss of sensitivity.

No Signals on some Wavelengths.—May be caused by the rotary vanes of the tuning capacitor touching the stationary ones; loss of emission in the local oscillator valve; fractures of short-circuits in inductor windings; poor contacts on wave-change switches; misalignment or poor tracking of the tuning gang capacitor; excessive aerial coupling producing " blind spots " (straight receivers).

A check of the frequency-changer valve by substitution is well worth-while, since loss of emission and consequent failure of the local oscillator on some wavelengths is common. Low anode voltage on the oscillator, due to anode feed resistors increasing in value, or to incorrect mains-tapping adjustment (or low mains voltages), or an inefficient reservoir smoothing capacitor are all possible causes of uncertain oscillation.

Fault-finding Hints

Where a valve is suspected of being faulty, another equivalent type should be tried in its place. An important exception, however, is the rectifier. Before substituting another valve in this position it is essential to check that no short-circuit exists across the main H.T. line. In A.C. models this can quickly be done by disconnecting the mains-supply leads, removing the rectifier valve and measuring the resistance between chassis and filament (or cathode in the case of indirectly heated rectifiers). This should not be less than 10,000 ohms, and will probably be considerably more; the actual value depends upon the screen-voltage networks and any bleeder resistors. This precaution is necessary, since rectifier failures are often caused by a short-circuit on the H.T. line, and the substitution of a fresh valve before the original fault is cleared would lead to further damage. Similarly, it is a wise precaution to check the bias voltage and inter-stage coupling capacitor of any valve that has to be replaced, since the life of a new valve may be sensibly reduced if run with no bias or with a positive voltage applied to the control grid.

Where it is suspected that capacitors or resistors have become open-circuit the temporary connection of a similar value component in parallel often permits a quick check to be made; particularly in cases of excessive mains hum. Complete removal of suspected components should, where possible, be avoided until the suspicion is confirmed. A sudden but not violent increase in mains-hum level may be due to a faulty earthing system, though modern receivers do not often suffer from inherent mains hum.

Leaky capacitors—a common source of " noise " and distortion —can be tested most satisfactorily with a " Megger " insulation tester or a component bridge, though it will usually be necessary to disconnect at least one connecting wire. A simple insulation tester is described in Section 7.

When testing components or valves by removal or substitution it is most important that only one change or test should be made at a time and that the circuit should be restored to its original condition at the completion of each test. Serious damage can be done by haphazard alterations.

Sources of crackles and the like can often be located by the careful movement of components with an insulated prod. A plastic crochet hook is a useful accessory, since the hook enables wires to be firmly gripped in otherwise inaccessible spots.

" Ringing " and microphony can usually be traced by gently tapping each valve with an insulated prod. An elastic band wrapped round the end of the prod will make it easier to detect microphony. If the valves prove faultless, the oscillator section of the tuning capacitor should be similarly tested. Another possible cause of microphony is a poor connection to the can of an electrolytic capacitor.

Cross-modulation (an unwanted programme appearing as a background to other strong signals, but not audible at intermediate points on the tuning dial) arises either from overloading the early stages of a receiver (less frequent since the advent of variable-mu valves) or from external demodulation and the subsequent mixing of signals. The second condition can occur as a result of rectification taking place at poor joints in the aerial and earth system; or in surrounding metal structures such as drain-pipes, telephone lines and so on. The cure is to solder all joints in the aerial/earth system and to bond together the different sections of metal structures in the vicinity of the aerial or, where this is not possible, to change the route taken by the lead-in wire.

Hum-modulation (somewhat similar to cross-modulation except that the unwanted programme is replaced by hum) can usually be eliminated by the connection of a 0·1-μF capacitor between the " live " side of the mains lead and earth, or by placing two 0·1 μF capacitors across the H.T. secondary winding of the mains transformer with the junction of the capacitors connected to the centre-tap of the winding. It may also be necessary to provide R.F. paths to earth for other metalwork such as gramophone motors and assembly plates, loudspeaker grills and so on.

R.F. switches, particularly where ganged wafer types are employed, are a frequent cause of noisiness and lack of sensitivity. Carbon tetrachloride or one of the commercial cleaning materials intended specifically for this purpose will usually cure the trouble. The cleansing agent can be applied with a small brush while rotating the switch. The repair of distorted contact springs requires dexterity; but can often be accomplished with the aid of a small pair of pliers or tweezers or the tools made for this purpose. A useful switch lubricant consists of two drops of fine oil in a teaspoonful of lighter fuel. The lubricant can be applied with a clean feather.

When the work of repair is finished, a routine check of valves and voltages should be made. This may prevent further and possibly more serious trouble later on. Resistors should also be carefully examined for signs of overheating and, if necessary, replaced by higher-wattage types. The chassis, cabinet and tuning dial should be thoroughly cleaned, and a little fine oil applied to any rotating mechanism such as the tuning drive.

When testing a receiver known to suffer from intermittent faults, the symptoms may sometimes be induced by temporary application of voltages about 10 per cent above normal, either by adjustment of the mains-input tapping or, in the case of A.C. models, with the aid of an auto-transformer. It is important not to remove or disturb the chassis until the fault has been heard, otherwise the trouble may be temporarily cleared, only to return after the receiver has been restored to its owner.

A quick check of the oscillator section of a superheterodyne receiver can be made by connecting a voltmeter across the cathode resistor of the mixer valve and short-circuiting the oscillator grid to chassis: the voltage drop across the resistor should change appreciably as the valve stops oscillating.

A simple check to ascertain whether the A.G.C. is functioning correctly consists of measuring the screen voltage of the I.F. valve under "no-signal" conditions, tuning in a strong carrier and noting the change in reading. With a standard mains-operated receiver the screen voltage should show an increase of the order of 10 volts.

Drive Cords

The failure of tuning and control-drive systems is still a common fault, particularly where the receiver has received rough handling. While their repair is generally a fairly straightforward task, occasionally this calls for a considerable degree of mechanical dexterity.

If full details of the drive system are not available, it is worth spending a little time in carefully tracing out the purposes of the various pulleys and springs before attempting to re-thread the system.

A useful accessory, when threading cords in inaccessible corners, takes the form of a steel rod with a hook at one end and a small two-pronged fork at the other; but care should be taken that all rough edges are removed.

Always use a good-quality cord, that will not chafe or stretch easily: it will usually be found advisable to pre-stretch the cord by suspending it for several hours from a hook with a weight attached to the lower end. Nylon cord is usually recommended.

A common fault, when repairing drives, is to wind too many turns around the drive spindle, causing the turns to ride up and bind, making the drive stiff and increasing back-lash. The correct figure usually lies between $1\frac{1}{2}$ to $2\frac{1}{2}$ turns, depending upon the particular layout of the drive system.

Where one end only of the cord is terminated in a spring, it will usually prove satisfactory to begin threading from the fixed end. When tying off a cord, or making a loop, the use of a small tubular aluminium rivet, through which the cord is doubled back, and the rivet then securely pinched, has much to recommend it.

REPLACEMENT OF VALVES

Defective valves should, whenever possible, be replaced by identical types or direct equivalents. Owing to the enormous range of types manufactured during the last fifteen or so years, however, such replacement is not always the simple matter which the set-owner imagines. Many older valve types are no longer available or are in extremely short supply as a result of obsolescence.

In such cases it will often be necessary to replace the valve with an alternative type; this may involve a change of valve-base connections, a different valve-holder and/or circuit changes. To assist in the replacement of valve types that are no longer available, most valve manufacturers provide detailed information on the alterations necessary when changing to recommended alternative type numbers; a library of such information should be assiduously compiled by the service engineer.

Some of the major considerations which arise when new valve types have to be substituted for obsolescent types are summarised below.

Modern-type valves used as voltage amplifiers may cause instability owing to their higher gain. Particular attention should therefore be paid to keeping the grid and anode leads well separated and in providing short earth leads to internal shields, screen by-pass capacitors, etc.

Valves with similar characteristics to the obsolete valve may be available with a different base; substitution of a new holder may prove more convenient than changes to the circuit.

The effect of changes in power consumption must be carefully considered; extra current may result in the power pack being overloaded; less current may result in a general rise of potentials throughout the receiver. Always check that all valves are being operated within their current ratings.

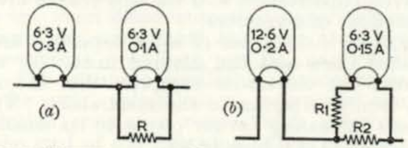


FIG. 1.—USE OF RESISTORS WHEN SUBSTITUTING VALVES WITH DIFFERENT HEATER RATINGS.

(*a*) The resistance R is required to carry the surplus current of 0·2 amp.

Then, from Ohm's Law $R = \frac{V}{C} = \frac{6 \cdot 3}{0 \cdot 2}$ ohms = 31·5 ohms.

(*b*) The resistance $R1$ is required to drop 6·3 volts at a current of 0·15 amp.

$$R1 = \frac{6 \cdot 3}{0 \cdot 15} \text{ ohms} = 42 \text{ ohms.}$$

The resistance $R2$ is required to carry the surplus current of 0·05 amp.

$$R2 = \frac{12 \cdot 6}{0 \cdot 05} \text{ ohms} = 252 \text{ ohms.}$$

Valves of lower heater ratings than the original can usually be substituted in both parallel- and series-connected heater chains with the aid of series- or parallel-connected resistors or a combination of both (see Fig. 1). It should be noted, however, that owing to the very different temperature coefficients of a valve heater and an external resistor, care must be exercised in this type of modification, since it may lead to very substantial surge currents being passed through the valve heater.

The substitution of new valve types in the R.F., mixer or I.F. stages should be followed by the complete re-alignment of the receiver.

Excessive oscillator output of a new frequency-changer valve may cause spurious responses and whistles; output can be reduced by connecting 1k resistors in series with the grid/osc. coil leads on the appropriate wavebands.

More efficient rectifier valves may cause the breakdown of insulation of electrolytic smoothing capacitors; these should be checked and replaced if necessary.

REPLACEMENT OF FIXED CAPACITORS

Several different types of capacitors are found in modern radio receivers, and while certain of these types are interchangeable (provided, of course, that similar values and voltage ratings are used), there are a few applications for which some types are more suitable than others.

Mica Capacitors

Mica capacitors have high insulation resistance, low power loss, good stability and low inductance. All these features make mica capacitors suitable for use in R.F. tuned circuits, for fixed padding and tracking, and for fixed tuning of I.F. transformers. Mica capacitors, however, have relatively large bulk for a given capacitance, and for this reason are little used in the A.F. sections of a receiver.

In practice, two main types of mica capacitor are used, the normal moulded mica and the silvered mica. In the silvered mica capacitors the electrodes comprise thin layers of silver fired on and firmly adhering to the mica sheet. The silvered-mica type finds increasing favour owing to its smaller size and its stability, which is of a high order.

Ceramic Capacitors

Ceramic capacitors have become popular for a wide range of applications, and many different types are available. These are roughly classified into two main types: low-permittivity and high-permittivity types, both of which are used in radio receivers.

An important use of the low-permittivity types—particularly on the higher frequencies—is for counteracting frequency drift in oscillators due to changes in temperature. If a ceramic capacitor with an appreciable negative temperature coefficient is connected across the tuned circuit of the oscillator, then its capacitance will decrease as the circuit warms up, and this can be made to balance out the usually positive temperature coefficient of the rest of the circuit. When replacing such capacitors it is obviously important to choose a capacitor with the correct temperature coefficient, and this characteristic forms part of the colour coding (see page 157). The original calculation of the value and temperature coefficient of such capacitors lies outside the scope of normal servicing, where it is largely a question of exact replacement. But occasionally, where the operation of the original compensating capacitor is unsatisfactory, the use of a capacitor with a slightly different temperature coefficient may improve frequency stability. In this connection a coding of N750 means a negative temperature coefficient of 750 parts per million per degree centigrade.

High-permittivity ceramic capacitors, which have the advantages of compactness and low price in comparison with mica capacitors, are used mainly for those R.F. applications where tolerances of ± 10 or ± 20 per cent are acceptable: for example, in almost all coupling or decoupling applications, such as oscillator-feed capacitors, I.F. filter capacitors, R.F. and I.F. decoupling capacitors and the like. Until recently, the stability of ceramic capacitors has not generally been regarded as high enough for their incorporation in tuned circuits as padders and the like, except as mentioned above when used for temperature compensation. However, even for such exacting requirements, ceramics are now being increasingly used.

Paper Capacitors

Paper capacitors, particularly the paper tubular types, have for many years been used for a wide variety of applications in radio receivers, especially where tolerances of ± 10 and ± 20 per cent are acceptable. The relatively high capacitance/bulk ratio makes them particularly suited for A.F. applications. In the past the main disadvantage of paper tubular capacitors (resulting from the containers) has been their gradual loss of insulation resistance over long periods, particularly in humid conditions. The ultimate insulation resistance is of especial importance for such applications as inter-valve coupling, where a low insulation resistance causes high positive voltages to appear on the grid of the following valve, causing distortion or damage. The insulation resistance, for example, of the simplest form of waxed-coated, cardboard-cased type of capacitor often drops to as low as 5 MΩ after a year or two, and should therefore be avoided for inter-valve coupling, the decoupling of the A.G.C. line, and for many television applications. On the other hand, such types are perfectly satisfactory for the decoupling of anode, screen and cathode circuits in radio receivers. For R.F. application, types with low inductance should be used.

In recent years new types of paper capacitors, having greater resistance to humidity, have become available, the improvements relating mainly to the type of impregnant and the container. It has also been found that jelly (usually petroleum jelly) or liquid impregnants are advisable for use where appreciable A.C. stress (over about 100 volts) or high D.C. voltages (over 1,000 volts) occur. The A.C. ratings should be most carefully watched when replacing isolating capacitors: for example, in the earth lead of A.C./D.C. receivers, and those used between mains leads and chassis for the reduction of intermodulation hum.

Metallised paper capacitors, which are a fairly recent development, have the advantage of being much more compact than the normal foil and paper types. Two main categories are available: the completely coated type and the " castellated " type. With the latter, care should be taken that the container meets the requirements for insulation resistance in the same way as for the normal paper and foil types.

Electrolytics

The great advantage of the electrolytic capacitor is the extremely high capacitances that are possible, and this type is used almost exclusively for smoothing applications, and also for cathode by-passing of audio amplifying stages. Although early types were not always very reliable, in recent years they have been much improved. New manufacturing techniques (particularly etched foils or fabricated-plate construction) have also made possible a great reduction in size.

The manufacturers usually specify two voltages, one the maximum working voltage and the other the maximum surge voltage. The working voltage is equal to the maximum direct voltage *plus* the maximum peak-ripple voltage that occurs, allowing in both cases for mains variations, etc. For this reason, the rating of the first smoothing capacitor (to which a greater ripple voltage will be applied) may be appreciably higher than any subsequent smoothing capacitors. The surge voltage is that which occurs when the set is first switched on, or that under certain accidental conditions, e.g., the open-circuiting of the H.T. line. The surge rating is usually 100 volts above the working voltage for the higher-voltage types, and about 75 volts for the medium-voltage types. The ratings of electrolytic capacitors should be increased when the capacitor is run under high-ambient-temperature conditions.

When electrolytic capacitors have been out of service for an appreciable period of time the insulation resistance falls sharply. For example, when a faulty electrolytic is replaced from stock, the initial insulation resistance on first switching on the receiver may be only a fraction of its normal value. This fact may give rise to a heavy initial current through the capacitor, heating the electrolyte, and this in turn will further decrease the insulation resistance; thus starting a chain of events that may lead to the complete breakdown of the capacitor, the rectifier or possibly even the power transformer.

For this reason, unless capacitors rated well above the circuit peak voltage are used, it may be advisable to re-age (re-form) any electrolytic capacitor that has been out of service for more than, say, six months. Even if stored under good conditions, capacitors should be re-formed every twelve months. Wherever the storage is doubtful, as in an unduly high ambient temperature or in the tropics, then re-forming must be done more frequently, intervals of three to six months being necessary. Re-forming may best be done by applying the D.C. working voltage to the capacitor in series with a resistor of such a value as to limit the initial current to a safe value. For an 8-μF, 450-volt capacitor a resistance of 10,000 ohms would be found satisfactory. For convenience, the capacitor can be placed in series with two 15-watt electric lamps (series connected) and a D.C. supply—not necessarily smoothed—about 20 volts above the working voltage of the capacitor. When first connected, the lamps will probably light, but after some little time—and certainly within one hour—they should cease to glow. A milliammeter may then be inserted into the circuit and the re-forming process continued for about 30 minutes after the current has dropped to below 1 mA.

A service department should arrange that electrolytic capacitors are used strictly in the order in which they have been stocked. It is also preferable to err on the generous side in regard to voltage ratings, and to ensure that they are not subjected to undue heat. It should be noted, however, that when an electrolytic capacitor has been used for any length of time at voltages lower than those at which it is rated, it may no longer be safe to apply the full rated value.

Final Touches

If the repair has been carried out in the servicing workshop, the receiver should be thoroughly examined and checked before returning it to its owner, no matter how trifling the original fault. It is a good plan to subject all receivers to a soak test, *i.e.* operate the receiver continuously for a fixed number of hours. This is because once a receiver has passed through the hands of a service engineer, any further troubles that develop within the next few months are liable to be attributed by the owner to poor servicing, even where the second fault has no connection with the original trouble. Mains leads and plugs should be examined for fraying or looseness, resistors should be checked for signs of overheating and replaced by higher-wattage types if necessary. Particular care should, of course, be taken to ensure that no traces of solder are left on the chassis. The chassis and cabinet should be thoroughly cleaned; a small electric blower will be found a great help in removing dust and grime; the dial plate cleaned; cabinet scratches removed with spirit stain; knobs securely tightened; and the cabinet polished.

Attention to detail of this kind soon pays results in increased goodwill, and in the larger service departments many of these tasks can be performed by junior staff. Records of faults and repairs should always be kept, for future guidance as well as for accounting purposes. The accounting side of the business needs careful organising to ensure that work cannot be charged to the wrong customer, and that sufficient detail is recorded to satisfy any later enquiries.

SERVICING V.H.F./F.M. RECEIVERS

While much trouble-tracing on A.M./F.M. and F.M. only sets will be similar to that described for A.M. receivers, it must be remembered that the R.F. and 10·7-Mc/s I.F. circuits may easily be affected by small changes in the positioning of wires or components, or by deterioration of valves and insulation materials that might pass unnoticed on the lower frequencies. In particular, slight contact resistance in valve-holders, aerial input sockets and in wave-change switches are common causes of poor V.H.F. performance.

Faults common to both A.M. and F.M. reception can often be traced most easily with the model switched to one of the A.M. bands. Where an A.M./F.M. receiver operates correctly on A.M. but is completely inoperative on F.M., the V.H.F. oscillator valve should be checked. A method of checking oscillation in this stage is to check that a change in anode current of the valve occurs when the grid is temporarily short-circuited to chassis.

Various forms of microphony and instability may be experienced on V.H.F. receivers. These can often be traced to varying contact resistance in valve-holders, the vibration of small floating components or too poor contact between screening cans and chassis, or between the V.H.F. front-end unit and chassis. Instability may also be due to deterioration of decoupling capacitors or to incorrectly routeing of wires resulting in an increase in stray capacitance between input and output circuits of an I.F. stage. A positive test for instability is to connect a sensitive voltmeter across the discriminator load resistor under conditions of no-signal input; instability will be denoted by a meter reading, although no audible signal may be heard. Microphony in receivers using permeability tuning can be caused by incorrect tension in the cord drive.

An increase in noise and greater susceptibility to electrical interference may indicate deterioration of the alignment, but, alternatively, could be due to reduced gain in one or more of the R.F./I.F. stages. It should be noted that for the amplitude-limiting properties of a ratio-detector to function most efficiently the signal presented to the ratio-detector diodes should be fairly high. Loss of gain in the early stages may be due to deterioration of one or more valves, lowering of insulation resistance across points at R.F. potential (switches, valve-holders, capacitors, I.F. transformers, etc.) or to a fault in the aerial or aerial plug and socket. Stage gain could also be low due to low screen-grid voltages, caused, for example, by feed resistors going high in value; voltage and resistance checks will usually show up such faults.

SERVICING PRINTED WIRING PANELS

The main difference in the servicing of receivers and record reproducers using printed-wiring panels is in the replacement of faulty components, calling as it does for greater skill and care in soldering. Too large or too hot a soldering-iron may cause blistering and damage to the laminated board. Very sparing use of solder is also necessary, as otherwise it may run between adjacent copper wiring foils and be difficult to clear. Apart from heat blistering the panel, it is also easy—as a result of bending or placing strain upon the panel—to cause hairline breaks, often of an intermittent nature, to appear in the copper-foil wiring. Occasionally faulty panels may also be encountered in which the copper foil tends to come away from the laminated board.

Tools

The following tools and aids are recommended:

(1) A low-wattage soldering-iron with a small point or wedge bit. The ratings should be less than 50 watts, and preferably less than 35 watts.
(2) Supply of 60/40 resin-cored solder.
(3) Soft wire brush (such as suede-shoe brush).
(4) Pair of diagonal wire cutters.
(5) Pair of long-nosed pliers.
(6) Small wire pick or soldering aid.
(7) Needle-point probe for circuit testing.
(8) Magnifying glass for detection of small cracks.

General Precautions

(1) Avoid damaging the copper foil. Be careful when removing components not to cause small breaks in the foil. Should a small break occur, this can usually be " jumped " with molten solder. Larger breaks should be repaired with single strand connecting wire.

(2) Never apply excessive pressure to the wiring board, as this can easily cause cracks or breaks in the foil.

(3) Excessive heating from large soldering-irons or due to over-long application of a hot iron may cause the bond between the board and the copper foil to break or blister.

(4) When replacing components avoid large deposits of solder. These can easily cause a short-circuit or intermittent fault by bridging adjacent copper foils.

(5) When brushing off molten solder small particles may be left sticking to the board. Before installing a new component remove these particles with a cloth dipped in solvent.

Replacing Components

It is best to clean and tip with solder any new components before inserting them through the holes in the laminated base.

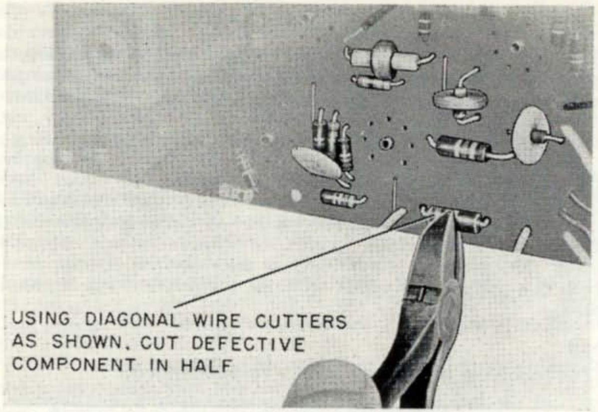


FIG. 2.—PRINTED PANEL SERVICING—I.

When leads to components are very short the component to be replaced should be cut in half and then cut away from the internal leads, using diagonal wire cutters. This provides a useful additional length of lead.

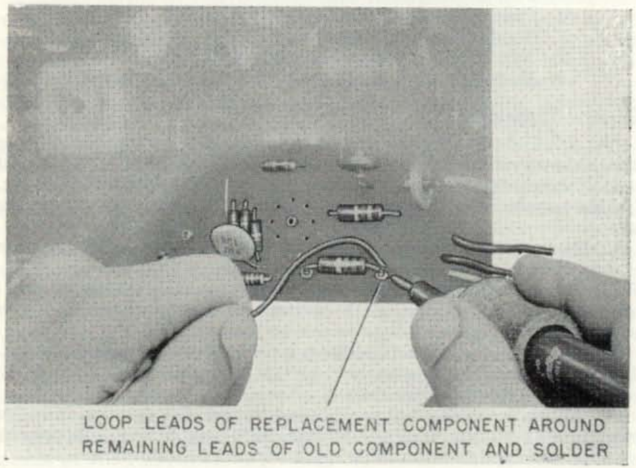


FIG. 3.—PRINTED PANEL SERVICING—II.

Make a small loop in each lead of the new component and slip these over the existing connecting leads. To keep mechanical strength and stability leads should be kept short. Solder in place quickly to avoid overheating the panel.

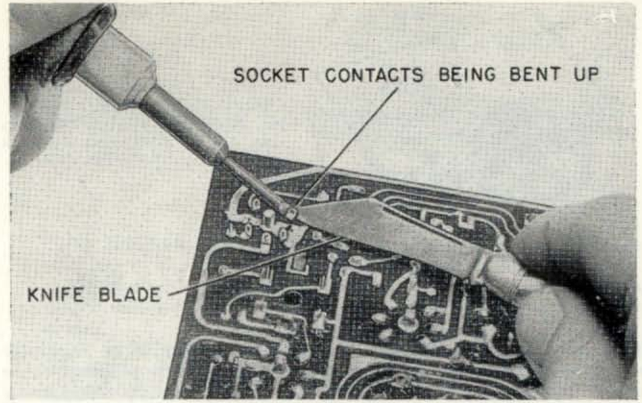


FIG. 4.—PRINTED PANEL SERVICING—III.

To remove a valve socket or similar component, apply soldering-iron and brush to each lug. Apply iron to lug and bend it upwards from copper foil with knife blade. Rebrush connections while solder is molten. Cut lugs close to board and lift socket. When replacing enlarge holes slightly if necessary to avoid forcing socket lugs through board.

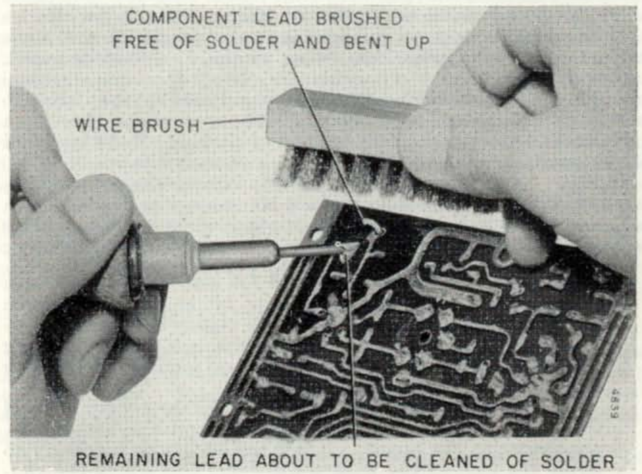


FIG. 5.—PRINTED PANEL SERVICING—IV.

Method of removing a component mounted in such a manner that its leads cannot be cut to free it from the board.

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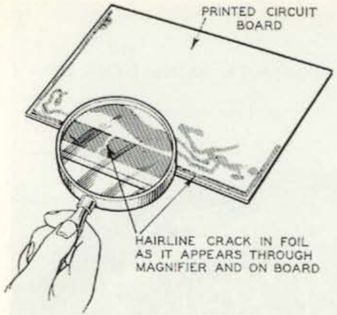


FIG. 6.—A MAGNIFYING GLASS IS AN AID TO DETECTING HAIRLINE CRACKS IN THE COPPER FOIL.

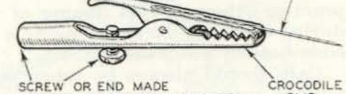
The wired ends of resistors and capacitors should be carefully trimmed and bent over so that when soldered into position there is no tendency for the component to force the copper foil away from the base. A method of overcoming this with simpler and non-critical circuits is to clip away the defective component with wire cutters, leaving as much as possible of the original connecting leads in place, and then to shape the leads of the replacement component into small loops which can be slipped over the original leads and soldered into place; if the original leads are very short it may prove advisable to cut the old component in half with wire cutters and then strip the component away from its internal leads to provide slightly longer connecting wires. It should be noted, however, that when components are changed in more critical circuits, such as where parasitic or spurious oscillation is liable to occur with a change of stray capacitance or slight change in position of a component, this method of clipping off the lead and soldering the new component to the wire ends can result in instability. In such circuits it is better to remove the old component completely and to solder the new component in its place. In all cases where it is necessary to unsolder wires and lugs on the wiring side of the board, the following procedure should be used:

(1) Heat the connection on the foil side of the panel with a small soldering-iron. When the solder becomes molten brush it away with a soft wire brush, taking care not to overheat the connection, and remove the iron while brushing away the solder. It may require several sequences of heating and brushing to remove all the solder.

(2) Insert the blade of a knife between the copper foil and the bent-over component lead and bend the latter perpendicular to the board. It will sometimes be necessary to apply the iron to the joint while doing this where the connection has not been broken by the brushing.

(3) While applying the iron to the joint, gently " wiggle " the component until it comes away from the panel.

FIG. 7.—ADAPTING A CROCODILE CLIP AS A NEEDLE PROBE.



(4) Remove any small particles of solder which may be sticking to the protective coating of the circuit board.

(5) If there is a thin layer of solder left over the hole, pierce this with the new component wires after heating the solder.

(6) Place the new component in position and cut the connecting leads as necessary. Bend over the ends against the copper foil and resolder the joint.

(7) Finally, recoat the affected area with a protective coating such as polystyrene dope.

Measurements

Resistance and component measurements are usually possible from the component side of the board, but, should it be necessary to work on the wiring side, it should be remembered that the protective coating over the foil forms an insulator: this can easily be penetrated by using a probe consisting of a brass needle soldered to a crocodile clip.

Alternative methods of mounting valve-holders may be encountered: in some panels the main part of the holder is on the wiring side of the board; in others on the component side. Count pins anti-clockwise when viewed from the top of the socket, and clockwise when viewed from below.

To assist tracing unknown circuits, it may prove helpful to bring a 60-watt lamp fairly close to the panel. As the panel is usually to some extent translucent, an outline of the components can then be seen from the wiring side.

SERVICING TRANSISTOR RECEIVERS

Servicing transistor equipment presents a number of pitfalls for the unwary, including the possibility of destroying or damaging the transistors. Some engineers also find that work on the very small personal receivers can be most time consuming unless logical servicing procedures are followed.

Until considerable experience has been gained of handling transistors, the engineer should keep continuously in mind the ways in which transistors can be damaged during servicing. First, correct battery polarity must be carefully observed. Connection of the wrong battery polarity, even momentarily, may cause a transistor permanently to lose gain and become more noisy, and may even—particularly with V.H.F. transistors—destroy it completely. Since the pnp transistor should have its collector ("anode") negative—the direct opposite to valve practice—there is real danger of wrongly connecting a battery during testing. To overcome this hazard to the user, non-reversible battery plugs are fitted.

Care should always be taken not to allow excess voltages or voltage surges to develop accidentally across the various electrodes. The internal resistances of transistors—particularly power transistors—are low, so that even relatively low voltages may cause currents sufficient to damage or burn out the junction. One way in which such voltages can be introduced into a receiver is by the use of the resistance-measuring or continuity-testing ranges of a multi-test meter having an internal battery. Never use a low-sensitivity continuity tester, and make sure that any testmeter has an internal resistance of several thousand ohms; when in doubt connect an external resistor in series with the meter or disconnect the transistors from the circuit under test. Do not overlook the possibility that some soldering-irons, particularly when hot, may have a small leakage potential between their casing and earth, so that it may be advisable to earth the outer casing. Mains-operated servicing instruments, such as signal and audio generators, should have insulating capacitors inserted in the output leads (suggested values R.F. 0·1 μF, A.F. 8 μF). Excessive signal inputs during alignment should be avoided. When carrying out tests or measurements take care not to short-circuit the base of a transistor to its collector, and never run a transistor with its collector open-circuited. Surge voltages may also be introduced by the discharge of one of the many large-value electrolytics found in transistor equipment. With a power transistor, a loudspeaker or equivalent load must always be in circuit, as otherwise high voltages will appear on the collector. Where output transistors are mounted in a "heat sink" (which may consist of the chassis itself or a small metal clip) they should not be operated (except at very reduced ratings) out of the "sink". To improve heat transfer between transistor and "sink", it is often smeared with silicone grease—this should not be removed.

The soldering of transistors and germanium crystal diodes into and out of circuit should be carried out as rapidly as possible with low-wattage irons. This is to prevent excessive heat from travelling along the connecting wires into the body of the component. The use of a "heat shunt" is to be recommended; this can take the form of gripping the wire between the point of soldering and the transistor with a cool pair of pliers, so that there is good thermal contact between the wire and the pliers. The pliers then absorb most of the heat: an alternative device which leaves both hands free is shown in Fig. 8. Transistor wires are tinned and plated to enable soldering to be carried out quickly. Solder as far as possible from the body of the transistor, but do not

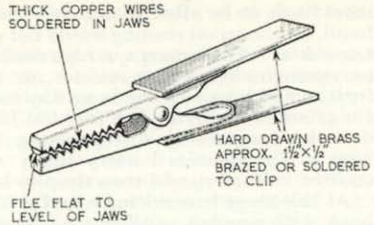


FIG. 8.—A USEFUL HEAT SHUNT MADE FROM A CROCODILE CLIP.

leave very long leads, which may cause the transistor to vibrate. Do not bend transistor leads too close to the body of the transistor.

Transistors are sensitive to light and therefore normally have an opaque coating. This coating should not be scratched or removed, as otherwise the transistor may pick-up A.C. hum from a fluorescent or other light bulb.

Servicing Methods

When a transistor receiver does not work satisfactorily the first step is to measure the battery voltage *under load*. While some receivers operate efficiently at much lower battery voltages than others, in general it will be advisable to discard batteries which are down to about two-thirds of their nominal voltage, *i.e.*, about 4 volts for a 6-volt receiver, or 6 volts for a 9-volt model. Where two separate 4·5-volt batteries or a centre-tapped 9-volt battery is used in conjunction with a single-ended push–pull output stage, any marked difference in the voltages of the two sections may cause distortion. After checking battery voltages, connect a milliammeter in series with one of the battery leads in order to measure total consumption, as this test will help to locate short-circuits in transistors or components.

The next step is usually to measure the emitter voltages up to and including the driver transistor. These should be reasonably close to values specified by the makers, taking into account the actual battery voltage (it is often best to insert a new battery for testing to ensure that the correct voltages are being applied). Since the emitters are not normally fed through high-value resistors, a 1,000-ohms/volt testmeter will give sufficiently accurate readings. This is unlike some other transistor measurements, such as base voltages, which almost invariably require a high-sensitivity testmeter of 20,000 ohms/volt or more for readings to agree with makers' figures.

Then measure the collector currents of the push–pull output stage. Under no-signal conditions the standing current of an output transistor in small portable receivers should usually fall to between about 1 and 4 mA, with somewhat higher currents for domestic and A.M./F.M. sets designed for better-quality audio.

If the above measurements appear to be in order the fault is most likely to be other than a defective transistor. On the other hand, an abnormal reading would not positively denote a defective transistor. For instance, a high emitter voltage might be due to an open-circuit emitter resistor, or to a faulty bias chain. A further check can be made on the transistor itself by observing the effect of removing the forward bias on the base (this can be done by temporarily disconnecting the resistor connecting the base to the *negative* battery line); with a good transistor the emitter voltage should then drop to less than 0·1 volt.

At this stage in servicing a useful tool is a non-metallic crochet hook with a notch suitable for gripping wires at one end and a fine point for probing or cleaning away solder at the other. With the smaller sets, many of the faults are due to wires touching or breaking, or to poorly soldered connections; a careful visual examination with a good magnifying glass, while gently pushing or tapping the parts with the crochet hook, with the set's volume control advanced, may help pin-point the trouble.

If the fault cannot be located by the tests outlined above it will be advisable to trace the signal through the circuit. One method is to check the sensitivity at various points in the circuit against a good receiver of the same type; this overcomes the problems introduced by the use of different test instruments, though is not always possible in the smaller service station. Test signals can be injected into A.F. circuits via an electrolytic capacitor and into the R.F. circuits via a 0·1-μF paper capacitor.

Where coupling or decoupling capacitors are suspect, these can be checked for open-circuit most easily by temporarily connecting an equivalent capacitance across the suspect component. With models using more than one stage of A.F. amplification, loss of capacitance in an electrolytic capacitor is very likely to cause A.F. instability resulting in "motor-boating". Loss of capacitance due to "drying-out" of electrolytic capacitors is one of the more common faults in these sets leading to I.F. or A.F. instability.

When testing, it is important to remember that it is not only the transistors which may be damaged by excessive test voltages: electrolytic capacitors, for instance, may be rated at only 3 or 6 volts, and can easily be damaged, particularly by applying voltages of reversed polarity.

The most common cause of distortion in transistor receivers is to be found in the output stage. Cross-over distortion tends to increase as the battery voltage drops or where the characteristics of the two transistors differ, or the bias currents differ. An accurate method of test is to inject a 400-c/s signal to the base of the driver stage and to use an oscilloscope to examine the voltage wave-form developed across the common emitter resistor. The wave-form at this point should be composed of half-sine waves at double the input frequency. In theory the amplitude of the adjacent peaks should be equal, but in practice they may differ by up to about 30 per cent before distortion becomes objectionable in a portable receiver. Often where the output transis-

tors differ it will be necessary to replace both, so as to obtain a correctly matched pair.

If no oscilloscope is available, it may prove useful to measure the output power which can be developed before distortion becomes noticeable. The output power can usually be measured on the 10-volt A.C. range of a 20,000-ohms/volt testmeter, taking into account the output impedance. For example, 180 mW (which should usually be available from transistors of the OC72 type) across a 25-ohm load should give a reading of about 2·1 volts.

In servicing these sets it is best to work to the rule of exact component replacements, both electrically and physically: wrong positioning of some components, for example those in the detector circuit, can result in spurious signals. Again, receivers can often be made to function apparently satisfactorily with certain components—particularly those in bias stabilisation networks—removed or shorted out, but a set should never be left in this condition, as it might render it susceptible to thermal runaway when operated in extreme temperatures. For the same reason, component tolerances in bias networks should be carefully observed.

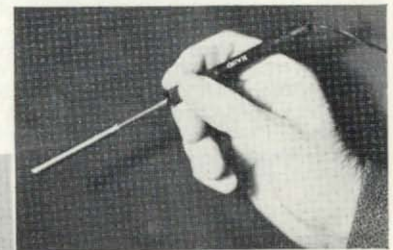


FIG. 9 (*above*).—MINIATURE SOLDERING-IRON.

The introduction of transistors and printed wiring panels has created a need for small, low-power soldering-irons. This is one of a range of "pencil" irons (6–24 watts) made by Oryx Electrical Laboratories Ltd.

FIG. 10 (*left*).—ADVANCE TRANSISTOR TESTER.

Grounded emitter current gain of transistors can be tested with the transistors either in or out of circuit. Leakage current (grounded emitter) can be tested with transistors out of circuit.

Although the most common cause of distortion is cross-over effect with falling battery voltage, small personal receivers carried in the pocket or operated in workshops may easily pick up metal filings, etc., which can reach the speech coil of the loud-speaker. This can usually be removed by careful cleaning and by using a lump of plasticine to pull any filings off the magnet.

Many faults can be traced simply by observing the total consumption. No-signal consumption will depend on temperature. If the oscillator and I.F. stages are working but there is no output, consumption will vary as the set is tuned through loud signals, due to A.G.C. action, though to a lesser extent than when the output stage is functioning. A useful quick check of the oscillator is to place the transistor set near to another receiver tuned to a weak station on a frequency higher by the I.F. than that to which the faulty set is tuned. Suppose the second set is tuned to say 200 metres (1,500 kc/s), rock the tuning control of the transistor set around 291 metres (1,030 kc/s) and listen for whistles. Absence of whistles would probably indicate that the oscillator is inoperative.

If the set has an earphone socket this should not be overlooked as a possible source of trouble, caused by failure of the plug contacts to close when the earphone plug is removed.

When a user complains of short battery life even though current consumption seems correct, this may be due to the manner in which the set is operated. For example, battery life will be much shortened by long, continuous periods of operation with the volume control turned well up. A battery normally provides much better service when used intermittently. Make sure there is no leakage current when the switch is turned to "off"—leakage may be due to distortion of any miniature switch contacts.

Cores of miniature I.F. transformers are best left alone unless definitely in need of alignment; such cores are rather easily stripped and thus ruined.

Ferrite-rod and ferrite-slab aerials are liable to fracture if knocked smartly. A broken rod or slab can usually be repaired by gluing with Durafix, Araldite or similar adhesives. Sometimes the break occurs out of sight under one of the coils; to check, hold the suspect rod by its ends and flex gently. Thin wires to rod aerials, etc., can easily be broken, and care is required when dismantling and servicing.

It is most inadvisable to cut the leads from transistors and crystal diodes with side cutters, as this can cause internal damage, due to mechanical shock travelling along the leads. If necessary to do so, a mechanical shock sink—such as a pair of flat-nosed pliers—should be imposed between the transistor and the point where the leads are to be cut. Other forms of mechanical shock, due to sudden jolts and jars, should be avoided; it is a wise precaution to use a padded working surface.

[SECTION 9]

RECEIVER ALIGNMENT

THE sensitivity, selectivity and, to a certain extent, the quality of reproduction of a superheterodyne receiver depend upon the correct alignment of its I.F. circuits and of its tuning circuits. In most broadcast receivers this involves the adjustment of its I.F. transformers and the tracking of the local oscillator circuit with the aerial-input circuit. With the larger receivers, it may also be necessary to align the tuned circuit of the R.F. amplifying stage, and to adjust the I.F. wave-trap and possibly an image-frequency rejector.

In a superheterodyne receiver the tuning of the local oscillator must track at a constant difference in frequency (equal to the I.F.) from the signal-frequency tuned circuit(s). Absolute accuracy of tracking is, in practice, seldom achieved, but, by the use of a fixed or variable "padder" capacitor in the oscillator tuned circuit and by the careful adjustment of the circuit at two points on each waveband—one towards the higher-frequency end, the other towards the lower-frequency end—substantially correct tracking can be obtained throughout the tuning span.

Alignment of the oscillator with the signal-frequency circuits is thus normally achieved by the adjustment, near the higher-frequency end of the tuning span, of small variable capacitors ("trimmers") and, towards the lower-frequency end, of variable capacitors ("padders") or of dust-iron, ferrite or brass cores in the coils. Adjustment of the tuned circuits at the I.F. is achieved by either variable trimming capacitors or variable cores.

The misalignment of the R.F. and I.F. circuits gives rise to such effects as: lack of sensitivity over whole or part of the tuning range; prevalence of heterodyne whistles and poor selectivity; inaccurate calibration of the tuning dial; poor quality due to uneven response of the I.F. circuits; double-humped or flat tuning; tunable whistles on all signals due to I.F. instability.

Equipment Needed for Complete Re-alignment

Although it is sometimes possible to improve reception solely by the adjustment of the trimmers, injudicious and haphazard peaking of circuits is extremely risky, and may easily lead to a worsening of sensitivity at other points in the tuning range. The re-alignment of a receiver should therefore not be undertaken unless the time and equipment required for a complete check are available.

The equipment required is as follows :

A modulated signal generator with a frequency range covering the full receiver range and the I.F. and fitted with a calibrated attenuator. If a greater degree of accuracy than is obtainable with a normal signal generator (1–2 per cent) is required—for example, on bandspread short-wave ranges—a crystal-controlled sub-standard or frequency meter may be needed.

A dummy aerial suitable for use with the signal generator. This is normally supplied with the generator.

A meter capable of measuring the audio-power output of the receiver. This may take the form of a sensitive A.C. voltmeter connected across the primary of the output transformer (in series with a 0·1 μF capacitor), or preferably a power-output meter capable of being matched to the standard output impedances of 3 and 15 ohms, and connected across the secondary of the output transformer.

A supply of non-metallic trimming tools of various shapes and sizes. Box spanners may also be required for the adjustment of certain types of trimmers.

Soft wax, sealing wax or quick-drying cellulose paint may be needed for the sealing of trimmers and cores.

ALIGNMENT PROCEDURE

Adjustment of I.F. transformer cores or trimmers should always be followed by complete re-alignment of the R.F. section. I.F. circuits should be aligned to a frequency as close as possible (within 5 kc/s) to that specified by the manufacturer, otherwise considerable difficulties may be experienced in the correct tracking of the R.F. circuits. An exception may occur where local conditions make it essential to avoid particular intermediate frequencies.

Where possible, the re-alignment procedure recommended by the manufacturer should be carefully followed; particularly with regard to the order in which the various wavebands are adjusted. The trimmers are often common to more than one waveband, and accurate alignment will then be impossible unless the circuits are adjusted in the correct order.

Before re-alignment is attempted, both the receiver and the signal generator should be allowed to reach normal working temperatures. Ten to fifteen minutes are usually sufficient, but a longer period may be necessary where accurate S.W. calibration is required.

With A.C./D.C. receivers, and those A.C. models using A.C./D.C. technique, particular care is required to minimise the risk of shock and of damage to equipment. Always examine the circuit diagram to ascertain whether there is a direct connection between chassis and power-supply leads. Where an isolating transformer is not available, always check that the chassis is at earth potential before starting work. This can be done by connecting the receiver to A.C. mains, switching on and testing by means of

sensitive A.C. voltmeter or neon bulb in series with an earth lead ; reversing the mains-input plug where the chassis is found to be above earth potential.

Where the receiver cannot be operated with the chassis at earth potential, great care should be taken not to touch the chassis unless standing on a rubber mat or to allow any piece of earthed equipment (signal generator, electric soldering-iron, etc.) to come into contact with the chassis. Isolating capacitors should be included in the output leads from the signal generator.

I.F. Alignment

Connect the output meter across either the primary (via a 0·1 μF capacitor) or secondary of the output transformer, according to impedance.

Connect the output leads from the audio-modulated signal generator to the control grid of the frequency-changer valve (via a 0·01-μF isolating capacitor) and chassis, the outer (screened) lead being connected to chassis. Where the wiring to the control grid has to be disconnected, care should be taken to ensure that a D.C. continuity exists between grid and chassis ; if necessary an additional 1-MΩ resistor may be connected between these points.

Short-circuit the oscillator section of the ganged tuning capacitors and tune the receiver to 550 or 2,000 m. (*i.e.*, vanes of the tuning capacitors fully in mesh). Turn the volume control to maximum gain and the tone control to maximum H.F. response.

Set the signal generator to the required I.F. and inject a modulated signal just sufficient to give a reading on the output meter. The output from the signal generator should be kept at a minimum at all times during I.F. and R.F. alignment and progressively reduced as the circuits are brought into alignment.

Adjust the I.F. trimmers or variable cores of the I.F. transformers for maximum response in the following order : second I.F. transformer (secondary) ; second I.F. transformer (primary) ;

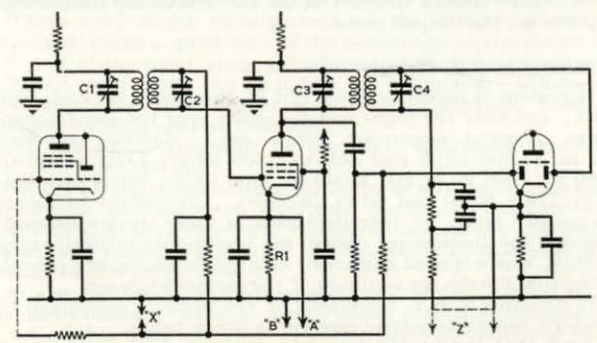


Fig. 1.—Typical Circuitry for the I.F. Stages of a Receiver.

first I.F. transformer (secondary); first I.F. transformer (primary). Unless otherwise stated in the manufacturer's instructions, repeat these adjustments to ensure utmost accuracy.

Where possible, re-seal the trimmers or cores after adjustment.

Finally, remove the short-circuit from the oscillator section of the ganged tuning capacitors.

Most modern British superheterodyne broadcast receivers are designed for an I.F. of about 470 kc/s; the manufacturer's specification, however, should always be consulted. Where the correct I.F. is unknown, the point of maximum response should be found and the receiver aligned to that frequency. Some older models use an I.F. of about 110 kc/s.

In some receivers the I.F. transformers are stagger tuned in order to give a bandpass response curve: for instance, the primary windings may be peaked at 473 kc/s and the secondarys at 467 kc/s. Occasionally it may be found preferable to render the A.G.C. circuits inoperative during alignment; this may be done by short-circuiting the points marked X in Fig. 1.

I.F. Wave-trap

Some receivers are fitted with either a series-tuned (acceptor) or parallel-tuned (rejector) wave-trap adjusted to the I.F. Its function is to reduce break-through of transmissions at or near this frequency. Alignment should be made after the I.F. circuits have been adjusted and before the final alignment of the R.F. circuits. Standard procedure is as follows:

Connect the output leads from the signal generator to the aerial and earth sockets of the receiver through a dummy aerial.

Tune the receiver to 550 m.

Set the volume control at maximum gain and the tone control at maximum H.F. response.

Inject a strong modulated signal at the frequency to which the I.F. stages have been aligned.

Adjust the core or trimmer of the I.F. wave-trap for minimum response on the output meter.

Alignment of R.F. Circuits

Alignment is usually carried out at two points on each waveband; one near the high- and the other near the low-frequency limits. Typical alignment points are: Medium waveband, 200 m. (1,500 kc/s) and 500 m. (600 kc/s); Long waveband, 1,000 m. (300 kc/s) and 2,000 m. (150 kc/s); Short waveband, 16 m. (18·8 Mc/s) and 50 m. (6 Mc/s). Convenient frequencies are usually given by manufacturers in their service literature, although the frequencies chosen are not unduly critical, except, perhaps, where special alignment calibration marks are provided on the dial for the convenience of the service engineer.

An example of R.F. alignment on the medium waveband of a standard superheterodyne receiver is given below.

Check that the tuning cursor or drum, or both, are correctly

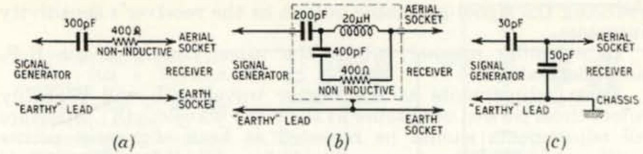


FIG. 2.—DUMMY AERIALS FOR R.F. ALIGNMENT.

(*a*) Simple system. (*b*) 'Standard' type recommended for M.W. alignment. (*c*) Suitable system for car radios.

adjusted in relation to the position of the rotary vanes of the ganged tuning capacitors.

Test the tuning mechanism for slip and backlash, and make any necessary adjustments prior to circuit alignment.

Connect the output leads from the modulated signal generator to the aerial and earth sockets of the receiver through a dummy aerial, taking care that the "earthy" lead (usually the outer conductor) is connected to the earth socket. Connect the output meter to the receiver.

Set the signal generator to the higher of the two alignment frequencies (*e.g.*, 1,500 kc/s, 200 m.).

Switch the receiver to the medium waveband.

Set the tuning cursor accurately to the selected wavelength and adjust the medium-wave oscillator trimmer until the signal is heard. The correct adjustment position will be that which gives a maximum response on the output meter.

Adjust the signal-frequency circuit of the frequency-changer valve for maximum output, reducing the signal-generator output as receiver sensitivity increases.

Adjust the tuned circuit of the R.F. amplifier stage (where such a stage is provided) in a similar manner; *i.e.*, set the trimmer to give maximum response on the output meter.

Where only slight misalignment of the receiver circuits is suspected, make a quick test of the sensitivity at the centre and L.F. end of the band, since adjustment of the trimmers may be sufficient to restore the accuracy of alignment. Where the performance of the receiver is still unsatisfactory, however, continue re-alignment as follows:

Set the signal generator to the lower alignment frequency (*e.g.*, 600 kc/s, 500 m.).

Set the tuning cursor accurately to the selected wavelength and adjust the medium-wave oscillator padder or medium-wave oscillator dust-iron core until the signal is heard. The correct adjustment position will again be that which gives a maximum reading on the output meter.

Adjust the tuned signal-frequency or "aerial" circuit of the frequency-changer valve by means of the padder (often omitted) or adjustable dust-iron core to give maximum output, rocking the ganged tuning capacitors slightly during each adjustment and reducing the signal-generator output as the receiver's sensitivity increases.

In a similar manner, adjust the tuned circuit of the R.F. amplifier valve.

These adjustments at the higher wavelength will probably affect those carried out earlier at the lower wavelength; therefore all adjustments should be repeated at both alignment points until no further improvement can be obtained. Where it is impossible to eliminate completely this fault, which is known as "pulling", the final adjustment should be made at the higher-frequency position (*e.g.*, 1,500 kc/s).

The alignment procedure outlined above is equally applicable to the long and short wavebands, in each case adjustment to the trimmers being made at the higher frequency and adjustment to the cores or padders being made at the lower alignment frequency. In some receivers, however, certain of the adjustment points are omitted on one or more of the wavebands, and the procedure must be modified accordingly. On portable receivers, for example, only trimming capacitors may be provided on L.W., and in such cases the receiver is usually aligned at 1,500 m. (200 kc/s).

It is difficult to secure accurate alignment over an entire waveband, especially where the frequency ratio is high. Practical alignment is therefore often a matter of compromise, and some variation in sensitivity will usually remain, no matter how carefully the circuits are adjusted. For normal broadcast reception such discrepancies are usually of little practical importance.

Where the layout of trimmers and inductors is unknown, this must be traced before commencing alignment. Most manufacturers supply such information, but failing this, examination of the circuit wiring and comparison of the relative sizes of the various inductors must be resorted to. By lightly touching adjustment screws with a metal screw-driver while the receiver is succesively switched to each waveband, the strength of the resulting clicks will prove a valuable guide as to which components belong to which circuits.

Alignment of S.W. Ranges

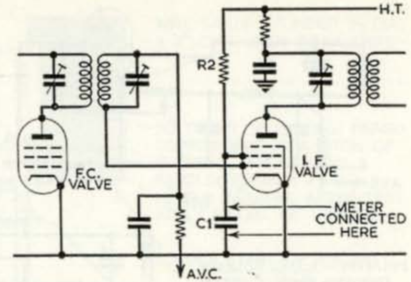
Although the re-alignment of short wavebands is fundamentally similar to that already described for the medium waveband, certain additional precautions are necessary if maximum performance is to be obtained.

Standard dummy aerials are usually unsatisfactory for S.W. operation, and should therefore be replaced by a 400-ohm non-inductive resistor connected between the signal generator and the aerial socket of the receiver.

As the frequency is increased, the second channel ("image") response will become more prominent. This is due to the decreasing percentage difference between signal and oscillator frequencies. Care should therefore be taken to ensure that the receiver is adjusted to the correct frequency and not to that of

FIG. 3.—TYPICAL I.F. CIRCUITRY FOR A BATTERY RECEIVER.

A.G.C. action varies the voltage drop across R2. A voltmeter across C1 measures the screen voltage of the I.F. amplifier. Resonance is indicated by an increase in this screen voltage.



the second-channel. The oscillator circuit is usually designed to track at a frequency higher than that of the signal frequency, though this arrangement is sometimes reversed. Generally speaking, there are two positions of the oscillator trimmer which give a satisfactory response, and the one requiring the lesser capacitance should be chosen.

Alignment without an Output Meter

Should neither an output meter nor sensitive A.C. voltmeter (0–5 or 0–150 volts) be available, alternative methods of indicating circuit resonances can be employed.

Where a "magic eye" or similar type of visual tuning indicator is fitted, this provides a rough indication of the signal voltage reaching the demodulator valve, and can therefore be used in much the same way as an output meter: an unmodulated signal generator can then be used. This form of indicator tends to be sluggish in response, and is not recommended.

A.G.C. circuits permit reasonably accurate alignment to be made with a sensitive D.C. voltmeter, indication of circuit adjustment being obtained by noting the effect of the A.G.C. voltage on one of the controlled stages. With this system, the injected signal should be unmodulated and of adequate strength to overcome the initial delay of the A.G.C. circuit. The D.C. voltmeter may be connected in any of several possible ways, two of which are shown in Fig. 1 (points "A" and "B") and in Fig. 3. That shown in Fig. 1 is recommended for mains-operated receivers; a voltmeter measuring 0-10 volts being connected across the bias resistor of the I.F. valve. As the circuits are brought into resonance, the A.G.C. applies additional bias to the grid of this valve, reducing the anode current and hence the voltage drop across the bias resistor. Resonance is thus indicated by a *decrease* in voltage. In Fig. 3—recommended for battery-operated models—a D.C. voltmeter measuring 0–100 volts is connected between the screen grid of the I.F. valve and chassis. The action is similar, but resonance is indicated by an *increase* in reading. With these systems it is possible to

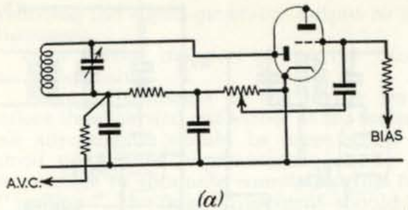


Fig. 4 (*a*).—A.G.C. Voltage Derived from the Demodulator Diode.

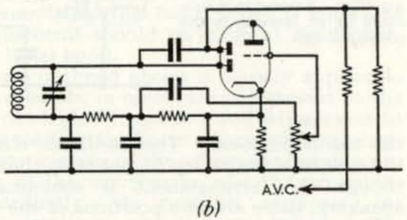


Fig. 4 (*b*).—A.G.C. Voltage Derived from a Separate Diode, Fed from the I.F. Transformer Secondary.

align a receiver on incoming broadcast signals, since the varying modulation depth will not affect the reading.

The details given in the preceding paragraph apply to the adjustment of all circuits up to and including the primary of the final I.F. transformer, but the type of indication to be expected when adjusting the secondary of this transformer depends upon the design of the receiver. As this circuit is brought into resonance it tends to extract power from the primary, thus when the A.G.C. voltage is derived from the anode of the I.F. valve, as in Fig. 1, a voltmeter connected across R1 would show a slight increase in reading at resonance. Where, however, the A.G.C. is derived from the signal diode (Fig. 4 (*a*)) or from a separate diode connected to the *secondary* of the final I.F. transformer (Fig. 4 (*b*)), the voltmeter reading will decrease at resonance.

Portable and Transistor Receivers

Where receivers are normally operated from internal frame or ferrite-rod aerials, the R.F. alignment signal should be injected by means of magnetic coupling to these aerials, and not by direct connection between the signal generator and the receiver. The R.F. signal should preferably be injected by means of standard shielded coil spaced about 1 ft. away from the frame or ferrite-rod aerial. A standard coil is shown in Fig. 5. Where a coil of this type is not available, a small loop aerial of about four turns and approximately the size of the frame aerial should be connected to the output leads of the signal generator and set up at least 2 ft. from the receiver. For preliminary adjustments, it may be necessary to place the output lead of the generator near the grid of the frequency changer, but this type of coupling should not be used for the final adjustments. Final adjust-

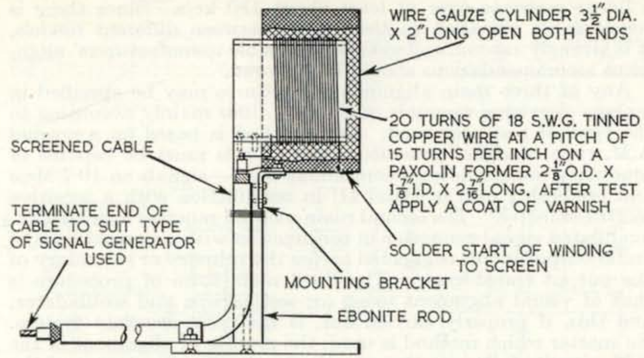


Fig. 5.—Construction of a Dummy Aerial for the Alignment of Models with Frame or Ferrite-rod Aerials.

ments of ferrite-rod aerials are normally made by sliding the coils along the rod, afterwards preventing further movement by a quick-drying adhesive.

The receiver should always be aligned with the batteries and loudspeaker in the same position relative to the frame aerial as they are under normal conditions, as otherwise the inductance of the frame aerial is likely to be affected when the receiver is reassembled within its cabinet.

The alignment of transistor receivers follows basically similar procedures to that of valve portables. Particular points to note are as follows: I.F. signals are usually injected to the base connection of the mixer transistor via a 0·1–0·5μF capacitor from the "direct" generator output connection. Signal generators and other mains-operated servicing instruments should not be connected directly to transistor equipment (due to risk of leakage current); connect isolating capacitors in each lead. Keep injected signals low to avoid damage to transistors. Either single- or double-tuned I.F. transformers may be encountered. Some makers recommend "stagger tuning" of I.F. tuned circuits to improve overall response.

ALIGNMENT OF F.M. RECEIVERS

The audio quality of an F.M. receiver depends to a considerable extent upon the accuracy of alignment of the ratio detector transformer and the I.F. stages, as the response curve should be as nearly linear as possible over the full band-width and balanced about the nominal I.F., see Fig. 6 (*a*). In practice, the band-width of most models is less than the 230 kc/s desirable for high-fidelity reproduction, but every effort should be made to achieve a linear response over at least about 180 kc/s. Since there is considerable variation in the details between different models, it is strongly recommended that if possible manufacturers' alignment recommendations should be followed.

Any of three main alignment procedures may be specified in makers' servicing manuals, and these differ mainly according to the type of test gear used. One method is based on a normal A.M. type of signal generator (though this must be capable of producing unmodulated—continuous-wave—signals on 10·7 Mc/s and preferably also in Band II) in conjunction with a sensitive multi-testmeter. The second main method requires a frequency-modulated signal generator in conjunction with a normal type of audio output meter connected across the primary or secondary of the output transformer. The third main form of procedure is that of visual alignment using an oscilloscope and wobbulator, and this, if properly carried out, is the most accurate system. No matter which method is used, the process of alignment of the F.M. circuits falls into three sections: (1) the adjustment of the I.F. transformers from the frequency changer as far as the discriminator transformer; (2) the alignment of the discriminator transformer; and (3) the alignment of the R.F. circuits of the oscillator and mixer, and of any I.F. break-through traps.

Where visual display equipment or an F.M. signal generator is not available, the procedure given in Table 1 will give good results, provided care is taken. Equipment required: signal generator covering 10·7 Mc/s; high-sensitivity voltmeter (5–10 volts full-scale deflection, 20,000 ohms/volt or better); micro-ammeter, 200–250 μA full-scale deflection; and, for unbalanced ratio

TABLE 1.—ALIGNMENT OF RATIO DETECTOR AND F.M./I.F. CIRCUITS

Recommended order of procedure when using unmodulated signal generator

Circuit(s)	*Meter and Adjustment*
1. Primary of ratio detector transformer	Connect voltmeter as *X* in appropriate section of Fig. 6. Adjust core for maximum reading
2. I.F. transformers (working backwards from last I.F. stage to mixer output)	As 1, reducing input as necessary to maintain reading of about 4 volts
3. Secondary of ratio detector transformer	Micro-ammeter as *Y* in Fig. 6. Adjust for zero reading centrally between two peaks of opposite polarity
4. Readjust primary of radio detector transformer	As 1
5. Readjust I.F. transformers	As 2
6. Finally, readjust ratio detector transformer secondary	As 3

7. Check response curve to ensure that the peaks (Fig. 6 (*a*)) are centrally balanced about zero point. To check this, measure *Y* readings at 10·6 Mc/s and 10·8 Mc/s (or as appropriate if I.F. is other than 10·7 Mc/s). Readings should be within a few micro-amperes of each other.

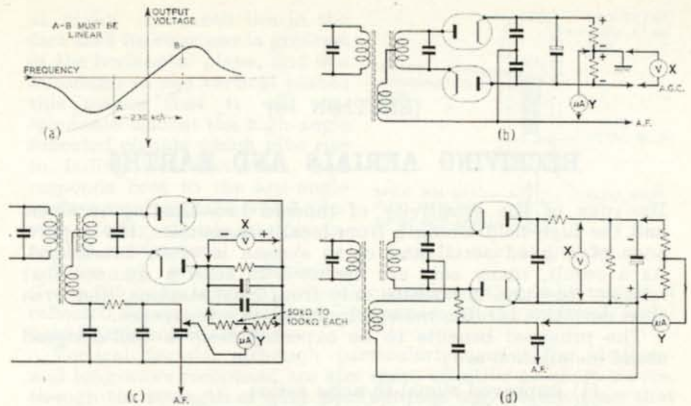


FIG. 6.—ALIGNMENT OF BALANCED (*b*) AND UNBALANCED (*c*) AND (*d*) RATIO DETECTORS.

In practice, the ideal linear bandwidth of about 230 kc/s cannot always be achieved, and it may be necessary to accept a figure of about 180 kc/s.

detectors, a pair of matched carbon resistors between 50k and 100k. In practice, the voltmeter and micro-ammeter may take the form of a single multi-testmeter.

An unmodulated 10·7 Mc/s is injected into the I.F. strip (often by means of a capacitive clip or loop of wire placed on the V.H.F. frequency-changer valve envelope), and the procedure is then as outlined in Table 1.

When adjusting intermediate-frequency transformers at 10·7 Mc/s or above, it is necessary to use television-type trimming tools of non-metallic material with a long handle. It is most essential to allow plenty of time for the receiver to reach a stable operating temperature before starting adjustments. After adjustment, transformer and coil cores should be sealed.

Some receivers using an unbalanced ratio detector incorporate a preset variable resistor to provide an A.M. rejection control. Should it be necessary to reset this, inject an A.M. signal from a high-quality signal generator known to be free of all frequency modulation and adjust the control for minimum audio output.

If output from the V.H.F. local oscillator reaches the aerial it will radiate and may cause interference to nearby television receivers. Many V.H.F. front-end units include a trimmer which can be adjusted to neutralise radiation. Unless radiation is troublesome, it is usually best not to attempt to reset this control, as incorrect setting can cause instability. When necessary, adjustment can best be carried out with the aid of a sensitive valve voltmeter fitted with a V.H.F. probe, adjusting for minimum oscillator voltage on the aerial socket or intervalve coupling coil.

[SECTION 10]

RECEIVING AERIALS AND EARTHS

BECAUSE of the sensitivity of modern broadcasting receivers and the high field strength from local transmitters, the importance of a good aerial and earth system is often overlooked. As a result, many sets are operated in such a manner that reliable reception is possible only from local stations, and even then reception is often marred by needless interference.

The principal benefits to be expected from a well-designed aerial installation are:

(1) improved signal-to-noise ratio;
(2) reduced local electrical interference;
(3) increased sensitivity (better distant-station reception on all wavelengths);
(4) greater freedom from the effects of night-fading on distant stations.

The fact that an output signal of programme value can be obtained with a short length of wire attached to the aerial socket of the receiver should not be regarded as indication that nothing more elaborate, in the form of an aerial, need be provided. It is also important to recognise that in almost all aerial systems for reception on the medium- and long-wave bands, the earth forms an important, integral part of the system, quite apart from other factors such as safety.

Aerial systems designed especially for the reduction of electrical interference are described in Section 11.

Vertical Rod Aerials

One of the most effective types of aerial for broadcast reception consists of a rigid or semi-rigid vertical aerial element, mounted on the top of a mast or attached to a chimney or some convenient high point, combined with an external insulated-wire downlead which forms an electrical extension to the aerial and should be taken directly to the receiver. The vertical aerial element may consist of sections of taper-jointed, high-tensile, light-alloy tubing supported in resilient insulators to a bracket for convenient mounting. The vertical height of such rod aerials may be from 10 to 20 ft., and will be most effective when mounted so that the highest point is some 50 ft. or so above ground.

This type of aerial will give excellent results not only within the recognised service area of medium- and long-wave stations, but will perform very satisfactorily at much greater distances, where signal fading from ionospheric reflections may be expected

at night. Its merit lies in the fact that its response is greatest in the horizontal plane, and is a minimum in the vertical plane; this means that it will discriminate against the high-angle reflected signals which give rise to fading and distortion, and responds best to the low-angle surface-wave signals, which provide steady signals in the extended service area.

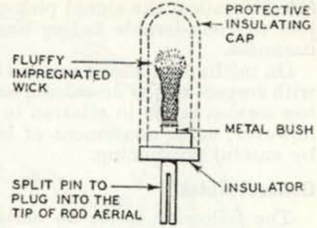


FIG. 1.—CORONA DISCHARGER.

Even at greater distances (from 200 miles upward), where normal reception is by means of reflected waves, the low-angle properties of the vertical aerial help to minimise fading.

Vertical aerials, although particularly useful for medium- and long-wave reception, are also quite effective on short waves, though the strength of semi-local stations may be less than that obtained with horizontal aerials. They are, however, very effective in receiving long-distance transmissions from all directions.

In certain atmospheric conditions corona discharge may occur from the tip of a rod aerial. A device such as that shown in Fig. 1 will permit continuous discharge of the rod without causing radio interference.

Inverted-L and T Aerials

The inverted-L aerial, Fig. 2, is probably the most widely used of all outdoor aerials. It consists essentially of a horizontal length of wire, insulated at both ends and continued downwards at the end nearer the receiver. The aerial should be erected as high as possible, and may be anything from 30 to 150 ft. in length.

It is not always appreciated that on medium and long waves, the effective part of the aerial is the vertical downlead; the horizontal section being used to add top capacitance to the vertical section so as to increase its electrical length and raise the electrical impedance of the aerial as presented to the receiver. However, although the top section is quite unresponsive to the surface wave from a transmitter, it will pick up signals reflected downwards from the ionosphere, and thus at medium distances

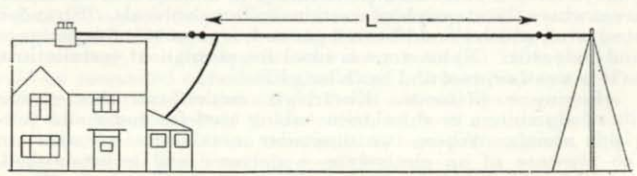


FIG. 2.—INVERTED-L TYPE AERIAL.

(50–500 miles) the signal pick-up may be high, but will be subject to considerable fading and distortion during the hours of darkness.

On medium and long waves the aerial is almost non-directional with respect to the downlead, and it is immaterial which way the top section is run in relation to the direction of the transmitter: however, some abatement of local interference can be achieved by careful positioning.

General Notes

The following notes on aerial construction and maintenance are applicable to normal types, such as the inverted-L and T aerials, to special short-wave types and to the installation of rod, anti-static and community aerials.

Wire. Hard-drawn enamelled wire of not less than 16 S.W.G. is probably the most efficient electrically, with stranded 7/22 copper wire a close second. The stranded wire offers certain mechanical advantages, and is the more widely used; however, it is less resistive than enamelled wire to the effects of a corrosive atmosphere. With stranded wire, care should be taken to see that there are no broken strands, as these can cause crackling on short waves.

Insulators. For maximum efficiency on short waves, insulators having a long leakage path should be chosen. Where the small egg-shaped insulators are used, at least two, and preferably three, should be connected in series. The aerial and lead-in should be insulated from any guttering or projecting walls, and a low-loss feed-through fitted to enable the lead-in to be brought into the house. A wide range of aerial accessories and fittings, such as gutter insulators, stand-off brackets and clips, are commercially available, and their judicious use will greatly facilitate the erection of neat and sturdy aerials.

Position. The aerial and lead-in should be kept well clear of trees and walls.

Supports. Where wooden masts are used, these should be liberally treated with creosote, particular attention being paid to any part to be sunk in the ground. The mast should be capped with a disc of hardwood secured by two or three long French (oval-section) nails.

Rigging. Good materials should be used to counteract the effects of wind and weather. For example, standard galvanised pulleys have a short life, particularly in coastal and industrial areas where the atmosphere contains salt or chemicals. Stranded steel wire, which should be well greased, is most suitable for guys and halyards. Nylon rope is ideal for permanent installations as it is weatherproof and has a long life.

Aluminium Elements. Electrolytic action can shorten the life of aluminium or duralumin tubing used for radio and television aerials. Where two dissimilar metals are in contact in the presence of an electrolyte, a galvanic cell is established, and the metal forming the negative pole is attacked. These

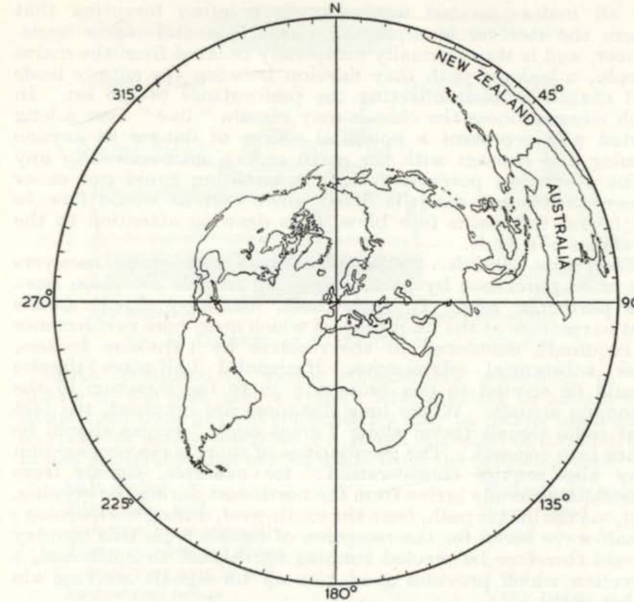


FIG. 3.—GREAT-CIRCLE MAP, CENTRED ON LONDON.

When planning S.W. aerial installations, it is important to note that radio waves travel along great circle routes, and that the radio direction of certain countries may lie along unexpected bearings.

conditions occur, for example, in coastal or industrial districts when brass or steel bolts have been used to fasten aluminium-alloy rods. Electrolytic action can be reduced by using cadium-plated screws or anodised tubing and by painting all joints so as to keep out moisture and thus prevent the electrolyte forming.

Under movement duralumin and similar materials tend to crystallise and eventually to fracture. Undue vibration of rod aerials should therefore be damped down by the connection of insulated cords to points of maximum movement.

Safety. To provide protection from lightning and to prevent static charges building up on outdoor aerials and causing damage to the receiver, a lightning arrester or substantial knife-switch should be connected outside the building. Proprietary types of lightning arresters often take the form of a small spark gap, one side of which is connected to the aerial, while the other goes to earth. As the action is automatic, they are preferable in the main to switches, which may be forgotten.

An efficient earth also provides an important safety factor for all mains-operated receivers: it is often forgotten that where the receiver incorporates a double-wound mains transformer, and is thus normally completely isolated from the mains supply, a leakage path may develop between the supply leads and chassis without affecting the performance of the set. In such circumstances the chassis may remain " live " over a long period and represent a potential source of danger to anyone coming into contact with the earth socket, grub-screws or any point at chassis potential. Such a situation could not occur where an efficient earth is fitted, since current would flow to earth and the mains fuse blow, thus drawing attention to the existence of a fault.

Short-wave Aerials. High-performance short-wave receivers are often purchased by persons desiring reliable reception from one particular area. In such cases, half-wave dipole aerials (cut to resonate at the frequency on which maximum performance is required), connected to the receiver by twin-wire feeders, offer substantial advantages. Horizontal half-wave dipoles should be erected to run broadside on to the direction of the incoming signals. Where long distances are involved, the fact that radio signals travel along " great circle " routes should be taken into account. The peculiarities of short-wave propagation may also require consideration: for example, signals from Australia generally arrive from the north-east during the evening, and, via the longer path, from the south-west, during the morning; a half-wave aerial for the reception of signals from this country should therefore be erected running north-west to south-east, a direction which provides good pick-up for signals arriving via either path.

General. An aerial should not be erected across a public highway without permission having been obtained from the appropriate authorities, neither should one be run across power or telephone lines unless official permission is given.

Where aerial-installation work is undertaken, the radio service engineer should, in his own interests, be fully insured against any possible claims for faulty installation, etc. For example, the owner of an aerial which has blown down, causing injury or damage to third parties, may, in turn, claim against the firm which installed the aerial. A number of insurance companies have policies covering this type of work. Commercially manufactured types of radio and television aerials often carry insurance, for a specified period, covering lightning and certain other risks.

Earths

The importance of a good earth from the point of view of the overall effectiveness of the aerial system and also from that of safety has already been stressed. It should also be mentioned that, despite the greater efficiency of modern smoothing filters, a good earth may reduce hum and interference levels considerably.

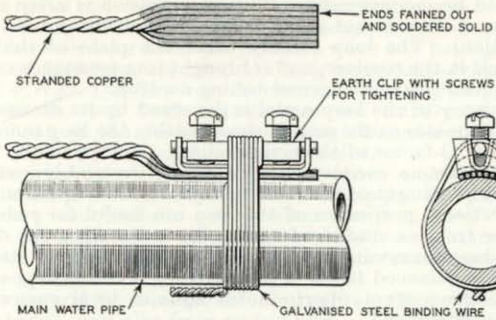


FIG. 4.—CLAMPING AN EARTH-WIRE TO A WATER-PIPE.

Earth conductivity varies considerably according to the nature of the soil, and a system which would be satisfactory under conditions of good conductivity may be totally inadequate in rocky or sandy districts. A rough appraisal of conductivity in any particular area can be made from the following table:

Salt water	Extremely good
Rich farm soil . . .	Very good
Average country soil . . .	Good
Town residential areas, rocky or sandy soil . . .	Poor
Industrial areas . . .	Very poor

Efficient earthing systems can be made by sinking a 3–4-ft. copper rod, or several shorter rods spaced a foot or two apart, or a large copper plate, as deeply as possible in moist soil; a large biscuit tin is also most efficient.

A rising-main water-pipe is also most suitable, provided that its surface is thoroughly cleaned, after which the connection should be made by means of a tightly fitting clamp (see Fig. 4). Gas, hot-water or drain pipes should never be used, nor should any connection be made to an existing telephone earth. The earth-continuity conductor of three-wire domestic electric supplies may be used, but is not recommended, since local electrical interference may be introduced into the receiver by this means.

The earth lead should be of substantial-gauge wire or stranded copper wires, as short and as direct as possible, preferably with an insulated covering. The lead should be soldered to the earth rod or plate and at any joints in it length; it should be protected where it enters the ground by a short length of suitable piping.

The Frame or Loop Aerial

For broadcast reception, the vertical loop or frame aerial has its principal application in portable receivers, where an external aerial would be inconvenient (although provision is often made for the use of an external aerial when the receiver is used in a fixed location). The loop usually takes the place of the first tuned circuit in the receiver, and is brought into resonance on the desired frequency by the normal tuning controls.

The efficiency of the loop aerial is governed by its dimensions —becoming greater as the area enclosed within the loop increases —and by the Q-factor of the coil winding. Unfortunately with most normal frame aerials the Q-factor is invariably reduced by the close proximity of the metal chassis and loudspeaker.

The directional properties of the loop are useful for reducing interference from an undesired station by orientating the direction of the loop for minimum pick-up from the unwanted station. If the loop is balanced to earth (by earthing a centre tap, or by screening), the system discriminates against local man-made electrical interference.

In order to obtain a high Q-factor, and thus increase efficiency, the winding may be with Litz wire, say 9/40 S.W.G., but acceptable results can be achieved with solid wire of about 26 S.W.G. In practice, various methods of winding the loop—single-layer solenoid, wound flat, solenoid folded flat, etc.—are used, and the loop is supported and held together in a number of ways.

While the results on medium waves are usually satisfactory, more difficulty is experienced on long waves. If the loop consists of the tuned circuit inductance, this is expensive and difficult to manufacture because of the large number of turns of fragile wire involved. Frequently, therefore, the medium-wave loop is series-loaded by a small coil, to bring the total inductance up to the value required. Such an arrangement is not likely to prove very efficient, but may suffice where, for example, only Droitwich reception is required. A somewhat more efficient method is to couple the medium-wave loop to the long-wave tuning coil by a tight coupling coil. An extension of this system, occasionally used, is a single-turn loop coupled to tuning coils on both medium and long waves. For this system to be efficient the Q-factor of the single turn must be made as high as possible, and a conductor of large cross-section is essential (about 0·1 sq. in.). The main advantage of this type of loop is that the centre may be easily earthed; this, as already mentioned, reduces the pick-up of electrostatic waves, and thus discriminates against electrical interference.

The Ferrite-rod Aerial

The relative poor efficiency of the series-loaded loop aerial on long waves has led to an increasing use being made of ferrite-rod aerials. This type of aerial is basically a loop aerial using a small coil wound on a high permeability rod which concentrates the flux from a relatively large area. An aerial of this type is directional in the same way as the more orthodox form of loop, minimum reception being obtained when the rod is pointing directly towards the transmitting station.

A typical rod aerial for medium-wave and long-wave reception consists of an 8-in. rod, $\frac{5}{16}$ in. diameter, with two coils wound on thin-walled formers, the medium-wave coil having forty-four turns of 9/46 Litz wire, and the long-wave coil having 138 turns of 42 S.W.G. D.S.C. wire. In each case the coil forms the input inductance, and final adjustments are usually made during alignment of the receiver by sliding the coils along the rod; afterwards apply a quick-drying adhesive.

The winding of both the medium-wave and long-wave coils on the same former may introduce damping, and hence loss of efficiency on medium waves when the long-wave winding is short-circuited. For this reason some manufacturers prefer to split the rod into two sections, one for medium waves, the other for long waves.

Ferrite-rod aerials should be kept as far as possible from metalwork, and also from undue heat. The sensitivity of these aerials depends largely upon the size and permeability of the rod, but usually provides considerably better results on long waves than can be obtained with series-loaded loops, though the medium-wave performance may not be quite so good as with a well-designed frame.

Other Types

The plate or capacitance aerial, normally used only with mains receivers, generally consists of a metal foil fixed inside the cabinet. A useful feature is that, unlike normal loop systems, it provides reasonable pick-up on the short-wave band. It is not always appreciated that the addition of a good earth to a receiver using a plate aerial may reduce sensitivity. This is because the capacitance of the plate completes the return path to earth of signals picked up in the mains wiring, though when used in this condition the system is susceptible to mains-borne interference. Where such interference is experienced, some improvement may be effected by the connection of a fairly long (20 ft. or more) earth lead.

The " throw-out " aerial (usually a wire about 6–10 ft. long) functions in the same way as the plate aerial, but here again it is worth noting that, since it is sometimes tightly coupled to the grid of the first valve, adding extra length may decrease rather than increase sensitivity unless the input circuits are re-aligned.

Although popular at one time the " mains " aerial, in which one side of the mains lead is connected to the receiver input via a capacitance of about 30 pF (often this takes the form of a " third " lead in the mains cable), has now fallen into disfavour, mainly on account of its susceptibility to mains-borne electrical interference.

Vertical telescopic aerials are not widely used in this country, except for portable receivers in which the short-wave performance is considered particularly important. Since its characteristics remain constant, the loose coupling used for aerials of

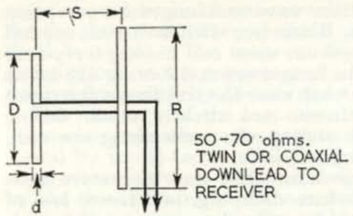


FIG. 5. DIPOLE AND REFLECTOR DIMENSIONS FOR F.M./V.H.F. AERIALS.

The aerial elements will be mounted in the horizontal plane to receive transmissions from the first F.M. stations.

Diameter of Tubing (in.)	*Dipole Length* D *(in.)*	*Reflector Length* R *(in.)*	*Spacing* S *(in.)*
½	$\frac{5270}{F\ (Mc/s)}$	$\frac{5666}{F\ (Mc/s)}$	
⅜	$\frac{5400}{F\ (Mc/s)}$	$\frac{5783}{F\ (Mc/s)}$	$\frac{1770}{F\ (Mc/s)}$
¼	$\frac{5453}{F\ (Mc/s)}$	$\frac{5902}{F\ (Mc/s)}$	

unknown impedance is obviated, and the rod is often coupled directly to the hot end of the first tuned circuit.

Aerials for F.M. Reception

While many F.M. receivers contain built-in dipole aerials suitable for use in areas of good signal strength, and others may be operated from normal long-wire types, the provision of a special aerial for the reception of F.M. signals will provide a worth-while increase in signal strength in many locations. In general, simple horizontal dipoles constructed from high-tensile light-alloy tubing will be sufficient, and, where necessary, these may be supplemented by a reflector element. Formulæ for the calculation of dipole and reflector lengths are given in Fig. 5. The polarisation of the transmitting aerial must be taken into account when erecting such aerials. The B.B.C. is employing horizontal polarisation for its initial F.M. stations.

Where the pick-up of an internal dipole is insufficient, but the area is one where reasonable signal strengths are to be expected, a simple indoor room aerial may give improved results. Due to shielding and out-of-phase reflections, etc., pick-up of Band II V.H.F. signals may vary greatly at points only a few feet apart. A simply constructed room aerial is recommended by the B.B.C. for use in such circumstances. As shown in Fig. 6, the aerial comprises a length of about 10–15 ft. of good-quality twin electric-lighting flex, one end of which is untwisted for a length of approximately 2 ft. 6 in. A piece of cord is then used to bind the flex to prevent further untwisting. The two separated wires are spread out horizontally to form a half-wave dipole element, approximately 5 ft. long. The twisted flex forms a feeder line, the end of which can be connected to the 75-ohm-impedance sockets in

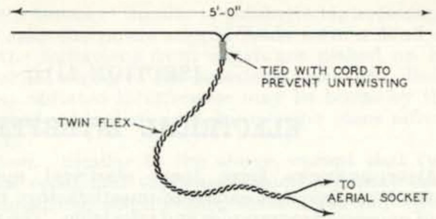


FIG. 6.—SIMPLE V.H.F. DIPOLE FROM GOOD-QUALITY LIGHTING FLEX.

the V.H.F. receiver. The horizontal dipole may be run along the picture rail or fixed in some other convenient position. For optimum results, it will probably be necessary to try the aerial in several positions, and to try the effect of tilting the arms slightly. Unlike when swinging a ferrite-rod or frame aerial on A.M. stations, optimum and minimum pick-up of an F.M. transmission may not show up as any appreciable change in receiver output, but in general, minimum pick-up will be denoted by rise in background noise and by increased susceptibility to ignition and other electrical interference.

Multi-path Distortion

Where part of the signal picked-up by a V.H.F. aerial arrives indirectly, due to reflections from large objects, etc., the phase differences which occur as a result of the differing path lengths cause the signal to be both amplitude and phase modulated. In severe cases this spurious modulation cannot be rejected by the receiver's A.M.-limiting circuits and causes an unpleasant breaking up of the high audio frequencies (sometimes termed the "tissue paper" effect), most noticeable on high-quality installations. This type of distortion can occur almost anywhere in the service area of a transmitter, but is usually most troublesome in areas of low signal strength, where the receiver's A.M.-limiting circuits are least effective. Multi-path distortion is sometimes mistaken for a loudspeaker or alignment fault, but can be identified by noting whether all stations are similarly affected; multi-path distortion is unlikely to be of the same intensity on different stations.

The cure for multi-path distortion is much the same as for the basically similar television "ghosting", that is to adjust the aerial for minimum indirect pick-up. The following suggestions are made by one manufacturer:

(*a*) When using an internal aerial move the receiver to different positions in an attempt to find a place where there is no distortion.

(*b*) Check with a simple dipole in the immediate vicinity of the receiver, *e.g.*, picture-rail dipole.

(*c*) Check with an outdoor or loft aerial.

(*d*) In very severe cases it will be advisable to instal an efficient directional outdoor aerial.

[SECTION 11]

ELECTRICAL INTERFERENCE

DISTURBANCES from local electrical appliances are among the most frequent causes of unsatisfactory reception, particularly of overseas programmes and television. The radio service engineer, by providing technical advice and by making available suppression devices to meet local requirements, can do much to assist the listener to overcome this problem and to enable him to distinguish between avoidable and unavoidable interruptions to programmes.

The Engineering Branch of the G.P.O is prepared to assist licence holders in the tracing of man-made interference and to offer advice on its suppression. Applications for assistance, which is provided free of charge, should be made by the licence holder on form T.466G " Electrical Interference Questionnaire " obtainable from any Head Post Office. This service is restricted to cases where the reception of the local broadcasting and television stations is affected, and no investigations are made in respect of interference to overseas stations and short-wave transmissions.

Electrical apparatus which utilises commutation (*e.g.*, D.C. motors and generators), vibrating contact points (*e.g.*, electric shavers), spark discharge (*e.g.*, automobile ignition) or any mechanism whereby an electrical spark, however minute, is produced will radiate damped R.F. waves, covering a wide frequency spectrum, unless preventive measures are taken. Certain other electrical appliances may also radiate R.F. energy. Radiations of either type may be rendered audible by a radio receiver in the form of continuous crackling, sporadic clicks, buzzing or humming noises, a number of which are characteristic of the source causing the trouble. Such disturbances are readily distinguishable from natural atmospherics, which are likely to be troublesome only in hot weather and which occur in no regular sequence.

Interference may reach the receiver by :

Direct Radiation from the Source. Except for electro-medical apparatus and car interference on H.F. and V.H.F., radiation is likely to occur only over a comparatively short range, especially on the broadcast bands. Arcing between the collector and overhead wires of trolley buses or between the shoes and rails of electric trains may, however, cause interference by direct radiation to programmes transmitted on medium and long wavebands.

Conducted Interference. This is probably the most frequent path of transmission on medium and long waves. The electrical disturbances are conducted along the power-supply lines and injected into the receiver by way of the mains lead.

Mains-radiated Interference. Similar to conducted interference. except that in this case the power-supply leads form a kind of transmitter aerial, the radiations from which are picked up by the aerial or the internal wiring of the broadcast receiver. Both conducted and mains-radiated interference may be borne by the power lines over considerable distances, in extreme cases affecting an entire district.

Secondary Radiation. Similar to the above, except that two direct radiation links occur and the transmission line may take the form of telephone wiring, neighbouring aerials, gas and water pipes and so on.

Interference can be received in three ways : (1) pick-up by the aerial and lead-in wires; (2) injection into the receiver via the mains supply leads; and (3) by stray electric fields. Apart from cause (2) both mains-operated and battery-operated receivers can be equally affected.

CURE OF INTERFERENCE

In order to reduce or eliminate interference, it is necessary :

1. To ascertain the path by which the interference reaches the receiver.
2. To identify, wherever possible, the source of interference, and to ensure that adequate suppression is applied.
3. Failing this, or where complete suppression at the source is not practicable, to fit interference filters at the receiver, or close to the receiver end of the path.

The manner in which the interference reaches the receiver can usually be ascertained by carrying out a few simple tests, though it should be noted that, in practice, a combination of two or more routes is not uncommon. Where interference occurs only intermittently it may be necessary to ask the owner of the receiver to carry out these tests while the interference is present.

1. Remove the aerial and earth leads from the receiver and short-circuit the appropriate sockets. Directly radiated and mains-radiated interference should then cease altogether or be greatly reduced, whereas mains-conducted interference may be hardly, if at all, affected.
2. Test the relative strength of interference under no-signal conditions at the high- and low-frequency ends of each waveband. Directly radiated interference tends to increase as the wavelength decreases, and will usually be much increased in strength on the short wavebands. Disturbances from mains-conducted interference, on the other hand, will normally become stronger as the wavelength is increased and be most troublesome on the long waveband.
3. If a battery-operated receiver be available, the effect of switching off the electric power at the main house switchboard should be noted. Should the interference continue

it is unlikely that mains-borne R.F. signals are the cause. If the interference ceases, it would seem that interference is entering the premises via the mains supply wiring, or alternatively, that the source is located within the premises concerned.

Identifying the Source of the Trouble

Often the interference source will be obvious or easily traced from the characteristic nature of the disturbance and from observation of the times at which it is experienced. The source of directly radiated interference is normally restricted to within a radius of a few hundred feet of the receiver.

More troublesome causes may be traced with the assistance of a portable battery receiver, preferably fitted with a frame aerial. Portable receivers which have no frame aerial can be used by simple observation of the strength of the interference, provided that it is possible to move freely within the search area.

Mains-borne and mains-radiated interference, which may originate at a considerable distance from the receiver, may prove much more difficult to trace; it will not be possible to pin-point the direction of the source until the search has been narrowed to the area within which directly radiated interference can be received. The effect of removing the fuses, one at a time, from each of the house circuits and of switching off the power at the main switchboard should be noted: this procedure will usually establish whether or not the interference is arising from defective switches, cable joints or apparatus within the building. Where mains-borne interference originates outside the premises, and the source is not obvious, it will usually be necessary to obtain assistance from the Engineering Branch of the G.P.O., who have developed specialised techniques for tracing elusive sources of interference.

Suppression at the Source

On the ground that "prevention is better than cure", interference should wherever possible be suppressed at the source, though in practice suppression at the receiver as well as at the source is often necessary. The aim of most suppression devices is to confine any R.F. currents which may be generated to that particular circuit, or at least to the apparatus concerned, by the use of suitable isolating resistors or chokes in conjunction with by-pass capacitors. Sufficient suppression can often be achieved by the use of by-pass capacitors alone; where they alone are ineffective, chokes should be included in the line circuit to offer high impedance. Since these chokes often carry considerable current, they must be of low resistance and suitably rated for the apparatus concerned.

A wide range of interference-suppression devices which are suitable for most normal requirements has been developed and marketed.

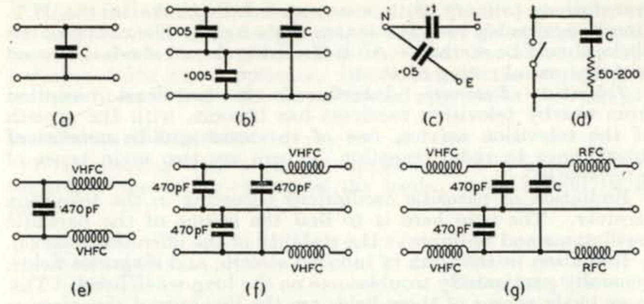


FIG. 1.—CIRCUITS OF COMMONLY USED INTERFERENCE-SUPPRESSION DEVICES.

(*a*) For two-core cable appliances. (*b*) For three-core cable appliances. (*c*) For three-pin socket. (*d*) For thermostats. Types (*e*) and (*f*) are for suppression of television interference from two- and three-core appliances. Type (*g*) is an all-wave filter for broadcast and television interference suppression. The value of *C* may vary between 0·01 and 0·5 μF. On type (*c*) the values given are the largest permissible.

Commutator Motors. Capacitor or inductor-capacitor filters should be connected as close as possible to the motor. An R.F. choke should be included in the earth lead if the performance is better without the earth connection.

A.C. Synchronous and Induction Motors. These do not usually cause interference; and the exceptions can generally be suppressed with a simple capacitor filter.

A.C. Repulsion Motors. The capacitor unit should be connected across the mains-supply feed to the motor and not across the brushes.

Small Motors. Unearthed motors in portable appliances are a prolific source of interference. The centre point of a capacitor filter of the type shown in Fig. 1 (*b*) is taken to the motor frame. This tends to place the frame above earth potential, but the possibility of shock is avoided by keeping the capacitors small in value.

Flashing Electric Signs, Thermostats, etc. Capacitors should be connected across the contacts in series with resistances to introduce time-lag. R.F. chokes must be included in the mains supply lead.

Lifts. The makers of the equipment usually supply the necessary suppressors for preventing the radiation of interference from the motor control panel or trailing cables.

Electro-medical Equipment. Direct radiation on short waves and mains-conducted disturbances may be produced over considerable distances. Complete suppression can often be achieved only by operation of the equipment in a screened room with choke filters on all wires passing out of this room.

Neon Signs. Capacitor filters should be connected across the transformer primary with a screened L.F. choke in the H.T. circuit, preferably near the centre of the sign. The casing of the choke should be earthed. All H.T. wiring should also be screened with the metal casing earthed.

Television Receivers. Interference to broadcast reception from nearby television receivers has become, with the growth of the television service, one of the most prolific sources of interference to radio reception. There are two main types of interference :

Radiation of parasitic oscillations occurring in the television receiver. The cure here is to find the source of the parasitic oscillations and to improve the stability of the offending stage(s).

Radiation in the form of induced electric and magnetic fields, generally particularly troublesome on the long-wave band. The most likely source of these fields are the line-output transformer and associated parts at E.H.T., the deflector coils and the high-impedance circuits near these components. The remedy for this type of interference obviously lies primarily in the design and construction of the television receiver. However, when encountered, improvement can often be effected by careful placing of the television receiver in relation to the radio receiver, avoiding, for instance, back-to-back siting on either side of a party wall, or by altering the run in of the radio aerial to ensure that this is as far away as possible from the television receiver. More drastic remedies include the fitting of a perforated foil screen to the back of the television receiver or the application of a proprietary preparation of colloidal graphite.

Fluorescent Lighting. A small capacitor, usually of 0·02 μF, is fitted across the starter contacts to suppress radio interference, which may be generated within the lamp, and also to give a cleaner break to assist starting. Occasional interference of a continuous nature, however, may be experienced on medium and short waves either by direct or mains-conducted radiation. This interference may not arise immediately in a new tube, and if the tube is handled it may stop temporarily. Proprietary suppressors designed to eliminate this form of interference are available.

Suppressor Components

It is most important that components of adequate A.C. rating should be used in suppressors, and for this reason only components specifically designed for this purpose should be fitted.

Capacitors for suppression work have particularly strict requirements, since not only must there be a large safety factor against voltage breakdown, but the insulation resistance should also be very high and the series inductance as low as possible. Further, the capacitors are often fitted in close proximity to motors, and must be capable of withstanding high temperatures. A voltage breakdown in a suppressor fitted to domestic apparatus could easily become a source of danger to the user. For all these reasons, it cannot be too strongly emphasised that only capacitors expressly manufactured for the purpose should be used.

When fitting capacitor suppressors, it is also necessary to ensure that there is no danger that the user of the appliance may receive a shock due to the leakage current. For example, on a portable three-wire appliance, the value of the capacitance between line and frame should not exceed approximately 0·005 μF.

Installation of Suppressors

When dealing with three-pin appliances, it is important to remember the colour-coding of the leads, which should be as follows :

Line (L)	Red
Neutral (N)	Black
Earth (E)	Brown or Green

A three-pin *socket* which has been correctly wired will have the thick earth socket on top, the neutral socket on the bottom left and the line socket on the bottom right. These positions are those when looking into a socket mounted on the wall, and must be reversed when looking at the back of the socket for wiring purposes. Unfortunately by no means all domestic sockets are correctly wired. A simple test can be made by checking with an inspection lamp connected to test prods : the lamp should light when connected between line and earth, but not when connected between earth and neutral. Appliances or plugs wrongly connected represent a potential danger to the user.

When fitting suppressors to appliances the leads of all suppressor components should be kept as short and as direct as possible; this is particularly important when clearing interference to television or Band II reception, but the rule is one that should be kept at all times. Aim at keeping the leads down to a maximum of 1½ in. whenever possible.

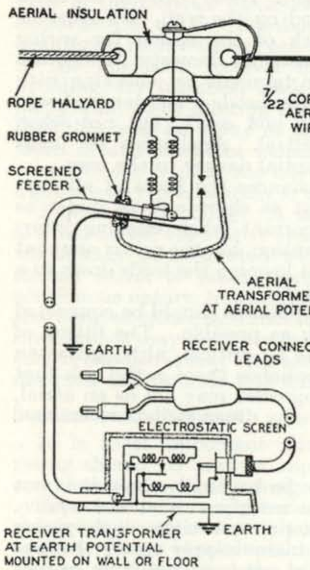
Capacitor suppressors fitted to appliances should be connected as close to the source of the spark as possible. The fitting of choke-type suppressors is not quite so critical, although when installed at a distance from the appliance there is the risk that the portion of lead prior to the suppressor may act as an aerial, so that the possibility of interference by direct radiation remains.

Suppression at the Receiver

Suppression at the receiver may be required where it is not possible to identify or to suppress interference at the source. Standard procedure is to connect filter circuits either at the mains input to the receiver or where the mains supply enters the premises; and/or the use of a special screened aerial to reduce radiation pick-up.

It should be emphasised that interference radiation is normally confined to within a few feet of the house wiring, structural steelwork, tubing, roadway, etc. An aerial with the main part situated well clear of surrounding objects will seldom pick up any appreciable amount of unwanted noise, particularly on medium and long waves. At the same time it will provide a strong signal input to the receiver, which, through A.G.C. action, will thus operate at lower sensitivity and be less susceptible to conducted and induced interference than would otherwise be the case. This statement is borne out by an analysis of the G.P.O. interference investigation reports, which shows that the most frequent cause of unsatisfactory reception is the use of an inefficient aerial/earth system. In districts subject to mains-borne interference, the use of a " mains aerial " is strongly to be deprecated.

Indoor receiving aerials and the downleads of external aerials pass through the " noise belt ", and pick up energy from the induction and radiation fields surrounding the interference sources. A frame aerial correctly balanced to earth will discriminate against the electrostatic field of local interference, and can be most effective in reducing interference pick-up (see also Section 10).



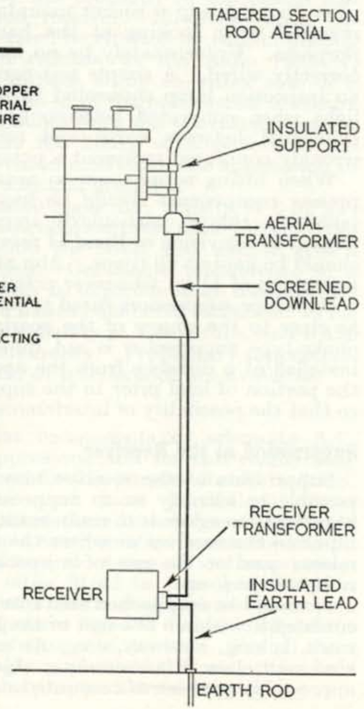


FIG. 2 (*above*).—DETAILS OF THE BELLING AND LEE ELIMINOISE AERIAL SYSTEM.

FIG. 3 (*right*).—PRINCIPLES OF A NOISE-REDUCING AERIAL INSTALLATION.

With external aerials, the pick-up of interference can be very largely reduced by using screened and balanced downleads from aerials which are mounted sufficiently high to be above the more intense fields found inside the building. The screen of the downlead is earthed to prevent the transmission of signals or interference to the inner conductors, allowing these to pass the aerial signal, unaffected by interference, to the receiver.

Both co-axial and screened twin downleads have been employed in aerials of this type, but the latter are to be preferred, since they permit a more complete separation of signal and screening circuits, especially on medium and long waves, where the function of the aerial depends upon its ground connection.

Matching Transformer Systems

A typical installation is illustrated in Fig. 3, with the corresponding circuit arrangement shown in Fig. 4. At low frequencies signals are normally picked up by that portion of the downlead screen which is between the earth-connecting point and the aerial : the remainder of the downlead, which is normally within the building, is responsive neither to signals nor to interference. The aerial in this example is a vertical rod mounted as previously described. It is connected at its lower end to the twin conductors of a screened downlead through an impedance-matching, balanced transformer, which must be electrically screened. This is usually effected by enclosing it in a metallic weatherproof housing, connected either to the aerial element or to the aerial-support bracket. In the first instance (Fig. 4 (*b*)) the transformer housing will be at aerial potential, but, since there can be no electrical charge within a closed metal surface, the transformer circuits are still effectively screened from the wave field. If the housing is attached to the aerial bracket (Fig. 4 (*c*)) (which is insulated from the aerial), it is connected to the braided screen of the downlead and continues directly to earth.

The sensitivity of a vertical aerial used in this way for reception of medium- and long-wave signals is not significantly reduced, except by the losses introduced in the windings of the transformer, and in the downlead conductors, and these are very small at the frequencies in question.

The screen of the downlead in this type of aerial is responsive to signals in its upper section, since it forms part of the aerial–earth interceptor ; because of this action the reduction in interference level may prove to be inadequate in some locations, *e.g.*, in multi-storey flats where electrical noise may be created at quite high levels (both structurally and intensively). If the upper part of the downlead cannot be removed from the interference field, the screen should be disconnected from the aerial transformer circuit and a separate earth lead brought down by a route which avoids the interference field (Fig. 4 (*d*)). The screen should remain earthed at the lower end, and will now act solely as a screen, not being part of the aerial and not therefore carrying

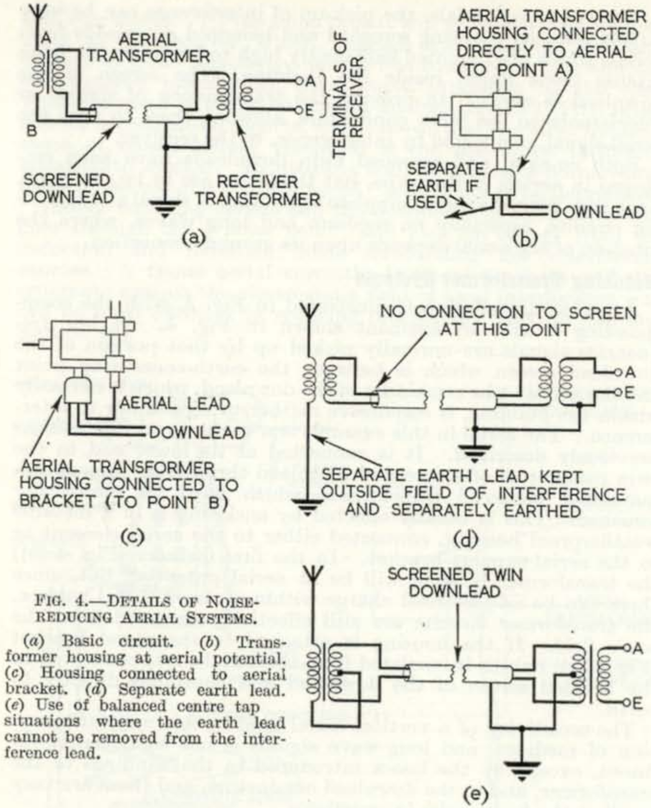


FIG. 4.—DETAILS OF NOISE-REDUCING AERIAL SYSTEMS.

(*a*) Basic circuit. (*b*) Transformer housing at aerial potential. (*c*) Housing connected to aerial bracket. (*d*) Separate earth lead. (*e*) Use of balanced centre tap situations where the earth lead cannot be removed from the interference lead.

any signal energy. The sensitivity of the aerial will remain unchanged by this modification.

In situations where it is impracticable to remove the downlead or earth return from the interference field, the circuit may be completed through the twin conductors connected to the impedance-matching aerial transformer, either by a balanced centre tap, as shown in Fig. 4 (*e*), or by direct connection to one limb of the circuit. The screen of the downlead is isolated at the aerial transformer as in the previous example. This system will ensure freedom from interference, but the sensitivity will fail because the whole of the lower section of the downlead aerial return is screened, not only from interference, but also from the signal

field. Since the most effective part of the aerial is the upper vertical element, the loss introduced by the screened lower section will not generally be greater than 3–4 db, while the reduction in extraneous noise may considerably exceed this figure, giving a significant overall improvement.

The performance of noise-reducing aerial systems is usually maintained throughout the short-wave spectrum, although some variation in response will occur in the impedance-matching transformer system, as a result of the wide changes in aerial impedance which arise as the received frequencies approach the fundamental of one of the harmonic resonant frequencies of the aerial and downlead.

The transformers have a comparatively uniform response over the range 150 kc/s to 20 Mc/s. For this purpose they are usually wound in sections arranged so that their distributed inductances are appropriately coupled to their corresponding secondary winding sections, in such a way that the self-capacitance of the low-frequency windings acts as a by-pass to high-frequency signals, these being effectively applied to the low-inductance sections in series with them.

[SECTION 12]

USEFUL FORMULÆ

COMPARED with the designer, the radio service engineer has regular need for relatively few circuit formulæ, and the selection given below will cover most normal requirements.

Ohm's Law

$$E = I \times R$$

where E is the potential difference in volts, I the direct current in amperes and R the resistance in ohms.

The formula may also be stated :

$$I = \frac{E}{R} \quad \text{and} \quad R = \frac{E}{I}$$

EXAMPLES : (1) *What is the voltage drop across a 33,000-ohm resistor through which a current of 2 mA is flowing?*

$$E = I \times R = \frac{2}{1{,}000} \times 33{,}000 = \underline{66 \text{ volts}}$$

(2) *What value of cathode bias resistor should be used to obtain a 3-volt bias voltage for a tetrode valve operating with a plate current of 8 mA, a screen current of 2 mA and no grid current?*

$$R = \frac{E}{I \text{ (total)}} = \frac{3 \times 1{,}000}{(8 + 2)} = \underline{300 \text{ ohms}}$$

N.B.: In this type of problem it should be remembered that the current flowing through the cathode resistor is the sum of anode, screen, suppressor grid and grid currents.

(3) *What will be the current flowing through a 10,000-ohm bleeder resistor connected across a 250-volt power supply?*

$$I = \frac{E}{R} = \frac{250 \times 1{,}000}{10{,}000} = \underline{25 \text{ mA}}$$

N.B.: The multiplication by 1,000 gives the answer in milliamperes.

Power

The following formulæ apply to D.C. circuits.

$$W = E \times I$$

By consideration of Ohm's Law this may be stated also in the following forms :

$$W = I^2R$$

or

$$W = E^2/R$$

where W is the power in watts, E the potential difference in volts, I the current in amperes and R the resistance in ohms.

Resistors

Resistors in Series

$$R \text{ (total)} = R_1 + R_2 + R_3 \ldots$$

Thus the total resistance of a chain of resistors in series is the sum of the individual resistors which form the chain.

EXAMPLE : *What is the effective resistance of a 33k resistor and a 0·25M resistor connected in series?*

Note that all values must be changed into a common unit before addition.

$$R = R_1 + R_2 = 33\text{k} + 0{\cdot}25\text{M} = 33{,}000 + 250{,}000$$
$$= \underline{283{,}000 \text{ ohms}}$$

Resistors in Parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$$

Where there are only two resistors, this formula may be stated :

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

N.B.: The effective resistance of a number of resistors in parallel must always be less than that of any one of the individual resistors.

EXAMPLES : (1) *What is the effective resistance of 2,000-ohm, 5,000-ohm and 10,000-ohm resistors connected in parallel?*

$$\frac{1}{R} = \frac{1}{2{,}000} + \frac{1}{5{,}000} + \frac{1}{10{,}000} = \frac{5 + 2 + 1}{10{,}000}$$
$$\therefore R = \underline{1{,}250 \text{ ohms}}$$

(2) *What value resistor should be connected in parallel across a 60,000-ohm resistor in order to reduce the effective circuit resistance to 20,000 ohms?*

$$20{,}000 = \frac{60{,}000 \times R}{60{,}000 + R}$$

$$\therefore 20{,}000\ (60{,}000 + R) = 60{,}000R$$
$$\therefore R + 60{,}000 = 3R$$
$$\therefore R = \underline{30{,}000 \text{ ohms}}$$

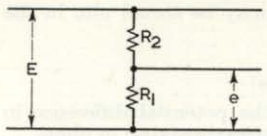


FIG. 1.—POTENTIAL DIVIDER.

Potential Divider

Where two resistors are connected across a supply (see Fig. 1), the voltage across one, in the absence of a load, is derived from the following formulæ :

$$e = E \times \frac{R_1}{R_1 + R_2}$$

Where a load is drawn from a potential divider, the differing currents in each section of the divider must be taken into account.

EXAMPLE : *A potential divider is to be connected across a 200-volt H.T line so as to provide an output of 100 volts at 5 mA with a standing current of 4 mA, see Fig. 2.*

The current flowing through R_1 will be $5 + 4 = 9$ mA since R_1 must provide a voltage drop of 100 volts.

Then, from Ohm's Law,

$$R_1 = \frac{E}{I} = \frac{100}{9} \times 1{,}000 \simeq 11{,}000 \text{ ohms}$$

and $$R_2 = \frac{100}{4} \times 1{,}000 = \underline{25{,}000 \text{ ohms}}$$

Biasing

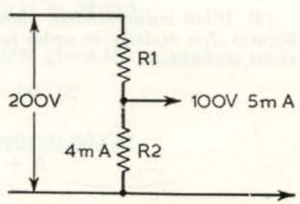
Cathode biasing resistors may be calculated from the following formula :

$$R\,(\text{cathode}) = \frac{\text{grid bias volts required}}{\text{total cathode current}}$$

The value of the associated by-pass capacitor is given approximately by

$$C \simeq \frac{1}{6{\cdot}28 \times f \times (R/10)}$$

FIG. 2.—EXAMPLE OF POTENTIAL DIVIDER.



where C is the by-pass capacitor in microfarads, f is the lowest frequency to be by-passed and R the resistance across C.

Capacitors

Capacitors in Series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots$$

Where there are only two capacitors, this formula may be stated :

$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$

EXAMPLE : *What is the effective capacitance of a 250-pF capacitor in series with a 0·001-μF capacitor?*

$$C = \frac{250 \times 1{,}000}{250 + 1{,}000} = \frac{250{,}000}{1{,}250} = \underline{200 \text{ pF}}$$

Capacitors in Parallel

$$C = C_1 + C_2 + C_3 \ldots$$

EXAMPLE : *What is the effective capacitance of a 0·0002-μF capacitor in parallel with a 50-pF capacitor?*

$$C = 200 + 50 = \underline{250 \text{ pF}}$$

Inductors

Inductances in Series

$$L = L_1 + L_2 + L_3 \ldots$$

Inductances in Parallel

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

Capacitive Reactance

The reactance of a capacitor in an A.C. circuit is derived from the formulæ :

$$X_c = \frac{1{,}000{,}000}{2\pi f C}$$

where X_c is the capacitive reactance in ohms, f the frequency in cycles per second, C the capacitance in microfarads and π is approximately 3·14.

EXAMPLE : *What is the reactance of a 0·1-μF capacitor at 5,000 c/s?*

$$X_c = \frac{1{,}000{,}000}{2 \times 3{\cdot}14 \times 5{,}000 \times 0{\cdot}1} = \frac{200}{0{\cdot}628} = 318 \text{ ohms}$$

The values shown in Table 1 are typical of those encountered in radio servicing.

TABLE 1

C	X_c (ohms)				
	50 c/s	100 c/s	1,000 c/s	5,000 c/s	15,000 c/s
100 pF	31,800,000	15,900,000	1,590,000	318,000	106,000
500 pF	6,370,000	3,180,000	318,000	63,700	21,200
0·001 μF	3,180,000	1,590,000	159,000	31,800	10,600
0·005 μF	637,000	318,000	31,800	6,370	2,120
0·01 μF	318,000	159,000	15,900	3,180	1,060
0·1 μF	31,800	15,900	1,590	318	106
1·0 μF	3,180	1,590	159	31·8	10·6

C	X_c (ohms)				
	500 kc/s	1 Mc/s	5 Mc/s	10 Mc/s	50 Mc/s
10 pF	31,800	15,900	3,180	1,590	318
50 pF	6,370	3,180	637	318	63·7
100 pF	3,180	1,590	318	159	31·8
500 pF	637	318	63·7	31·8	6·37
0·001 μF	318	159	31·8	15·9	3·18
0·005 μF	63·7	31·8	6·37	3·18	0·637

Resonance of a Tuned Circuit

$$f = \frac{1{,}000{,}000}{2\pi \times \sqrt{(L \times C)}}$$

$$\simeq \frac{159{,}000}{\sqrt{(L \times C)}}$$

where f is the resonant frequency in kilocycles per second, L is the inductance in microhenrys and C is the capacitance in picofarads.

Square Roots

The solution of the formula for the resonance of a tuned circuit, and for a number of other radio-circuit formulæ, requires the extraction of the square roots of large numbers. This process is most simply achieved by means of logarithm tables, or tables of square roots, or by the use of a slide rule. However, where these aids are not available the following method may be used.

EXAMPLE : *To find the square root of* 50,243.

Mark off the complete number into groups of two, starting from the right-hand side or, if decimals are involved, from the decimal point, *i.e.*, 5′02′43.

Find from the table below the largest square contained in the first group of either one or two figures.

First group .	1–3	4–8	9–15	16–24	25–35	36–48	49–63	64–80	81–99
Largest square .	1	4	9	16	25	36	49	64	81
Root . .	1	2	3	4	5	6	7	8	9

In our example this will be 4, so the root is 2. Proceed as for long division :

```
   2
 √5′02′43
  4
  1
```

Then bring down the next group of *2* figures, and write down to the left of this *twice* the root found for the first group. Then find the largest number by which this figure, when written in front of the number and multiplied by the number will divide into the remainder. This process is best grasped by reference to the example below :

```
             2 2
           √5′02′43
            4
  42 × 2   |1 02
              84
              18
```

The same process is then repeated as many times as is necessary :

```
             2  2  4·1
           √5′02′43
            4
  42 × 2   |1 02
              84
  444 × 4    |18 43
              17 76
  4481 × 1      |6700
                 4481
```

Thus the square root of 50,243 to the nearest whole number is 224.

FREQUENCY–WAVELENGTH CONVERSION

The conversion of wavelengths to frequencies and frequencies to wavelengths, a process often required by the service engineer

WAVELENGTH/FREQUENCY CONVERSION TABLE

	0	1	2	3	4	5	6	7	8	9
10	30,000	29,703	29,412	29,126	28,846	28,571	28,302	28,037	27,778	27,523
11	27,273	27,027	26,786	26,549	26,316	26,087	25,862	25,641	25,424	25,210
12	25,000	24,793	24,590	24,390	24,193	24,000	23,809	23,622	23,437	23,256
13	23,077	22,901	22,727	22,556	22,388	22,222	22,059	21,898	21,739	21,583
14	21,429	21,277	21,127	20,979	20,833	20,690	20,548	20,408	20,270	20,134
15	20,000	19,867	19,737	19,608	19,480	19,355	19,231	19,108	18,987	18,868
16	18,750	18,634	18,518	18,405	18,293	18,182	18,072	17,964	17,857	17,752
17	17,647	17,544	17,442	17,341	17,241	17,143	17,045	16,949	16,854	16,760
18	16,667	16,575	16,483	16,393	16,304	16,216	16,129	16,043	15,957	15,873
19	15,790	15,707	15,625	15,544	15,464	15,385	15,306	15,228	15,151	15,075
20	15,000	14,925	14,851	14,778	14,706	14,634	14,563	14,493	14,423	14,354
21	14,286	14,218	14,151	14,084	14,019	13,954	13,889	13,825	13,762	13,699
22	13,636	13,575	13,513	13,453	13,493	13,333	13,274	13,216	13,158	13,100
23	13,043	12,987	12,931	12,875	12,820	12,766	12,712	12,658	12,605	12,552
24	12,500	12,448	12,397	12,346	12,295	12,245	12,195	12,146	12,097	12,048
25	12,000	11,952	11,905	11,858	11,811	11,765	11,719	11,673	11,628	11,583
26	11,538	11,494	11,450	11,407	11,364	11,321	11,278	11,236	11,194	11,152
27	11,111	11,070	11,029	10,989	10,949	10,909	10,870	10,830	10,791	10,753
28	10,714	10,676	10,638	10,601	10,563	10,526	10,489	10,453	10,417	10,381
29	10,345	10,309	10,274	10,239	10,204	10,169	10,135	10,101	10,067	10,033
30	10,000	9,967	9,934	9,901	9,868	9,836	9,804	9,772	9,740	9,709
31	9,677	9,646	9,615	9,585	9,554	9,524	9,494	9,464	9,434	9,404
32	9,375	9,346	9,317	9,288	9,259	9,231	9,202	9,174	9,146	9,109
33	9,091	9,063	9,036	9,009	8,982	8,955	8,929	8,901	8,876	8,850
34	8,823	8,798	8,772	8,746	8,721	8,696	8,671	8,645	8,621	8,596
35	8,571	8,547	8,523	8,499	8,375	8,451	8,427	8,403	8,380	8,356
36	8,333	8,310	8,287	8,264	8,242	8,219	8,197	8,174	8,152	8,130
37	8,108	8,086	8,065	8,043	8,021	8,000	7,979	7,958	7,937	7,916
38	7,895	7,874	7,853	7,833	7,813	7,792	7,772	7,752	7,732	7,712

39	7,692	7,672	7,653	7,633	7,614	7,595	7,576	7,557	7,538	7,519
40	7,500	7,481	7,463	7,444	7,426	7,407	7,389	7,371	7,353	7,335
41	7,317	7,299	7,282	7,264	7,246	7,229	7,211	7,194	7,177	7,160
42	7,143	7,126	7,109	7,092	7,075	7,059	7,042	7,026	7,009	6,993
43	6,977	6,961	6,944	6,928	6,912	6,897	6,881	6,865	6,850	6,834
44	6,818	6,803	6,787	6,772	6,757	6,742	6,727	6,711	6,696	6,682
45	6,667	6,652	6,637	6,622	6,608	6,593	6,579	6,565	6,550	6,536
46	6,522	6,508	6,494	6,479	6,466	6,452	6,438	6,424	6,410	6,397
47	6,383	6,369	6,356	6,343	6,329	6,316	6,302	6,289	6,276	6,263
48	6,250	6,237	6,224	6,211	6,198	6,186	6,173	6,160	6,148	6,135
49	6,122	6,110	6,097	6,085	6,073	6,061	6,048	6,036	6,024	6,012
50	6,000	5,988	5,976	5,964	5,952	5,941	5,929	5,917	5,905	5,894
51	5,882	5,871	5,859	5,848	5,836	5,825	5,814	5,803	5,791	5,780
52	5,769	5,758	5,747	5,736	5,725	5,714	5,703	5,692	5,682	5,671
53	5,660	5,650	5,639	5,629	5,618	5,607	5,597	5,587	5,576	5,566
54	5,556	5,545	5,535	5,525	5,515	5,505	5,494	5,485	5,474	5,464
55	5,455	5,445	5,435	5,425	5,415	5,405	5,396	5,386	5,376	5,367
56	5,357	5,347	5,338	5,329	5,319	5,310	5,300	5,291	5,282	5,272
57	5,263	5,254	5,245	5,236	5,227	5,217	5,208	5,199	5,190	5,181
58	5,172	5,164	5,155	5,146	5,137	5,128	5,119	5,111	5,102	5,093
59	5,085	5,076	5,068	5,059	5,050	5,042	5,034	5,025	5,017	5,008
60	5,000	4,992	4,983	4,975	4,967	4,959	4,951	4,942	4,934	4,926
61	4,918	4,910	4,902	4,894	4,886	4,878	4,870	4,862	4,854	4,846
62	4,839	4,831	4,823	4,815	4,808	4,800	4,792	4,785	4,777	4,769
63	4,762	4,754	4,747	4,739	4,732	4,724	4,717	4,710	4,702	4,695
64	4,687	4,680	4,673	4,666	4,658	4,651	4,644	4,637	4,630	4,622
65	4,615	4,608	4,601	4,594	4,587	4,580	4,573	4,566	4,559	4,552
66	4,546	4,539	4,532	4,525	4,518	4,511	4,504	4,498	4,491	4,484
67	4,477	4,471	4,464	4,458	4,451	4,444	4,438	4,431	4,425	4,418
68	4,412	4,405	4,399	4,392	4,386	4,380	4,373	4,367	4,360	4,354
69	4,348	4,342	4,335	4,329	4,323	4,316	4,310	4,304	4,298	4,292
70	4,286	4,279	4,273	4,267	4,261	4,255	4,249	4,243	4,237	4,231

(cont'd overpage)

F

WAVELENGTH/FREQUENCY CONVERSION TABLE (*contd.*)

	0	1	2	3	4	5	6	7	8	9
71	4,225	4,219	4,213	4,207	4,202	4,196	4,190	4,184	4,178	4,172
72	4,167	4,161	4,155	4,149	4,144	4,138	4,132	4,126	4,121	4,115
73	4,110	4,104	4,098	4,093	4,087	4,081	4,076	4,071	4,065	4,060
74	4,054	4,048	4,043	4,038	4,032	4,027	4,021	4,016	4,011	4,005
75	4,000	3,995	3,989	3,984	3,979	3,973	3,968	3,963	3,958	3,952
76	3,947	3,942	3,937	3,932	3,927	3,922	3,916	3,911	3,906	3,901
77	3,896	3,891	3,886	3,881	3,876	3,871	3,866	3,861	3,856	3,851
78	3,846	3,841	3,836	3,831	3,826	3,822	3,817	3,812	3,807	3,802
79	3,797	3,793	3,788	3,783	3,778	3,774	3,769	3,764	3,759	3,754
80	3,750	3,745	3,741	3,736	3,731	3,727	3,722	3,718	3,713	3,708
81	3,704	3,699	3,694	3,690	3,685	3,681	3,676	3,672	3,667	3,663
82	3,658	3,654	3,649	3,645	3,641	3,636	3,632	3,628	3,623	3,619
83	3,614	3,610	3,606	3,601	3,597	3,593	3,589	3,584	3,580	3,576
84	3,571	3,567	3,563	3,559	3,554	3,550	3,546	3,542	3,538	3,534
85	3,529	3,525	3,521	3,517	3,513	3,509	3,505	3,501	3,496	3,492
86	3,488	3,484	3,480	3,476	3,472	3,468	3,464	3,460	3,456	3,452
87	3,448	3,444	3,440	3,436	3,433	3,429	3,425	3,421	3,417	3,413
88	3,409	3,405	3,401	3,397	3,394	3,390	3,386	3,382	3,378	3,375
89	3,371	3,367	3,363	3,359	3,356	3,352	3,348	3,344	3,341	3,337
90	3,333	3,330	3,326	3,322	3,319	3,315	3,311	3,307	3,304	3,300
91	3,297	3,293	3,289	3,286	3,282	3,279	3,275	3,271	3,268	3,264
92	3,261	3,257	3,254	3,250	3,247	3,244	3,240	3,236	3,233	3,229
93	3,226	3,222	3,219	3,215	3,212	3,208	3,205	3,202	3,198	3,195
94	3,191	3,188	3,185	3,181	3,178	3,175	3,171	3,168	3,165	3,161
95	3,158	3,154	3,151	3,148	3,145	3,141	3,138	3,135	3,131	3,128
96	3,125	3,122	3,118	3,115	3,112	3,109	3,106	3,102	3,099	3,096
97	3,093	3,090	3,086	3,083	3,080	3,077	3,074	3,070	3,067	3,064
98	3,061	3,058	5,055	3,052	3,049	3,046	3,043	3,040	3,036	3,033
99	3,030	3,027	3,024	3,021	3,018	3,015	3,012	3,009	3,006	3,003

when re-aligning or checking the calibration of receivers, is governed by the following formulæ :

$$\text{Wavelength (metres)} = \frac{300{,}000}{\text{frequency (kc/s)}}$$

$$= \frac{300}{\text{frequency (Mc/s)}}$$

$$\text{Frequency (kc/s)} = \frac{300{,}000}{\text{wavelength (metres)}}$$

$$\text{Frequency (Mc/s)} = \frac{300}{\text{wavelength (metres)}}$$

To avoid the necessity of working out these formulæ, use may be made of the tables given on pages 150–52. Any conversion can then be carried out without difficulty, provided that the correct position of the decimal point is determined from the summary provided below.

Wavelength–Frequency Conversions

Values between 10 and 99·9 metres = 30,000–3,003 kc/s, *i.e.*, use the values exactly as obtained from the tables.

Values between 100 and 999 metres = 3,000·0–300·3 kc/s, *i.e.*, insert a decimal point before the last figure shown in the tables.

Values between 1,000 and 9,990 metres = 300·00–30·03 kc/s, *i.e.*, insert a decimal point before the last *two* figures shown in the tables.

Values between 1 and 9·99 metres = 300·00–30·03 Mc/s, *i.e.*, result is given in Mc/s provided a decimal point is inserted before the last *two* figures shown in the tables.

Frequency–Wavelength Conversions

Values between 10 and 99·9 kc/s = 30,000–3,003 m., *i.e.*, use values directly as given in the tables.

Values between 100 and 999 kc/s = 3,000·0–300·3 m., *i.e.*, insert a decimal point before the last figure shown in the tables.

Values between 1,000 and 9,990 kc/s (1 and 9·99 Mc/s) = 300·00–30·03 m., *i.e.*, insert a decimal point before the last two figures shown in the tables.

Values between 10 and 99·9 Mc/s = 30·000–3·003 m., *i.e.*, insert a decimal point before the last three figures shown in the tables.

Output Transformer Ratio

$$N = \sqrt{\left(\frac{R_L}{Z}\right)}$$

where N is the transformer turns-ratio, R_L the optimum load resistance of the output valve and Z the impedance of the loud-speaker.

EXAMPLE: *What should be the turns-ratio of a transformer designed to match a 3-ohm loudspeaker to a valve which requires a load of 5,000 ohms for optimum performance?*

$$N = \sqrt{\left(\frac{5{,}000}{3}\right)} = \sqrt{(1{,}666)} = 40{\cdot}8.$$

The primary winding should therefore have 40·8 times as many turns as the secondary winding.

Extension of Meter Ranges

Ammeter Shunts:

$$\text{Shunt} = \frac{\text{meter resistance}}{(n-1)}$$

where n is the number of times by which the full-scale deflection is to be increased.

EXAMPLE: *It is desired to measure currents up to 500 mA. on a 10-mA. f.s.d. meter with an internal resistance of 30 ohms. What value shunt should be placed in parallel across the meter?*

$$\text{Shunt} = \frac{30}{(50-1)} = \frac{30}{49} \simeq 0{\cdot}63 \text{ ohm}.$$

Voltmeter Series Resistors:

$$R = \text{meter resistance} \times (n-1)$$

where n is the number of times by which the full-scale deflection is to be increased and R is the required series resistor.

Milliammeter as Voltmeter:

To use a milliammeter as a voltmeter a suitable resistor should be connected in series with the meter. The value of this resistor can be calculated from the formula:

$$R = \frac{E}{\text{meter current (f.s.d.)}} - \text{meter resistance}$$

where E is the required full-scale deflection of the voltmeter.

[SECTION 13]

COLOUR CODES

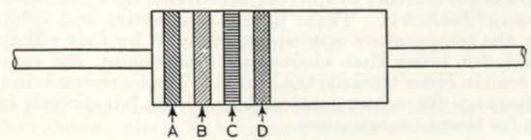
Resistors

The complete information on resistors given by modern colour coding systems includes: value, tolerance and grade. These characteristics are indicated either: (1) by a series of three or more colour rings which are read from the end of the resistor towards its centre; or, alternatively, (2) by reading first the body colour; secondly, the tip colour; thirdly, the spot or band colour. In system (2) the fourth colour (tolerance) is indicated by marking the second tip, but, since the colours normally differ from those used to designate value, no confusion is likely to arise.

In each system the first colour to be read indicates the first figure of the value; the second colour gives the second figure of the value; and the third colour gives the number by which the first two figures should be multiplied in order to arrive at the true value of the resistor. The fourth colour shows the tolerance: the accepted tolerances being ± 1, ± 2, ± 5, ± 10 and ± 20 per cent. Where no tolerance is indicated, it may be assumed that the tolerance is ± 20 per cent.

FOUR-BAND COLOUR CODE FOR FIXED RESISTORS

Colour	*1st Figure "A"*	*2nd Figure "B"*	*Multiplying Value "C"*	*Tolerance "D" (%)*
Silver . . .	—	—	10^{-2}	±10
Gold . . .	—	—	10^{-1}	± 5
Black . . .	—	0	1	—
Brown . . .	1	1	10	± 1
Red . . .	2	2	10^2	± 2
Orange . . .	3	3	10^3	—
Yellow . . .	4	4	10^4	—
Green . . .	5	5	10^5	—
Blue . . .	6	6	10^6	—
Violet . . .	7	7	10^7	—
Grey . . .	8	8	10^8	—
White . . .	9	9	10^9	—
None . . .	—	—	—	±20



SERIES OF RESISTOR PREFERRED VALUES AND THEIR ASSOCIATED TOLERANCES

Tolerance			Tolerance		
±5%	±10%	±20%	±5%	±10%	±20%
1·0	1·0	1·0	3·3	3·3	3·3
1·1	—	—	3·6	—	—
1·2	1·2	—	3·9	3·9	—
1·3	—	—	4·3	—	—
1·5	1·5	1·5	4·7	4·7	4·7
1·6	—	—	5·1	—	—
1·8	1·8	—	5·6	5·6	—
2·0	—	—	6·2	—	—
2·2	2·2	2·2	6·8	6·8	6·8
2·4	—	—	7·5	—	—
2·7	2·7	—	8·2	—	—
3·0	—	—	9·1	—	—

Grade 1, high-stability, composition resistors are coded as (1) above, the grade being denoted by either a fifth band of Salmon Pink or the body being of that colour.

Examples. A resistor with a blue body, a grey tip and an orange spot would have a value of 68,000 ohms with a tolerance of ± 20 per cent. The addition of a silver band or tip would indicate a tolerance of ± 10 per cent.

A resistor with four bands of colour, the end one being orange, the next orange, followed by brown and gold would have a value of 330 ohms with a tolerance of ± 5 per cent. In this case the body colour would have no significance, unless Salmon Pink, which would indicate a Grade 1 resistor.

Capacitors

Although many capacitors continue to be marked directly with their value and rating, several systems of colour coding are also in use. These differ according to the type of capacitor and the extent of the information to be conveyed, though in all cases the same basic code to that used for resistors is adopted, except for the 0·1 and 0·01 multipliers. Information that may be shown by colour coding includes : value, temperature coefficient, tolerance and voltage rating. In addition, the connection to the outer foil of tubular paper capacitors may be indicated by a band of colour, usually black, being placed on the casing close to the appropriate connection. All values are colour coded in picofarads (to convert to microfarads divide by 1,000,000).

Ceramic Dielectric. These have a distinctive end colour, denoting the temperature coefficient, followed by four colour dots, the first dot being that nearest the end colour, the remainder being read in order towards the centre. The tolerance is indicated in percentage for values greater than 10 pF, but directly in picofarads for lesser capacitances.

COLOUR CODE FOR CERAMIC CAPACITORS

	Tip	1st Dot	2nd Dot	3rd Dot	4th Dot	
Colour	Temp. Coeff.	1st Significant Figure	2nd Significant Figure	Multiplier	Tolerance	
					More than 10 pF	Less than 10 pF
Black	NP0	0	0	1	±20%	±2·0 pF
Brown	N030	1	1	10	± 1%	±0·1 pF
Red	N080	2	2	100	± 2%	—
Orange	N150	3	3	1,000	± 2·5%	—
Yellow	N220	4	4	10,000	—	—
Green	N330	5	5	—	± 5%	±0·5 pF
Blue	N470	6	6	—	—	—
Violet	N750	7	7	—	—	—
Grey	P030	8	8	0·01	—	±0·25 pF
White	P100	9	9	0·1	±10%	±1·0 pF

Tubular, Metallised-paper. The values may be colour coded in picofarads, indicated by three dots, having the same significance as in the third, fourth and fifth columns in the table for ceramic dielectric capacitors.

Alternative Methods. While the above systems are those recommended for current usage, several other methods may be met in practice. For example, one colour only may be used to denote tolerance, two colours to denote tolerance and voltage rating, three colours to denote capacitance in picofarads, five colours to denote capacitance in picofarads (first three colours), tolerance (fourth dot) and voltage rating (fifth dot). The order in which the dots are to be read is sometimes indicated by an arrow, but in all cases is from left to right, the first dot being that nearest to one end.

In such instances, tolerance and voltage rating are coded as follows :

Colour	Tolerance (%)	Voltage Rating
Black	—	—
Brown	1	100
Red	2	200
Orange	3	300
Yellow	4	400
Green	5	500
Blue	6	600
Violet	7	700
Grey	8	800
White	9	1,000
Silver	10	—
Gold	5	—

Coding of American capacitors also differs slightly from that described above : the R.M.A. three-dot code is used for capacitors having a tolerance of 20 per cent, the dots indicating the capacitance in picofarads; the R.M.A. six-dot code gives (*top row*) first, second and third significant figures; (*bottom row*) voltage, rating, tolerance and decimal multiplier. American fixed ceramic capacitors have a broad band then four narrow bands or dots giving temperature coefficient, first significant figure, second significant figure, decimal multiplier and tolerance, this system being similar to that described for British capacitors of this type. American war-surplus mica and moulded paper capacitors are marked according to the American War Standards or Joint Army–Navy specifications. These markings are similar in appearance to the R.M.A. six-dot system, but the first dot of the top row indicates type (black/mica, silver/paper), the second and third dots give first and second significant figures, while the bottom row indicates characteristic, tolerance and decimal multiplier.

Pick-up Styli

Colour coding has been adopted to identify pick-up styli, as follows:

On case:

Green	Standard (78 r.p.m.)
Red	Long playing
Violet	Universal

On tip:

Red	0·001 in.
Lemon	0·002 in.
Green	0·0025 in.
French Blue	0·003 in.
Orange	0·0035 in.
Violet	Universal

Colour band on shaft:

Black	Hard metal
White	Diamond
Sky Blue	Oval tip
No colour	Sapphire

Colour Code for Current-operated Fuses

Colour	*Rating (A)*	*Colour*	*Rating (A)*
Green and yellow	0·010	Green	0·750
Red and turquoise	0·015	Blue	1·0
Eau-de-Nil	0·025	Light blue	1·5
Salmon pink	0·050	Purple	2·0
Black	0·060	Yellow and purple	2·5
Grey	0·100	White	3·0
Red	0·150	Black and white	5·0
Brown	0·250	Orange	10·0
Yellow	0·500		

[SECTION 12]

BROADCASTING STATIONS

The wavebands allocated for broadcasting are shown below.

On the shorter wavebands, however, the table is not always strictly enforced, and a few broadcasting stations operate on wavelengths beyond the limits shown.

Broadcasting Allocations

Band	*Frequency*	*Wavelength*	*Area*
Long Waveband	150–285 kc/s	2,000–1,053 m.	Region 1
Medium Waveband	525–1,605 kc/s	571–187 m.	All Regions. Region 2, 525–535 kc/s under 250 watts
120 m. band	2·300– 2·498 Mc/s	130·3 –120 m.	Region 1. Regions 2 and 3, 2·300–2·495 Mc/s only
90 m. band	3·200– 3·400 Mc/s	93·69–88·18 m.	All Regions
75 m. band	3·900– 4·00 Mc/s	76·9 –75·0 m.	Region 3. Region 1, 3·95–4·0 Mc/s only. Region 2 excluded
60m. band	4·75–5·06 Mc/s (except 4·995–5·005 Mc/s)	63·10–59·25 m. (except 60·05–59·95 m.)	All Regions
49 m. band	5·950– 6·200 Mc/s	50·39–48·36 m.	All Regions
41 m. band	7·100– 7·300 Mc/s	42·23–41·07 m.	Regions 1 and 3 only
31 m. band	9·500– 9·775 Mc/s	31·56–30·70 m.	All Regions
25 m. band	11·700–11·975 Mc/s	25·63–25·0 m.	All Regions
19 m. band	15·10 –15·45 Mc/s	19·86–19·40 m.	All Regions
16 m. band	17·70 –17·90 Mc/s	16·94–16·75 m.	All Regions
13 m. band	21·45 –21·75 Mc/s	14·00–13·79 m.	All Regions
11 m. band	25·60 –26·10 Mc/s	11·71–11·49 m.	All Regions

Region 1 roughly comprises Europe, Africa, the U.S.S.R. and Turkey.

Region 2 is the Western Hemisphere, comprising the Americas, Greenland and all countries under the control of the Federal Communications Commission of the United States.

Region 3 includes Australasia, Oceania and Asia, except for the territories included in Regions 1 and 2.

V.H.F./U.H.F. Broadcast and Television Bands

Band I	41– 68 Mc/s	7·3–4·4 m.
Band II	87·5–100 Mc/s	3·4–3 m.
Band III	174–216 Mc/s	1·7–1·4 m.
Band IV	470–585 Mc/s	64–51 cm.
Band V	610–960 Mc/s	49–31 cm.

MAJOR EUROPEAN BROADCASTING STATIONS

Wavelength (metres)	Frequency (kc/s)	Station or Programme	Country
1,986	151	Hamburg	Germany
1,986	151	Moscow I	U.S.S.R.
1,935	155	Tromso	Norway
1,935	155	Brasov	Roumania
1,829	164	Paris Inter. (Allouis)	France
1,734	173	Moscow I	U.S.S.R.
1,734	173	V.O.A. (Munich)	Germany
1,648	182	Reykjavik	Iceland
1,648	182	" Europe No. 1 " (Saar)	Germany
1,622	185	Deutschlandsender	Germany (G.D.R.)
1,571	191	Motala	Sweden
1,500	200	Droitwich	U.K.
1,435	209	Kiev I	U.S.S.R.
1,376	218	Oslo	Norway
1,322	227	Warsaw I	Poland
1,287	233	Luxembourg I	Luxembourg
1,271	236	Leningrad I	U.S.S.R.
1,224	245	Kalundborg	Denmark
1,181	254	Lahti	Finland
1,141	263	Moscow II	U.S.S.R.
1,103	272	Prague II	Czechoslovakia
1,068	281	Minsk I	Bielorussia
882	340	Moscow II	U.S.S.R.
567	529	Beromunster	Switzerland
557	539	Budapest	Hungary
547	548	A.F.N. (Munich)	Germany
547	548	Moscow II	U.S.S.R.
539	557	Helsinki I	Finland
539	557	Monte Ceneri	Switzerland
530	566	Athlone	Eire
522	575	Leipzig	Germany (G.D.R.)
522	575	Stuttgart	Germany
522	575	Riga	Latvia
514	584	Vienna II	Austria
514	584	Madrid	Spain
506	593	Sundsvall	Sweden
506	593	Frankfurt	Germany
498	602	Regional (Lyons)	France
491	611	Berlin I	Germany (G.D.R.)
484	620	Brussels National	Belgium
477	629	Vigra	Norway
470	638	Prague I	Czechoslovakia
470	638	B.B.C.	Cyprus
464	647	Third Programme	U.K.
457	656	Naples I, etc.	Italy
457	656	Murmansk	U.S.S.R.
451	665	Vilnus	Lithuania
451	665	A.F.N. (Kaiserslautern)	Germany
451	665	Lisbon I	Portugal
445	674	Regional (Rennes)	France
439	683	Belgrade I	Yugoslavia
439	683	Berlin (R.I.A.S.)	Germany
434	692	Northern	U.K.
427	701	Bratislava	Czechoslovakia
422	710	Regional (Marseilles)	France
417	719	" Free Europe " (Munich)	Germany
412	728	Athens	Greece
412	728	Schwerin	Germany (G.D.R.)

MAJOR EUROPEAN BROADCASTING STATIONS

Wavelength (metres)	Frequency (kc/s)	Station or Programme	Country
407	737	Poznan	Poland
402	746	Hilversum I	Holland
397	755	Lisbon II	Portugal
393	764	Sottens	Switzerland
388	773	Stockholm	Sweden
388	773	Linz	Austria
384	782	Deutschlandsender	Germany (G.D.R.)
384	782	Radio Club of Portugal	Portugal
379	791	Regional (Limoges)	France
375	800	Leningrad II	U.S.S.R.
375	800	Munich	Germany
371	809	Scottish	U.K.
367	818	Warsaw II	Poland
363	827	Freiburg	Germany
363	827	Sofia I	Bulgaria
359	836	Regional (Nancy)	France
355	845	Rome II	Italy
351	854	Bucharest	Roumania
348	863	Regional (Paris I)	France
344	872	Moscow III	U.S.S.R.
344	872	A.F.N. (Frankfurt)	Germany
341	881	Welsh	U.K.
341	881	Deutschlandsender	Germany (G.D.R.)
334	899	Milan I	Italy
330	908	London	U.K.
327	917	Ljubljana	Yugoslavia
324	926	Brussels National	Belgium
321	935	Lwow	U.S.S.R.
318	944	Regional (Toulouse)	France
315	953	Prague I	Czechoslovakia
309	971	Hamburg	Germany
306	980	Göteborg	Sweden
303	989	Berlin (R.I.A.S.)	Germany
301	998	Andorra	Andorra
298	1,007	Hilversum II	Holland
295	1,016	Rheinsender	Germany
293	1,025	Graz-Dobl	Austria
293	1,022	Madrid	Spain
290	1,034	Tallinn	Estonia
288	1,043	Dresden	Germany (G.D.R.)
285	1,052	West	U.K.
283	1,061	Kalundborg II	Denmark
280	1,070	National (Paris II)	France
278	1,079	Katowice	Poland
276	1,088	Midland	U.K.
274	1,097	Bratislava	Czechoslovakia
271	1,106	A.F.N. (Stuttgart)	Germany
269	1,115	Bari II, etc.	Italy
267	1,124	Brussels Regional	Belgium
265	1,133	Zagreb	Yugoslavia
261	1,151	Northern Ireland	U.K.
259	1,160	Regional (Strasbourg)	France
255	1,178	Hörby	Sweden
253	1,187	Petofi	Hungary
251	1,196	V.O.A. (Munich)	Germany
249	1,205	Regional (Bordeaux I)	France
247	1,214	Light Programme	U.K.
247	1,214	B.F.N. Network	Germany

Major European Broadcasting Stations

Wavelength (metres)	*Frequency (kc/s)*	*Station or Programme*	*Country*
245	1,223	Falun	Sweden
244	1,232	Bratislava	Czechoslovakia
242	1,241	National Network	France
240	1,250	Dublin, etc.	Eire
238	1,259	Stettin	Poland
238	1,259	" Courier " V.O.A.	Greece
235	1,277	National (Strasbourg)	France
233	1,286	Prague II	Czechoslovakia
232	1,295	Norden (B.B.C.)	Germany
227	1,313	Stravanger	Norway
227	1,322	Leipzig	Germany (G.D.R.)
225	1,331	Rome I, etc.	Italy
224	1,340	Crowborough (European Service)	U.K.
223	1,349	National Network	France
218	1,376	Regional (Lille)	France
213	1,403	Regional Network	France
211	1,421	Sarrebrücken	Germany
210	1,430	Skive, etc.	Denmark
208	1,439	Luxembourg	Luxembourg
207	1,448	Turin II, etc.	Italy
206	1,457	West	U.K.
205	1,466	Monte Carlo	Monaco
202	1,484	International Common Frequency	—
201	1,493	Paris Inter Network	France
199	1,511	Brussels Regional	Belgium
196	1,529	Vatican City	Vatican
195	1,538	Ravensburg, etc.	Germany
194	1,546	Third Programme	U.K.
193	1,554	Paris Inter (Nice)	France
189	1,586	Oldenburg, etc.	Germany
188	1,594	International Common Frequency	—
187	1,602	Nuremburg, etc.	Germany

B.B.C. Light Programme Stations

Wavelength (metres)	*Frequency (kc/s)*	*Station*	*Power (kW)*
1,500	200	Droitwich	400
247	1,214	Brookmans Park	60
247	1,214	Moorside Edge	58
247	1,214	Westerglen	50
247	1,214	Burghead	20
247	1,214	Lisnagarvey	10
247	1,214	Newcastle-upon-Tyne	2
247	1,214	Redmoss	2
247	1,214	Redruth	2
247	1,214	Plymouth	0·3
247	1,214	Londonderry	0·25

B.B.C. Home Service Stations

Wavelength (metres)	*Frequency (kc/s)*	*Station*	*Programme*	*Power (kW)*
434	692	Moorside Edge	Northern	150
434	692	Whitehaven	Northern	2
434	692	Cromer	Northern	2
371	809	Westerglen	Scottish	100
371	809	Burghead	Scottish	100
371	809	Redmoss	Scottish	5
371	809	Dumfries	Scottish	2
341	881	Washford	Welsh	100
341	881	Penmon	Welsh	8
341	881	Towyn	Welsh	5
341	881	Wrexham	Welsh	0·25
330	908	Brookmans Park	London	140
285	1,052	Start Point	West of England	120
285	1,052	Fremington	West of England	2
276	1,088	Droitwich	Midland	150
276	1,088	Norwich	Midland	7·5
261	1,151	Lisnagarvey	N. Ireland/Northern	100
261	1,151	Stagshaw	N. Ireland/Northern	100
261	1,151	Scarborough	N. Ireland/Northern	2
261	1,151	Londonderry	N. Ireland/Northern	0·25
206	1,457	Clevedon	West of England	20
206	1,457	Bartley	West of England	10
206	1,457	Brighton	West of England	2
206	1,457	Bexhill	West of England	2
206	1,457	Redruth	West of England	2
206	1,457	Folkestone	West of England	1
202	1,484	Barrow	Northern	2
202	1,484	Cardiff	Welsh	1
202	1,484	Ramsgate	London	2

B.B.C. Third Programme Stations

Wavelength (metres)	*Frequency (kc/s)*		*Power (kW)*
464	647	Daventry	150
464	647	Edinburgh	2
464	647	Glasgow	2
464	647	Newcastle-upon-Tyne	2
464	647	Redmoss	2
194	1,546	Belfast	*
194	1,546	Bournemouth	*
194	1,546	Brighton	*
194	1,546	Dundee	*
194	1,546	Exeter	*
194	1,546	Fareham	*
194	1,546	Leeds	*
194	1,546	Liverpool	*
194	1,546	Preston	*
194	1,546	Plymouth	*
194	1,546	Redruth	*
194	1,546	Stockton-on-Tees	*
194	1,546	Swansea	*

* Between 0·25 and 2 kW.

B.B.C. FREQUENCY-MODULATED STATIONS

Station	*Home Programme*		*Light Programme* (*Mc/s*)	*Third Programme* (*Mc/s*)
	Mc/s	*Programme*		
Channel Isles	97·1	W. of England	91·1	94·45
Divis (N. Ireland)	94·5	N. Ireland	90·1	92·3
Douglas (Isle of Man)	92·8	Northern	88·4	90·6
Dover	94·4	London	90·0	92·4
Fort William	93·7	Scottish	89·3	91·5
Galashiels	93·5	Scottish	89·1	91·3
Holme Moss	93·7	Northern	89·3	91·5
Kinlochleven	94·1	Scottish	89·7	91·9
Kirk o' Shotts	94·3	Scottish	89·9	92·1
Llandonna (Anglesey)	94·0	Welsh	89·6	91·8
Llandrindod Wells	93·5	Welsh	89·1	91·3
Llangollen (N.E. Wales)	93·3	Welsh	88·9	91·1
Londonderry	92·7	N. Ireland	88·3	90·55
Meldrum (N.E. Scotland)	93·1	Scottish	88·7	90·9
North Hessary Tor (S. Devon)	92·5	W. of England	88·1	90·3
Oban	93·3	Scottish	88·9	91·1
Orkney	93·7	Scottish	89·3	91·5
Oxford	93·9	Midland	89·5	91·7
	95·85	W. of England		
Peterborough	94·5	Midland	90·1	92·3
Pontop Pike (Newcastle)	92·9	Northern	88·5	90·7
Rosemarkie (N. Scotland)	94·0	Scottish	89·6	91·8
Rowridge (Isle of Wight)	92·9	W. of England	88·5	90·7
Sandale (Carlisle)	92·5	Scottish	88·1	90·3
	94·7	Northern		
Sutton Coldfield	92·7	Midland	88·3	90·5
Talconeston (Norwich)	94·1	Midland	89·7	91·9
Thrumster (Wick)	94·5	Scottish	90·1	92·3
Wenvoe (S. Wales)	92·125	W. of England	89·95	96·8
	94·3	Welsh		
West Cornwall	94·1	W. of England	89·7	91·9
West Wales (Blaen Plwyf)	93·1	Welsh	88·7	90·9
Wrotham (Kent)	93·5	London	89·1	91·3

Further stations, to be completed by 1964: Forfar, Grantown-on-Spey, Lewis, Pitlochry, Shetland, Skye, East Lincolnshire, Enniskillen, Pembroke, Sheffield, S.W. Scotland.

[SECTION 15]

VALVE AND TRANSISTOR DATA

THIS section gives heater ratings, valve-base connections and equivalents for the valves commonly fitted to modern A.M. and F.M. radio receivers.

Symbols Used to Indicate Pin Connections

The recommended electrode letter symbols of the British Standards Institution, listed in B.S. 1409 : 1947, have, wherever possible, been followed. Those used in the tables on the following pages are explained below:

a	anode
k	cathode
g	grid
h	heater
f	filament
M	external conductive coating
s	internal shield
t	target (tuning indicator)

In cases where a valve has more than one electrode system of the same type, electrodes of the same type are distinguished by the addition of " primes ". The example below is for a double diode with separate cathodes :

$$k' \quad a'' \quad h \quad h \quad k'' \quad s \quad a'$$

In the case of multiple valves using different electrode systems, the respective electrodes are distinguished by the addition of the following subscripts :

d	diode
t	triode
p	pentode
h	hexode, heptode, etc.

For example, in the case of a double-diode triode with common cathode, the following symbols would be used :

$$g \quad k \quad h \quad h \quad a'_d \quad a''_d \quad a_t$$

Subscripts are omitted wherever confusion is not likely to arise, for example in the case of the grids in the pentode system of a diode pentode.

Base type.—The type of base used on the valve is given in the base column, the different types being illustrated in Fig. 1. The bracketed numbers refer to the pin connection table.

Valve Practice

The following are among the recommendations made by the British Valve Association for the correct use of valves :

Manufacturers' ratings should be carefully observed.

Heater or filament voltages should not vary by more than 7 per cent from rated values.

The potential difference between the cathode and heater should not normally exceed 150 volts unless the valve has been specially designed for A.C./D.C. operation.

Ventilation should be adequate to ensure a safe bulb temperature at all times.

A limiting resistor should always be placed in series with a rectifying valve when used in conjunction with a capacitor-input filter.

It is generally undesirable to use spare socket contacts as connecting tags.

There should always be a D.C. continuity between each electrode and cathode; and the resistance of this connection should be the least practicable.

The heat dissipated at the electrodes should be the minimum possible: common causes of excessive dissipation are incorrect tuning of associated circuits, unnecessarily high no-signal currents, parasitic oscillations.

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
AZ31	Full-wave rectifier	4·0	1·1	P (1)*
AZ41	Full-wave rectifier	4·0	0·72	B8A (128)
B65	Double triode	6·3	0·6	K (2)
B109	V.H.F. double triode	26·0	0·1	B9A (129)
B152	Double triode	12·6 c.t.	0·15	B9A (32)
B309	Double triode	12·6 c.t.	0·15	B9A (32)
B329	Double triode	12·6 c.t.	0·15	B9A (32)
B339	Double triode	12·6 c.t.	0·15	B9A (32)
B719	V.H.F. double triode	6·3	0·45	B9A (129)
CBL31	Double diode output pentode	44	0·2	K (3)
CCH35	Triode hexode frequency changer	7	0·2	K (4)
CL33	Output pentode	33	0·2	K (5)
CY31	Half-wave rectifier	20	0·2	K (6)
D77	Double diode	6·3	0·3	B7G (7)
D152	Double diode	6·3	0·3	K (7)
DAC32	Diode triode	1·4	0·05	K (8)
DAF91	Diode A.F. pentode	1·4	0·05	B7G (9)
DAF96	Diode A.F. pentode	1·4	0·025	B7G (9)
DD41	Double diode	4·0	0·5	MO (10)
DF33	Vari-mu R.F. pentode	1·4	0·05	K (11)
DF91	Vari-mu R.F. pentode	1·4	0·05	B7G (12)
DF96	R.F. pentode	1·4	0·025	B7G (12)
DF97	Vari-mu R.F. pentode	1·4	0·025	B7G (130)
DH63	Double diode triode	6·3	0·3	K (13)
DH76	Double diode triode	13	0·16	K (13)
DH77	Double diode triode	6·3	0·3	B7G (14)
DH81	Double diode triode	6·3	0·3	B8G (73)

Bracketed numbers refer to pin connection table.

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
DH101	Double diode triode	19·0	0·1	B8G (73)
DH107	Double diode triode	19	0·1	B7G (14)
DH109	Triple diode triode	28·0	0·1	B9A (25)
DH118	Double diode triode	14·0	0·1	B8A (15)
DH119	Double diode triode	13·0	0·1	B9A (131)
DH142	Double diode triode	14	0·1	B8A (15)
DH147	Double diode triode	6·3	0·2	K (13)
DH149	Double diode triode	6·3	0·15	B8G (16)
DH150	Double diode triode	6·3	0·225	B8A (15)
DH718	Double diode triode	6·3	0·23	B8A (15)
DK32	Heptode frequency changer	1·4	0·05	K (17)
DK91	Heptode frequency changer	1·4	0·05	B7G (18)
DK92	Heptode frequency changer	1·4	0·05	B7G (19)
DK96	Heptode frequency changer	1·4	0·025	B7G (19)
DL35	Output pentode	1·4	0·1	K (20)
DL92	Output pentode	2·8 c.t.	0·05	B7G (21)
DL94	Output pentode	2·8 c.t.	0·05	B7G (22)
DL96	Output pentode	1·4	0·05	B7G (21)
DL145	Double diode triode	15	0·1	B8A (15)
DM70	Tuning indicator	1·4	0·025	B8D (23)
DM71	Tuning indicator	1·4	0·025	B8D (23)
DN143	Double diode output pentode	6·3	0·8	B8G (24)
EABC80	Triple diode triode	6·3	0·45	B9A (25)
EAC91	Single diode triode	6·3	0·3	B7G (132)
EAF41	Diode vari-mu R.F. tetrode	6·3	0·2	B8A (26)
EAF42	Diode vari-mu R.F. pentode	6·3	0·2	B8A (27)
EB34	Double diode	6·3	0·2	K (28)
EB41	Double diode	6·3	0·3	B8A (29)
EB91	Double diode	6·3	0·3	B7G (7)
EBC33	Double diode triode	6·3	0·2	K (13)
EBC41	Double diode triode	6·3	0·23	B8A (15)
EBC81	Double diode triode	6·3	0·23	B9A (131)
EBC90	Double diode triode	6·3	0·3	B7G (14)
EBF80	Double diode vari-mu R.F. pentode	6·3	0·3	B9A (30)
EBF83	Double diode, vari-mu pentode (12-v. H.T.)	6·3	0·3	B9A (133)
EBF89	Double diode, vari-mu pentode	6·3	0·3	B9A (133)
EBL21	Double diode output pentode	6·3	0·8	B8G (24)
EBL31	Double diode output pentode	6·3	1·2	K (3)
ECC40	Double triode	6·3	0·6	B8A (31)
ECC81	Double triode	12·6 c.t.	0·15	B9A (32)
ECC82	Double triode	12·6 c.t.	0·15	B9A (32)
ECC83	Double triode	12·6 6·3	0·15 0·3	B9A (32)
ECC85	Double triode	6·3	0·435	B9A (125)
ECF80	Triode pentode frequency changer	6·3	0·43	B9A (134)
ECF82	Triode pentode frequency changer	6·3	0·45	B9A (134)
ECH21	Triode heptode frequency changer	6·3	0·33	B8G (33)
ECH35	Triode hexode frequency changer	6·3	0·225	K (4)
ECH42	Triode hexode frequency changer	6·3	0·23	B8A (34)
ECH81	Triode heptode frequency changer	6·3	0·3	B9A (35)
ECH83	Triode-heptode (12 v. H.T.)	6·3	0·3	B9A (35)
ECL80	Triode output pentode	6·3	0·3	B9A (36)
ECL82	Triode output pentode (separate cathodes)	6·3	0·78	B9A (135)
ECL83	Triode output pentode (separate cathodes)	6·3	0·6	B9A (136)
ECL86	A.F. triode pentode	6·3	0·7	B9A (154)
EF22	Vari-mu R.F. pentode	6·3	0·2	B8G (37)
EF37	R.F. pentode	6·3	0·2	K (38)

Type	*Description*	*Heater Voltage*	*Heater Currents*	*Base*
EF37A	Low-hum, A.F. pentode	6·3	0·2	K (38)
EF39	Vari-mu R.F. pentode	6·3	0·2	K (38)
EF40	Low-microphony A.F. pentode	6·3	0·3	B8A (39)
EF41	Vari-mu R.F. pentode	6·3	0·2	B8A (40)
EF42	R.F. pentode	6·3	0·33	B8A (94)
EF80	Low-microphony A.F. pentode	6·3	0·3	B9A (41)
EF85	Vari-mu R.F. pentode	6·3	0·3	B9A (41)
EF86	Low-microphony A.F. pentode	6·3	0·2	B9A (42)
EF89	R.F. pentode	6·3	0·2	B9A (41)
EF91	R.F. pentode	6·3	0·3	B7G (100)
EF92	Vari-mu R.F. pentode	6·3	0·2	B7G (100)
EF93	Vari-mu R.F. pentode	6·3	0·3	B7G (51)
EF95	V.H.F. pentode	6·3	0·175	B7G (137)
EF98	Transistor driver pentode (12 v.)	6·3	0·3	B7G (138)
EF183	Vari-mu R.F. pentode	6·3	0·3	B9A (152)
EF184	R.F. pentode	6·3	0·3	B9A (152)
EK90	Heptode frequency changer	6·3	0·3	B7G (52)
EL33	Output pentode	6·3	0·9	K (5)
EL37	Output pentode	6·3	1·4	K (5)
EL41	Output pentode	6·3	0·7	B8A (40)
EL42	Output pentode	6·3	0·2	B8A (40)
EL84	Putput pentode	6·3	0·76	B9A (43)
EL85	Output pentode	6·3	0·2	B9A (149)
EL90	Output pentode	6·3	0·45	B7G (113)
EL91	Output pentode	6·3	0·2	B7G (71)
EL95	Output pentode	6·3	0·2	B7G (113)
ELL80	Double pentode	6·3	0·55	B9A (153)
EM34	Tuning indicator (dual sensitivity)	6·3	0·2	K (44)
EM80	Tuning indicator	6·3	0·3	B9A (127)
EM81	Tuning indicator	6·3	0·3	B9A (139)
EM84	Tuning indicator	6·3	0·21	B9A (140)
EM840	Tuning indicator	6·3	0·25	B9A (140)
EM85	Tuning indicator	6·3	0·3	B9A (140)
EM87	Voltage level indicator	6·3	0·3	B9A (140)
EZ35	Full-wave rectifier	6·3	0·6	K (45)
EZ40	Full-wave rectifier	6·3	0·6	B8A (46)
EZ41	Full-wave rectifier	6·3	0·4	B8A (46)
EZ80	Full-wave rectifier	6·3	0·6	B9A (47)
EZ81	Full-wave rectifier	6·3	1·0	B9A (47)
EZ90	Full-wave rectifier	6·3	0·6	B7G (89)
FC2A	Octode frequency changer	2	0·13	M (48)
GZ30	Full-wave rectifier	6·3	2·0	K (49)
GZ32	Full-wave rectifier	6·3	2·3	K (49)
GZ33	Full-wave rectifier	5·0	2·8	K (49)
GZ34	Full-wave rectifier	5·0	1·9	K (141)
HABC80	Triple diode triode	19·0	0·15	B9A (25)
HBC90	Double diode triode	12·6	0·15	B7G (14)
HBC91	Double diode triode	12·6	0·15	B7G (14)
HD24	Double diode triode	2·0	0·1	O (50)
HF93	Vari-mu R.F. pentode	12·6	0·15	B7G (51)
HK90	Heptode frequency changer	12·6	0·15	B7G (52)
HL23DD	Double diode triode	2·0	0·05	MO (53)
HL41DD	Double diode triode	4·0	0·65	MO (55)
HL42DD	Double diode vari-mu triode	4·0	0·65	MO (55)
HL92	Output pentode	50	0·15	B7G (56)
HN309	Triode output pentode	12·6	0·3	B9A (136)
HY90	Half-wave rectifier	35	0·15	B7G (57)
IW4/350	Full-wave rectifier	4·0	2·0	A (58)
KBC32	Double-diode triode	2	0·05	K (61)
KF35	Vari-mu R.F. pentode	2	0·05	K (59)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
KK32	Octode frequency changer	2	0·13	K (60)
KL35	Output pentode	2	0·15	K (20)
KLL32	Double output pentode	2	0·3	K (62)
KT2	Output tetrode	2	0·2	O (63)
KT33C	Output tetrode	13 25	0·6 0·3	K (64)
KT61	Output tetrode	6·3	0·95	K (65)
KT66	Output tetrode	6·3	1·27	K (65)
KT71	Output tetrode	48	0·16	K (65)
KT74	Output tetrode	15	0·16	K (65)
KT76	Output tetrode	15	0·16	K (65)
KTW61	Vari-mu R.F. pentode	6·3	0·3	K (67)
KTW61M	Vari-mu R.F. pentode	6·3	0·3	K (66)
L63	Triode	6·3	0·3	K (68)
L77	Triode	6·3	0·15	B7G (69)
LN119	Triode pentode (separate cathodes)	50·0	0·1	B9A (135)
LN152	Triode pentode	6·3	0·3	B9A (36)
ME41	Tuning indicator	4·0	0·5	MO (70)
N17	Output pentode	1·4 2·8	0·1 0·05	B7G (21)
N18	Output pentode	1·4 2·8	0·1 0·05	B7G (21)
N19	Output pentode	1·4 2·8	0·1 0·05	B7G (22)
N25	Output pentode	2·8 c.t.	0·025	B7G (22)
N78	Output pentode	6·3	0·64	B7G (71)
N108	Output pentode	4·0	0·1	B7G (71)
N118	Output tetrode	40·0	0·1	B8A (72)
N119	Output pentode	45·0	0·1	B9A (43)
N142	Output pentode	45·0	0·1	B8A (40)
N144	Output pentode	6·3	0·2	B7G (71)
N145	Output pentode	40·0	0·1	B8A (72)
N147	Output pentode	6·3	0·9	K (5)
N148	Output tetrode	6·3	0·45	B8G (73)
N150	Output pentode	6·3	0·7	B8A (40)
N151	Output pentode	6·3	0·2	B8A (40)
N155	Output pentode	6·3	0·2	B9A (149)
N709	Power pentode	6·3	0·76	B9A (43)
N727	Output pentode	6·3	0·45	B7G (113)
OM1	Half-wave rectifier	30·0	0·2	K (74)
OM4	Double diode triode	6·3	0·2	K (13)
OM6	Vari-mu R.F. pentode	6·3	0·2	K (38)
OM10	Triode hexode frequency changer	6·3	0·2	K (4)
OZ4	Cold cathode full-wave rectifier	—	—	K (75)
Pen DD4020	Double diode output pentode	40·0	0·2	M (76)
Pen 25	Output pentode	2·0	0·15	MO (77)
Pen 44	Output tetrode	4·0	2·1	MO (78)
Pen 45	Output tetrode	4·0	1·75	MO (78)
Pen 45DD	Double diode output tetrode	4·0	2·0	MO (79)
PL82	Output pentode	16·5	0·3	B9A (43)
PP3/250	Directly heated output triode	4·0	1·0	A (80)
PX4	Directly heated output triode	4·0	1·0	A (80)
PX25	Directly heated output triode	4·0	2·0	A (80)
PY82	Half-wave rectifier	19·0	0·3	B9A (81)
PZ30	Multiple rectifier	52·0	0·3	K (82)
QP25	Double pentode	2·0	0·2	M (83)
R2	Full-wave rectifier	4·0	2·5	A (58)
R52	Full-wave rectifier	5·0	2·0	K (49)
SP41	R.F. pentode	4·0	0·95	MO (84)
TH41	Triode heptode frequency changer	4·0	1·3	MO (85)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
TP25	Triode pentode	2·0	0·2	MO (86)
U10	Full-wave rectifier	4·0	1·0	A (87)
U31	Half-wave rectifier	26·0	0·3	K (6)
U50	Full-wave rectifier	5·0	2·0	K (88)
U52	Full-wave rectifier	5·0	3·0	K (88)
U70	Full-wave rectifier	6·3	0·6	K (45)
U76	Half-wave rectifier	30·0	0·16	K (6)
U78	Full-wave rectifier	6·3	0·6	B7G (89)
U107	Half-wave rectifier	40·0	0·1	B7G (90)
U118	Half-wave rectifier	40·0	0·1	B8A (91)
U119	Half-wave rectifier	38·0	0·1	B9A (81)
U142	Half-wave rectifier	31·0	0·1	B8A (91)
U143	Full-wave rectifier	4·0	1·1	K (88)
U145	Half-wave rectifier	40·0	0·1	K (91)
U147	Full-wave rectifier	6·3	0·6	K (45)
U149	Full-wave rectifier	6·3	0·5	B8G (92)
U150	Full-wave rectifier	6·3	0·6	B8A (46)
U381	Half-wave rectifier	38·0	0·1	B9A (81)
U404	Half-wave rectifier	40·0	0·1	B8A (91)
U709	Half-wave rectifier	6·3	0·95	B9A (47)
U718	Full-wave rectifier	6·3	0·63	B8A (46)
UABC80	Triple diode triode	28·0	0·1	B9A (25)
UAF41	Diode vari-mu R.F. pentode	12·6	0·1	B8A (93)
UAF42	Diode vari-mu R.F. pentode	12·6	0·1	B8A (27)
UBC41	Double diode triode	14·0	0·1	B8A (15)
UBC81	Double diode triode	14·0	0·1	B8A (131)
UBF80	Double diode vari-mu R.F. pentode	17·0	0·1	B9A (30)
UBF89	Double diode, vari-mu pentode	19·0	0·1	B9A (133)
UBL21	Double diode output pentode	55·0	0·1	B8G (24)
UCC85	V.H.F. double triode	26·0	0·1	B9A (129)
UCF80	Triode pentode	27·0	0·1	B9A (134)
UCH21	Triode heptode frequency changer	20·0	0·1	B8G (33)
UCH41	Triode hexode frequency changer	12·6	0·1	B8A (34)
UCH42	Triode hexode frequency changer	12·6	0·1	B8A (34)
UCH81	Triode heptode frequency changer	19·0	0·1	B9A (35)
UCL82	Triode pentode (separate cathodes)	50·0	0·1	B9A (135)
UCL83	Triode pentode (separate cathodes)	38·0	0·1	B9A (136)
UF41	Vari-mu R.F. pentode	12·6	0·1	B8A (40)
UF42	High slope R.F. pentode	21·0	0·1	B8A (94)
UF80	R.F. pentode	19·0	0·1	B9A (41)
UF85	Vari-mu R.F. pentode	19·0	0·1	B9A (41)
UF86	Low noise A.F. pentode	12·6	0·1	B9A (42)
UF89	Vari-mu R.F. pentode	12·6	0·1	B9A (142)
UL41	Output pentode	45·0	0·1	B8A (40)
UL46	Low microphony output pentode	45·0	0·1	B8A (40)
UL84	Output pentode	45·0	0·1	B9A (43)
UM34	Tuning indicator (dual sensitivity)	12·6	0·1	K (44)
UM35	Tuning indicator (dual sensitivity)	12·6	0·1	K (143)
UM80	Tuning indicator	19·0	0·1	B9A (139)
UU6	Full-wave rectifier	4·0	1·4	MO (95)
UU7	Full-wave rectifier	4·0	2·3	MO (95)
UU9	Full-wave rectifier	6·3	0·6	B8A (46)
UU12	Full-wave rectifier	6·3	0·95	B9A (47)
UY21	Half-wave rectifier	50	0·1	B8G (96)
UY41	Half-wave rectifier	31	0·1	B8A (91)
UY85	Half-wave rectifier	38·0	0·1	B9A (81)
VP23	Vari-mu R.F. pentode	2·0	0·05	MO (97)
VP41	Vari-mu R.F. pentode	4·0	0·65	MO (84)
W17	Vari-mu R.F. pentode	1·4	0·05	B7G (12)
W21	Vari-mu R.F. pentode	2·0	0·1	M (98)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
W25	Vari-mu R.F. pentode	1·4	0·025	B7G (12)
W61	Vari-mu R.F. pentode	6·3	0·3	K (99)
W76	Vari-mu R.F. pentode	13	0·16	K (38)
W77	Vari-mu R.F. pentode	6·3	0·2	B7G (100)
W81	Vari-mu R.F. pentode	6·3	0·3	B8G (37)
W107	Vari-mu R.F. pentode	12·6	0·1	B7G (100)
W118	Vari-mu R.F. pentode	13·0	0·1	B8A (94)
W119	Vari-mu R.F. pentode	13·0	0·1	B9A (41)
W142	R.F. pentode	12·6	0·1	B8A (40)
W143	Vari-mu R.F. pentode	6·3	0·2	B8G (101)
W145	Vari-mu R.F. pentode	13·0	0·1	B8A (94)
W147	Vari-mu R.F. pentode	6·3	0·2	K (38)
W148	Vari-mu R.F. pentode	6·3	0·3	B8G (37)
W149	Vari-mu R.F. pentode	6·3	0·15	B8G (37)
W150	Vari-mu R.F. pentode	6·3	0·2	B8A (102)
W719	Vari-mu R.F. pentode	6·3	0·3	B9A (41)
W727	Vari-mu R.F. pentode	6·3	0·3	B7G (51)
W729	Vari-mu R.F. pentode	6·3	0·3	B9A (41)
WD119	Double diode, vari-mu R.F. pentode	19·0	0·1	B9A (30)
WD142	Diode vari-mu R.F. pentode	12·6	0·1	B8A (27)
WD709	Double diode, vari-mu R.F. pentode	6·3	0·3	B9A (30)
X17	Heptode frequency changer	1·4	0·05	B7G (18)
X18	Heptode frequency changer	1·4	0·05	B7G (103)
X24	Triode hexode frequency changer	2·0	0·2	M (104)
X25	Pentagrid frequency changer	1·4	0·025	B7G (19)
X61M	Triode hexode frequency changer	6·3	0·3	K (4)
X71M	Triode hexode frequency changer	13·0	0·16	K (4)
X76M	Triode hexode frequency changer	13·0	0·16	K (4)
X78	Triode hexode frequency changer	6·3	0·3	B7G (105)
X79	Triode hexode frequency changer	6·3	0·3	B9A (106)
X81	Triode hexode frequency changer	6·3	0·3	B8G (107)
X81M	Triode hexode frequency changer	6·3	0·3	B8G (107)
X101	Triode hexode frequency changer	19·0	0·1	B8G (107)
X109	Triode hexode frequency changer	19·0	0·1	B9A (106)
X118	Triode heptode frequency changer	28·0	0·1	B8A (117)
X119	Triode heptode frequency changer	19·0	0·1	B9A (35)
X142	Triode hexode frequency changer	14·0	0·1	B8A (34)
X143	Triode hexode frequency changer	6·3	0·33	B8G (33)
X145	Triode hexode frequency changer	28·0	0·1	B8A (34)
X147	Triode hexode frequency changer	6·3	0·3	K (4)
X148	Triode hexode frequency changer	6·3	0·3	B8G (108)
X150	Triode hexode frequency changer	6·3	0·225	B8A (34)
X719	Triode heptode frequency changer	6·3	0·3	B9A (35)
X727	Heptode frequency changer	6·3	0·3	B7G (52)
Y25	Tuning indicator	1·4	0·025	B8D (23)
Y61	Tuning indicator	6·3	0·3	K (109)
Y63	Tuning indicator	6·3	0·3	K (109)
Y119	Tuning indicator	19·0	0·1	B9A (139)
Z77	High slope R.F. pentode	6·3	0·3	B7G (100)
Z142	R.F. pentode	21·0	0·1	B8A (94)
Z150	R.F. pentode	6·3	0·33	B8A (94)
Z152	R.F. pentode	6·3	0·3	B9A (41)
Z309	R.F. pentode	12·6 c.t.	0·3	B9A (144)
Z329	R.F. pentode	7·3	0·3	B9A (41)
Z719	R.F. pentode	6·3	0·3	B9A (41)
Z729	Low noise A.F. pentode	6·3	0·2	B9A (42)
ZD17	Diode pentode	1·4	0·05	B7G (9)
ZD25	Diode pentode	1·4	0·025	B7G (9)
ZD152	Double diode pentode	6·3	0·3	B9A (30)
1A7	Heptode frequency changer	1·4	0·05	K (17)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
1C1	Heptode frequency changer	1·4	0·05	B7G (18)
1C2	Heptode frequency changer	1·4	0·05	B7G (19)
1C3	Pentagrid frequency changer	1·4	0·025	B7G (19)
1C5	Output pentode	1·4	0·1	K (20)
1D5	Vari-mu R.F. tetrode	2·0	0·06	K (126)
1D5	Half-wave rectifier	40·0	0·2	O (110)
1F1	Vari-mu R.F. pentode	1·4	0·025	B7G (12)
1F2	R.F. pentode	1·4	0·05	B7G (12)
1F3	Vari-mu R.F. pentode	1·4	0·05	B7G (12)
1FD1	Diode pentode	1·4	0·025	B7G (9)
1FD9	Diode pentode	1·4	0·05	B7G (9)
1H5	Diode triode	1·4	0·05	K (8)
1L4	R.F. pentode	1·4	0·05	B7G (21)
1M1	Tuning indicator	1·4	0·025	B8D (23)
1M3	Tuning indicator	1·4	0·025	B8D (23)
1N5	R.F. pentode	2·8 c.t.	0·05	K (11)
1P1	Output pentode	2·8 c.t.	0·025	B7G (22)
1P10	Output pentode	2·8 c.t.	0·05	B7G (21)
1P11	Output pentode	1·4	0·1	B7G (22)
1R5	Heptode frequency changer	1·4	0·05	B7G (18)
1S5	Diode pentode	1·4	0·05	B7G (9)
1T4	Vari-mu R.F. pentode	1·4	0·05	B7G (12)
1U5	Diode pentode	1·4	0·05	B7G (111)
3Q4	Output tetrode	1·4 2·8	0·1 0·05	B7G (21)
3S4	Output pentode	2·8 1·4	0·05 0·1	B7G (21)
3V4	Output tetrode	1·4 2·8	0·1 0·05	B7G (22)
5U4	Full-wave rectifier	5·0	3·0	K (88)
5V4	Full-wave rectifier	5·0	2·0	K (49)
5Y3	Full-wave rectifier	5·0	2·0	K (88)
5Z4	Full-wave rectifier	5·0	2·0	K (49)
6A8	Heptode frequency changer	6·3	0·3	K (112)
6AB8	Triode pentode	6·3	0·3	B9A (36)
6AJ8	Triode heptode frequency changer	6·3	0·3	B9A (35)
6AK6	Output pentode	6·3	0·15	B7G (51)
6AK8	Triple diode triode	6·3	0·45	B9A (25)
6AM5	Output pentode	6·3	0·2	B7G (71)
6AM6	R.F. pentode	6·3	0·3	B7G (100)
6AL5	Double diode	6·3	0·3	B7G (7)
6AQ5	Output tetrode	6·3	0·45	B7G (113)
6AQ8	Double triode	6·3	0·435	B9A (125)
6AT6	Double diode triode	6·3	0·3	B7G (14)
6B8	Double diode vari-mu R.F. pentode	6·3	0·3	K (114)
6BA6	Vari-mu R.F. pentode	6·3	0·3	B7G (51)
6BE6	Heptode frequency changer	6·3	0·3	B7G (52)
6BH6	R.F. pentode	6·3	0·15	B7G (115)
6BJ6	Vari-mu R.F. pentode	6·3	0·15	B7G (115)
6BQ5	Output pentode	6·3	0·76	B9A (43)
6BW6	Output tetrode	6·3	0·45	B9A (116)
6BW7	R.F. pentode	6·3	0·3	B9A (41)
6BX6	R.F. pentode	6·3	0·3	B9A (41)
6BY7	Vari-mu R.F. pentode	6·3	0·3	B9A (41)
6C4	Output triode	6·3	0·15	B7G (69)
6C9	Triode heptode frequency changer	6·3	0·45	B8A (117)
6C10	Triode hexode frequency changer	6·3	0·23	B8A (34)
6C12	Triode heptode frequency changer	6·3	0·3	B9A (35)
6C31	Triode heptode frequency changer	6·3	0·83	K (4)
6D2	Double diode	6·3	0·3	B7G (7)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
6F1	R.F. pentode	6·3	0·35	B8A (122)
6F6	Output pentode	6·3	0·7	K (5)
6F12	R.F. pentode	6·3	0·3	B7G (100)
6F13	R.F. pentode	6·3	0·35	B8A (94)
6F15	Vari-mu R.F. pentode	6·3	0·2	B8A (94)
6F16	Vari-mu R.F. pentode	6·3	0·2	B8A (40)
6F18	Vari-mu R.F. pentode	6·3	0·2	B9A (41)
6F19	Vari-mu R.F. pentode	6·3	0·3	B9A (41)
6F23	R.F. pentode	6·3	0·3	B9A (41)
6F26	Vari-mu R.F. pentode	6·3	0·3	B9A (41)
6FD12	Double diode, vari-mu R.F. pentode	6·3	0·3	B9A (30)
6H6	Double diode	6·3	0·3	K (28)
6J5	Triode	6·3	0·3	K (68)
6K7	Vari-mu R.F. pentode	6·3	0·3	K (38)
6K8	Triode hexode frequency changer	6·3	0·3	K (118)
6L6	Output tetrode	6·3	0·9	K (65)
6L13	Double triode	12·6 c.t.	0·15	B9A (32)
6L18	Triode	6·3	0·3	B8A (145)
6L19	Double triode	6·3	0·4	B8A (31)
6L34	V.H.F. triode	6·3	0·3	B7G (146)
6LD3	Double diode triode	6·3	0·23	B8A (15)
6LD12	Triple diode triode	6·3	0·45	B9A (25)
6LD13	Double diode triode	6·3	0·2	B9A (131)
6LD20	Double diode triode	6·3	0·25	B8A (15)
6M1	Tuning indicator	6·3	0·3	K (109)
6M2	Dual sensitivity tuning indicator	6·3	0·2	K (150)
6N8	Double diode, vari-mu pentode	6·3	0·3	B9A (30)
6P15	Output pentode	6·3	0·76	B9A (43)
6P17	Output pentode	6·3	0·2	B7G (71)
6P25	Output tetrode	6·3	1·1	K (65)
6P26	Output tetrode	6·3	0·6	K (65)
6Q7	Double diode triode	6·3	0·3	K (13)
6SH7	R.F. pentode	6·3	0·3	K (119)
6SL7	Double triode	6·3	0·3	K (2)
6SN7	Double triode	6·3	0·6	K (2)
6T8	Triple diode triode	6·3	0·45	B9A (25)
6U5	Tuning indicator	6·3	0·3	UX (120)
6U7	Vari-mu R.F. pentode	6·3	0·3	K (38)
6U8	Triode pentode frequency changer	6·3	0·45	B9A (134)
6V4	Full-wave rectifier	6·3	0·6	B9A (47)
6V6	Output tetrode	6·3	0·45	K (65)
6X4	Full-wave rectifier	6·3	0·6	B7G (89)
6X5	Full-wave rectifier	6·3	0·65	K (45)
6X6	Tuning indicator	6·3	0·3	K (109)
6Y6	Output tetrode	6·3	0·125	K (65)
7B6	Double diode triode	6·3	0·3	B8G (16)
7B7	Vari-mu R.F. pentode	6·3	0·15	B8G (37)
7C5	Output tetrode	6·3	0·45	B8G (73)
7C6	Double diode triode	6·3	0·15	B8G (16)
7D9	Output pentode	6·3	0·2	B7G (71)
7H7	Vari-mu R.F. pentode	6·3	0·3	B8G (37)
7R7	Double diode vari-mu R.F. pentode	6·3	0·3	B8G (121)
7S7	Triode hexode frequency changer	6·3	0·3	B8G (108)
7Y4	Full-wave rectifier	6·3	0·5	B8G (92)
8A8	Triode pentode frequency changer	9·0	0·3	B9A (134)
8D3	R.F. pentode	6·3	0·3	B7G (100)
9D6	Vari-mu R.F. pentode	6·3	0·2	B7G (100)
9U8	Triode pentode frequency changer	9·5	0·3	B9A (134)
10C1	Triode heptode frequency changer	28·0	0·1	B8A (117)
10C2	Triode pentode frequency changer	28·0	0·1	B8A (147)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
10C14	Triode heptode frequency changer	19	0·1	B9A (35)
10F3	R.F. pentode	22	0·1	B8A (94)
10F1	R.F. pentode	22·0	0·1	B8A (122)
10F9	Vari-mu R.F. pentode	13·0	0·1	B8A (94)
10F18	Vari-mu R.F. pentode	13	0·1	B9A (41)
10FD12	Double diode, vari-mu R.F. pentode	19	0·1	B9A (30)
10L1	V.H.F. triode	19	0·1	B7G (146)
10L14	R.F. double triode	26	0·1	B9A (35)
10LD3	Double diode triode	14·0	0·1	B8A (15)
10LD11	Double diode triode	15·0	0·1	B8A (15)
10LD12	Triple diode triode	28	0·1	B9A (25)
10LD13	Double diode triode	13	0·1	B9A (131)
10P13	Output tetrode	40·0	0·1	B8A (72)
10P14	Output tetrode	40·0	0·1	K (65)
10P18	Output pentode	45	0·1	B9A (43)
10PL12	Triode beam tetrode	50	0·1	B9A (135)
12A6	Output tetrode	12·6	0·15	K (5)
12AC6	Vari-mu pentode (12 v. H.T.)	12·6	0·15	B7G (51)
12AD6	Frequency changer (12 v. H.T.)	12·6	0·15	B7G (52)
12AE6	Double diode triode (12 v. H.T.)	12·6	0·15	B7G (14)
12AH8	Triode heptode frequency changer	12·6 c.t.	0·15	B9A (123)
12AT6	Double diode triode	12·6	0·15	B7G (14)
12AT7	Double triode	12·6 c.t.	0·15	B9A (32)
12AU7	Double triode	12·6 c.t.	0·15	B9A (32)
12AX7	Double triode	12·6 c.t.	0·15	B9A (32)
12BA6	Vari-mu R.F. pentode	12·6	0·15	B7G (51)
12BE6	Heptode frequency changer	12·6	0·15	B7G (52)
12C8	Double diode pentode	12·6	0·15	K (114)
12J7	R.F. pentode	12·6	0·15	K (38)
12K5	Transistor driver tetrode (12 v. H.T.)	12·6	0·45	B7G (151)
12K7	Vari-mu R.F. pentode	12·6	0·15	K (38)
12K8	Triode hexode frequency changer	12·6	0·15	K (118)
12Q7	Double diode triode	12·6	0·15	K (13)
12SL7	Double triode	12·6	0·15	K (2)
12U5	Tuning indicator	12·6	0·15	K (109)
14B6	Double diode triode	12·6	0·15	B8G (16)
14H7	Vari-mu R.F. pentode	12·6	0·15	B8G (37)
14R7	Double diode vari-mu R.F. pentode	12·6	0·15	B8G (121)
14S7	Triode hexode frequency changer	12·6	0·15	B8G (108)
19AQ5	Output tetrode	19·0	0·15	B7G (113)
19Y3	Half-wave rectifier	19	0·3	B9A (81)
20D4	Triode heptode frequency changer	6·3	0·3	B9A (148)
20F2	R. F. pentode	11	0·2	B8A (94)
20L1	Double triode	12·6	0·2	B8A (31)
20P3	Output tetrode	20	0·2	K (65)
20P5	Output tetrode	20	0·2	B8A (72)
25A6	Output pentode	25·0	0·3	K (5)
25L6	Output tetrode	25·0	0·3	K (65)
25Z4	Half-wave rectifier	25·0	0·3	K (74)
25Z6	Full-wave rectifier	25·0	0·3	K (28)
35A5	Output tetrode	35·0	0·15	B8G (73)
35L6	Output tetrode	35·0	0·15	K (65)
35W4	Half-wave rectifier	35·0	0·15	B7G (57)
35Z3	Half-wave rectifier	35·0	0·15	B8G (124)
35Z4	Half-wave rectifier	35·0	0·15	K (6)
35Z6	Full-wave rectifier	35·0	0·3	K (28)
50C5	Output tetrode	50·0	0·15	B7G (56)
50L6	Output tetrode	50·0	0·15	K (65)
52KU	Full-wave rectifier	5·0	2·0	K (49)

Type	*Description*	*Heater Voltage*	*Heater Current*	*Base*
65ME	Tuning indicator	6·3	0·3	B9A (127)
141TH	Triode hexode frequency changer	14·0	0·1	B8A (34)
171DDP	Double diode vari-mu R.F. pentode	17·0	0·1	B9A (30)
311SU	Half-wave rectifier	31·0	0·1	B8A (91)
332 Pen	Output pentode	33·0	0·2	K (5)
451PT	Output pentode	45·0	0·1	B8A (40)
1629	Tuning indicator	12·6	0·15	K (109)

Valve Substitution

When a valve socket has to be changed, care should be taken to :

(1) Keep anode and grid leads as far apart as possible in R.F. and I.F. stages.

(2) Keep heater leads as far as possible from grid leads.

(3) Make sure that screening cans and shields are properly wired to chassis.

(4) Keep R.F. grid connections as short as possible and use screened leads for top cap connections.

See also page 97 for precautions to be taken when substituting modern valves for obsolete types.

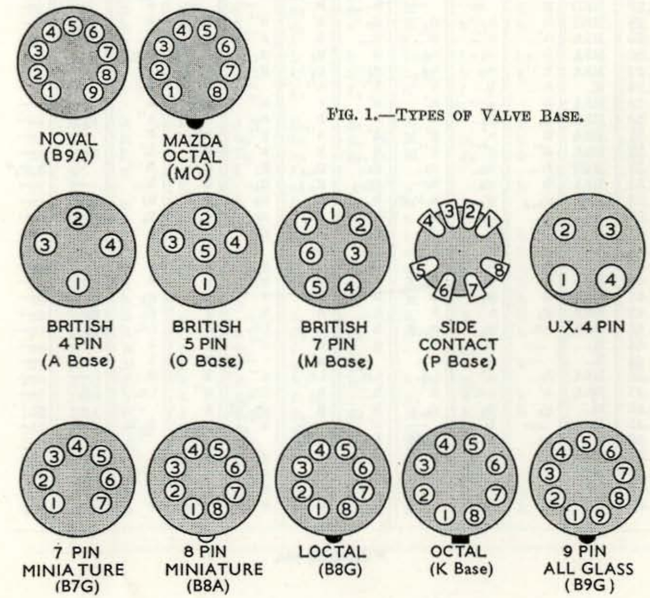


FIG. 1.—TYPES OF VALVE BASE.

Ref.	Base Type	Pin 1	2	3	4	5	6	7	8	9	Cap
1	P	—	h	h	—	a'	—	—	h	a''	—
2	K	g'	a'	k'	g''	a''	k''	h	h	—	—
3	K	s	h	a_p	a'	a''	g_2	h	k, g_3	—	g_1
4	K	s	h	a_h	$g_{2,4}$	$g_{t,3}$	a_t	h	k	—	g_1
5	K	—	h	a	g_2	g_3	—	h	k, g_3	—	—
6	K	—	h	—	—	a	—	h	k	—	—
7	B7G	k'	a''	h	h	k''	s	a'	—	—	—
8	K	s	f	a_t	—	a_d	—	f	—	—	g
9	B7G	f, g_3	—	a_d	g_2	a_p	g_1	f	—	—	—
10	MO	h	k'	a'	s	a''	M	k''	h	—	—
11	K	s	h	a	g_2	—	—	h, g_3	—	—	g_1
12	B7G	s, f, g_3	a	g_2	—	g_3	g_1	f	—	—	—
13	K	s	h	a_t	a'	a''	—	h	k	—	g
14	B7G	g	k	h	h	a'	a''	a_t	—	—	—
15	B8A	h	a	i.c.	s	i.c.	g	k	h	—	—
16	B8G	h	a_t	g	k	a'	a''	k	h	—	—
17	K	s	f	a	$g_{3,5}$	g_1	g_2	f	—	—	g_4
18	B7G	f, g_5	a	$g_{2,4}$	g_1	g_5	g_3	f	—	—	—
19	B7G	f	a	g_2	g_1	g_4	g_3	f, g_5	—	—	—
20	K	s	f	a	g_2	g_1	—	f, g_3	—	—	—
21	B7G	f	a	g_1	g_2	$f_{c.t.}$, g_3	a	f	—	—	—
22	B7G	f	a	g_2	—	$f_{c.t.}$, g_3	g_1	f	—	—	—
23	B8D	g	—	—	h	h	—	—	a	—	—
24	B8G	h	a_p	g_1	g_2	a'	a''	k, g_3	h	—	—
25	B9A	a'	a''	k'', s	h	h	a'''	k	g	a_t	—
26	B8A	h	a_t	a_d	k	g_2	g_1	k	h	—	—
27	B8A	h	a_p	a_d	g_3	g_2	g_1	k, s	h	—	—
28	K	s	h	a'	k'	a''	—	h	k''	—	—
29	B8A	h	—	k'	a'	s	a''	k''	h	—	—
30	B9A	g_2	g_3	k	h	h	a_p	a'	a''	g_1	—
31	B8A	h	a'	g'	k'	a''	g''	k''	h	—	—
32	B9A	a''	g''	k''	h	h	a'	g'	k'	$h_{c.t.}$	—
33	B8G	h	a_h	a_t	g_t	$g_{2,4}$	g_1	g_3	h	—	k, g_1*
34	B8A	h	a_h	a_t	$g_{t,3}$	$g_{2,4}$	g_1	k	h	—	—
35	B9A	$g_{2,4}$	g_1	s, k, g_5	h	h	a_h	g_3	a_t	g_t	—
36	B9A	a_t	g_t	k	h	h	a_p	g_1	g_2	g_3	—
37	B8G	h	a	g_2	g_3	s	g_1	k	h	—	—
38	K	s	h	a	g_2	g_3	—	h	k	—	g_1
39	B8A	h	a	—	g_3	g_1	g_2	s, k	h	—	—
40	B8A	h	a	g_3, k	i.c.	g_2	g_1	k	h	—	—
41	B9A	k	g_1	k	h	h	s	a	g_2	g_3	—
42	B9A	g_2	s	k	h	h	a	s	g_1	g_3	—
43	B9A	i.c.	g_1	g_3, k	h	h	i.c.	a	i.c.	g_2	—
44	K	—	h	a'	g	t	a''	h	k	—	—
45	K	—	h	a'	—	a''	—	h	k	—	—
46	B8A	h	a'	i.c.	i.c.	i.c.	a''	k	h	—	—
47	B9A	a'	i.c.	k	h	h	i.c.	a''	i.c.	i.c.	—
48	M	g_2	g_1	$g_{3,5}$	h	h	g_6, M	a	—	—	g_4
49	K	—	h	—	a'	—	a''	—	k, h	—	—
50	O	a_t	a'	f, M	f	a''	—	—	—	—	g
51	B7G	g_1	s, g_3	h	h	a	g_2	k	—	—	—
52	B7G	g_1	k, g_5	h	h	a	$g_{2,4}$	g_3	—	—	—
53	MO	h	—	a_t	—	a'	s	a''	h	—	g
54	MO	h	k	a	—	g	s	—	h	—	—

* Locking pin.

Ref.	Base Type	Pin 1	2	3	4	5	6	7	8	9	Cap
55	MO	h	k	a_t	—	a'	—	a''	h	—	g
56	B7G	k	g_1	h	h	g_1	g_2	a	—	—	—
57	B7G	—	—	h	h	a	$h_{c.t.}$	k	—	—	—
58	A	a'	a''	k, h	h	—	—	—	—	—	—
59	K	s	f	a	g_2	g_3	—	f	—	—	g_1
60	K	s	f	a	$g_{3,5}$	g_1	g_2	k, g_6	—	—	g_4
61	K	s	f	a_t	a'	a''	—	f	—	—	g
62	K	—	f	a'	g'_1	g_1''	a''	f, g_3', g_3''	g_2', g_2''	—	—
63	O	—	a	g_1	f	f	g_2	—	—	—	—
64	K	$h_{c.t.}$	h	a	g_2	g_1	—	h	k	—	—
65	K	M	h	a	g_2	g_1	—	h	k	—	—
66	K	M	h	a	g_2	g_3	—	h	k	—	g_1
67	K	—	h	a	g_2	g_3	—	h	k	—	g_1
68	K	s	h	a	—	g	—	h	k	—	—
69	B7G	a	i.c.	h	h	a	g	k	—	—	—
70	MO	h	k	a	—	g	—	t	h	—	—
71	B7G	g_1	k, g_3	h	h	a	i.c.	g_2	—	—	—
72	B8A	h	a	i.c.	i.c.	g_2	g_1	k, g_3	h	—	—
73	B8G	h	a	g_2	—	—	g_1	k	h	—	—
74	K	—	h	a	—	a	—	h	k	—	—
75	K	—	—	a'	—	a''	—	—	h	—	—
76	M	a'	a_p	a''	h	h	k, g_3	g_2	—	—	g_1
77	MO	f, g_3	—	a	g_2	g_1	—	—	f	—	—
78	MO	h	k	a	g_2	g_1	M	—	h	—	—
79	MO	h	k, g_3	a	g_2	a'	M	a''	h	—	g_1
80	A	a	g	f	f	—	—	—	—	—	—
81	B9A	i.c.	i.c.	k	h	h	i.c.	i.c.	i.c.	a	—
82	K	—	h	a'	k'	a''	$h_{c.t.}$	h	k''	—	—
83	M	f +	g_2'', g_2'	a''	g_1''	g_1'	a'	f —, g_3'', g_3'	—	—	—
84	MO	h	k	a	g_2	g_3	M	—	h	—	g_1
85	MO	h	k, g_5	a_h	a_t	g_3, g_t	M	$g_{2,4}$	h	—	g_1
86	MO	f	—	a_p	a_t	g_3, g_t	M	g_2	h	—	g_1
87	A	a'	a''	f	f	—	—	—	—	—	—
88	K	—	h	—	a'	—	a''	—	h	—	—
89	B7G	a'	—	h	h	—	a''	k	—	—	—
90	B7G	h	a	k	—	—	a	h	—	—	—
91	B8A	h	a	—	i.c.	i.c.	i.c.	k	h	—	—
92	B8G	h	—	a'	—	—	a''	k	h	—	—
93	B8A	h	a_t	a_d	k	g_2	g_1	k, s	h	—	—
94	B8A	h	a	s	g_3	g_2	g_1	k	h	—	—
95	MO	h, k	—	a'	—	a''	M	—	h	—	—
96	B8G	h	a	—	a	—	a	k	h	—	—
97	MO	h	—	a	g_2	g_3	M	—	h	—	g_1
98	M	M	g_1	g_3	f	f	—	g_2	—	—	a
99	K	M	h	a	g_2	g_3	—	h	k	—	g_1
100	B7G	g_1	k	h	h	a	s, g_2	g_2	—	—	—
101	B8G	h	a	g_2	s, g_3	—	g_1	k	h	—	—
102	B8A	h	a	g_3, k	g_3, k	g_2	g_1	k, g_3	h	—	—
103	B7G	f, g_5	a	g_2	g_1	g_4	g_3	f	—	—	—
104	M	a_t	g_t, g_3	$g_{2,4}$	f	f	M	a_h	—	—	g_1
105	B7G	$g_{2,4}$	g_1	k, h	h	a_h	a_t	g_t, g_3	—	—	—
106	B9A	$g_{2,4}$	g_1	k	h	h	a_h	g_t, g_3	a_t	i.c.	—
107	B8G	h	a_h	a_t	g_t, g_3	$g_{2,4}$	g_1	k	h	—	—
108	B8G	h	a_h	a_t	g_t, g_3	$g_{2,4}$	g_1	s, k, g_5	h	—	—

Ref.	Base Type	Pin 1	2	3	4	5	6	7	8	9	Cap
109	K	—	h	a	t	g	—	h	k	—	—
110	O	a	—	h	h	k	—	—	—	—	—
111	B7G	f, g_3	a_p	g_2	a_d	—	g_1	f	—	—	—
112	K	s	h	a	$g_{3,5}$	g_1	g_2	h	k	—	g_4
113	B7G	g_1	k	h	h	a	g_2	g_1	—	—	—
114	K	s	h	a_p	a′	a″	g_2	h	g_3	—	g_1
115	B7G	g_1	k	h	h	a	g_2	s, g_3	—	—	—
116	B9A	i.c.	g_1	k	h	h	—	a	g_2	g_3	—
117	B8A	h	a_h	a_t	g_t, g_3	$g_{2,4}$	g_1	k, g_5	h	—	—
118	K	s	h	a_h	$g_{2,4}$	g_1, g_t	a_t	h	k	—	g_3
119	K	s	h	k, g_3	g_1	k, g_3	g_2	h	a	—	—
120	UX	h	a	g	t	k	h	—	—	—	—
121	B8G	h	a_p	a′	a″	g_2	g_1	s, k, g_3	h	—	—
122	B8A	h	a	s, g_3	g_2	k	g_1	k	h	—	—
123	B9A	$g_{2,4}$	g_1	k	h	h	a_h	g_t, g_3	a_t	$h_{c.t.}$	—
124	B8G	h	a	—	—	—	—	k	h	—	s *
125	B9A	a′	g′	k′	h	h	a″	g″	k″	s	—
126	K	—	f	a	g_2	—	—	f	—	—	g_1
127	B9A	g	k	i.c.	h	h	i.c.	a	i.c.	t	—
128	B8A	i.c.	a	i.c.	i.c.	i.c.	a	f	f	—	—
129	B9A	a″	g″	k″	h	h	a′	g′	k′	s	—
130	B7G	f, s	a	g_2	g_3	f, s	g_1	f	—	—	—
131	B9A	a	g	k	h	h	a′d	s	a″d	i.c.	—
132	B7G	a_d	k_d	h	h	k_t	g	a_t	—	—	—
133	B9A	g_2	g_1	k, s	h	h	a	a′d	a″d	g_3	—
134	B9A	a_t	g_1	g_2	h	h	a_p	k_p, g_3, s	k_t	g_t	—
135	B9A	g_t	k_p, s, g_3	g_{1p}	h	h	a_p	g_{2p}	k_t	a_t	—
136	B9A	a_t	g_t	k_t	h	h	a_p	k_p, g_3	g_2	g_1	—
137	B7G	g_1	k, g_3, s	h	h	a	g_2	k, g_3, s	—	—	—
138	B7G	g_1	k, s	h	h	a	g_2	g_3	—	—	—
139	B9A	g	k, g′	i.c.	h	h	i.c.	a	i.c.	t	—
140	B9A	g	i.c.	k, g′	h	h	t	def. el.	i.c.	a	—
141	K	i.c.	h	—	a′	—	a″	—	h, k	—	—
142	B9A	s	g_1	k	h	h	s	a	g_2	g_3	—
143	K	h	i.c.	a″	t	g	a′	k	h	—	—
144	B9A	k	g_1	k	h	h	$h_{c.t.}$	a	g_2	g_3, s	—
145	B8A	h	a	i.c.	s	i.c.	g	k	h	—	—
146	B7G	g	k	h	h	k	g	a	—	—	—
147	B8A	h	a_h	a_t	g_t	g_2	g_1	k, s, g_3	h	—	—
148	B9A	$g_{2,4,5}$	g_1	k	h	h	a_h	g_3	a_t	g_t	—
149	B9A	g_1	g_1	k	h	h	g_3	a	g_3	g_2	—
150	K	i.c.	h	a′	g	t	a″	h	k	—	—
151	B7G	k	g_2†	h	h	g_1	g_1	a	—	—	—
152	B9A	k	g_1	k	h	h	s	a	g_2	g_3	—
153	B9A	g'_2	g^1_1	a′	h	h	g''_1	k, g_3 s	a″	g''_2	—
154	B9A	g_t	k_t	g_2	h	h	a_p	k_p, g_3 s	g_1	a_t	—

* Locking pin. † Control grid.

CIVILIAN EQUIVALENTS OF SELECTED SERVICE TYPE VALVES AND TRANSISTORS

Service Type	Equivalent	Service Type	Equivalent	Service Type	Equivalent
CV21	VP41	CV852	6C4	CV1932/4	6J5 *
CV24	HL41	CV882	7B6	CV1941/3	6K7 *
CV65	PEN 25	CV885, 6	7C5 *	CV1944/6	6K8 *
CV131	9D6, EF92	CV887	7C6	CV1947/8	6L6 *
CV133	6C4	CV895	7H7	CV1977	UL41
CV140	6AL5, EB91	CV900	7R7	CV1985	6SL7
CV171	W21	CV901	7Y4	CV1988	6SN7
CV281	X61M	CV917	12J7	CV2128	ECH81
CV283	6AL5	CV918	12K7	CV2500	35Z4
CV303	EF22	CV1039	MU14, IW4-350	CV2862	AZ31
CV358	EF37, A			CV2926	EBL31
CV378	GZ32	CV1053	EF39	CV2398	EL33
CV394	EM34	CV1055	EBC33	CV2954	FC2A
CV452	6AT6, EBC90	CV1067	6J5	CV2996	HL41DD
CV453	6BE6, EK90	CV1071	5U4	CV3630	PEN 44
CV454	6BA6, EF93	CV1075	KT66	CV3631	PEN 45DD
CV492	12AX7, ECC83	CV1103	Y63, EM35	CV3753	U31
		CV1186	6F6	CV3759	R2
CV493	6X4, EZ90	CV1268	5Y3	CV3761	UU7
CV504	6U5	CV1281	KTW61	CV3793	VP23
CV509/11	6V6 *	CV1286	6L6	CV3804	W21
CV515	6Y6G	CV1296	MU14	CV3819/20	X24
CV525	12A6	CV1301	6H6	CV3882	EBC41
CV526	12A6GT	CV1331	VP23	CV3883	EAF42
CV549/50	25A6 *	CV1335	SP41	CV3884	ECC40
CV551/3	25L6 *	CV1342	QP25	CV3885	EF40
CV559	25Z6	CV1345	TP25	CV3886	EF41
CV561/2	35L6 *	CV1347	ECH35	CV3887	EF42
CV565	35Z3	CV1359	ME41	CV3888	ECH42
CV571	50L6	CV1401	CL33	CV3889	EL41
CV572/4	6X5 *	CV1402	CY31	CV3890	EL42
CV575	5U4	CV1407	PEN 45	CV3891	EZ40
CV578/80	6A8 *	CV1411	TH41	CV3892	AZ41
CV586	EL37	CV1413	UU6	CV3908	6BH6
CV587/9	6Q7 *	CV1414	VP41	CV3909	6BJ6
CV593	GZ32	CV1438	KT61	CV3927	12K8GT
CV703	12K8	CV1463	CBL31	CV5055	EM81
CV706	6U7G	CV1574	SP41	CV5065	6U8/ECF82
CV713	6F6G/GT	CV1581	ECH35	CV5072	EZ81
CV726	35Z3	CV1800/2	1A7 *	CV5080	EF37A
CV729	5V4G, GZ32	CV1803/5	1C5 *	CV5110	EF39
CV731	6F6	CV1806	1D5	CV7003	OC44
CV764	1D5	CV1818/20	1H5 *	CV7004	OC45
CV782	1R5, DK91	CV1821/3	1N5 *	CV7005	OC71
CV784	1S5, DAF91	CV1854/6	5Y3 *	CV7006	OC72
CV785	1T4, DF91	CV1863/4	5Z4	CV7008	GET6
CV818	3Q4	CV1893/4	6B8 *	CV7009	GET10
CV820	3S4, DL92	CV1911/2	6F6 *	CV7011/12	V30/30P
CV841	5U4GT	CV1929/31	6H6 *		

* In practically all cases, the first CV number is the equivalent of the type suffixed G, and the last CV number is the equivalent of the GT type valve, *i.e.*, in the case of CV509/11, CV509 = 6V6G, CV510 = 6V6, CV511 = 6V6GT.

Type	Near Equivalents
AZ31	U143
B36	12SN7GT
B65	6SN7GT
B109	UCC85, 10L14
B152	ECC81, B309, 12AT7
B309	ECC81, 12AT7, B152
B319	PCC84, 7AN7, 30L1
B329	12AU7, ECC82
B339	ECC83, 12AX7, 6L13
B719	6AQ8, ECC85, 6L12
BVA132	HL23DD
BVA142	VP23
BVA162	Pen 25
BVA172	TP25
BVA211	R2, 431U, R4, U14, UU5, IW4–350
BVA214	As BVA 211
BVA215	As BVA211
BVA216	As BVA211
BVA243	6K7G, OM6, EF39, VPT62, W147
BVA246	As BVA243
BVA247	As BVA243
BVA264	6AG6G, EL33, KT61, N147, 6P25
BVA265	As BVA264
BVA266	As BVA264
BVA267	As BVA264
BVA274	6K8G, OM10, ECH35, X61M, X147, 6C31
BVA275	As BVA274
BVA276	As BVA274
CCH35	OM10
CL33	332 Pen
CY31	OM1, U201
D1	T4D
D77	DD6, 6AL5, 6D2, EB91, D152
D152	DD6, 6AL5, 6D2, EB91, D77
DAC32	1H5G, HD14
DAF91	ZD17, 1FD9, 1S5
DAF96	1AH5, 1FD1, ZD25
DF33	1N5GT
DF91	W17, 1F3, 1T4
DF92	1F2, 1L4
DF96	1F1, 1AJ4, W25
DH63	6Q7G
DH76	12Q7G
DH77	EBC90, 6AT6
DH81	7B6
DH109	UABC80, 10LD12
DH118	10LD3, DH142, UBC41, 141DDT
DH119	UBC81, 10LD13
DH142	UBC41, 10LD3, DH118, 141DDT
DH147	EBC33, OM4, 6Q7G
DH149	7C6
DH150	EBC41, 62DDT, 6LD3, DH718
DH718	EBC41, 62DDT, 6LD3, DH150

Type	Near Equivalents
DH719	EABC80, 6AK8, 6T8
DK32	1A7GT, X14
DK91	1R5, 1C1, X17
DK92	1AC6, 1C2, X18
DK96	1C3, 1AB6, X25
DL35	1C5G, N14
DL92	N17, 1P10, 3S4
DL94	3V4, 1P11, N19
DL96	1P1, 3C4, N25
DL145	10LD11
DM70	1M1, 1M3
DN143	EBL21
EA50	SD61, 6D1
EABC80	6AK8, DH719, 6T8, 6LD12
EAF42	WD150, 6CT7
EB34	6H6GT
EB91	D77, D152, DD6, 6AL5, 6D2
EBC33	DH147, OM4, 6Q7G
EBC41	DH150, 62DDT, 6LD3, 6CV7
EBC81	6LD13
EBC90	6AT6, DH77
EBF80	ZD152, WD709, 6N8
EBF89	6FD12, 6DC8
EBL21	DN143
EC90	6C4, L77
EC91	6L34, 6AQ4
EC92	6AB4
ECC35	6SL7GT
ECC81	B152, B309, 12AT7
ECC82	B329, 12AU7
ECC83	B339, 6L13, 12AX7
ECC85	B719, 6L12, 6AQ8
ECC91	6J6
ECF80	6BL8
ECF82	6U8
ECH21	X143
ECH35	X147, X61M, OM10
ECH42	6C10, 6CU7, 62TH, X150
ECH81	6AJ8, 6C12, X719
ECL80	6AB8, LN152
ECL82	6BM8
EF22	W143
EF37A	OM5B
EF39	OM6, W147, 6K7GT
EF41	W150, 6F15, 6CJ5, 62VP
EF42	Z150, 6F13 (near)
EF50	Z90, 63SPT
EF80	Z152, Z719, 6BX6
EF85	W719, 6BY7, 6F19
EF86	Z729, 6267
EF89	6DA6
EF91	SP6, Z77, 6AM6, 6F12, 8D3
EF92	VP6, W77, 6CQ6, 9D6
EF93	W727, 6BA6
EF95	6AK5
EK90	X77, X727, 6BE6
EL33	6AG6G
EL37	KT66
EL38	6CN6
EL41	N150, 6CK5, 67PT
EL42	N151

Type	Near Equivalents
EL81	6CJ6
EL83	6CK6
EL84	N709, 6BQ5, 6P15
EL85	N155
EL90	6AQ5, N727
EL91	N77, N144, 6AM5, 6P17
EL821	6CH6
EM34	6CD7, 6M2, 64ME
EM80	6BR5, 65ME
EM81	6DA5
EZ35	6X5GT, U147
EZ40	U150, UU9, 66KU
EZ80	6V4
EZ81	U709, UU12
EZ90	U78, 6X4
FC2A	K80B, VO2, VHT2A
FW4–500	U18/20, 451U
GZ30	5Z4GT, R52
GZ32	5V4G, 54KU
HBC90	12AT6
HBC91	12AV6
HF93	12BA6
HK90	12BE6
HL92	50C5
HN309	PCL82
HY90	35W4
IW4–350	R2, R42, MU14, 1867
KT61	N147, 6P25, 6AG6G
KT63	6F6G
KT66	EL37, 6L6G (near)
KT71	50L6
KT81	7C5 (near)
L63	6J5G
L77	EC90, 6C4
LN119	UCL82 (near), 10PL12
LN152	ECL80, 6AB8
LN309	PCL83
LZ319	8A8, 9A8, 30C1, PCF80
LZ329	PCF80, 30C1
N17	1P10, 3S4, DL92
N18	3Q4
N19	1P11, 3V4, DL94
N25	1P1, 3C4, DL96
N78	6BJ5
N118	10P13
N119	UL84, 10P18
N142	45A5, 451PT, UL41
N144	6AM5, 6P17, EL91, N77
N145	10P13
N147	6AG6G, EL33, 6P25
N148	7C5
N150	6CK5, 67PT, EL41
N152	PL81, 21A6
N153	15A6, N309, PL83
N154	16A5, N329, PL82
N155	EL85
N308	30P4
N309	15A6, N153, PL83
N329	16A5, PL82, N154, 30P16
N339	21A6, N152, PL81
N359	PL81

Type	Near Equivalents
N369	30P12
N379	30P18
N709	6BQ5, 6P15, EL84
N727	6AQ5, EL90
OM1	CY31, U201
OM4	EBC33, DH147
OM6	EF39, W147
OM10	X147, CCH35, ECH35
PCC84	30L1, B319, 7AN7
PCF80	30C1, 8A8, 9A8, LZ319
R2	IW4–350, R42, MU14, UU5
R52	GZ30, 5Z4GT
SP6	6AM6, 8D3, EF91, Z77
U10	UU5, 506BU, DW2, R41
U31	25Z4G
U50	5Y3G
U52	5U4G
U70	6X5GT, EZ35, U147
U76	35Z4GT
U78	6X4, EZ90
U118	U404
U119	UY85, U381
U142	UY41, 31A3, 311SU
U143	AZ31
U145	U404
U147	6X5GT, EZ35, U70
U149	7Y4
U150	66KU, EZ40
U404	U145
U709	EZ81, UU12
U718	EZ40, UU9
UABC80	DH109, 10LD12
UAF42	WD142, 12S7
UBC41	10LD3, DH142, 141DDT, DH118
UBC81	DH119, 10LD13
UBF80	171DDP, 17C8
UBF89	10FD12, WD119
UCC85	10L14, B109
UCH42	141TH, 14K7, X142
UCH81	10C14, 19D8
UCL82	10PL12, 50BM8, LN119
UF41	W142, 12AC5, 121VP
UF42	Z142
UL41	45A5, 451PT, N142
UL84	10P18, 45B5
UM34	10M2
UM35	10M2
UM80	Y119
UU9	EZ40, 66KU, U150
UU12	U709, EZ81
UY21	7H7
UY41	U142, 311SU, 31A3
UY85	U119, U381, 38A3
W17	1F3, 1T4, DF91
W25	1AJ4, 1F1, DF96
W76	12K7GT
W77	6CQ6, 9D6, EF92, VP6
W81	7H7
W118	W145, 10F9
W119	10F18

Type	Near Equivalents	Type	Near Equivalents
W142	12AC5, 121VP, UF41	1M1	DM70, DM71, Y25
W143	EF22	1M3	1M1, DM71, Y25
W145	10F9	1N5	DF33, Z14
W147	EF39, OM6	1P1	3C4, DL96, N25
W148	7H7	1P10	3S4, DL92, N17
W149	7B7	1P11	3V4, DL94, N19
W150	6CJ5, 6F16, 62VP, EF41	1R5	1C1, DK91, X17
W719	6BY7, 6F19, EF85	1S5	1FD9, DAF91, ZD17
W727	6BA6, EF93	1T4	1F3, DF91, W17
W729	6BY7, 6F19, EF85	3C4	1P1, DL96, N25
W739	6F18	3Q4	DL95, N18
WD119	UBF89, 10FD12	3S4	1P10, DL92, N17
WD142	UAF42, 12S7	3V4	1P11, DL94, N19
WD709	EBF80, ZD152	5U4	U52
X17	1C1, 1R5, DK91	5V4	GZ32
X18	1AC6, 1C2, DK92	5Y3	U50
X24	220TH, TH2	5Z4	GZ30
X25	1AB6, 1C3, DK96	6A8	X63
X71M	12K8GT	6AB8	ECL80, LN152
X76M	12K8GT	6AJ8	ECH81, X719
X81	7S7	6AK8	EABC80, DH719, 6T8
X118	10C1	6AL5	6D2, D77, D152, DD6, EB91
X119	UCH81, 10C14	6AM5	6P17, 7D9, N77, N144, EL91
X142	14K7, 141TH, UCH42	6AM6	6F12, 8D3, EF91, SP6, Z77
X143	ECH21	6AQ4	6L34, EC91
X145	10C1	6AQ5	EL90, N727
X147	ECH35	6AQ8	B719, ECC85
X148	7S7	6AT6	DH77, EBC90
X150	ECH42, 6C10, 62TH	6BA6	EF93, W727
X719	6AJ8, 6C12, ECH81	6BE6	X727, X77, EK90
X727	6BE6, EK90	6BM8	ECL82
Y25	DM71	6BQ5	EL84, N709, 6P15
Y61	6U5G, 6M1, 63ME, VFT6	6BR5	EM80
Y63	6U5G, 6M1, 63ME, VFT6	6BW7	8D6
Y119	UM80	6BX6	EF80, X719, Z152
Z63	6J7G	6BY7	EF85, W719, 6F26
Z77	6AM6, 6F12, 8D3, EF91, SP6	6C4	EC90, L77
Z142	UF42	6C10	62TH, ECH42, X150
Z150	EF42	6C12	ECH81, X719, 6AJ8
Z152	6BX6, EF80, Z719	6CA4	EZ81, UU12
Z329	30F5	6EL7	6F23
Z729	EF86	6CH6	7D10, EL821
ZD17	1S5, 1FD9, DAF91	6CJ5	EF41
ZD25	1AH5, 1FD1, DAF96	6CU7	6C10, ECH42
1A7	X14, DK32	6D2	6AL5, D77, DD6, EB91
1AB6	1C3, DK96	6F6	KT63
1AC6	1C2, DK92	6F12	6AM6, 8D3, EF91, SP6, Z77
1AH5	1FD1, DAF96	6F16	6CJ5, 62VP, EF41, W150
1AJ4	1F1, DF96	6F18	W739
1C1	1R5, DK91, X17	6F19	6BY7, EF85, W719
1C2	1AC6, DK92, X18	6FD12	EBF89
1C3	1AB6, DK96, X25	6G5G	6M1
1C5	DL35, N14	6H6	D63
1D5	40SUA, U4020	6J5	L63
1F1	1AJ4, DF96, W25	6J7GT	Z63
1F2	1L4, DF92	6K7	KTW63
1F3	1T4, DF91, W17	6K8	X65
1FD1	1AH5, ZD25, DAF96	6L13	12AX7, B339, ECC83
1FD9	1S5, DAF91, ZD17	6L34	EC91
1H5	DAC32, HD14	6LD3	62DDT, DH150, EBC41
1L4	1F2, DF92	6LD12	6AK8, EABC80, DH719

Type	Near Equivalents	Type	Near Equivalents
6LD13	EBC81	12AT7	B309, ECC81
6M1	63ME, Y63	12AU7	B329, ECC82
6M2	64ME, EM35	12AX7	6L13, B339, ECC83
6N8	EBF80	12BA6	HF93
6P15	6BQ5, EL84, N709	12BE6	HK90
6P17	6AM5, EL91, N144	12K7	W76
6P25	KT61	12K8	X76
6Q7	DH63	12Q7	DH76
6SN7	B65	12SN7	B36
6T8	6AK8, 6LD12, DH719, EABC80	14K7	UCH42
6U5	6M1, 63ME	14L7	10LD3, UBC41
6U7	6K7G, KTW63	19D8	10C14, UCH81
6U8	ECF82	21A6	N152, N339, N359, PL81
6V4	EZ80	25L6	KT32
6X4	EZ90, U78	25Z4	U31
6X5	EZ35, U70, U147	31A3	UY41
7B6	DH81	35W3	HY90
7B7	W149	35Z4	U76
7C5	N148	38A3	UY85, U381
7C6	DH149	40SUA	U4020
7D9	6AM5, EL91, N77, N144	45A5	UL41
7H7	W148	45B5	10P18, UL84
7S7	X148	50C5	HL92
7Y4	U82	50L6	KT71
8D3	6AM6, 6F12, EF91, SP6, Z77	52KU	R52
9D6	6CQ6, EF92, VP6, W77	53KU	GZ37, U54
9U8	PCF82	54KU	GZ32
10C1	X145	62DDT	EBC41, DH150, 6LD3
10C14	UCH81, X119	62TH	6C10, ECH42, X150
10F1	Z145	63ME	6U5G, VFT6, Y63, 6M1
10F9	W145	63SPT	EF50
10F18	W119	64ME	6M2, EM35
10FD12	UBF89, WD119	65ME	EM80, 6BR5
10L14	B109, UCC85	66KU	EZ40, U150, UU9
10LD3	141DDT, DH118, DH142, UBC41	67PT	EL41, N150
10LD11	DL145	141DDT	10LD3, DH118, DH142, UBC41
10LD12	DH109, UABC80	141TH	UCH42, X142
10LD13	DH119, UBC81	171DDP	UBF80
10P13	N145	311SU	31A3, U142, UY41
10P18	N119, UL84	332 PEN	CL33
10PL12	LN119, UCL82 (near)	442BU	UU5
12AT6	HBC90	451PT	45A5, N142, UL41
		460BU	UU5

Transistor Data

Type	Description	Connections
Brimar		
TK1001	Package of A.F. driver and output pair	Lead arrangement: emitter–base–collector reading anti-clockwise with white spot indicating collector
TK1000	Package of mixer and two I.F. transistors	
TS1	pnp small signal A.F. transistor (superseded)	
TS2	pnp small signal A.F. transistor (superseded)	
TS3	pnp small signal A.F. transistor (superseded)	
TS7	pnp R.F./I.F. transistor (fα 5·5 Mc/s)	
TS8	pnp R.F. transistor (fα 11 Mc/s)	
TS13	pnp A.F. transistor (replaces TS3)	
TS14	pnp A.F. transistor (replaces TS1, TS2)	
TS17	pnp large signal A.F. transistor	
TK23C	pnp large signal A.F. transistor	
TK40C	pnp large signal A.F. transistor	
TK41C	pnp large signal A.F. transistor	
TK42C	pnp large signal A.F. transistor	
Ediswan Mazda		
XA101	pnp I.F. amplifier transistor (fα 5 Mc/s)	"Base" centre lead with white spot near collector
XA102	pnp Mixer/oscillator R.F. transistor (fα 8 Mc/s)	
XA103	pnp I.F. amplifier transistor (fα 2 Mc/s)	
XA104	pnp Mixer/oscillator R.F. transistor (fα 4 Mc/s)	
XA111	pnp amplifier transistor (fα 5 Mc/s)	B E–C
XA112	pnp Mixer/oscillator R.F. transistor (fα 8 Mc/s)	
XA121	pnp drift I.F. amplifier transistor	E–B–M– –C (M metallising)
XA122	pnp drift mixer/oscillator R.F. transistor	
XA123	pnp drift H.F. mixer transistor (fα 30 Mc/s)	
XA124	pnp drift H.F. frequency changer transistor (fα 30 Mc/s)	
XA126	pnp drift H.F. amplifier transistor (fα 30 Mc/s)	
XA131	pnp drift V.H.F. amplifier transistor (fα 100 Mc/s)	B E–C red dot near collector
XB102	pnp A.F. amplifier-transistor	"Base" centre with white spot near collector
XB103	pnp A.F. amplifier or driver transistor	
XB104	pnp A.F. amplifier or driver transistor	
XB112	pnp A.F. amplifier or driver transistor	B E–C
XB113	pnp A.F. amplifier or driver transistor	B E–C
XC101	pnp A.F. output transistor	"Base" centre lead with white spot near collector
XC121	pnp A.F. output transistor	B E–C
XC131	pnp A.F. output transistor	
XC141	pnp A.F. power transistor	B–E when pins towards upper circumference with collector to flange
XC142	pnp A.F. power transistor	
XC155	pnp A.F. power transistor	
XC156	pnp A.F. power transistor	

Type	Description	Connections
G.E.C.		
GET7	pnp A.F. power transistor	Three leads reading clockwise: collector; emitter; base. The collector coded with white mark on sleeve. Red sleeve indicates emitter. Green sleeve indicates base
GET8	pnp A.F. power transistor	
GET9	pnp A.F. power transistor	
GET102	pnp M.F. high-gain transistor (fα 1·5 Mc/s)	
GET103	pnp M.F. general-purpose transistor (fα 1 Mc/s)	
GET105	pnp medium-power transistor (fα 0·9 Mc/s)	
GET106	pnp low-noise M.F. transistor (fα 1 Mc/s)	
GET113	pnp high-gain M.F. transistor (fα 1·5 Mc/s)	
GET114	pnp general purpose M.F. transistor (fα 1 Mc/s)	
GET115	pnp general-purpose medium-power transistor (fα 1 Mc/s)	
GET116	pnp general-purpose medium-power transistor (fα 1 Mc/s)	
GET691	pnp H.F. drift transistor (fα 30 Mc/s)	
GET692	pnp H.F. drift transistor	
GET873	pnp I.F. amplifier transistor (fα 6 Mc/s)	
GET874	pnp Mixer/oscillator transistor (fα 15 Mc/s)	

Note. GET103 replaces GET3; GET105 replaces GET5; GET106 replaces GET6; GET110 replaces GET10, GET115 replaces GET15. These are electrically similar but the earlier range had connections coded: collector (white) then clockwise base; emitter.

Type	Description	Connections
Mullard		
AF114	pnp alloy diffused V.H.F. transistor for use up to 100 Mc/s	E–B–M– –C (M metal case)
AF117	pnp alloy diffused transistor for use on L.W./M.W. sets	
OC16	pnp A.F. power transistor (superseded)	Emitter blue, base yellow collector side tab
OC19	pnp A.F. car radio power transistor	
OC26	pnp A.F. car radio power transistor	
OC44	pnp R.F. frequency changer transistor (fα 15 Mc/s)	E–B–C with red spot near collector
OC45	pnp I.F. amplifier transistor (fα 6 Mc/s)	
OC65	pnp A.F. subminiature transistor	
OC66	pnp A.F. subminiature transistor	
OC70	pnp A.F. transistor	
OC71	pnp A.F. transistor	
OC72	pnp large signal A.F. transistor	
OC78	pnp large signal A.F. transistor	
OC81	pnp large signal A.F. transistor	
OC170	pnp alloy diffused H.F. transistor (f_1 70 Mc/s)	E–B–M– –C (M metal case)
OC171	pnp alloy diffused V.H.F. transistor (f_1 70 Mc/s)	
Newmarket (Goltop)		
V6/R2	pnp I.F. transistor (fα 3 Mc/s)	E–B– –C
V6/R4	pnp R.F./I.F. transistor (fα 5·5 Mc/s)	E–B– –C
V6/R8	pnp R.F. transistor (fα 10 Mc/s)	E–B– –C
V10/15A	pnp A.F. transistor	E–B– –C
V10/30A	pnp A.F. transistor	E–B– –C
V10/50B	pnp M.F. transistor (fα 1·2 Mc/s)	E–B– –C
V15/10P	pnp A.F. power transistor	Collector 0BA screw emitter left
V15/20IP	pnp A.F. intermediate power transistor	—
V15/20P	pnp A.F. power transistor	As V15/10P
V15/20R	pnp H.F. drift transistor (fα 20 Mc/s)	—

Type	*Description*	*Connections*
Newmarket (*Goltop*) contd.		
V15/30P	pnp A.F. power transistor	As V15/10P
V30/10P	pnp A.F. power transistor	As V15/10P
V30/20IP	pnp A.F. intermediate power transistor	—
V30/20P	pnp A.F. power transistor	As V15/10P
V30/30P	pnp A.F. power transistor	As V15/10P
Newmarket (*NKT*)		
NKT151	pnp mixer-oscillator (M.W./S.W.)	E–B– –C
NKT152	pnp mixer-oscillator (M.W.)	E–B– –C
NKT153	pnp high-gain I.F. amplifier (470 kc/s.)	E–B– –C
NKT154	pnp medium-gain I.F. amplifier	E–B– –C
NKT155	pnp detector	E–B– –C
NKT161–5	As NKT151–5 but different shape	—
NKT251	pnp high-gain A.F. output	E–B– –C
NKT252	pnp medium-gain A.F. driver	E–B– –C
NKT253	pnp medium-gain A.F. output	E–B– –C
NKT254	pnp high-gain A.F. driver	E–B– –C
NKT255	pnp low-noise A.F. preamplifier	E–B– –C
NKT261–5	As NKT251–5 but different shape	—
NKT351	pnp intermediate power output	B E–C White spot near collector
NKT451	pnp extra high-gain power output	B–E when pins towards upper circumference with collector to flange
NKT452	pnp high-gain power output	
NKT453	pnp medium-gain power output	
NKT454	pnp TV line output	

FOREIGN TRANSISTOR CHART

The following selected list of foreign transistor type numbers will be found useful when dealing with imported receivers fitted with Japanese or American transistors. It should be noted that types grouped in this chart are not equivalents and may not prove interchangeable without circuit changes (this may often include different value neutralising capacitors and a change of bias). The British types shown are intended as an indication of the general category of the transistors concerned rather than as a definite replacement type—though in practice such replacement should often prove possible if the original type is unobtainable. Note that many Sony transistors are npn types; npn types are also commonly used in American designs.

General Category	*Selected U.S. Types*	*Selected Japanese Types*
R.F. pnp fα about 10 Mc/s. (OC44)	2N219, 2N411, 2N412	2SA15, 2S30, HJ23D, HJ55, 2S52, HJ60, 2S146, HJ57, 2T201, 2SA84
R.F. pnp fα about 6·5 Mc/s. (OC45)	2N218, 2N410, 2N409, 2N139 2N1524	2SA12, 2S45, HJ56, 2S31, 2S36, 2S53, HJ22D
A.F. pnp (OC71)	2N405, 2N406, 2N217, 2N363	2SB75, 2S32, 2S159, 2S44, HJ17D
A.F. pnp (OC72)	2N270, 2N408, 2N407, 2N109, 2N2102	2S38, 2S33, 2S56, 2S34, HJ51, 2SB77, 2S24, 2S163, HJ34, HJ34A, 2S91, 2T323
A.F. pnp small signal	2N175, 2N220, CK722	2S39
R.F. pnp fα about 30 Mc/s. (OC170)	2N140, 2N219, 2N370, 2N371, 2N372, 2N373, 2N374, 2N247	2S35, HJ37, HJ71, 2S141, 2S109, HJ32, HJ70, 2S43
A.F. Power pnp	2N301, 2N301A, 2N441	2S41, 2S42, HJ35
A.F. npn	2N366, 2N228, 2N649, 2N35	2T64, 2T65, 2T85, 2SD65
R.F./mixer npn	2N212, 2N193, 2N194, 2N314, 2N293, 2N147	2SC73, 2T76
I.F. npn	2N216, 2N313, 2N482, 2N483, 2N145, 2N146, 2N148, 2N169	2SC76

GERMANIUM DIODE COMPARISON TABLE

The following diodes are approximately equivalent, and can usually be interchanged:

(1) CG5C, CG12E, GD3, GEX33, GEX35, OA60, WG4A
(2) CG7C, GD4, GEX44, WG5A
(3) CG1E, CG4E, CG6E, GD5, GEX33, GEX55, OA61, WG6A
(4) CG6E, GD6, GEX34, GEX45/1, OA70, WG5B
(5) CG4E, CG10E, CG44H, GD8, GEX34, GEX45/1, GEX54, OA71, WG7D
(6) CG42H, GD9, OA81, OA85, OA86, GEX58
(7) GD11, GEX39, WG4B
(8) CG12E, GD12, GEX35, OA70, OA73, WG4A

BATTERY EQUIVALENTS

Voltage	*Type*	*Contacts*	*Drydex*	*Ever Ready*	*G.E.C.*	*Oldham*	*Siemens*	*Vidor*
H.T. Batteries								
300	—	—	500	B1489	—	—	S1532	—
175	166 v. H.T. + 9 v. G.B.	Wander plugs	H1066	Port. 32	BB337	K664	1182	L5008
144	135 v. H.T. + 9 v. G.B.	Wander plugs	H1107	Port. 40	BB366	K634	1264	L5023
136	124½ v. H.T. + 12 v. G.B.	Wander plugs	H1180	Port. 75	—	K776	1523	L5017
129	120 v. H.T. + 9 v. G.B.	Wander plugs	H1071	Port. 34	—	K661	1192	—
129	120 v. H.T. + 9 v. G.B.	Wander plugs	H1070	Port. 33	BB338	—	1193	L5037
126	114 v. H.T. + 12 v. G.B.	Wander plugs	H1136	Winner 126GB	BB375	K753	1312	L5030
120	Standard battery	Wander plugs	H1006	Winner 120	BB720	Green Band 120	H120	L5038
120	Triple capacity	Wander plugs	H2015	PP120	BB1203	—	V8	L5080
120	111 v. H.T. + 9 v. G.B.	Wander plugs	H1118	Winner 120GB	BB729	K675	HG120	L5045
120	114 v. H.T. + 6 v. G.B.	Wander plugs	H1050	Port. 30	BB334	K540	1153	—
108	—	Wander plugs	H1044	Winner 108	—	Green Band 108	H108	—
90	Small layer	2 press-studs	531	B131	—	KL31	—	L5547
90	Large layer	3-pin socket	538	B138	BB538	KL38	S138	—
90	Standard battery	Wander plugs	H1146	Port. 61	BB372	K744	1340	L5039
90	Large layer	3-pin socket	507	B107	BB502	KL7	S107	L5508
90	Large layer	2 press-studs	517	B117	—	KL17	S117	L5515
90	Small layer	3-pin socket	526	B126	BB526	KL26	S126	L5512
85½	Large layer	3-pin socket	529	B129	BB529	KL29	S129	L5529
67·5	Small layer	2 press-studs	501	B101	BB501	KL1	S101	L5500
45	Small layer	3-pin socket	504	B104	BB500	KL4	S105	L5528
45	—	3-pin socket	H1156	AD2	BB390	K757	1431	—
45	—	2 press-studs	502	B102	—	KL2	S102	—

Voltage	*Type*	*Contacts*	*Drydex*	*Ever Ready*	*G.E.C.*	*Oldham*	*Siemens*	*Vidor*
Combined H.T./L.T.								
90 v. H.T. + 1½ v. L.T.	Standard	4-pin socket	H1157	AD3	BB395	K748	1438	L5054
90 v. H.T. + 1½ v. L.T.	Large layer	4-pin socket	503	B103	BB503	KL3	S103	L5507
90 v. H.T. + 7½ v. L.T.	—	9-pin socket	548	B148	BB548	KL48	—	L5546
90 v. H.T. + 1½ v. L.T.	—	—	536	B136	BB536	KL36	S136	L5537
90 v. H.T. + 1½ v. L.T.	—	4-pin socket	537	B137	—	KL37	—	—
90 v. H.T. + 1½ v. L.T.	Small layer	4-pin socket	525	B125	—	—	—	L5509
90 v. H.T. + 1½ v. L.T.	Large layer	4-pin socket	541	B141	BB541	KL41	—	L5552
90 v. H.T. + 1½ v. L.T.	Small layer	4-pin socket	547	B147	BB547	KL47	—	L5551
90 v. + 7½ v. + 9 v.	Large layer	8-pin socket	—	B135	—	—	—	L5553
85½ v. H.T. + 7½ v. L.T.	—	9-pin socket	527	B127	—	KL27	S127	—
69 v. H.T. + 1½ v. L.T.	Small layer	4-pin socket	514	B114	BB514	KL14	S114	L5504
Grid Bias								
9 volts	Standard	Wander plugs	H1001	Winner 9	BB9	Green Band 9GB	CG2	L5059
L.T. Batteries								
7·5	—	2-pin socket	H1191	AD43	—	K796	1540	—
7·5	—	2-pin socket	H1189	AD40	—	K787	—	L5060
7·5	5 cells	2-pin socket	H1177	AD31	BB401	K769	1518	L5042
7·5	5 cells	2-pin socket	H1187	AD38	BB408	K782	1535	L5048
7·5	5 cells	2-pin socket	H1186	AD39	BB409	K783	1536	L5055
7·5	5 cells	2-pin socket	H1190	AD42	—	K788	—	L5058
4·5	3 cells	2-pin socket	H1176	AD28	BB398	K786	1538	L5043
1·5	2 cells	2-pin socket	H1184	AD35	BB405	K779	1529	L5040
1·5	4 cells	2-pin socket	H1158	AD4	BB391	K768	1436	L5041
1·5	8 cells	2-pin socket	H1178	AD32	BB402	K771	1517	L5049
1·5	8 cells	2-pin socket	H1183	AD34	BB404	K778	1533	L5050
1·5	8 cells	2-pin socket	H1155	AD1	BB389	K756	1432	—
1·5	6 cells	2-pin socket	H1168	AD14	—	K785	1470	L5071
1·5	—	2-pin socket	H1182	AD33	BB396	K777	—	—
1·5	—	2-pin socket	H1185	AD37	—	K781	1534	—

Voltage	*Type*	*Contacts*	*Drydex*	*Ever Ready*	*G.E.C.*	*Oldham*	*Siemens*	*Vidor*
Transistor Batteries								
9	Layer	2 press-studs	DT10	PP10	BB30	OT10	TR10	T6010
9	Layer	2 press-studs	DT7	PP7	BB27	OT7	TR7	T6007
9	Layer	2 press-studs	DT3	PP3	BB23	OT3	TR3	T6003
9	Layer	2 press-studs	DT4	PP4	BB24	OT4	TR4	T6004
9	Layer	2 press-studs	DT6	PP6	BB26	OT6	TR6	T6006
9	Layer	2 press-studs	DT9	PP9	BB29	OT9	TR9	T6009
6	Layer	2 press-studs	DT1	PP1	BB21	OT1	TR1	T6001
6	Layer	2 press-studs	DT8	PP8	BB28	OT8	TR8	T6008
4½ + 4½ 4½ + 4½	Layer Layer	4-pin socket	DT11	PP11	BB31	OT11	TR11	T6011
Miscellaneous								
1½	Torch cell	Cap and zinc	T20	U2	BA6103	K532	T1	V0002
1½	Baby torch cell	Cap and zinc	T15	U11	BA6104	K763	T12	V0011
1½	Leakproof torch cell	Cap and zinc	T21	LPU2	BA6123	LP532	T1LP	V0009
1½	Penlight cell	Cap and zinc	T5	U12	BA6102	K770	T13	V0028
1½	Penlight cell	Cap and zinc	T3	U16	BA6107	K795	T18	V0036
1½	One cell L.T.	Cap and zinc	T25	U17	—	—	—	V0007
3	Penlight battery	Cap and zinc	2T5	1915	BA6106	K773	T7	V0003
3	Baby torch battery	Cap and zinc	2T15	1839	BA6114	K612	T10	V0012
3	Bijou torch battery	Cap and zinc	2T10	8	BA6105	K609	T8	V0004
3	Cycle	Strip and spring	C60	800	BA6112	—	P1	V0001
4½	Pocket torch	Strip and spring	F40	1289	BA6108	—	P3	V0005
4½	Box battery	2 screw	H30	126	BA6110	K766	B6	V0008
6	Lantern battery	Strip and spring	L15	R996	BA6120	K767	1400	V0016

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RADIO SERVICING POCKET BOOK

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