ART AND SCIENCE IN SOUND REPRODUCTION

By F. H. Brittain, D.F.H.

Acoustics Engineer, Research Laboratories
The General Electric Co. Ltd.

TWO SHILLINGS AND SIXPENCE

ADDENDA and ERRATA

Page 12. Column 4 of table. KT66 as triode. Distortion figure =1%.

Page 16. Fig. 2. Junction of R19 and R20 should be earthed. VR1 =1MΩ. R15: 5% tolerance.

Page 26. Fig. 15. CH: 10H. 150mA.
Components list. T1 turns ratio $= \sqrt{\frac{4{,}000}{S}}$

Page 28. Fig. 17. CH1: 20H. 60mA.

Page 39. Components list. C34 is matched to C27.
C35 is matched to C28.

Page 42. Constructional Notes. R.F. coil types should read L1, L3=HA1. L2, L4=HA3.
Fig. 28. Volume control. A 0.05μF capacitor should be connected to the output terminal and a 500 kΩ variable resistor connected between this capacitor and earth.

Page 43. Components list. C13=22pF. C14=47pF.
R7 =47kΩ. R8 =47kΩ.
V1 see page 42.

Page 46. Fig. 32. A.G.C. line from C27 should be joined to junction of C10 and I.F.T. secondary, not to C11 as shown. R3 should be decoupled by a 0.1μF capacitor.
R16=47kΩ. R17=47kΩ. C21=100pF.

Page 48. Fig. 34. L1: Wearite 250μH R.F. choke or 5.6kΩ ¼ W resistor.

4/8 1953 (pre-RIAA)

ART AND SCIENCE
IN
SOUND REPRODUCTION

By F. H. Brittain, D.F.H.

Contents

	Page
Art and Science in Sound Reproduction ...	3
Amplifiers for the high quality reproduction of sound	7
6 watt economical amplifier	15
12, 20 and 30 watt amplifiers	20
14 watt D.C./A.C. amplifier and pre-amplifier	27
The design of a comprehensive pre-amplifier	32
Requirements of the pre-amplifier	33
Comprehensive pre-amplifier, tone-control and equaliser	37
Local station T.R.F. feeder unit	42
Superhet feeder unit	45
Television sound feeder unit	47
The metal cone loudspeaker	49

Published by The General Electric Co. Ltd. of England
Magnet House, Kingsway, London, W.C.2.

The circuit information given in this publication does not imply any licence under patents which may be involved.

ART AND SCIENCE IN SOUND REPRODUCTION

In any form of reproduction, visible or audible, there are nearly always some limitations inherent in the medium employed. It is the purpose of the scientist to reduce these limitations to a minimum. It is the purpose of the artist, in picture or sound, to circumvent these limitations, and even to use them for his own aesthetic purpose. In the sketch of the " Contented Cat " the artist has used the absence

of half-tones to enhance the feeling of satisfaction. Sound reproduction is very seldom " Sound Re-creation " and there are many cases where art can help science to give greater pleasure.

Art is an essential addition to the science of sound reproduction ; and it may be used to enhance realism to the point of deception. In order to make the best use of this art, it is desirable to know something of the limitations which may be found in sound reproduction. These limitations are not so obvious as those which occur in a picture, which could seldom be mistaken for the original scene, but the sound reproducing system is often blamed for shortcomings which are inherent in the medium. These limitations are to be found in the mind of the performer, right through the chain of events, and also in the mind of the listener.

The mind of the performer

The mind of the performer is apt to be influenced by his surroundings, such as the studio, which may make him adopt an unusual tone of voice or mode of playing. As an example, a B.B.C. announcer should not sound like a person having a normal conversation in the home. Similarly, a violin or piano will not be played in quite the same way, and will not produce quite the same tonal quality both in a large concert hall and in a small room.

To demonstrate the way that the tonal quality of a voice changes with the effort which is put into it, make the following experiment, preferably out of doors. Ask a friend to speak to you in a very quiet voice, not a whisper, at a distance of one foot from your ear. Notice the tonal quality of his voice with its deep rich tones and clear sibilants. Now listen to his normal speech from a distance of a few feet, the exact distance being that at which he sounds as loud as in the previous test. This tonal quality will have less of the low deep tones. Now repeat the test again, but this time with a very loud voice, but so far away that it sounds no louder to you than it did in the other two tests. It will sound quite " thin " and lacking in the lower tones; sibilants too will be less noticeable. From this test you will realise that you only know what your friend sounds like if you know how loudly he is talking. Musical instruments also change their tone quality with volume, but to a lesser degree than the voice.

REVERBERATION AND ECHO

Surroundings of the performer

The surroundings of the performer may also make themselves heard directly as reverberation and possibly, echo. A listener to a live performance will hear the reverberation coming to him from various directions, probably he only senses it as the general effect of the hall upon the sounds that he hears. Unfortunately, when it is reproduced, it will come to him from exactly the same position as the remainder of the reproduced sound, the loudspeaker. This factor alone precludes the achievement of complete realism in the reproduction of many sounds. It is here that the artist steps in and points out that since both the direct and the reverberant sound are reproduced from the same position in the living room, the listener can only separate them by their relative times of arrival and by their tone colour. Thus it becomes desirable to omit that reverberation which tends to muddle the direct sound and transmit only that which is an asset to the programme.

The microphone

A microphone, however perfect, does not function like the ears and mind of a listener, particularly in the way in which it differentiates between different sounds such as the direct sound and the reverberation. Reverberation and echo may even be considered as a separate source of sound compared with that direct from the voice or instrument. As an example of separation by position, get two people, preferably with similar voices, to stand at the end of a room, and, standing side by side, let them recite two different nursery rhymes together. It will be difficult for a listener at the remote end of the room to hear clearly either rhyme at will. Now let the two people separate to the two corners of the room; it will be quite easy to separate either rhyme at will, because they can be separated in space. A directional microphone can separate out sounds coming from different directions at the discretion of the operator, but he may or may not make the same choice of sound to be heard as would the listener.

The source of programme

The general practice of using only one transmitter or gramophone disc precludes the use of a number of microphones coupled to a similar number of loudspeakers in order that they may reproduce sounds from various positions relative to the listener. The experimental reproduction of sounds on two channels has been made using two radio transmitters, dual track disc records, and twin tracks on magnetic tape. They give more realistic sound reproduction but have not yet come into everyday use.

There is another way in which the source of programme introduces limitations. It may introduce unwanted noise, which may be due to interference from nearby radio stations, or surface noise and wear from gramophone records. In the first case, if the principal component of the noise is all at 9 kc/s it is possible to filter it out by means of a steep cut filter without losing very much of the programme. However, the sudden cutting off of the reproducing system at a particular frequency is very apt to produce the effect of " ringing " at the frequency of cutoff. It is usually more satisfactory to start cutting at a lower frequency but to make the rate of cut less severe. In the case of gramophone records, the first essential is to have a system with a complete absence of peaks anywhere in the frequency range reproduced by the loudspeaker. This will reduce " scratch " and surface noise to a very marked extent. Further reduction of surface noise and record wear can best be obtained by removing from the loudspeaker all those frequencies which are not actually recorded on the record. In addition, the high frequencies should be cut at the rate of about 6 db per octave and starting at such a frequency as the listener judges to give him an acceptable compromise between quality and interference.

THE LOUDSPEAKER

Perhaps the most serious limitation of a loudspeaker is its inability to change its size to suit the type of sound that it is attempting to reproduce. It is almost impossible to make a loudspeaker sound exactly like a human voice if it is heard from a short distance directly in front of it. If, however, the loudspeaker is playing in one room, and it is heard through an open connecting doorway, then it is quite possible to obtain a degree of realism which makes it impossible to tell whether the sound is reproduced or real. In the case of the human voice, the higher frequencies are radiated from the mouth and lips, whilst the lower frequencies are radiated from the chest. This the loudspeaker is unable to do. Greater realism may be obtained by listening to a loudspeaker through an open doorway which disguises the particular location and size of the source of the sound. In the case of the reproduction of an orchestra or other large source of sound, the effect will be even more marked. It will be found, when listening to a loudspeaker in this way, that, paradoxically as it may seem, greater realism is achieved from the diffused source of sound, and at the same time the quality of reproduction is made worse by the addition of the reverberation of the small room used to diffuse the sound from the loudspeaker. Not only is the loudspeaker unable to change its size but it is unable to reproduce different sounds so that they appear to the listener to come from different positions. This difficulty can be overcome by the expedient of using several different channels, each complete with its own microphone and loudspeaker; it needs at least two channels but has the advantage that it can give the illusion of movement to the reproduced sound. Such a system will gain in realism to a very great extent over a single channel. It should, in the ideal case, include channels on either side, above and behind the listener, as well as a whole series of channels in front of him. Such a system is not to be confused with " stereophonic " reproduction where two separate microphones feed two separate telephone earpieces, exactly as stereoscopic pictures are presented separately to each eye.

The listening room

The listening room plays a twofold part, first as an environment of the loudspeaker, and secondly, as an environment of the listener. Most loudspeakers have a low efficiency, but even so their performance is influenced by the characteristics of the room in which they are operated. This room should be large, its length, breadth, and height should not be identical but fairly similar, and it should be so furnished that it is fairly " dead," that is, have a short reverberation time. In practice, choose the biggest room in your home, and, since you cannot easily alter its dimensions, experiment with the loudspeaker in various positions in order to determine the position in the room which gives the smoothest reproduction of low frequencies. The room can be given a short reverberation time, at least to medium and high frequencies, by the addition of thick carpets, curtains and other soft furnishings.

So much for the environment of the loudspeaker; the environment of the listener is more difficult. Perhaps the first requirement is the exclusion of unwanted sounds, and the second is the ability to make realistically loud sounds when required. It will be shewn later that there is one loudness, and one loudness only at which a reproduced sound could be identical with the original. This loudness may sometimes be greater than your neighbours will tolerate ! In order to prevent the reverberation of the listening room " colouring " all reproduction, it should be made fairly " dead " as in the requirement for the loudspeaker, but if this is done, the position of the loudspeaker becomes more obvious although it can be heard in greater detail. A suitable compromise between this and listening through an open doorway must be found by the listener for himself. Finally, he must find the position in his room which is most suitable to his purpose. Greatest detail will be heard from a short distance in front of the loudspeaker, but the position of greatest realism will be much further away.

The listener

It is necessary to consider the operation of normal human ears because they are quite unlike any sort of microphone. Instead of having a fixed frequency response, it varies with the amount of sound reaching them. At a fairly high sound intensity the response of normal ears is almost flat over a very wide range of frequencies, but as the intensity is reduced, the loudness of the lower frequencies is reduced much more than the loudness of the middle and upper frequencies. To demonstrate the way in which the balance between the high and low frequencies changes with the intensity of the sound reaching the ears, make the following experiment, preferably out of doors. Ask a friend to speak to you in a quiet voice, not a whisper, eight or nine inches from your ear. His voice will sound quite loud to you because it is so close, and it will have both high and low tones in it. Now move backwards away from his voice until it is so weak that you can only just hear what he is saying. The lowest tones will now be quite inaudible, due to the action of the ear. Do not confuse this experiment demonstrating the action of the ear with the earlier experiment demonstrating the action of the voice. Both the voice and the ear must be operated at their correct levels for the final result to be natural. The extreme case is sometimes encountered where the performer is speaking rather more quietly than normally and is being reproduced much more loudly than normally. Such a case can be corrected by reducing the level of the reproduction to that of the original voice. If a considerable volume of speech is essential, as in public address, considerable improvement can be obtained by reducing all frequencies from about 800 cycles per second downwards at the rate of 6 db per octave. The ear has other peculiarities as well, such as the ability to concentrate on those components of a complex sound which arrive first. This feature is a help in listening to a direct sound through reverberation. The mechanism for effecting this separation lies partly in the ear and partly in the mind of the listener.

The listener's mind

The mind of the listener governs how much notice he takes of any information reaching his brain. It is possible to listen to the complex sounds from a motor car engine and to separate out the sounds associated with one particular piece of the mechanism. In the case of sound reproduction, few people have the chance of comparing the reproduced sound directly with the original. As a result they have to rely on memory of original sounds of a similar kind to that being reproduced. In seeking the best in sound reproduction, be certain that you have as good a memory of what it should sound like as possible, and do not condemn a loudspeaker because it does not sound like one.

The state of mind of the listener will affect the quality of the reproduction because it will alter the position he would choose from which to hear the original sounds. Some listeners prefer the back of the concert hall, others the middle, and some like to be quite near the front. The sound at the front is heard in great detail, the sound from the middle of the concert hall is blended with the acoustics of the hall and the sound from the back is strongly "coloured" by the hall. In addition, sounds of high frequency are dissipated more rapidly than those of low frequency as they travel back through the concert hall with the result that listeners at the back of the hall receive a different balance from those at the front. The engineer responsible for broadcasting or recording the sounds can only take an average position for the microphone. This position is usually nearer to the orchestra than any listener would choose to be because the microphone is unable to discriminate against reverberation in the same way as a listener. These listeners who like the back of the concert hall can simulate it to some extent by slightly reducing the higher frequencies in their reproducing system. They can not, of course, add the additional reverberation from the concert hall which should be present.

There are a number of critical individuals who deplore the actions of those listeners who turn the tone controls of their radio sets to " mellow " in order to produce the effect of soft music in the background. The listener is only trying to obtain the effect of distance, just as he might choose the back of a restaurant in which an orchestra is playing. If there is any cause for complaint, it is to the manufacturers of radio receivers for not providing a tone control which imitates the effect of distance.

In conclusion, it will be necessary to use art in sound reproduction until science has given us a medium without any limitations. And while art is present there can be no hard and fast rules.

Amplifiers for the High Quality Reproduction of Sound

The requirements of amplifiers for the high quality reproduction of sound, capable of taking full advantage of modern wide range recording technique, high quality V.H.F. and television sound broadcasting, are now widely appreciated.

Given due attention to certain basic requirements, briefly discussed in the following pages, an amplifier which will do full justice to the sources of high quality sound now available can readily be realised.

The advent of the long playing record has served to emphasise the need for suitable weighting of the overall characteristics now in common use, so that a comprehensive equaliser and tone control unit becomes an essential part of the equipment. Such a unit is particularly necessary when playing earlier 78 r.p.m. recordings, since modern high quality apparatus pitilessly exposes their limitations, and considerable restriction of the upper frequency range is essential if such recordings are to be enjoyed. Similar considerations also apply to the reproduction of medium wave broadcast programmes, where the ever present possibility of a 9 kc/s heterodyne whistle must be considered.

Two pre-amplifier tone control and equaliser units have been evolved for use with the amplifiers described herein for record reproduction and with the R.F. feeder units also described for the reproduction of broadcast sound programmes.

The performance of an amplifier is usually stated in terms of its ability to reproduce faithfully the components of a Fourier analysed waveform. This is convenient and corresponds to the manner in which the ear analyses sound waveforms and transmits intelligence to the brain, but the fact that the function of the system is to reproduce a waveform and not a band of frequencies should not be neglected. Sounds of a transient nature having identical frequency contents may yet be very different in audible character, the discrepancy being in the phase relationship of the component frequencies.

Design factors in high quality amplifiers

The most important factors in the design of an amplifier for high quality sound reproduction are :—

1. *Negligible non-linear distortion up to the maximum rated output.* (The term " non-linear " distortion includes the production of undesired harmonic frequencies of the sound wave). This requires that the dynamic input/output characteristic should be linear for all audible frequencies up to the maximum amplifier output.

2. *Linear frequency response at maximum output within the frequency range of at least 10 c/s-20,000 c/s.* This requirement is less stringent at the high frequency end but should the maximum power output at either end of the spectrum (but especially at low frequency end) be substantially less than at medium frequencies, filters must be arranged to reduce the level of these frequencies before they reach the amplifier ; otherwise severe intermodulation will occur. This is especially noticeable during the reproduction of an organ on incorrectly designed equipment, where pedal notes of the order of 16-20 c/s may cause bad distortion, even though they may be inaudible in the output.

3. *Negligible phase shift within the audible range.* Although the phase relationship between the component frequencies of a complex steady-state sound does not appear to affect the audible quality of the sound, the same is not true of sounds of a transient nature, the quality of which may be altered profoundly by disturbance of the phase relationship between component frequencies.

4. *Good transient response.* In addition to low phase distortion, other factors which are essential for good transient response are : elimination of transient changes in the gain of the amplifier due to current or voltage cut-off in any stages ; careful design of iron cored components and the reduction of such items to a minimum.

5. *Low output resistance.* This requirement is concerned with the attainment of good frequency and transient response from the loudspeaker system by ensuring that it has adequate electrical damping.

   The cone movement of a moving coil loudspeaker is restricted by air loading, suspension stiffness and resistance, and electromagnetic damping. In the case of a baffle-loaded loudspeaker, the efficiency is rarely higher than 5-10 per cent, and therefore, the air loading, which determines the radiation, is not high. In order to avoid a high bass resonant frequency, the suspension stiffness in a high grade loudspeaker is kept low, and obviously the power loss in such a suspension cannot be large. Electromagnetic damping is, therefore, important in controlling the motion of the cone. This effect is proportional to the current which can be generated in the coil circuit and is, therefore, proportional to the total resistance of the circuit. Maximum damping will be achieved when the coil is effectively short circuited, hence the output resistance of the amplifier should be much lower than the coil impedance.

6. Adequate power reserve. Realistic reproduction of orchestral music in an average room requires peak power output of the order of 10-15 watts using a baffle mounted moving coil loudspeaker of average efficiency. With a lower available maximum output some realism must be lost, but providing the listener is prepared to accept the limitations imposed by a restricted output extremely pleasing results can be obtained with an amplifier having a maximum output of some 6-8 watts.

Factors 1 and 6 postulate the use of a push-pull connected output stage, with its inherent reduction of second harmonic distortion, as well as the possibility of obtaining greater output from given valves. Such a stage will normally function under Class A conditions, except under special circumstances, e.g. in D.C./A.C. apparatus, where to obtain adequate output it becomes necessary to operate the output stage in Class AB with a lower load impedance than for pure Class A connection, where the grid bias is the same as for a single valve and the anode to anode load impedance doubled. Good regulation of H.T. supply is essential for all output stage conditions other than Class A.

Type of output valve—pentodes and tetrodes or triodes

When equipment has to be operated from a restricted anode supply, or when the utmost economy is desired, a tetrode or pentode is the only choice, but where these factors do not have to be considered the use of triodes or triode-connected pentodes or tetrodes is generally preferred in apparatus designed for the highest quality reproduction.

Tetrode or pentode output stages can, with care, be designed to give a performance approaching that of triodes under similar conditions, but the requirements are more rigorous. The characteristics of the stage are dependent solely on the character and amount of the negative feedback used, which must remain effective under all operating conditions for all frequencies within the audio frequency spectrum, if the quality is not to degenerate to the level usually associated with tetrodes without feedback. There is also more liability for parasitic oscillation and instability to occur in such an amplifier, but these disadvantages can be overcome by careful design.

The application of negative feedback to push-pull triodes largely removes the intermodulation distortion which is present in such stages without feedback, due to the curvature of the input/output characteristic, and which is responsible for the " harshness " and " mushiness " characteristic of amplifiers of this type.

The negative feedback should be applied over several stages of the amplifier from the secondary of the output transformer, improving the characteristic of the output transformer, and making no additional demands on the output capabilities of any stage of the amplifier.

The output transformer

The output transformer is probably the most critical component in a high quality amplifier. Incorrectly designed it is capable of producing distortion which is often mistakenly attributed to the valves. Distortion producible directly or indirectly by the output transformer may be listed as follows :

(*a*). Frequency distortion due to low winding inductance, high leakage reactance and resonance phenomena.

(*b*). Spurious distortion due to the phase shift produced by effect of these aberrations when negative feedback is applied across the transformer. This usually takes the form of parasitic oscillation due to phase shift produced in the high frequency region by a high leakage reactance.

(*c*). Intermodulation and harmonic distortion in the output stage caused by overloading at low frequencies when the primary inductance is insufficient.

(*d*). Harmonic and intermodulation distortion produced by the non-linear relationship between flux and magnetising force in the core material. This distortion is always present but will be greatly aggravated if the flux density in the core exceeds the safe limit.

(*e*). Harmonic distortion introduced by excessive resistance in the primary winding.

The design of a practical transformer has to be a compromise between these conflicting requirements and, in addition, the matching is rather critical with pentodes and tetrodes if the greatest output and least harmonic distortion is to be fed into the loudspeaker speech coil. A load impedance less than optimum gives less power and greater second harmonic content, while an impedance greater than optimum gives a little more power but bad third harmonic distortion. With triodes, pentodes or tetrodes triode connected, a load less than the optimum also increases the second harmonic content, but for load resistances greater than optimum the output and distortion both decrease.

The correct ratio for an output transformer is given by the formula :—

$$\frac{\text{Primary turns}}{\text{Secondary turns}} = \sqrt{\frac{\text{Optimum anode load impedance}}{\text{Load impedance of L.S. coil}}}$$

Specifications suitable for output transformers for each of the amplifiers described are given in the relevant parts list for the various amplifiers.

Input stages

The reduction of phase shift in amplifiers which are to operate with negative feedback is of prime importance, as instability will result should a phase shift of 180° occur at a frequency where the vector gain of the amplifier and feedback network is greater than unity. The introduction of more than one transformer into the feedback path is likely to give rise to trouble from instability and, since it is

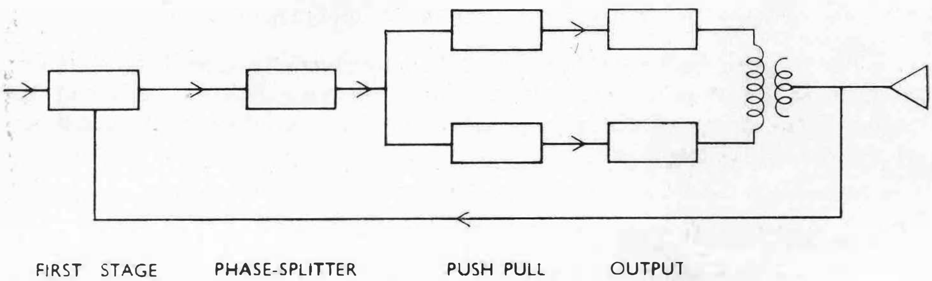


Fig. 1.

desirable to apply feedback over the output transformer, the rest of the amplifier should be resistor-capacitor coupled.

Fig. 1 indicates an arrangement in which each stage in the amplifier is working well within its capabilities and negative feedback is taken from the output transformer secondary to the cathode of the first stage.

Suggested complete circuit diagrams for amplifiers together with detailed constructional data appear later in this publication.

Minimising phase shift

In order to keep the phase shift in the amplifier shown in figs. 10, 12, and 15 as small as possible at low frequencies, the first stage has been directly coupled to the phase splitter eliminating one resistor-capacitor coupling. The first two stages are thus designed as a single entity. The phase splitter section, which consists of a triode with equal loads in the anode and cathode circuits, operates partly as a cathode follower, its grid being some 100V positive and coupled to the preceding anode circuit. Owing to the cathode follower action of V2 the operating conditions are not critical. The cathode bias resistor of V1 to which feedback is applied from the output transformer secondary, is kept as small as practicable to avoid a gain reduction in the first stage due to current feedback.

In the amplifiers shown in figs. 2 and 17 the above feature has not been employed. Both these amplifiers have fewer stages of amplification than those mentioned, and the likelihood of instability due to phase shift in the intervalve couplings is proportionately less.

Negative feedback

The reasons for the use of negative feedback are :

(*a*). To improve the frequency response of the amplifier and output transformer.

(*b*). To improve the linearity of the amplifier and output transformer.

(*c*). To reduce the phase shift in the amplifier and output transformer within the audible frequency range.

(*d*). To improve the low frequency characteristics of the output transformer and particularly to offset defects due to the non-linear relationship between flux and magnetising force.

(*e*). To reduce the output resistance of the amplifier.

(*f*). To reduce the effect of random changes of the parameters of the amplifier, supply voltage changes and any spurious defects.

The output resistance, upon which the loudspeaker usually depends for the majority of the damping required, can be reduced to a small fraction of the speech coil impedance. A ratio of load impedance/output resistance (sometimes known as damping factor) of 20-30 is easily obtained.

The design of the amplifier given in figs. 10, 12 and 15 is such that no difficulty should be experienced in the application of negative feedback up to a maximum of some 26db. Provided that the threshold of instability is not reached, the benefits of negative feedback rise as the amount of feedback is increased at the sole expense of loss of gain, but there will be little if any audible improvement to be gained with this amplifier by increasing the amount of feedback beyond 20db.

The feedback network is a purely resistive potential divider, the bottom limb of which is included in the cathode bias resistor of the first stage.

With component values as specified no trouble should be experienced from instability due to the effects of unintentional positive feedback. Should instability arise it will probably appear as oscillation at a supersonic frequency. This may be transient, occurring only at some part of the cycle when the amplifier is operated near maximum output. Its cause may be bad layout or an output transformer with a high leakage reactance or it may be due to resonance in the output transformer.

It is stressed that no tone or volume control may be included in any part of the amplifier which is affected by negative feedback.

The typical operating conditions of the output valves used in the amplifier designs in this booklet are tabulated below to assist the constructor in choosing a suitable valve where a limitation on H.T. supply prevails.

	KT61	N78	KT66	KT66	KT33C
Connection	as triode	as triode	as triode	as tetrode	as tetrode
V_a (b)	380	380	450	425	220
V_a	350	350	400	390	200
V_{g2}	—	—	—	275	200
I_a	73 mA	64·5 mA	125 mA	125 mA	113 mA
I_{g2}	—	—	—	18 mA	18 mA
V_{g1}	−11	−9·5	−38	−25	−19
$R_{k/valve}$	300Ω	330Ω	600Ω	500Ω	240Ω
R_l (a-a)	6kΩ	8kΩ	10kΩ	8kΩ	3·2kΩ
V_{in} (g1-g1)	23	21	84	70	44
P_{out}	6W	6W	12W	30W	15·5W
D	2%	1·6%	3·5%	6%	7·5%

D.C./A.C. apparatus

The disadvantage of the D.C./A.C. technique is that the common input/output earthline is also common to one side of the mains supply, and the danger of electric shock is very real when ancillary apparatus, such as a pick-up, is connected. However, by following the " bus-bar " earthline method of wiring mentioned earlier, the mains supply is kept off the chassis and input circuit, the latter being completed by connecting the bus-bar to chassis with a suitable capacitor. Unfortunately, the output circuit will be live because of the necessity of completing the feedback network, but the loudspeaker does not have to be handled, as does a pickup, and it is a simple matter to provide adequate insulation.

It should be noted that the metal canister of large electrolytic capacitors is not usually isolated from the electrodes. In isolating the mains from the chassis, therefore, the capacitor canister must be insulated from the fixing clip by a suitable ring of P.V.C. or similar insulating material.

It is essential that the sequence of connecting the valve heaters as indicated on the circuit diagram be adhered to, in order to keep the heater/cathode voltage of early stages as low as possible.

Precautions to be observed when using power valves

1. Isolate the grid and anode circuits.
2. Use grid and anode "stopper" resistances with triodes, grid and screen "stopper" resistances with pentodes or tetrodes.
3. Never exceed the maximum permissible grid leak resistor.
4. Use only an output transformer designed on generous lines and with low leakage inductance.
5. Do not exceed the maximum anode and screen wattage dissipation.
6. Cut off the H.T. supply before any adjustments are made to any part of the circuit.
7. The disconnection of a feedback from the loudspeaker amplifier while the output valves are operating will result in immediate oscillation and damage to the valves and transformer is likely. The use of a multi-way plug and socket as the loudspeaker outlet may contain a "jumper" which will break the H.T. negative connection to the transformer centre tap when the loudspeaker is unplugged.

Instability

It will be appreciated that with any amplifier, the output transformer secondary winding must be correctly phased relative to the input circuit for negative feedback to take place. Reversing the secondary winding connections will cause the amplifier to oscillate violently and will be quite capable of damaging a delicate loudspeaker suspension. Tests to determine the phasing should therefore be made with an indifferent loudspeaker.

Owing to the tolerance of components excessive phase shift may result which will cause instability at either very high or very low frequencies. Symptoms will be very low frequency "motor boating," high hum level, excessive anode voltage on the output valves or a "break up" effect on loud passages of music etc., the exact form depending upon the nature and degree of instability.

Should any effect of this nature be encountered, the feedback circuit should be disconnected to confirm that instability is the result of feedback. Should this prove to be so, the value of the feedback resistance, R_D, as shown in the amplifier circuit diagrams, may be increased in order to reduce the amount of feedback, and if stability can be achieved for a small increase in R_D it may be assumed that the feedback was excessive for the transformer used. In instances where instability persists in spite of a large increase in R_D a transitional phase shift net-work may be introduced into the circuit by connecting a small capacitor C_D across R_D. The value of this capacitor should be found experimentally, but it will probably be between 20 and 5000 pF, the exact value being rather critical.

Notes on components and layout

The equipments described herein are not critical as regards layout provided the constructor follows the generally accepted "good practice," the following points of which are typical :—

1. Provide adequate free air ventilation around the valves.
2. Capacitors, particularly electrolytic types, must be kept away from valves and other sources of high temperature.

3. Anode and grid leads are kept as short as possible and advantage taken of any given layout to keep the distance between them at a maximum. It is particularly important that the input and output circuits of the complete amplifier be as remote from each other as possible.

4. A single insulated earth tag for each stage terminates the bias resistor, grid resistor and any decoupling capacitors even if this means using slightly longer leads than if they were connected by the shortest possible path to chassis ; although, of course, these leads are kept as short as possible. These earth tags are connected together by a " bus-bar " of 14-16 s.w.g. copper wire, starting from the centre tap of the H.T. secondary winding and finally connected to chassis at the input terminals, the object of this arrangement being to prevent signal and/or supply current paths interacting which might cause instability or high hum level.

5. The output transformer is spaced from the mains transformer and smoothing inductors with the cores at right angles to minimise coupling.

High quality equipment demands the use of components of generous proportions and an 18 s.w.g. steel chassis of welded construction is recommended to obtain sufficient rigidity.

These remarks on the essential points to be observed in the construction of high quality audio frequency amplifiers are intended to serve only as a guide and much of the desired result depends on layout, circuit components etc. Practical amplifiers have been constructed to the basic circuits described in these pages and used in conjunction with a gramophone pickup, microphone or radio receiver at one end of the chain and a high quality loudspeaker at the other. They have demonstrated the high quality of reproduction possible with good modern components and careful amplifier design.

Although every care has been taken in the compilation of this information, the author can accept no responsibility for any dissatisfaction with results in individual cases, owing to the many details that must necessarily be dependent on the actual construction.

A 6 watt Economical Amplifier using Osram N78 Output Valves

An economical quality amplifier capable of supplying a maximum output in the region of six watts has been included for constructors who are prepared to accept the limitations of the low peak power handling capacity but nevertheless require above average reproduction of the various programme sources available.

The sensitivity for full output is 1 volt r.m.s. on radio and 20 mV r.m.s. on gramophone inputs.

Constructional notes (fig. 2)

The transformer T1 is a part of the tone control network and on no account should be omitted. It was not found necessary to include C_D in the particular amplifier constructed using a Haynes output transformer described below.

The mains transformer ratings are sufficiently generous to supply either of the R.F. feeder units described in this booklet, and it is left to the constructor to satisfy his own particular requirements regarding the method of connection.

14db of feedback is applied to the amplifier resulting in a level response from 25 c/s to 30 kc/s and —6db at 100 kc/s.

R25 and R26 should be connected to give an electrical centre top to the 6·3V heater winding in cases where this is not provided on T3.

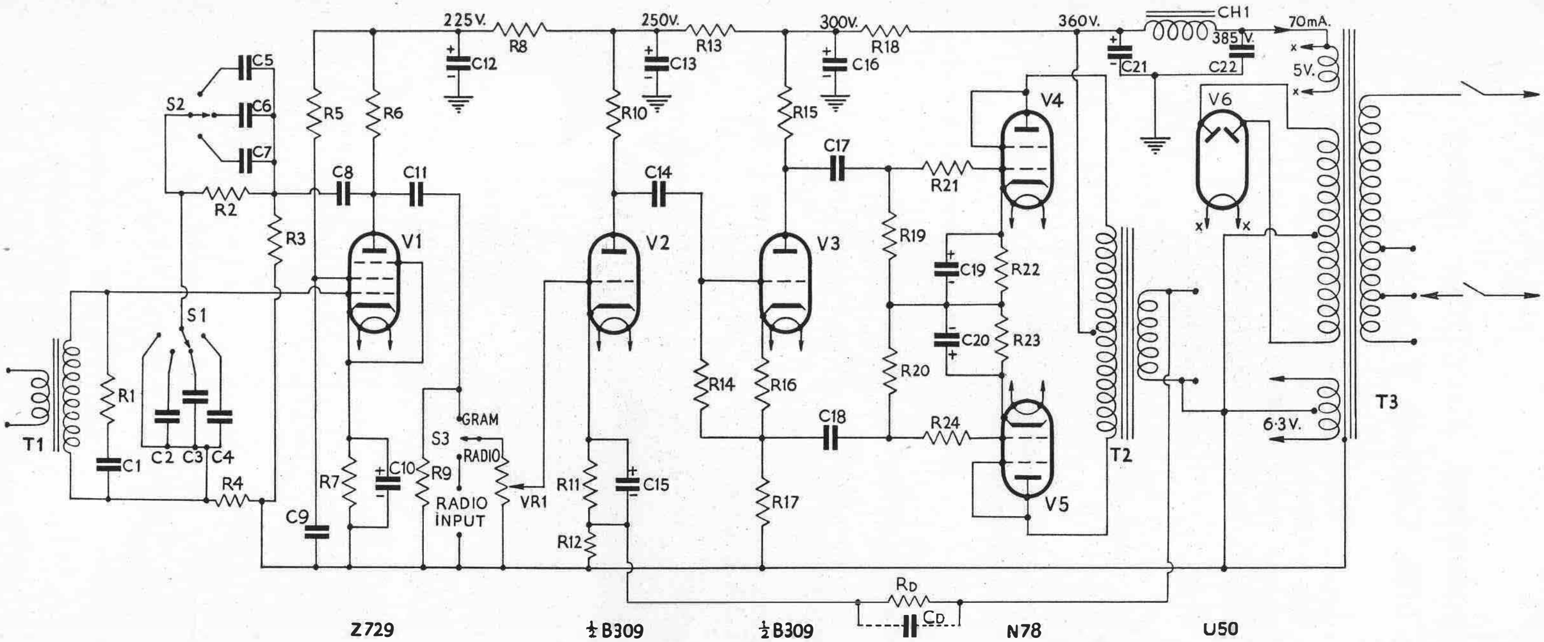
This amplifier is not intended for use with the G.E.C. metal cone loudspeaker.

Transformer Specification

Circuit ref. Fig. 2.	Specification
T1	Pickup transformer specified by maker
T2	High quality output transformer having a turns ratio equal to $\sqrt{\frac{8000}{S}}$ {where S = loudspeaker speech coil impedance}
T3	Mains transformer Primary 0—200, 220, 240V Secondary 350—0—350V 100mA 5V (U50) or 6·3V (U709) 2A 6·3V C.T. 5A
CH1	Smoothing inductor 10 H 100 mA

The following valve types are specified :

V1 Osram Z729	V2, V3 Osram B309 (double-triode)
V4, V5 Osram N78	V5 Osram U50 or U709



R1	10kΩ	¼W	20%	**R15**	22kΩ	1W	20%
R2	470kΩ	¼W	20%	**R16**	470Ω	¼W	20%
R3	4·7MΩ	¼W	20%	**R17**	22kΩ	1W	5%
R4	56kΩ	¼W	20%	**R18**	10kΩ	1W	5%
R5	1MΩ	¼W	20%	**R19**	220kΩ	¼W	20%
R6	220kΩ	½W	20%	**R20**	220kΩ	¼W	20%
R7	2·2kΩ	½W	20%	**R21**	22kΩ	¼W	20%
R8	22kΩ	½W	20%	**R22**	330Ω	wire wound	
R9	4·7MΩ	¼W	20%				
R10	100kΩ	½W	20%	**R23**	330Ω	wire wound	
R11	1·5kΩ	½W	20%				
R12	47Ω	½W	20%	**R24**	22kΩ	¼W	20%
R13	22kΩ	1W	20%	**R25**	47Ω	¼W	20%
R14	2·2MΩ	¼W	20%	**R26**	47Ω	½W	20%

R_D	440Ω for 15Ω speech coil	¼W	20%
	150Ω for 3Ω speech coil	¼W	20%

C1	0·001μF	—
C2	0·005μF	—
C3	0·0025μF	—
C4	0·001μF	—
C5	270pF	—
C6	50pF	—
C7	15pF	—
C8	0·1μF	—
C9	0·1μF	—

C10	50μF	12V
C11	0·02μF	—
C12	8μF	500V
C13	8μF	500V
C14	0·01μF	—
C15	50μF	12V
C16	8μF	500V
C17	0·1μF	—
C18	0·1μF	—
C19	50μF	12V
C20	50μF	12V
C21	16μF	500V
C22	16μF paper (4×4μF)	
C_D	see page 13	

Fig. 2. Circuit diagram and components list of the 6 watt economical amplifier using Osram N78 output valves.

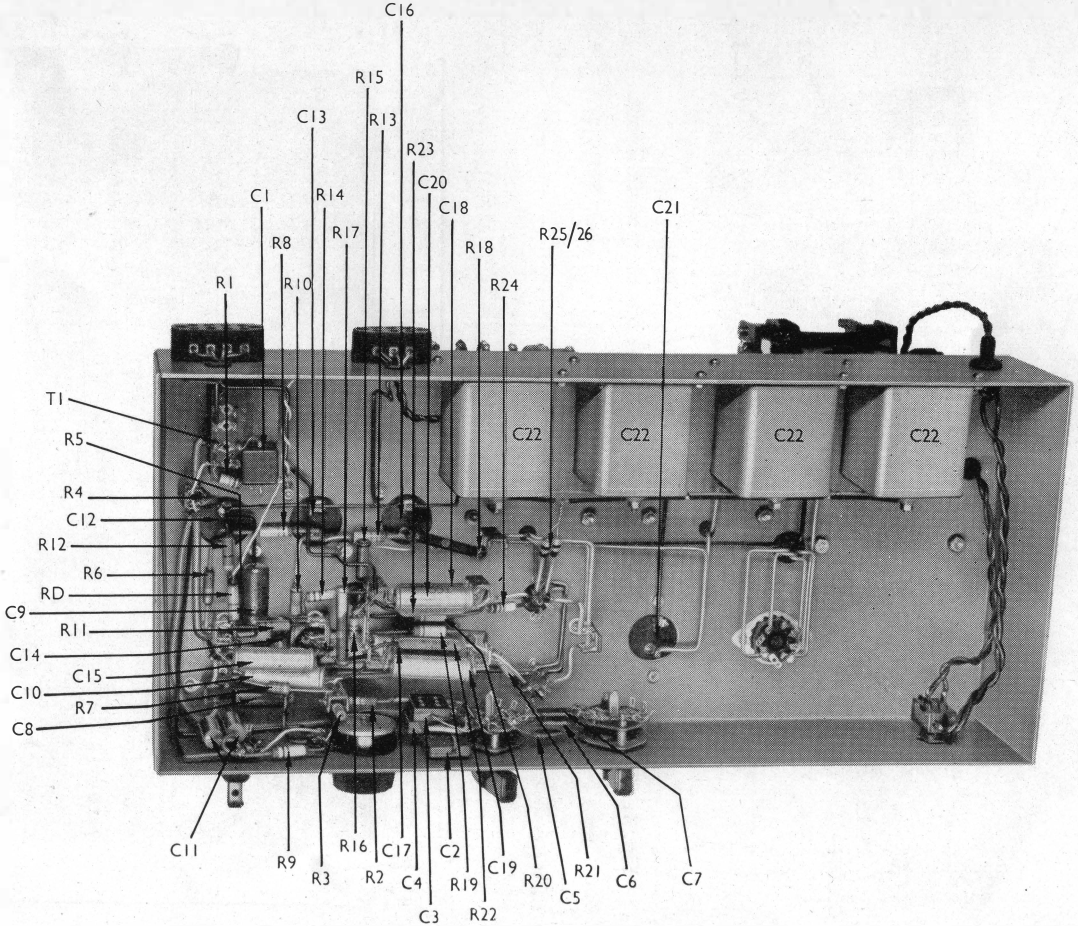


Fig. 3. Underside of the 6 watt amplifier showing the component layout.

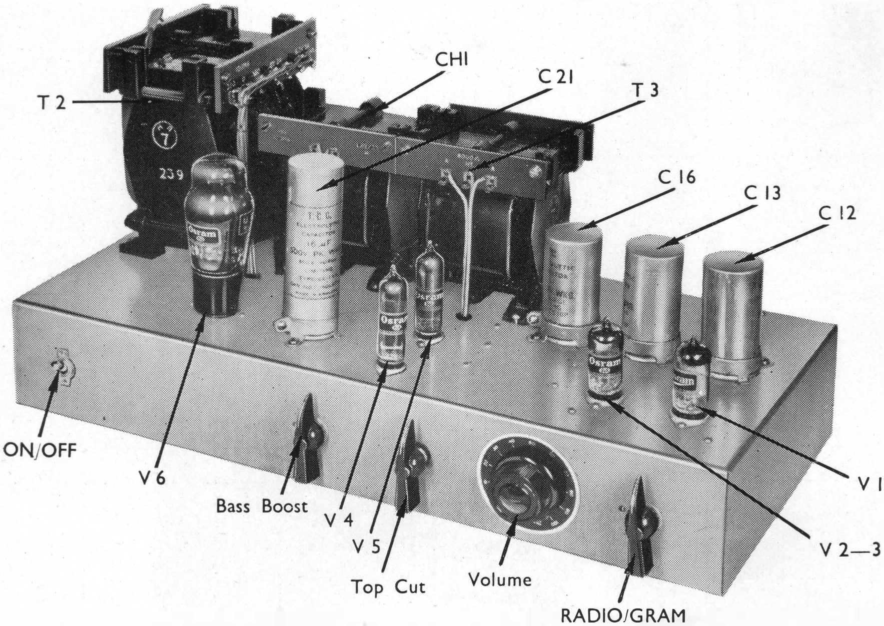


Fig. 4. Top view of the 6 watt amplifier showing the component layout.

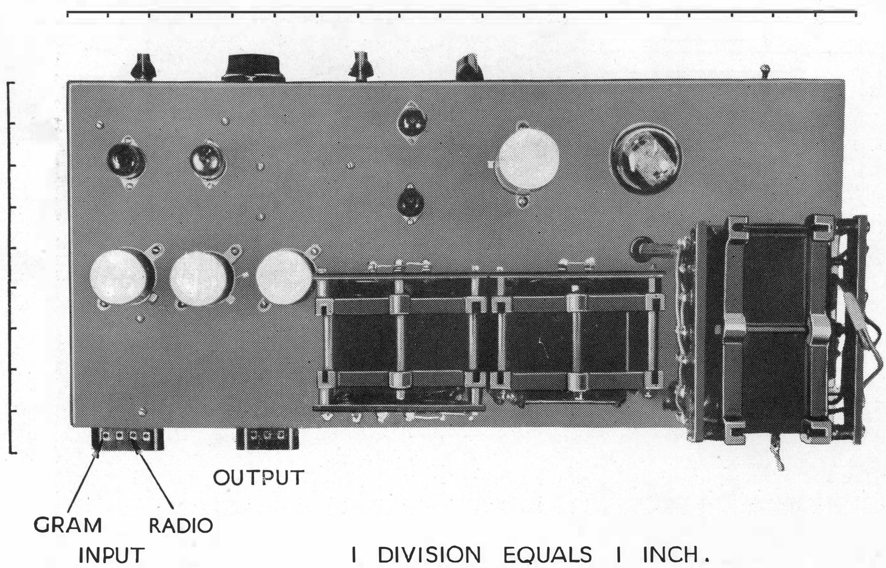


Fig. 5. Plan view of the 6 watt amplifier to facilitate accurate location of components.

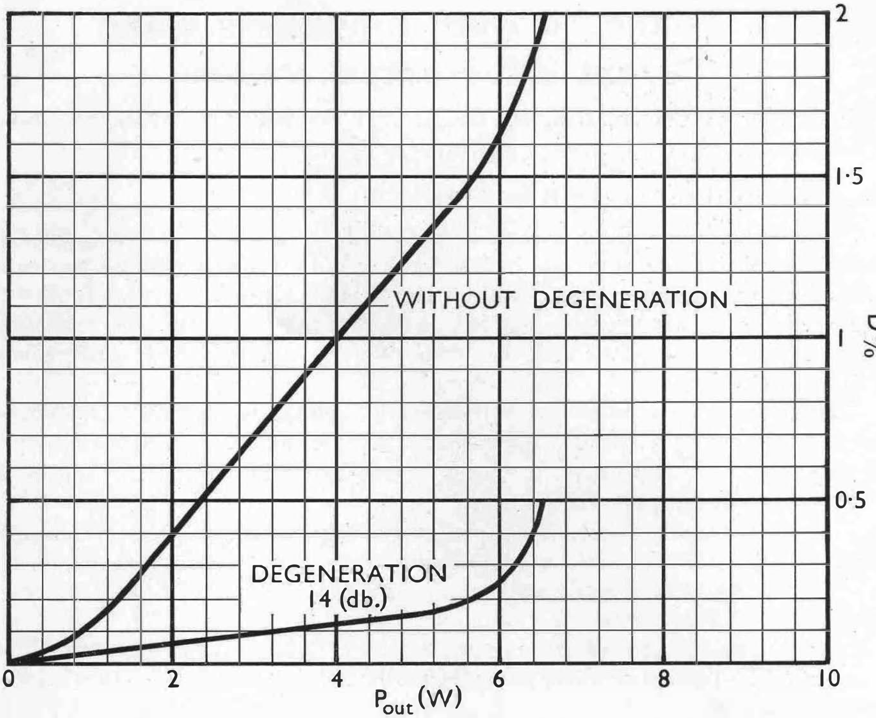


Fig. 6. Indicates the decrease in total harmonic distortion by applying negative feed-back to the 6 watt amplifier.

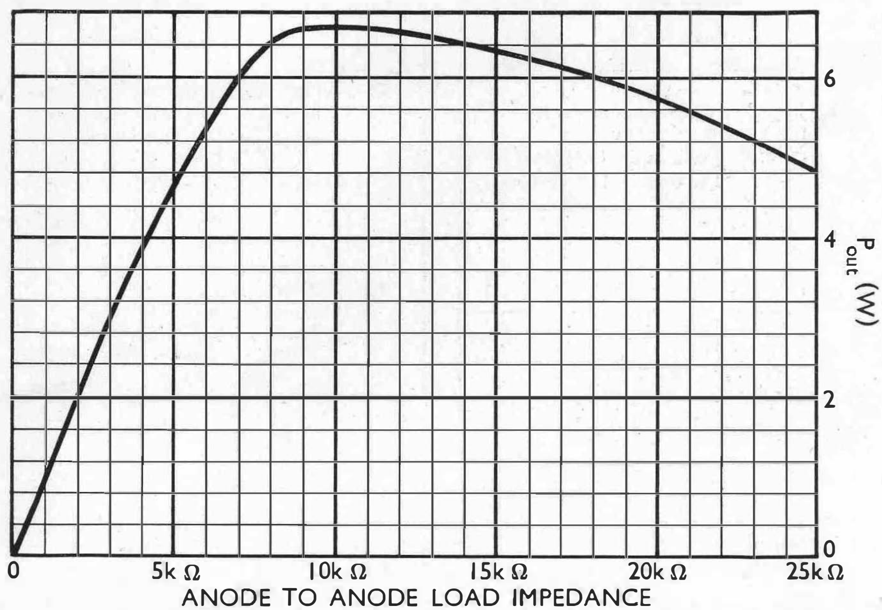


Fig. 7. Shows the wide variation of anode load allowed with the 6 watt amplifier.

12, 20 and 30 watt Amplifiers using Osram KT66 output valves

These amplifiers are basically similar and the following comments apply equally to all three.

Constructional notes (fig 8 and 12)

The 22kΩ phase splitter load resistors should be within 10% of each other to ensure sensible balance of voltage in the circuit. Wire wound resistors are recommended for providing automatic bias for the output valves, a tolerance of ± 5% is allowed. All other resistors may have a ±20% tolerance with the exception of automatic bias resistors and the push pull-driver stage anode load where ±10% is preferred.

The resistor R_D in the negative feedback loop depends largely on the output transformer for its minimum value but with the recommended transformers values of $1200\sqrt{S}\ \Omega$, $1500\sqrt{S}\ \Omega$ and $1900\sqrt{S}\ \Omega$ for the 12, 20 and 30W amplifiers respectively are satisfactory.

The valves in the voltage amplifying stages may be either Osram L63 (single triode) or Osram B65 (double triode) whichever is the more convenient.

The 12, 20 and 30 watt amplifiers are intended for use with one, two and three G.E.C. " FR " metal cone loudspeakers.

The Osram valves used are specified on the respective circuit diagrams The circuit of a 12—14 watt amplifier using Osram directly heated PX4 output triodes is given on page 26.

TRANSFORMER AND INDUCTOR SPECIFICATIONS FOR THE 12, 20 and 30 watt AMPLIFIERS

12 watt circuit

Circuit ref. Fig. 10	Specification
T1	High quality output transformer having a turns ratio equal to $\sqrt{\frac{10000}{S}}$ {where S=loudspeaker speech coil impedance} ratio for 15Ω speech coil=26:1 ,, 7·5 ,, 37:1 ,, 3·0 ,, 57:1 ,, 1·7 ,, 77:1
T2	Mains transformer Primary 0-210, 230, 250V Secondary 425-0-425V 200mA 5V 3A 6·3V C.T. 6/8A
L1	Smoothing inductor 20 henrys 40mA (min)
L2	10 henrys 200mA (min)

20/30 watt circuit

Circuit ref. Fig. 12	Specification
T1	High quality output transformer having a turns ratio equal to $\sqrt{\frac{2000}{S}}$ {where S=loudspeaker speech coil impedance} ratio for 15Ω speech coil=12:1 ,, 7·5 ,, 16:1 ,, 3·0 ,, 26:1 ,, 1·7 ,, 34:1
T2	**20W circuit** Mains transformer Primary 0 -210, 230, 250V Secondary 325-0-325V 300mA 5V 6A 6·3V C.T. 8/10A **30W circuit** As above but Secondary 425-0-425V 300mA 5V 6A 6·3V C.T. 8/10A
L1	Smoothing inductor 30 henrys 40mA (min)
L2	10 henrys 300mA (min)

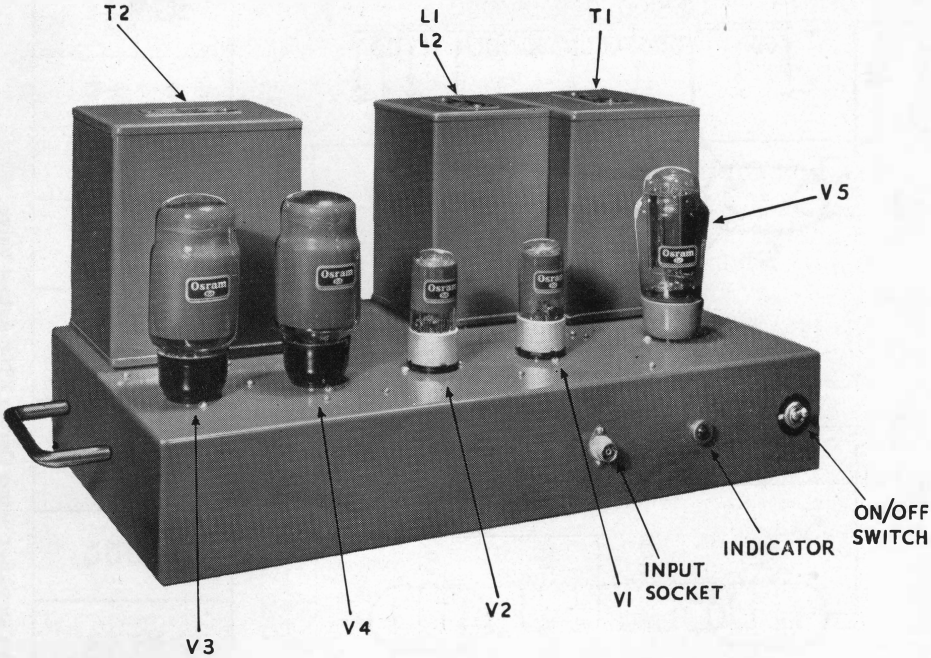
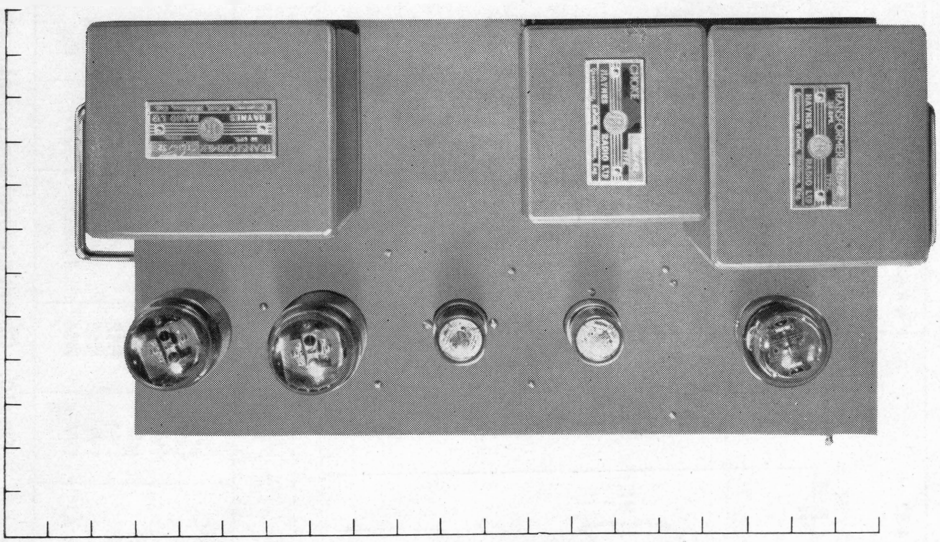
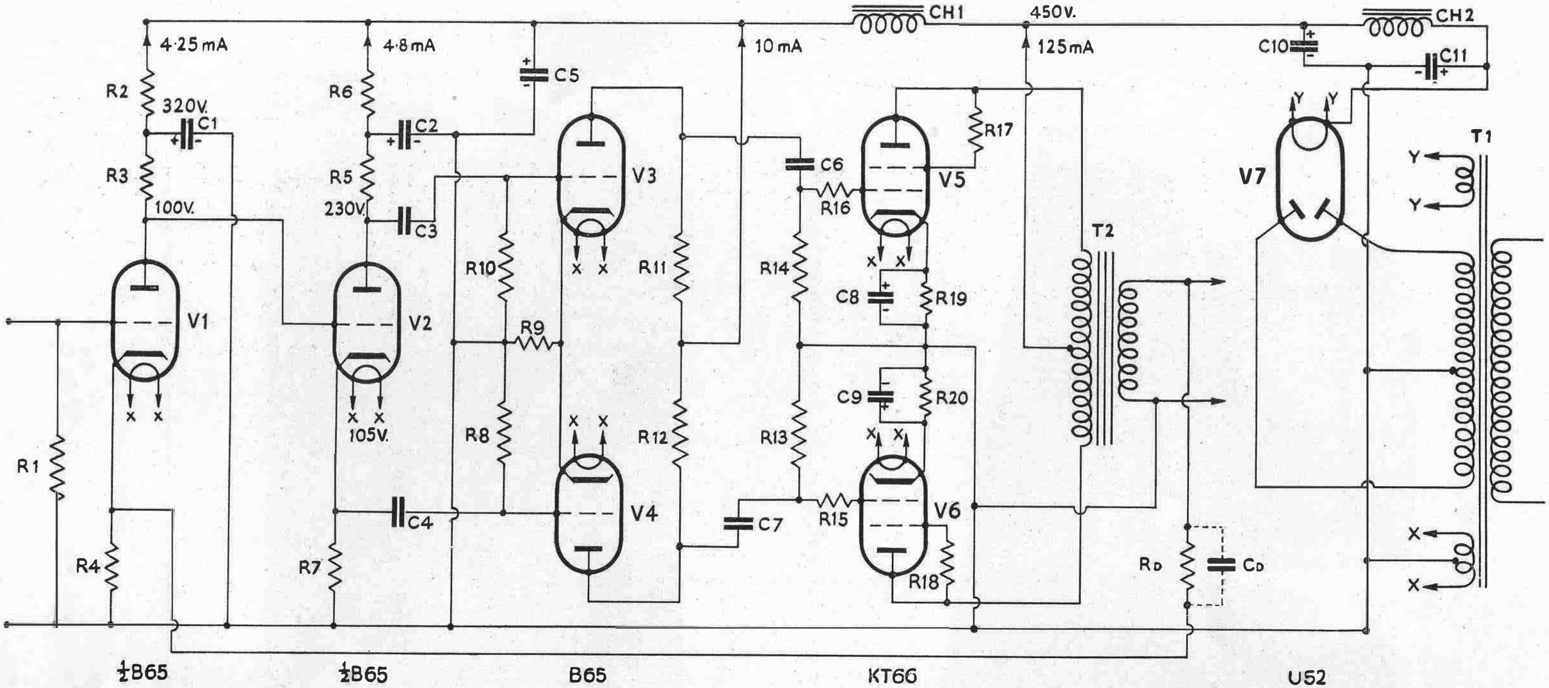


Fig. 8. Top view of the 12 watt amplifier showing the component layout.



One division equals 1 inch.

Fig. 9. Plan view of the 12 watt amplifier to facilitate accurate location of components.



R1	1MΩ	$\frac{1}{3}$W	**R8**	470kΩ	$\frac{1}{3}$W	**R15**	10kΩ	$\frac{1}{3}$W	**C1**	8μF	450V	**C7**	0·25μF	—
R2	33kΩ	1W	**R9**	390Ω	$\frac{1}{3}$W	**R16**	10kΩ	$\frac{1}{3}$W	**C2**	8μF	450V	**C8**	50μF	50V
R3	47kΩ	1W	**R10**	470kΩ	$\frac{1}{3}$W	**R17**	100Ω	$\frac{1}{2}$W	**C3**	0·05μF	—	**C9**	50μF	50V
R4	470Ω	$\frac{1}{3}$W	**R11**	56kΩ	2W	**R18**	100Ω	$\frac{1}{2}$W	**C4**	0·05μF	—	**C10**	8μF }	600V
R5	22kΩ	1W	**R12**	56kΩ	2W	**R19**	500Ω	5W	**C5**	8μF	—	**C11**	8μF }	paper
R6	22kΩ	1W	**R13**	100kΩ	$\frac{1}{3}$W	**R20**	500Ω	5W	**C6**	0·25μF	—	**C_D**	see page 13	
R7	22kΩ	1W	**R14**	100kΩ	$\frac{1}{3}$W	**R_D**	see page	20						

Fig. 10. Circuit diagram and components list of the 12 watt amplifier using Osram KT66 output valve.

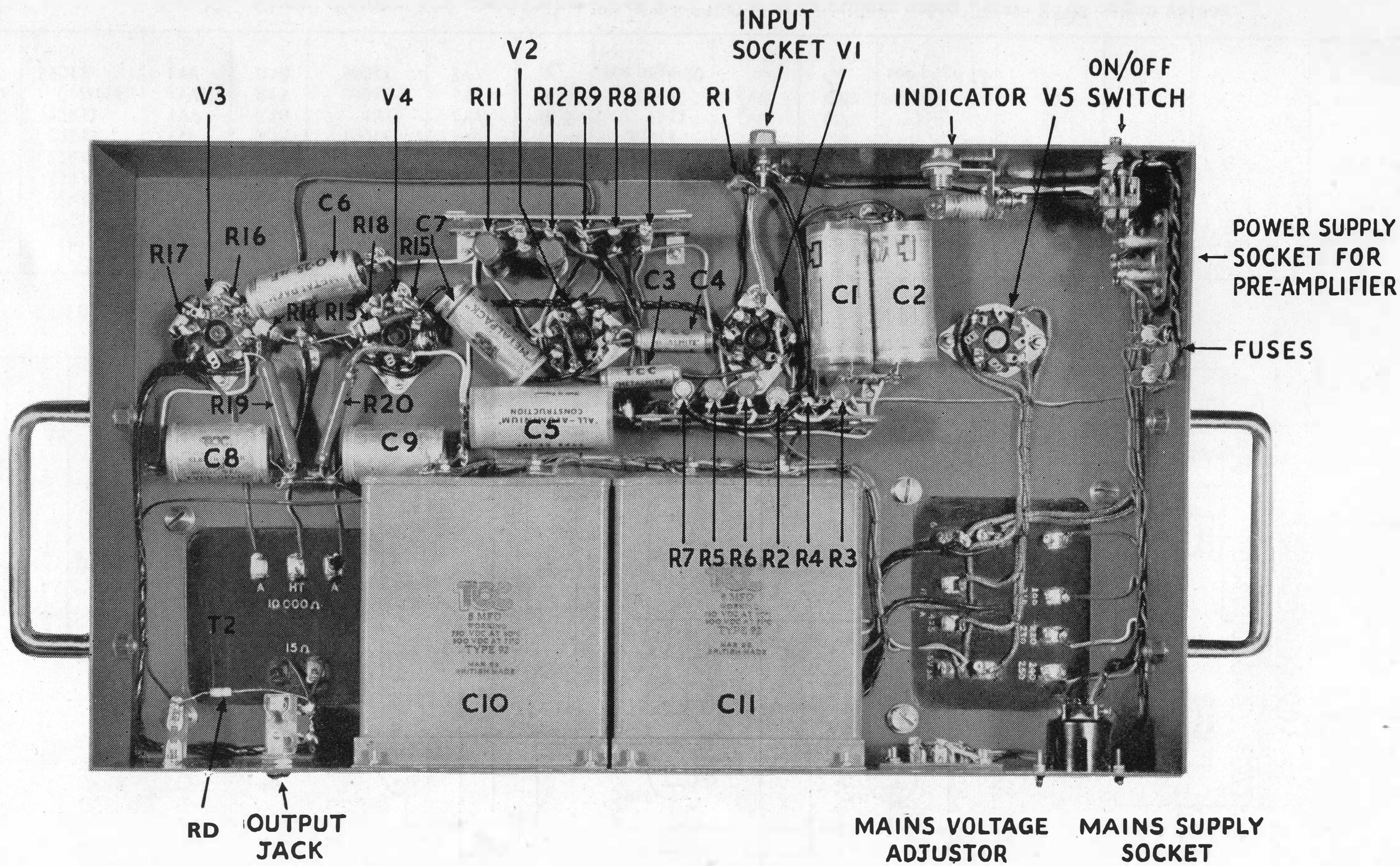
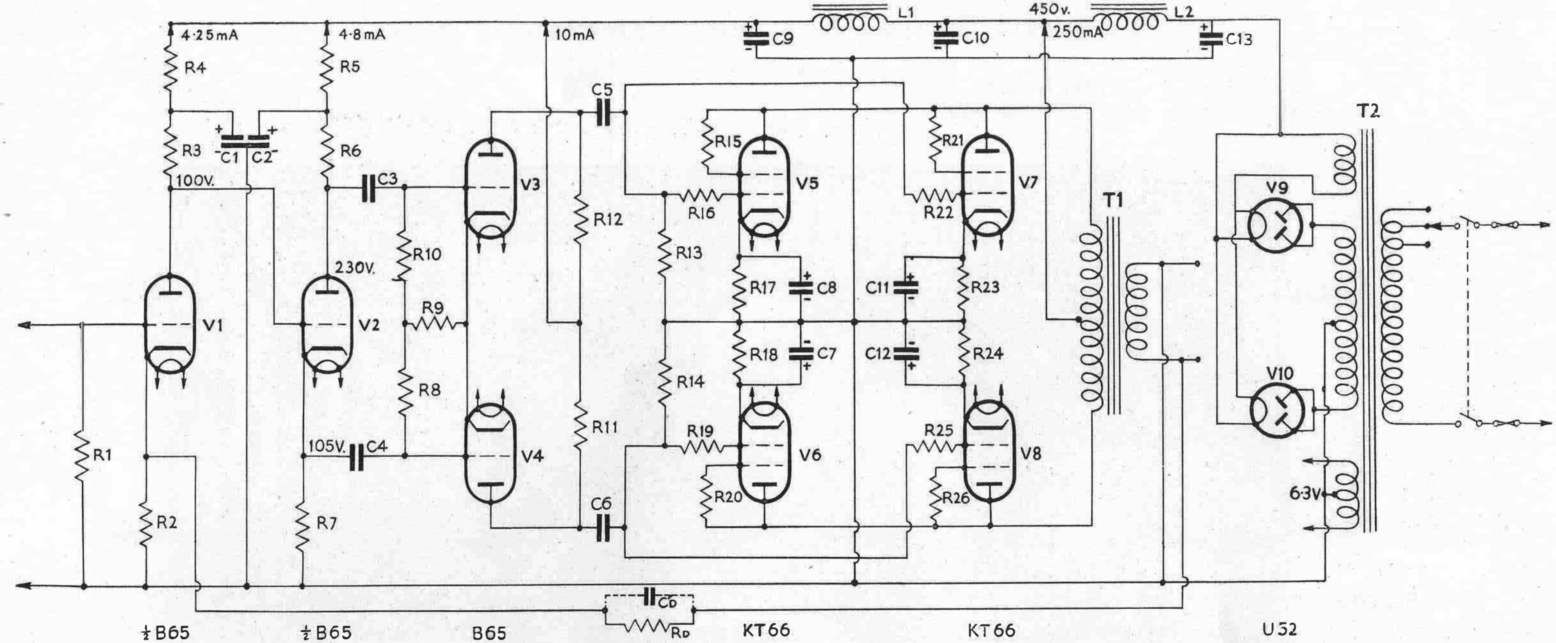


Fig. 11. Underside of the 12 watt amplifier showing the component layout.



R1	1MΩ	½W	**R10**	0·47MΩ	¼W	**R19**	1kΩ	½W	**C1**	8μF	450V	**C9**	8μF	600V paper
R2	470Ω	¼W	**R11**	56kΩ	2W	**R20**	100Ω	½W	**C2**	8μF	450V	**C10**	8μF	
R3	47kΩ	1W	**R12**	56kΩ	2W	**R21**	100Ω	½W	**C3**	0·05μF	—	**C11**	50μF	50V
R4	33kΩ	1W	**R13**	100kΩ	½W	**R22**	1kΩ	½W	**C4**	0·05μF	—	**C12**	50μF	50V
R5	22kΩ	1W	**R14**	100kΩ	½W	**R23**	500Ω	5W	**C5**	0·25μF	—	**C13**	8μF	600V paper
R6	22kΩ	1W	**R15**	100Ω	½W	**R24**	500Ω	5W	**C6**	0·25μF	—			
R7	22kΩ	1W	**R16**	1kΩ	½W	**R25**	1kΩ	½W	**C7**	50μF	50V			
R8	0·47MΩ	¼W	**R17**	500Ω	5W	**R26**	100Ω	½W	**C8**	50μF	50V			
R9	390Ω	½W	**R18**	500Ω	5W	**R_D**	see page 20		**C_D**	see page 13				

Fig. 12. Circuit diagram and components list of the 20/30 watt amplifiers using Osram KT66 output valves.

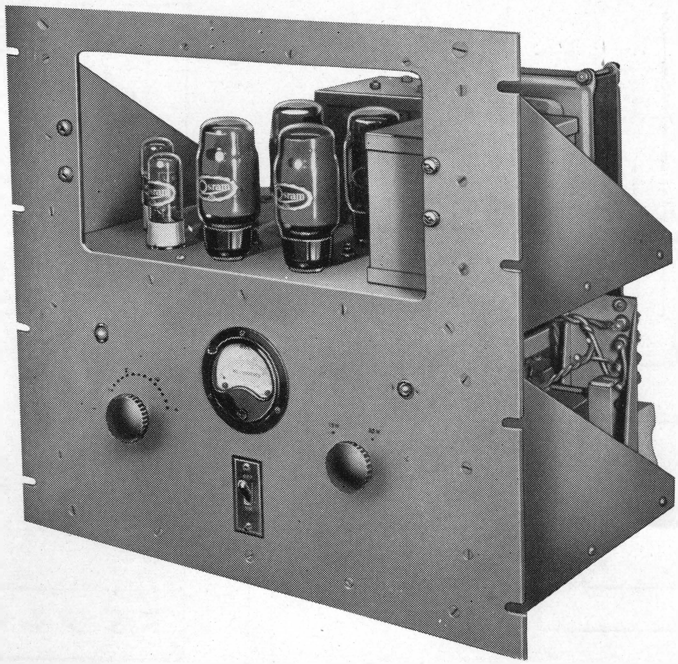


Fig. 13. The experimental 30 watt amplifier which D.T.N. Williamson designed for the M.O. Valve Co. Ltd. using 4 Osram KT66 valves triode-connected in the output stage.

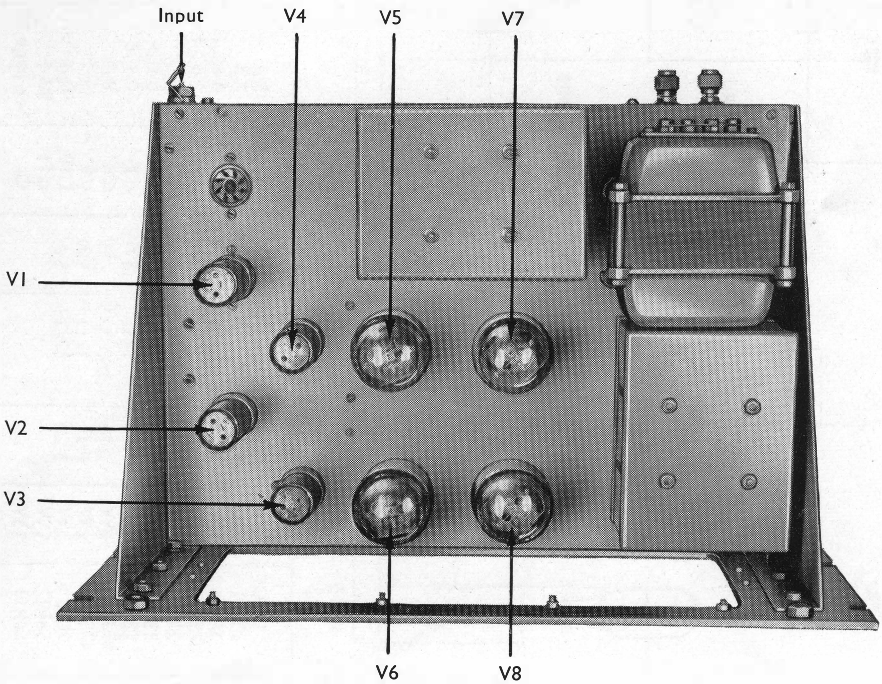
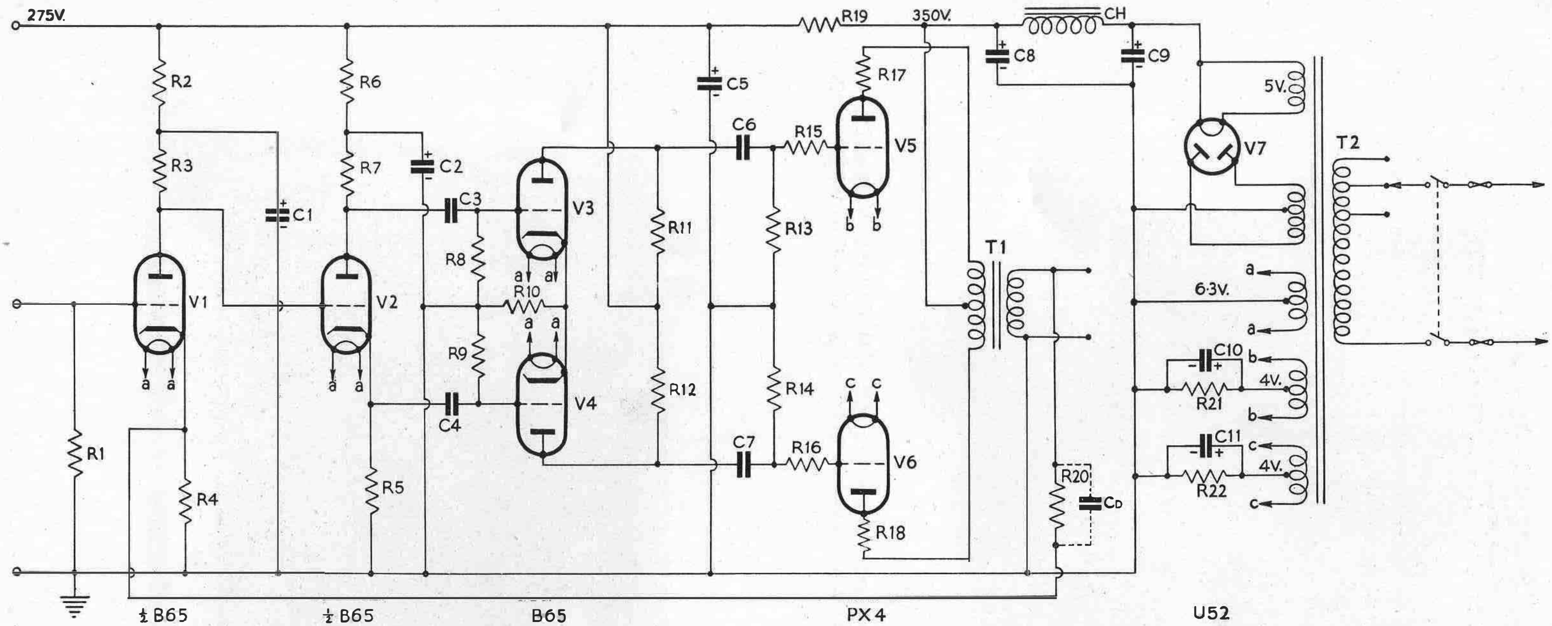


Fig. 14. Plan view of the amplifier shown above.



R1	1MΩ	¼W	**R13**	250kΩ	¼W	**C1**	8μF	450V	**V1**	Osram L63 or ½ B65	**T1** High quality output transformer having a turns ratio of where S = loudspeaker speech coil impedance.
R2	33kΩ	1W	**R14**	250kΩ	¼W	**C2**	8μF	450V	**V2**	,, L63 or ½ B65	
R3	47kΩ	1W	**R15**	1kΩ	¼W	**C3**	0·05μF	—	**V3**	,, L63 or ½ B65	
R4	470Ω	1W	**R16**	1kΩ	¼W	**C4**	0·05μF	—	**V4**	,, L63 or ½ B65	
R5	22kΩ	1W	**R17**	100Ω	½W	**C5**	8μF	450V	**V5**	,, PX4	**T2** Mains transformer standard primary. Secondary 325-0-325V at 120mA ; 5V at 3A ; 2×4V at 1A ; 6·3V at 2A.
R6	22kΩ	1W	**R18**	100Ω	½W	**C6**	0·1μF	—	**V6**	,, PX4	
R7	22kΩ	1W	**R19**	5kΩ	5W	**C7**	0·1μF	—	**V7**	,, U52	
R8	470kΩ	¼W	**R20**	1,200 √S	¼W	**C8**	8μF	600V paper			
R9	470kΩ	¼W	**R21**	1kΩ	5W	**C9**	8μF	600V paper			
R10	390Ω	¼W	**R22**	1kΩ	5W	**C10**	50μF	50V			
R11	56kΩ	1W				**C11**	50μF	50V			
R12	56kΩ	1W				**C_D**	See page 13				

Fig. 15. Circuit diagram and components list of the 14 watt amplifier using Osram PX4 output valves.

14 watt D.C./A.C. Amplifier and Pre-amplifier using Osram KT33C output valves

The use of D.C./A.C. technique is not generally preferred for high quality amplifiers but provided due care is taken in construction on the lines recommended on page 12 satisfactory results can be obtained. This amplifier is intended to operate on D.C. or A.C. supplies of 190—250 volts. The pre-amplifier tone control provides varying degrees of top cut and bass boost.

Constructional notes (fig. 17)

The power supply for the pre-amplifier is taken from the main amplifier, the valve heater being connected in series at the point X on fig. 17.

The prototype amplifier was unstable without the inclusion of a 0·005 μF capacitor C_D connected across R_D.

In cases where no earth is available C16 will be required, 0·05μF is satisfactory.

The output transformer is a product of Haynes Radio and has a ratio equal to $\sqrt{\frac{3200}{S}}$ where S=speech coil impedance.

The points A and D are provided for the connection of ancillary apparatus (other than the pre-amplifier) where it may be necessary to isolate this from the D.C. connection to the main amplifier.

The following valves are specified.

Amplifier	V1.	Osram Z63	Pre-amplifier
	V2.	Osram L63	V1. Osram Z63
	V3, V4.	Osram KT33C	
	V5, V6.	Osram U31	

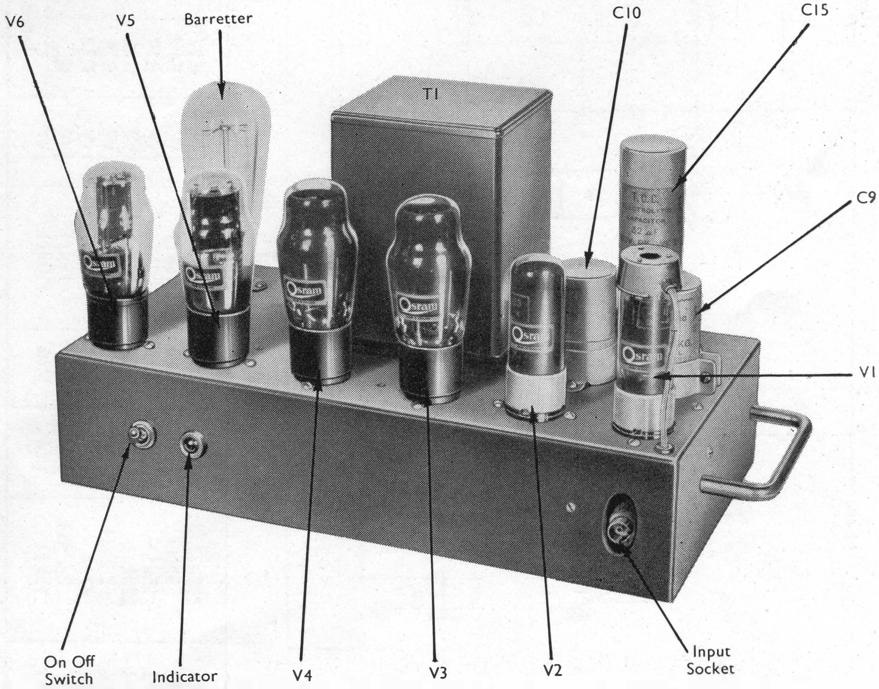
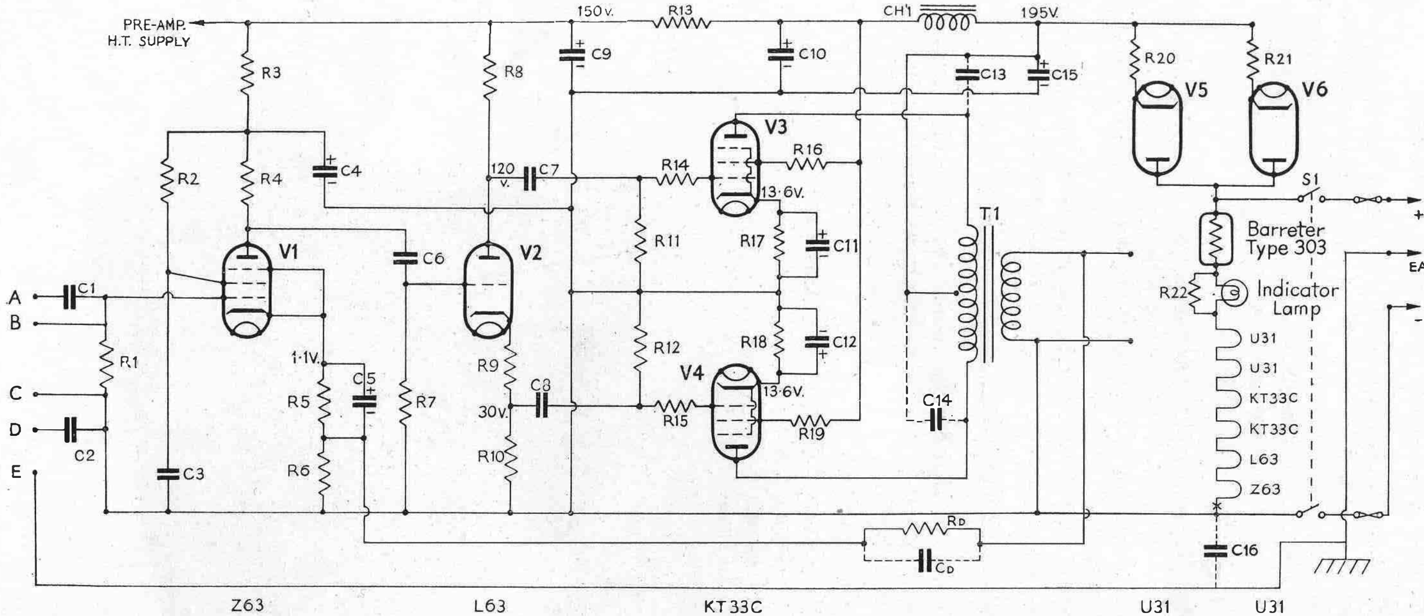


Fig. 16. Top view of the D.C./A.C. amplifier showing the component layout.



R1	390kΩ	½W	**R9**	1·5kΩ	½W	**R17**	220Ω	1W	**C1**	0·05μF	—	**C9**	30μF	350V
R2	1MΩ	½W	**R10**	15kΩ	½W	**R18**	220Ω	1W	**C2**	0·05μF	—	**C10**	30μF	350V
R3	15kΩ	½W	**R11**	220kΩ	1W	**R19**	100Ω	½W	**C3**	0·25μF	—	**C11**	25μF	25V
R4	220kΩ	½W	**R12**	220kΩ	½W	**R20**	100Ω	5W	**C4**	4μF	350V	**C12**	25μF	25V
R5	2·2kΩ	½W	**R13**	15kΩ	½W	**R21**	100Ω	5W	**C5**	50μF	12V	**C13**	1500pF	—
R6	47Ω	½W	**R14**	15kΩ	1W	**R22**	22Ω	3W	**C6**	0·05μF	—	**C14**	1500pF	—
R7	2·2MΩ	½W	**R15**	15kΩ	½W	**R_D**	$250\sqrt{S}$ Ω		**C7**	0·1μF	—	**C15**	32μF	450V
R8	15kΩ	1W	**R16**	100Ω	½W	Indicator lamp OS70			**C8**	0·1μF	—	**C_D**	see page 13	

Fig. 17. Circuit diagram and components list of the 14 watt D.C./A.C. amplifier using Osram KT33C output valves.

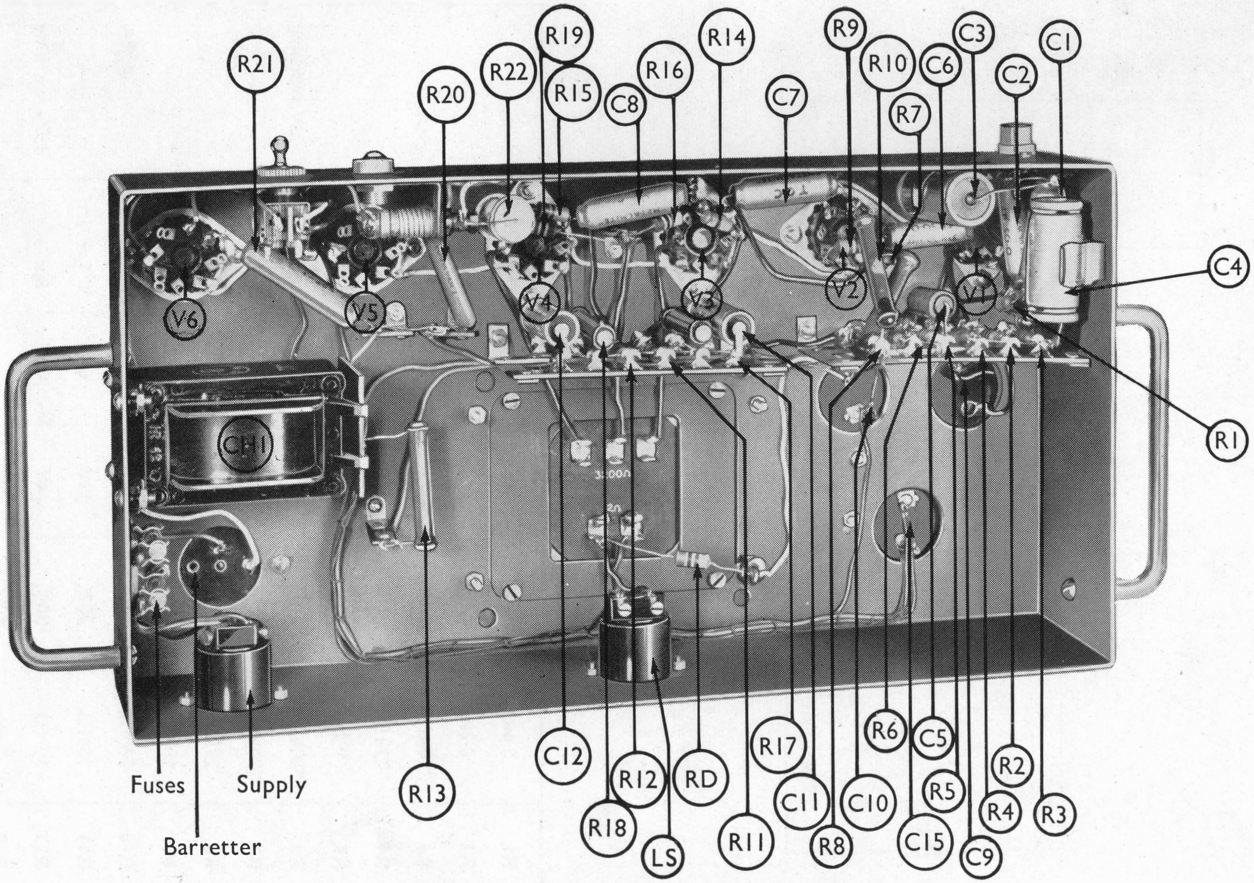


Fig. 18. Underside of the 14 watt D.C./A.C. amplifier showing the component layout.

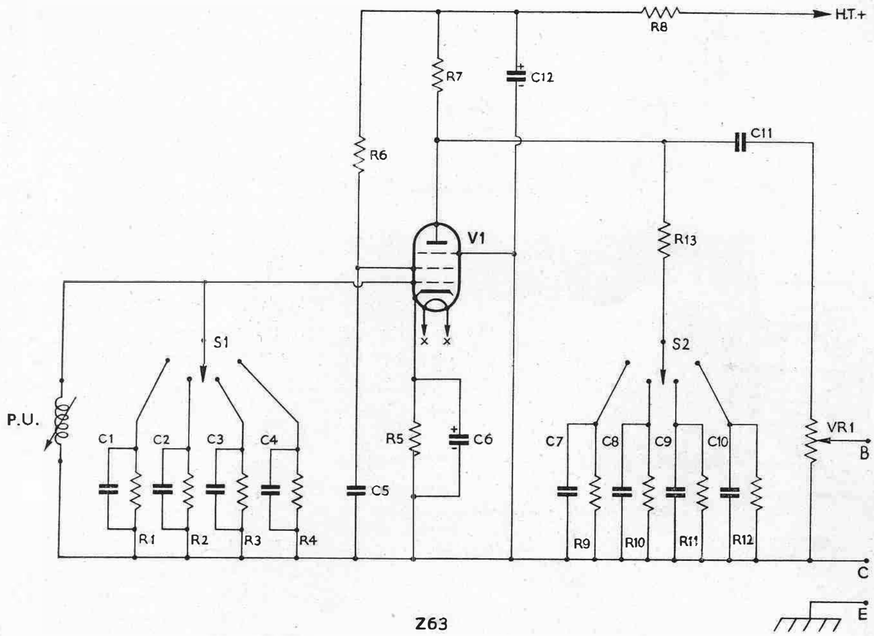
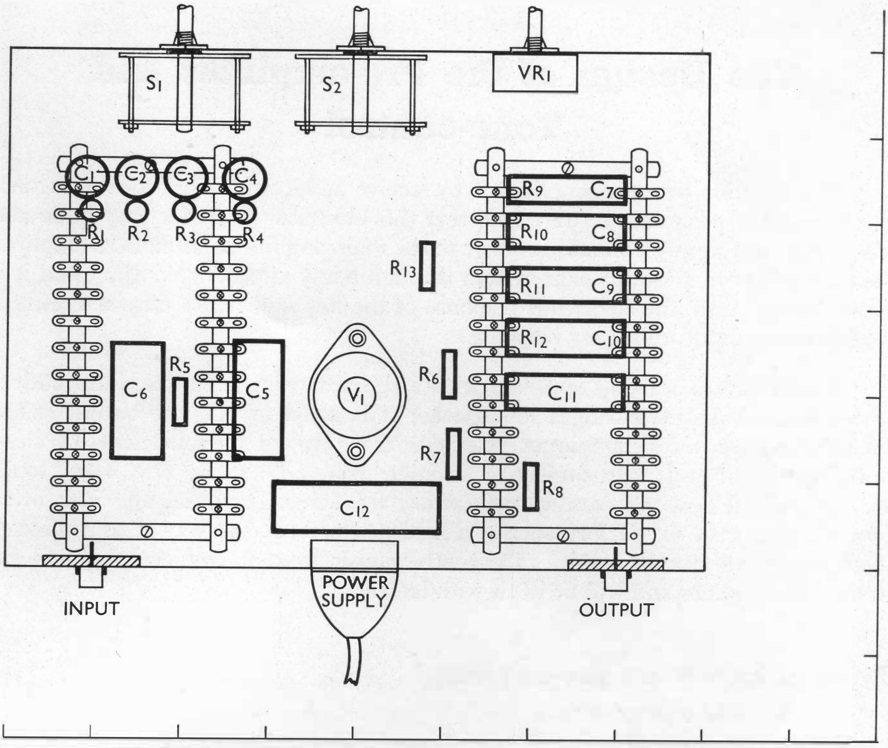


Fig. 19. Circuit diagram of D.C./A.C. pre-amplifier.

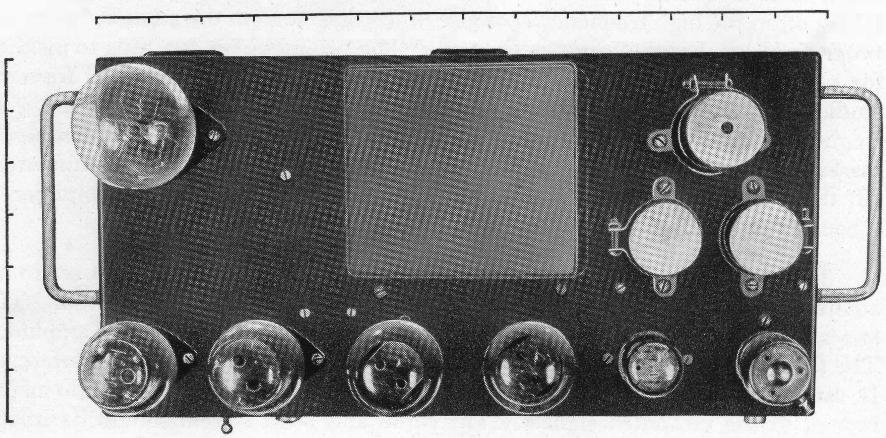
R1	5·6kΩ	10%	¼W	**C1**	0·00125μF	—
R2	8·2kΩ	10%	¼W	**C2**	0·005μF	—
R3	10kΩ	10%	¼W	**C3**	0·004μF	—
R4	22kΩ	10%	½W	**C4**	0·0015μF	—
R5	2·2kΩ	20%	½W	**C5**	0·25μF	—
R6	500kΩ	20%	½W	**C6**	50μF	12V working
R7	100kΩ	20%	½W	**C7**	0·25μF	—
R8	27kΩ	20%	½W	**C8**	0·1μF	—
R9	10MΩ	20%	¼W	**C9**	0·05μF	—
R10	10MΩ	20%	¼W	**C10**	0·03μF	—
R11	10MΩ	20%	¼W	**C11**	0·1μF	—
R12	10MΩ	20%	½W	**C12**	8μF	350V working
R13	5·6k	10%	¼W			
VR1	250kΩ	Variable resistor				

Components list of D.C./A.C. pre-amplifier.



I DIVISION EQUALS I INCH

Fig. 20. Line diagram of D.C./A.C. pre-amplifier showing the location of components.



I DIVISION EQUALS I INCH.

Fig. 21. Plan view of the D.C./A.C. amplifier to facilitate accurate location of components.

The Design of the Pre-amplifier and Tone-control

The function of a pre-amplifier is to receive an electrical input from a transducer or other programme source, correct this electrical input for amplitude and frequency, and supply a suitable voltage to the main amplifier. A modern amplifier supplies power to a loudspeaker system through a low impedance output, and it is customary to make the frequency response of the low impedance output a faithful replica of the input frequency response.

Loudspeakers are thus supplied with a constant voltage source, independent of frequency. In measuring a loudspeaker it is usual to plot the output sound pressure against a constant input voltage ; this form of measurement has been found to line up well with subjective listening tests. There are few, if any loudspeakers which have an entirely satisfactory frequency response, and it is often possible to correct the performance of a loudspeaker in such a way as to produce a more acceptable overall result. This correction is most conveniently carried out in the pre-amplifier and will be dealt with later.

Types of input to the pre-amplifier

1. Radio programmes
2. Records (disc)
3. Microphone
4. Magnetic tape.

Radio programmes

It is generally accepted that the B.B.C. broadcast transmitters have a flat frequency response, apart from the falling off in band width inevitable with the tuned radio frequency circuits, which they employ. There is in fact usually some falling off in the high frequency response of the output from the studios, before the programme reaches the transmitter at all. The pre-amplifier has thus to make up for a slight loss in high frequencies due to (1) the programme received from the studio (2) the tuned radio frequency circuits of the transmitter (3) the tuned radio frequency circuits of the receiver. The latter frequency response often completely masks the slight effects of the other two sources of frequency discrimination. All these effects operate in the same direction and require the pre-amplifier to " boost " the higher frequencies.

In the reception of radio programmes there is a very definite limit set to the amount of high frequency reproduction that can be usefully employed. This arises from two causes, one external to and one internal to the receiver and amplifiers. The first arises from other transmitters, atmospherics, and man-made interference. It varies greatly in different localities and depends only upon the ratio of the wanted to the unwanted signals. The aerial and earth system should be erected with this end in view. The second limitation to high frequency boost is set by the programme itself and the perfection of the amplifiers in use, including those at the broadcast station. If they have any appreciable amount of harmonic or cross modulation distortion, a high frequency boost is not possible since it accentuates the high frequency components of this distortion and makes their presence much more obvious.

It becomes necessary to make a compromise between the ideal frequency response on the one hand, and the amount of (*a*) extraneous noise and (*b*) the permissible audible distortion. Under the best conditions, near to a B.B.C. transmitter, it has been found possible to use a boost at the rate of 6db per octave 3db up at a frequency of about 6,000 c/s. Since some of this boost is used in correcting the high frequency fall off from the output of the studio, there is little left to correct for the radio frequency tuned circuits of the transmitter and receiver. It is therefore important to keep the high frequency losses of these circuits to a minimum, but it is even more important to avoid a " double humped " response which, in effect reduces the size of the carrier in relation to the side bands and will produce all the symptoms of over modulation in the detector circuits.

Where the conditions are less ideal the ratio of the wanted to the unwanted signals is much smaller, and it is generally found to be advantageous to reduce the band width of the receiving channel. If this is done by the use of a more selective radio receiver, no attempt must be made to restore the lost high frequencies by means of a boost in the pre-amplifier; it would boost equally the wanted and the unwanted high frequencies and also it would boost any distortion components arising anywhere in the system before the boost circuit. The reduction in interference is obtained at the expense of some slight loss in quality of the wanted programme, and it is up to the listener to decide on the necessary compromise.

There is one particular case where a definite single frequency causes interference, that is from a transmitter operating on an adjacent wavelength and producing, in combination with the required transmitter, a heterodyne whistle of about 9,000 c/s. It can be removed by the use of a steep cut filter in the pre-amplifier or, sometimes, by the use of a directional frame aerial if the direction of the interfering transmitter is different from that of the wanted station.

REQUIREMENTS OF THE PRE-AMPLIFIER

Broadcast reception

1. Under conditions of excellent reception, a high frequency boost circuit can be applied giving a lift of about 3db at a frequency of about 7,000 c/s and rising at a rate of 6db per octave up to 12,000 c/s. There is no reason in continuing the boost above this point since there is no signal to boost.

2. Under conditions of good reception, a boost can be applied as in (1) but with a steep cut filter to remove the 9,000 c/s heterodyne whistle. Note that the steep filter should not be so steep that it will " ring." In practice it is not very important to give the high frequency boost since it will be largely cut off by the steep whistle filter.

3. Under conditions of poor reception, it may be found that it is an advantage to cut the high frequencies severely from 4,000 c/s. Such a low frequency of cut will inevitably degrade the quality of the programme, but the quality of reception, that is, the balance between the wanted and the unwanted, may easily be improved. This is based on æsthetic considerations, not on audibility. It has been shown that speech repro-

duced over a wide band by means of a high quality reproducer is quite as easy to understand as speech reproduced over a narrow band, even in the presence of severe interference of a general character having a large number of component frequencies.

Pickups. In order to obtain the programme in an electrical form, it is necessary to employ a pickup, which of necessity, has both mechanical and electrical imperfections. It comes within the province of the pre-amplifier to correct the resulting electrical output to make it as nearly independent of frequency as possible. The principal correction to be made to the electrical response is to remove the effects of a mechanical resonance peak which ought, of course, to be above the highest working frequency on the record, but which frequently is much lower. It is not usual to correct the enhanced electrical output resulting from a bass resonance which is too high in frequency.

Record characteristics. The frequency/transverse velocity characteristic of a record (frequency/displacement characteristic, in the case of crystal pickups), is not constant with frequency but is modified to take advantage of the particular properties of the record material. The characteristics of various records are shown in fig. 22, page 35. They are not necessarily the characteristics published by the record manufacturers but are the characteristics which, when equalised to be flat, have given the best quality on a flat and almost perfect reproducing system. They do not differ to any great extent from the published record characteristics.

In the early days, all records had a falling characteristic below above 250 c/s, and a fairly flat response above this frequency up to the resonance of the recording cutter. A simple correction, rising gradually below 250 c/s was all that was necessary to correct the output. Today different recording companies use different low frequency characteristics and also different high frequency characteristics as well. It is therefore necessary to study the characteristics of the individual recording companies and to provide corrections in the pre-amplifier which can be varied with the make of record being played. These variations are of course superimposed upon the corrections necessary for the pickup in use.

Decca, 78 r.p.m.

These records require bass equalisation from a frequency of 400 c/s at the rate of 6db per octave, extending down to 40 c/s. Extension of the low frequency compensation below this point is undesirable because of the possibility of reproducing " rumble " from the recording and reproducing turntables. For the same reason it is sometimes necessary to curtail the bass equalisation at a frequency as high as 70 c/s. All Decca records should have a high frequency " roll off " to counteract the high frequency " pre-emphasis " of boost which is given in recording. This " roll off " should be at the rate of 6db per octave and start at a frequency of 6,000 c/s. It should be maintained up to a frequency of at least 15,000 c/s. These corrections are suitable for both the latest Decca records and all the earlier issues.

Columbia and H.M.V. (E.M.I.)., 78 r.p.m.

These records require bass equalisation from a frequency of 300 c/s at the rate of 6db per octave. Since there is less bass equalisation than in the case of Decca records, it is theoretically possible to equalise to a lower frequency with the

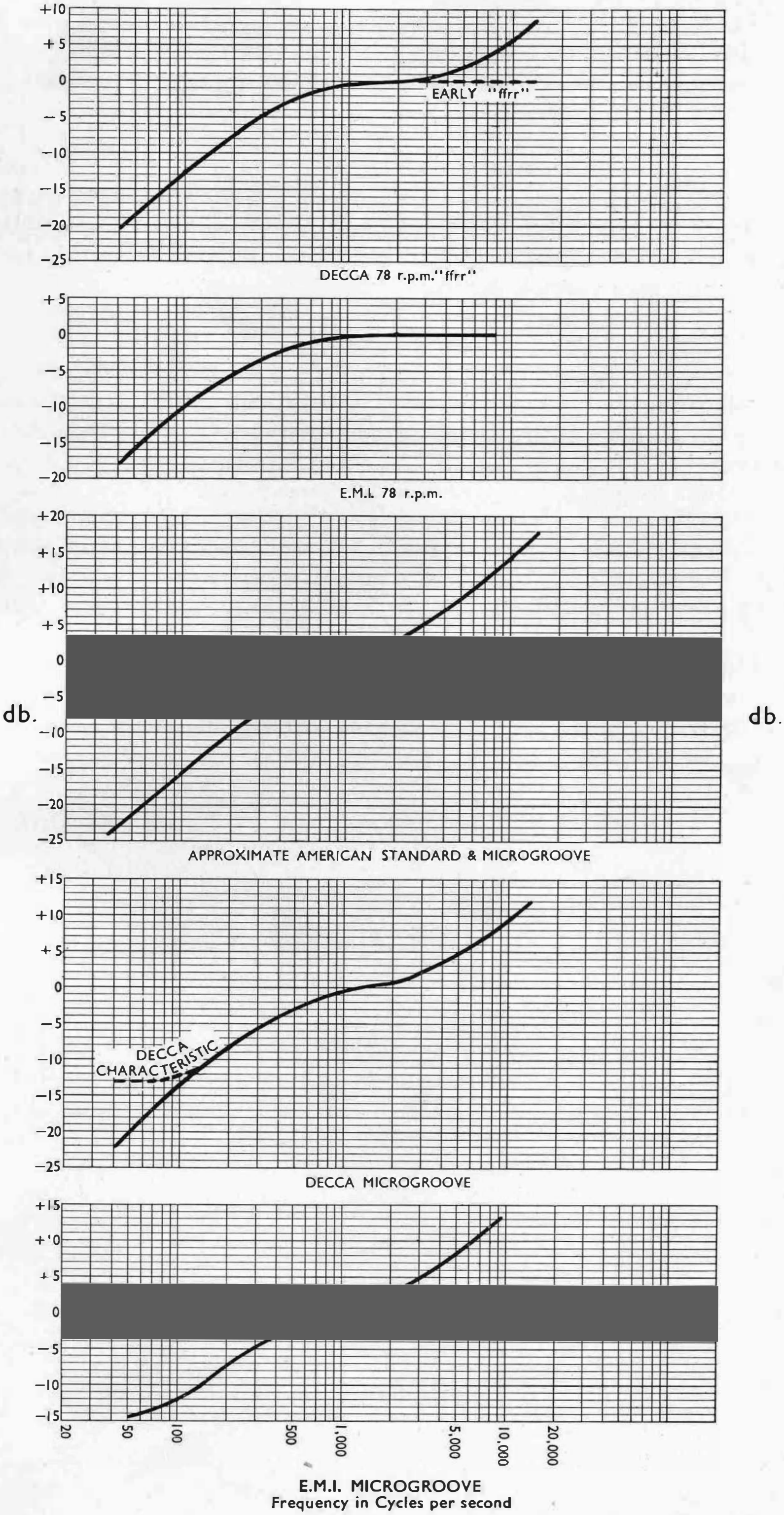


Fig. 22. Derived recording characteristics of the leading record manufacturers.
(not necessarily those published by the makers)

same risk of turntable rumble but it has been found in practise that the possibility of rumble becoming audible is about the same with both makes of record. There is no " pre-emphasis " and a flat response extending up to at least 8,000 c/s is necessary.

American standard records

These records require bass equalisation from a frequency of 600 c/s at the rate of 6db per octave. They have considerable high frequency "pre-emphasis," and require a " roll off " started at 2,500 c/s at the rate of 6db per octave. No records of this type have been available for test.

Decca, 33 r.p.m.

These records require bass equalisation from a frequency of 500 c/s. The problem of turntable " rumble " is more serious with microgroove recordings because of the low output from the record, and the necessity to use greater electrical amplification. It is frequently desirable to curtail bass equalisation at a frequency of 60 c/s. High frequency " pre-emphasis " requires a " roll off " starting at a frequency of 3,500 c/s and continuing up to at least 12,000 c/s. It is well to remember that the pickup used for 33 r.p.m. records will not necessarily require the same equalisation as that used for 78 r.p.m. records. It is desirable to switch the pickup correcting circuits at the same time as the 78-33 r.p.m. record correcting circuits.

Columbia and H.M.V. (E.M.I.), 33 and 45 r.p.m.

The record characteristics are not generally published, but the most satisfactory results have been obtained when assuming the characteristic shown in fig. 22.

A Comprehensive Pre-amplifier, Tone-control and Equaliser

The construction of a comprehensive unit for tone correction is somewhat complex but in this design the use of close tolerance components has been reduced to a minimum without the performance deteriorating.

The unit has six controls providing variable sensitivity, bass and treble compensation for the various disc recordings, a steep cut scratch and whistle filter, bass loudness and volume level.

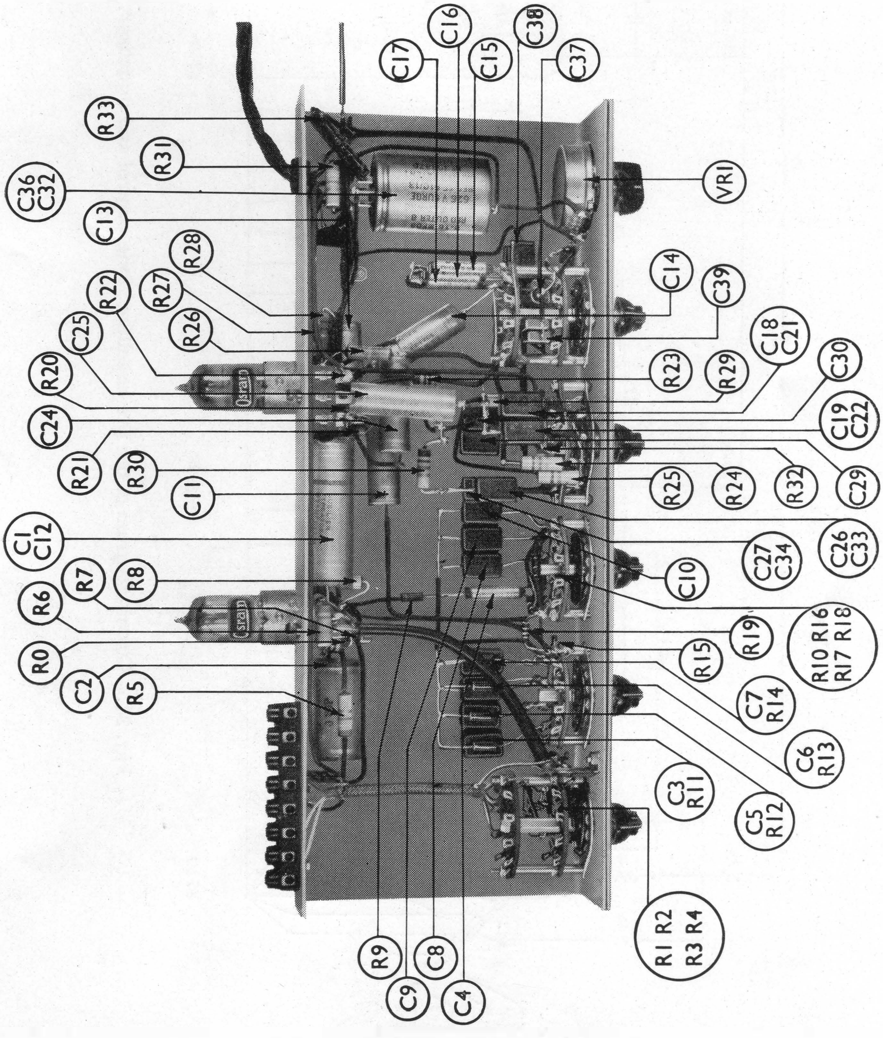


Fig. 23. Underside of the pre-amplifier, tone-control and equaliser showing the component layout.

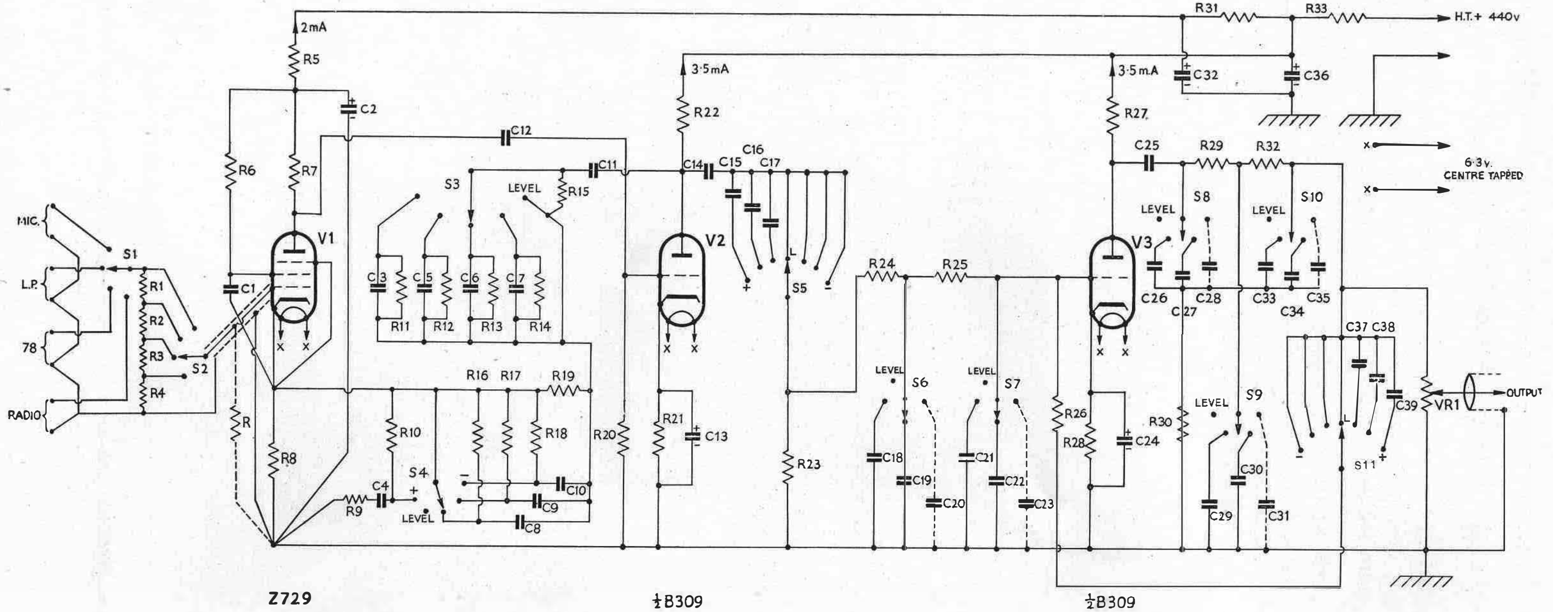


Fig. 24. Circuit diagram of the pre-amplifier, tone control and equaliser.

R1	220kΩ	¼W	20%	**R19**	180kΩ	¼W	10%
R2	100kΩ	¼W	20%	**R20**	1MΩ	¼W	20%
R3	100kΩ	¼W	20%	**R21**	820Ω	½W	10%
R4	22kΩ	¼W	20%	**R22**	47kΩ	½W	20%
R5	39kΩ	½W	10%	**R23**	1MΩ	¼W	20%
R6	330kΩ	½W	20%	**R24**	47kΩ	¼W	<5%
R7	100kΩ	½W	20%	**R25**	47kΩ	¼W	<5%
R8	1·8kΩ	½W	10%	**R26**	330kΩ	¼W	10%
R9	470Ω	¼W	10%	**R27**	47kΩ	½W	20%
R10	10MΩ	¼W	20%	**R28**	820Ω	½W	10%
R11	10MΩ	¼W	20%	**R29**	47kΩ	¼W	1%
R12	1·5MΩ	¼W	20%		or matched to R32		
R13	10MΩ	¼W	20%	**R30**	22kΩ	¼W	1%
R14	10MΩ	¼W	20%	**R31**	39kΩ	½W	10%
R15	10MΩ	¼W	20%	**R32**	47kΩ	¼W	1%
R16	10MΩ	¼W	20%		or matched to R29		
R17	10MΩ	¼W	20%	**R33**	10kΩ wire wound		
R18	10MΩ	¼W	20%				

S1, S2	Input attenuator	4-way 2 pole
S3	Bass compensation	5-way single pole
S4	Treble compensation	5-way single pole
S5, S11	Bass loudness	7-way 2 pole
S6, S7, S8, S9, S10	Steepcut	3-way 5 pole or 4-way 5 pole (see text)
VR1	250kΩ linear	Variable resistor

C1	0·25μF	—	—
C2	8μF	—	450V working
C3	0·0015μF	5%	—
C4	0·01μF	—	—
C5	0·0015μF	—	—
C6	0·002μF	—	—
C7	0·003μF	—	—
C8	150pF	—	—
C9	220pF	—	—
C10	330pF	—	—
C11	0·1μF	—	—
C12	0·02μF	—	—
C13	25μF	—	25V working
C14	0·1μF	—	—
C15	0·005μF	—	—
C16	0·01μF	—	—
C17	0·02μF	—	—
C18	680pF	<5%	—
C19	1000pF	<5%	—
C20	1500pF	<5%	—
C21	150pF	<5%	—
C22	330pF	<5%	—
C23	470pF	<5%	—
C24	25μF	—	25V working
C25	0·05μF	—	—
C26	220pF	1% or matched to C33	—
C27	330pF	1% or matched to C34	—
C28	470pF	1% or matched to C35	—
C29	470pF	1% or matched to 2 × C26	—
C30	680pF	1% or matched to 2 × C27	—
C31	1000pF	1% or matched to 2 × C28	—
C32	8μF	—	450V working
C33	220pF	1% or matched to C26	—
C34	330pF	1% or matched to C34	
C35	470pF	1% or matched to C35	—
C36	16μF	—	450V working
C37	0·005μF	—	—
C38	0·003μF	—	—
C39	0·002μF	—	—

Components list of the pre-amplifier, tone-control and equaliser.

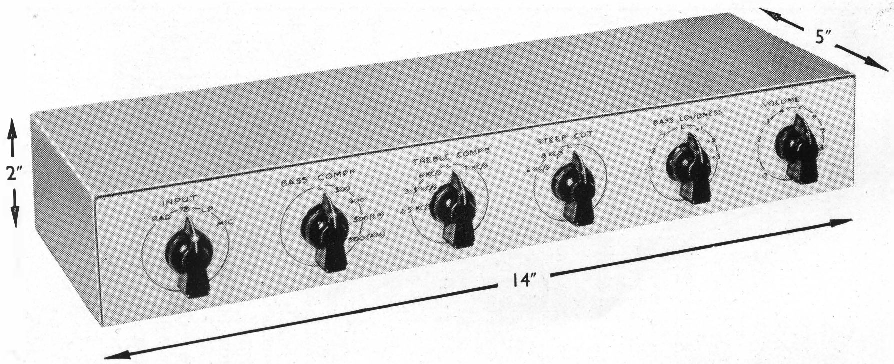


Fig. 25. Front view of the pre-amplifier, tone-control and equaliser.

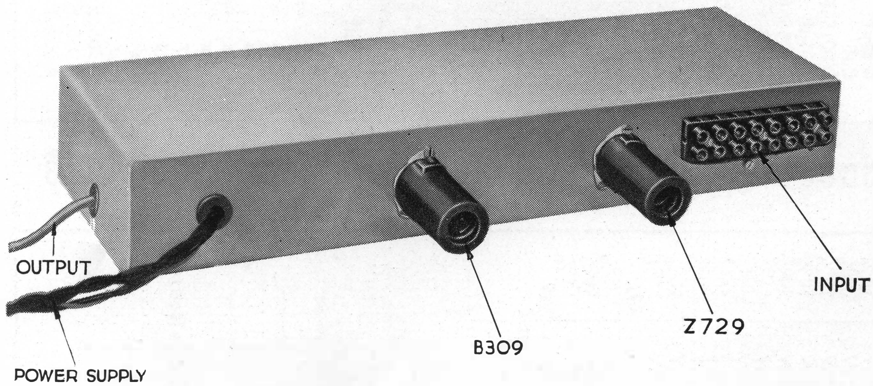


Fig. 26. Rear view of the pre-amplifier, tone-control and equaliser.

Constructional notes (fig. 24)

The unit is constructed in a " U " shaped chassis and it is recommended that the various components are soldered on the switch wafers thence mounted on the chassis. In some cases a number of low value capacitors have been used in parallel to simplify layout.

They are a number of cases where a particular component is obscured by its neighbour and therefore the two or more components are annotated together.

The resistor R (1MΩ $\frac{1}{4}$W) indicated by dotted lines on the circuit diagram is not required if S2 is a make before break wafer switch.

Capacitors C20, C23, C28, C31, and C35, shown in broken lines in fig. 24, are optional but should be included where a steep cut at 4 kc/s is required.

The following valves are specified.

V1	Osram Z729
V2, V3	Osram B309 (double triode)

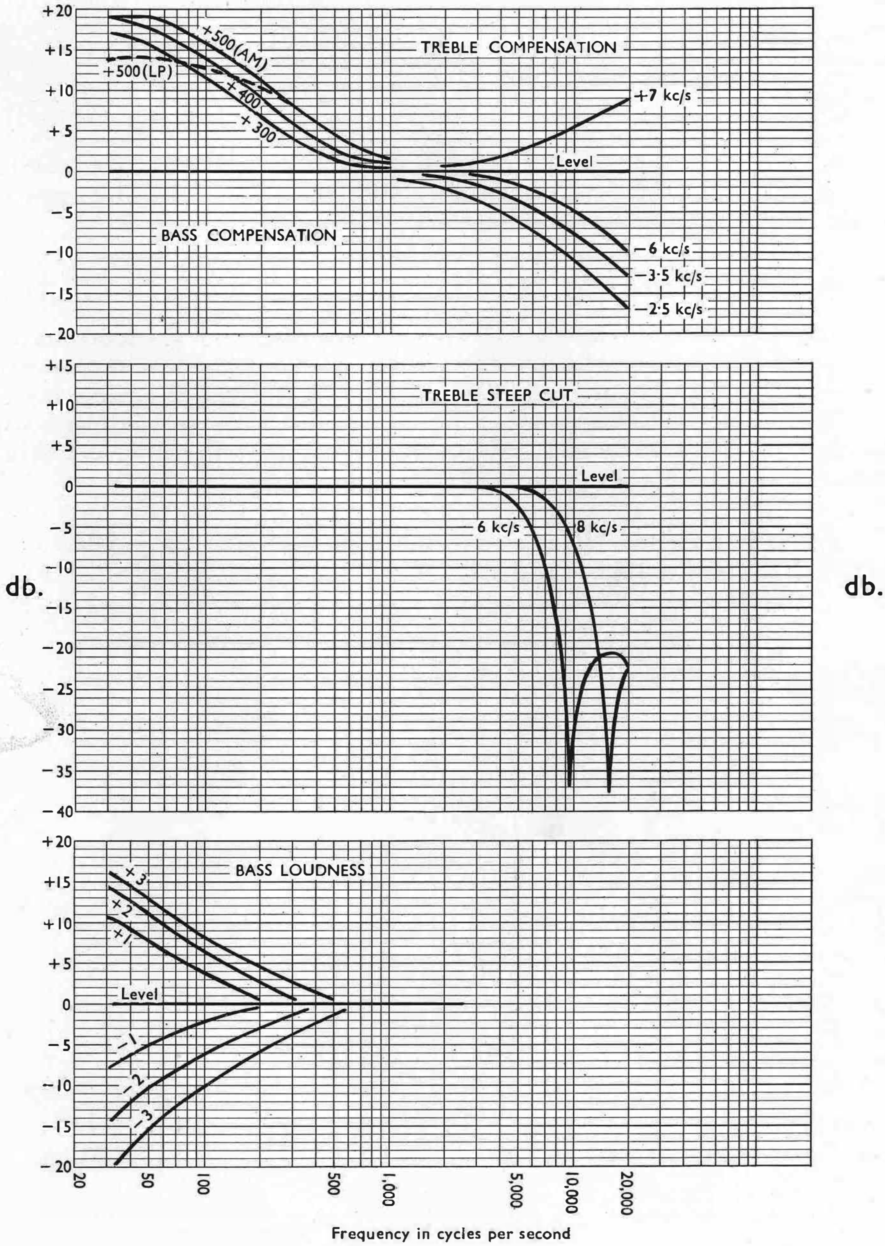


Fig. 27. Tone-control and equaliser characteristics.

Local station T.R.F. feeder unit

A T.R.F. feeder unit will give a slightly improved performance to the superhet type provided adequate signal strength is available, it also has the advantages of simple construction and ease of alignment.

Constructional notes (fig. 28)

The R.F. coils are Weymouth H types and the following types are required ; L1, L2—HA1, L3, L4—HA3, L5—HH1 and L6 HH3. The wavechange switch S1—6 is a 6 pole 2 way wafer type in two halves. They should be separated by at least two inches. The components are mounted on a 18 s.w.g. chassis 9 inches by 6 inches. Either W77 or Z77 may be used as the R.F. amplifier, Z77 being preferred where higher gain is required.

The variable resistor VR1 is a wire wound type and has a value of 250Ω when a Z77 valve is used or 10kΩ with a W77.

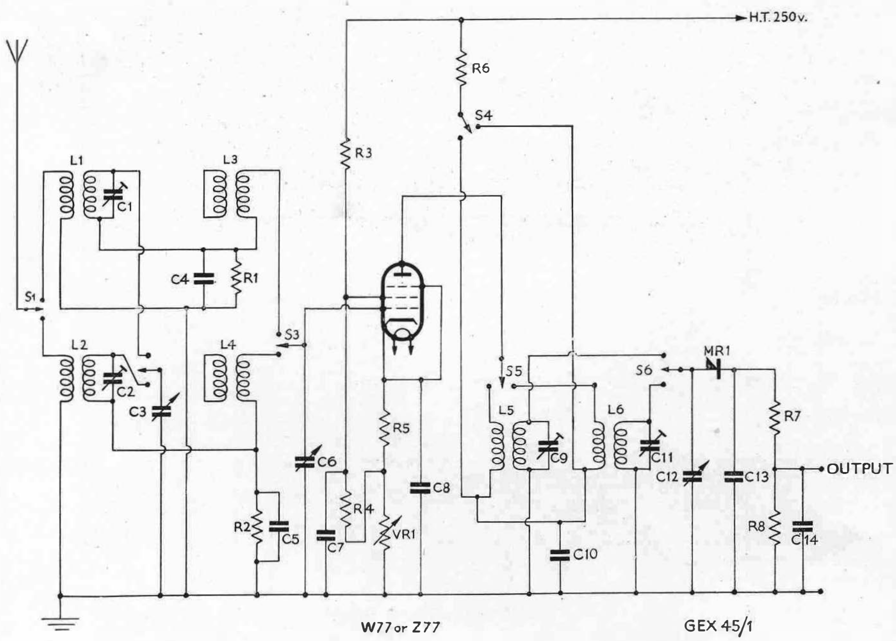


Fig. 28. Circuit diagram of the local station feeder unit.

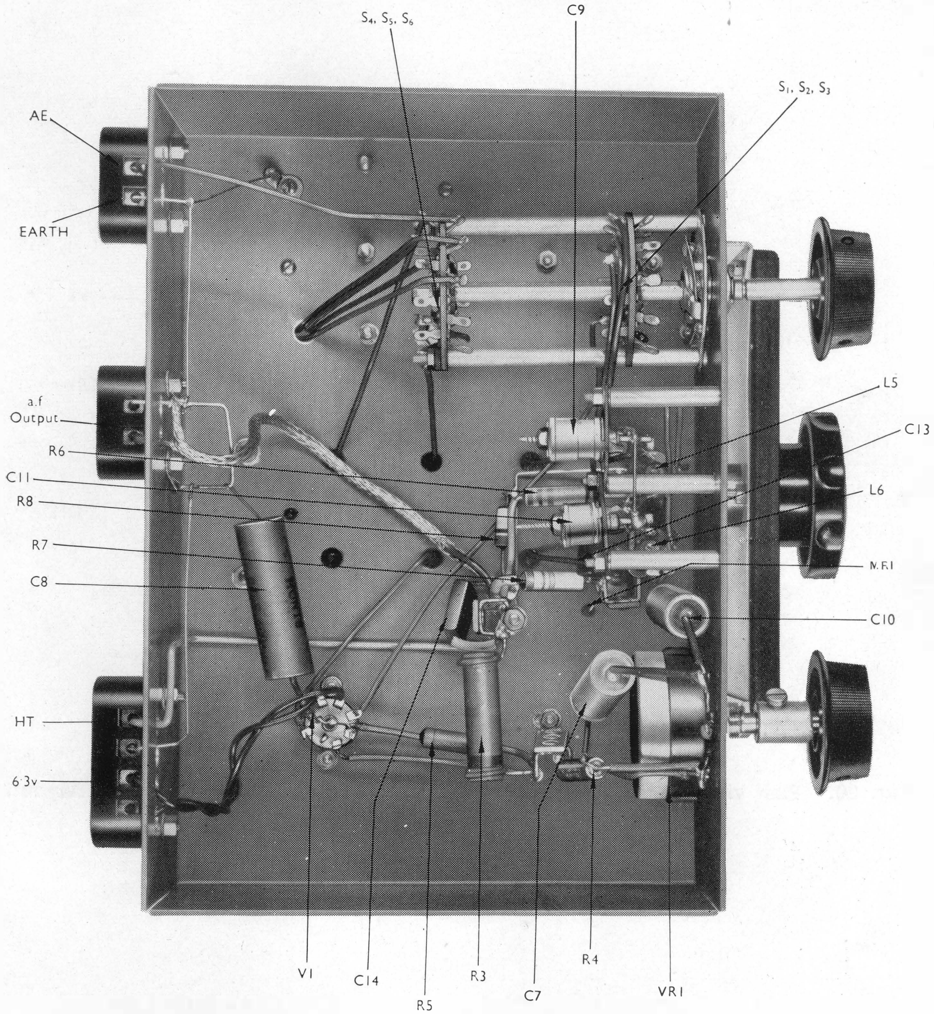


Fig. 29. Underside of the local station feeder unit showing the component layout.

C1	30pF trimmer	**R1**	6·8kΩ ½W
C2	30pF trimmer	**R2**	10kΩ ½W
C3	500pF	**R3**	5kΩ 3W
C4	·01μF	**R4**	10kΩ 3W
C5	·01μF	**R5**	220Ω ½W
C6	500pF	**R6**	1kΩ ½W
C7	·05μF	**R7**	22kΩ ½W
C8	0·1μF	**R8**	100kΩ ½W
C9	30pF trimmer		
C10	·05μF	**V1**	Osram W77 or Z77 (see page 44)
C11	30pF trimmer		
C12	500pF		
C13	100pF	**MR1**	G.E.C. Germanium diode GEX45/1
C14	100pF		

Components list of local station feeder unit.

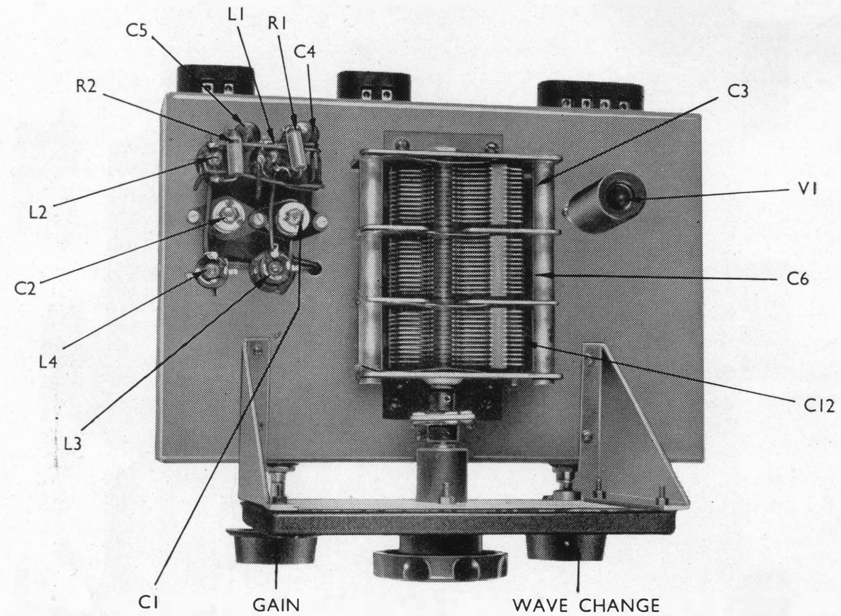


Fig. 30. Plan view of the local station feeder unit showing the component layout.

Superhet feeder unit

A design for a superheterodyne receiver is included in this publication because there are many areas where the selectivity and/or sensitivity of the T.R.F. unit is inadequate.

Constructional notes (fig. 32)

Switched pre-set tuning was decided upon and both the Weymouth type BM17 and E.T.A. type TS41 coil packs have been used with success.

Variable selectivity is provided in the first I.F. stage, the two bandwidths being about 5 and 16 kc/s, which may be further increased by stagger tuning of the I.F. transformers.

The Weymouth P4/M and P4/L I.F. transformer were found suitable for the components IFT1 and IFT2 respectively, the I.F. rejector being type Q2.

S1, S2 and S3 may be conveniently ganged to form a 3-pole, 3-way wafer switch.

The resistors R18 and R19 are included in order to drop the amplifier H.T. line voltage to the region of 220V, and suitable values are listed below :—

	350V	400V	450V
R18	2·2kΩ 1W	3·3kΩ 2W	5·6kΩ 2W
R19	2·2kΩ 1W	4·7kΩ 2W	5·6kΩ 2W

The following valves are specified :

V1	Osram X79	V2	Osram W77
V3	Osram L77	X1	G.E.C. germanium diode GEX45/1

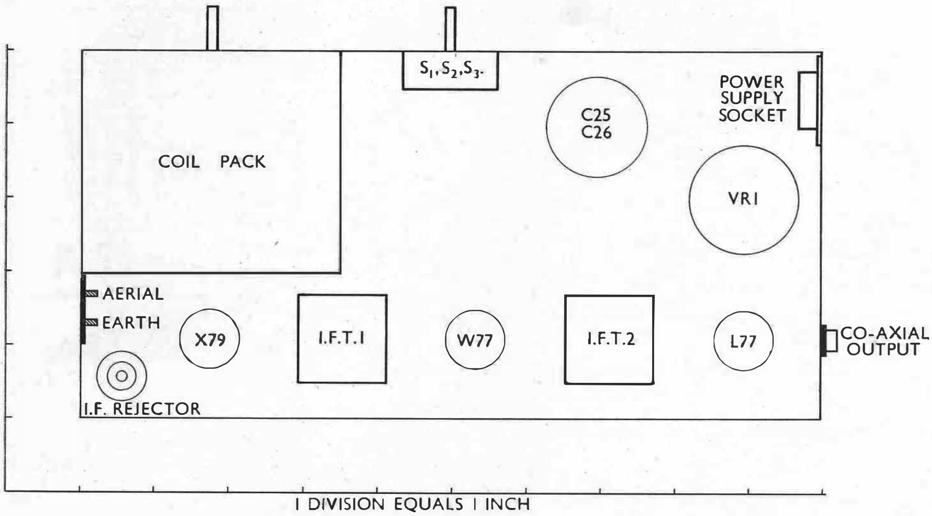
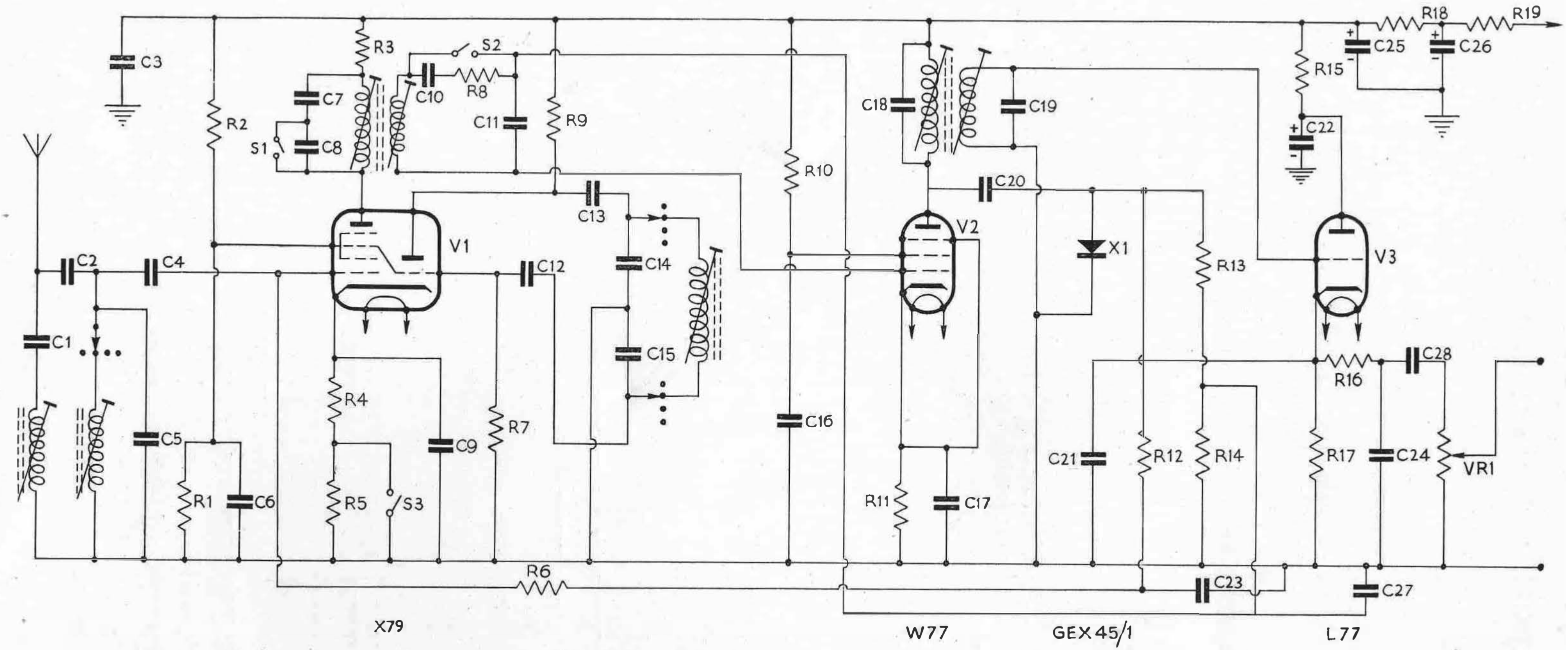


Fig. 31. Line diagram showing location of components.



R1	22kΩ	1W	**R12**	100kΩ	$\frac{1}{3}$W	**C1**	200pF	—	**C12**	200pF	—	**C23**	0·05μF	—
R2	33kΩ	2W	**R13**	100kΩ	$\frac{1}{3}$W	**C2**	15pF	—	**C13**	200pF	—	**C24**	200pF	—
R3	2·2kΩ	$\frac{1}{3}$W	**R14**	100kΩ	$\frac{1}{3}$W	**C3**	0·1μF	—	**C14**	200pF	—	**C25**	16μF	450V
R4	220Ω	$\frac{1}{3}$W	**R15**	20kΩ	1W	**C4**	100pF	—	**C15**	750pF	—	**C26**	16μF	450V
R5	10kΩ	$\frac{1}{3}$W	**R16**	5kΩ	$\frac{1}{3}$W	**C5**	200pF	—	**C16**	100pF	—	**C27**	0·05μF	—
R6	1MΩ	$\frac{1}{3}$W	**R17**	150kΩ	1W	**C6**	0·05μF	—	**C17**	0·05μF	—	**C28**	0·25μF	—
R7	47kΩ	$\frac{1}{3}$W	**R18** {	dependent	on H.T.	**C7**	100pF	—	**C18**	100pF	—			
R8	100Ω	$\frac{1}{3}$W	**R19** {	supply avail	able	**C8**	2000pF	—	**C19**	100pF	—			
R9	47kΩ	1W		see page 45		**C9**	0·05μF	—	**C20**	100pF	—			
R10	66kΩ	$\frac{1}{3}$W	**VR1**	100kΩ log	taper	**C10**	2000pF	—	**C21**	200pF	—			
R11	220Ω	$\frac{1}{3}$W				**C11**	100pF	—	**C22**	8μF	450V			

Fig. 32. Circuit diagram and components list of the superhet feeder unit.

Television Sound Feeder Unit

Owing to the fact that the bandwidth of the television sound channel is not strictly limited it is worth while using a high quality sound system in conjunction with an existing vision receiver.

Constructional notes (fig. 34)

The five sound channels are covered by one set of R.F. transformers tuned by Gecalloy dust cores or copper slugs and by small fixed capacitors shunted across the secondary.

The coil formers are G.E.C. type S34 with primaries and secondaries inter-wound using 32 s.w.g. wire. The primary of T1 is situated at the earthy end of the transformer. The copper slugs are identical in size to the Gecalloy cores, 17 mm. long, 7·75 mm. dia. screwed 1·25 mm. pitch.

In areas of low signal strength Z77 may be substituted for W77 to give increased gain.

The resistor R18 is included to drop the amplifier H.T. line voltage to the region of 230 volts. Suitable valves are 8·2kΩ 3W, 12kΩ 5W and 15kΩ 5W for amplifier H.T. line voltages of 350, 400 and 450 volts respectively.

If instability is encountered an R.F. choke may be added to the heater line between V1 and V2. It should take the form of 15 turns of 18 s.w.g. wire with a $\frac{3}{8}$ in. diameter spaced to 2 in.

Circuit reference	No. of turns	
	Primary	Secondary
T1	one	five
T2	five	five
T3	nine	nine

Frequency	Secondary tuning capacitor valves pF			Cores		
	C1	**C5**	**C11**	**T1**	**T2**	**T3**
Alexandra Palace 41·5 Mc/s	20	20	10	Gecalloy	Gecalloy	Gecalloy
Holm Moss 48·25 Mc/s	15	10	5	Gecalloy	Gecalloy	Gecalloy
Kirk-o-Shotts 53·25 Mc/s	10	10	5	Gecalloy	Gecalloy	Gecalloy
Sutton Coldfield, Aberdeen } 58·25 Mc/s	10	10	5	Gecalloy	Copper	Copper
Wenvoe, Pontop Pike } 63·25 Mc/s	10	5	5	Copper	Gecalloy	Copper

The following valves are specified :

V1 Osram W77 or Z77
V2 Osram W77 or Z77
X1, X2 G.E.C. germanium diode GEX34

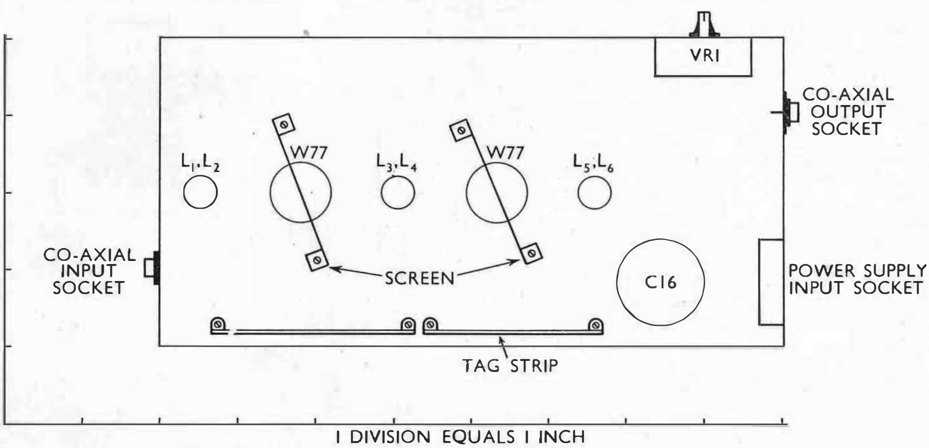
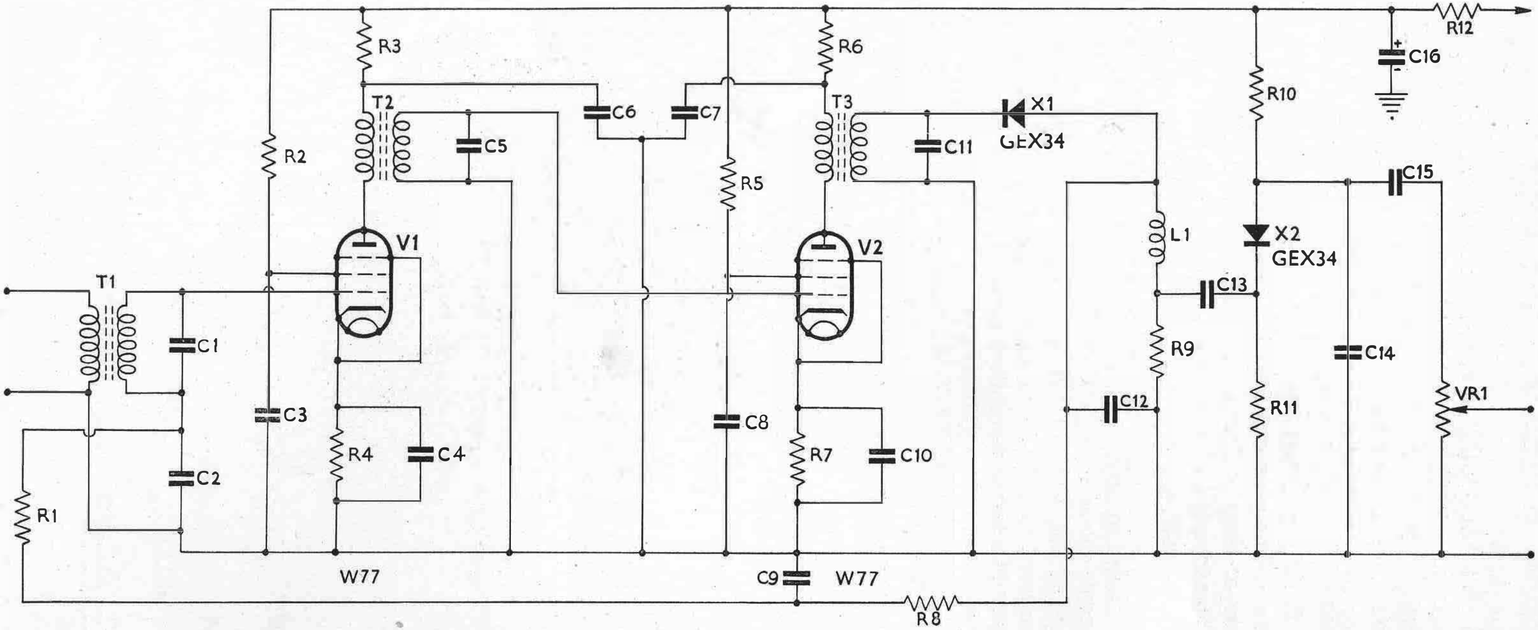


Fig. 33. Line diagram showing location of components.



R1	10kΩ	¼W	**R9**	47kΩ	¼W	**C1**	See page 47	**C9**	0·02μF
R2	10kΩ	½W	**R10**	4·7MΩ	½W	**C2**	1500pF	**C10**	1500pF
R3	2·2kΩ	½W	**R11**	4·7MΩ	½W	**C3**	1500pF	**C11**	See page 47
R4	220Ω	½W	**R12**	See text	page 47	**C4**	1500pF	**C12**	3pF
R5	10kΩ	½W	**VR1**	100kΩ	pre-set	**C5**	See page 47	**C13**	0·1μF
R6	2·2kΩ	½W				**C6**	1500pF	**C14**	300pF
R7	220Ω	½W				**C7**	1500pF	**C15**	0·25μF
R8	2·2MΩ	¼W				**C8**	1500pF	**C16**	8μF 350V

Fig. 34. Circuit diagram and components list of television sound feeder unit.

The G.E.C. 'F.R.' Metal Cone Loudspeaker BCS1851

This Metal Cone Loudspeaker has been specifically designed to give a very high quality of reproduction.

In order to attain this end, it was necessary to obtain a very wide and smooth frequency response, so that all frequencies usually found in speech and music could be accurately reproduced. In addition, it was necessary to ensure that the generation of any two frequencies should not result in the generation of any other frequency. It was this last requirement, usually known as intermodulation which necessitated the use of a metal cone, in place of the more usual paper one. In the reproduction of a solo instrument or voice, intermodulation distortion is not very noticeable, but in the reproduction of an orchestra it introduces a " muddled " quality which is one of the most serious failures of present day reproducers. Attempts have been made to reduce it by the use of two or more loudspeakers with separating filters, so that each loudspeaker only operates over part of the frequency range. This arrangement gives some improvement, but leads to difficulties with the cross-over networks. The correct solution to the problem lies in the design of a loudspeaker which is free from this defect.

The necessity to use metal for the material of the cone raised various design problems in connection with frequency response. Several of the conventional methods of controlling the frequency response of the cone, such as concentric rings formed in it, were found to increase cross modulation or muddle, and had to be abandoned. The problem was finally solved by the application of an entirely new technique of small local deformations to the cone which did not increase the cross modulation. It was also found necessary to use a central " bung " to avoid trouble from the cavity formed by the metal sides of the cone itself. The resultant frequency range of the loudspeaker, operated in a suitable cabinet, is 45 to 20,000 cycles/second.

Fig. 35. G.E.C. " F.R. " Metal cone loudspeaker BCS1851.

Cabinets : general

Some form of baffle is necessary with all types of cone loudspeaker to prevent radiation from the rear of the cone impairing the radiation from the front. A plain flat baffle is simple, but it is extremely difficult to keep it rigid in the very large sizes which are necessary for the reproduction of low frequencies. A hole in the wall is often satisfactory, but it should be remembered that the second room at the rear of the loudspeaker impresses its own resonances on to the cone and these may be far from desirable.

Cabinets : the most suitable type

A bass reflex or vented cabinet has been found to be most generally suitable for use with the metal cone loudspeaker. Such a cabinet consists of a Helmholtz resonator, the loudspeaker being mounted in one of its walls. The frequency of resonance of both the cone and the cabinet are made similar, with the result that both the quality and output of the lowest frequencies are improved in comparison with a completely sealed box. If it is not possible to tune the resonator to the required low frequency, using a port whose area is nearly equal to that of the cone, because of a restriction on the size of the cabinet, more satisfactory results will be obtained by the use of a sealed box. For use with the metal cone loudspeaker, a completely sealed box must not have a volume of less than 1 cu. ft. and it should preferably have at least twice this volume. Even then, it will not be possible to reproduce the lowest frequencies.

Cabinets : internal damping

Since a high intensity of sound is generated inside both a sealed box and a bass reflex cabinet, it is necessary to take quite elaborate precautions to ensure that there are no resonances of either the sides of the structure or of the air contained in it, and there should be no internal reflections. Resonance of the air inside the enclosure is best removed by the use of very soft porous material, such as cotton wool or, even better, cellulose wadding as used for packing very fragile articles. It must be placed where the greatest air particle motion for that particular mode of resonance occurs and it is generally necessary to use several thicknesses of the material. With the type of bass reflex cabinet recommended, three layers hung vertically down the middle of the cabinet, one behind the other, from the top to the bottom will generally prove to be adequate. Full details are given in the drawing supplied with the loudspeaker. Ordinary carpet felt is much too dense and should not be employed. If, due to the particular material used, the reproduction of the lowest frequencies is inadequate, greater output, at the very low frequencies only, can be obtained by reducing the length of the damping material so that it stops short at the top of the port. It so happens that the precautions taken for removing air resonances are also effective in removing internal reflections, if the material used is sufficiently soft and porous.

A sealed box should be treated in exactly the same way as a bass reflex cabinet, except that the damping material should occupy the full length of the box in all cases.

Resonances of the walls of the enclosure itself are very serious and can easily ruin the performance of the loudspeaker. Wood is the most satisfactory material for the cabinet but it should be at least $\frac{3}{4}$ in. thick, and considerably thicker if at all possible. The design of the cabinet should be such that the individual panels of which it is composed are as small and rigid as possible and should resonate at different frequencies. If other materials are used, remember that harder materials may well have less damping which may give rise to more serious resonances. A drawing of a suitable bass reflex cabinet is supplied with the loud speaker.

Power handling capacity

The power handling capacity of a loudspeaker will be limited by the maximum permitted excursion of the cone, excessive distortion of the reproduction or overheating of the speech coil. The cone of the G.E.C. metal cone loudspeaker is extremely strong and there is virtually no deterioration in the quality of the reproduction even at a peak electrical power of 10 watts, which should never be exceeded. The continuous rating of the loudspeaker is limited to 5 watts by the danger of burning out the speech coil. This may occur because the loudspeaker gives no warning that it is being grossly over-run. It is essential that the loudspeaker is only operated with a suitable cabinet to give adequate loading to the cone. Otherwise excessive movement will cause damage. Damage can also result from excessive cone movement caused by slight overloading of the power amplifier, even when the loudspeaker is used in a good cabinet. The first indication of this may well be a slight visible movement of the cone in and out on loud passages, which indicates asymmetry of the power amplifier output wave form. When the loudspeaker is reproducing loud sounds with an undistorted input, there should be no apparent movement of the cone in and out, but it will look slightly blurred in outline.

At higher frequencies, distortion in the amplifier may easily give rise to audible distortion which sounds so exactly like a loudspeaker rattle that it is very difficult to believe that it is due to valve overload. It is much more likely to be the amplifier causing the rattle than the loudspeaker.

Operating the G.E.C. 'F.R.' Metal Cone Loudspeaker

The amplifier : power required

The power which will be required will depend upon the type of reproduction which the listener demands. It has been found that for normal domestic listening in a living room, using one metal cone unit an undistorted power output of 12 watts is sufficient for very good reproduction. The amplifier should not be driven beyond 10 watts peak, leaving 2 watts as a safety factor. For the greatest realism, reproduced speech and music should be played at such a level that the sound, at the ear of the listener, is the same as the original sound if heard from an ideal position. The power required for the realistic reproduction of an orchestra will vary from about 20 watts in a medium-sized living room up to 150 watts in a large hall. It is most important that the amplifier should remain completely undistorted even on very high peaks, and it is to provide for these high peaks of short duration that these unusually high powers are necessary. The great strength of the G.E.C. loudspeaker permits it to handle a greater " peak " to mean ratio than other loudspeakers. As will be seen from the leaflet accompanying the loudspeaker, the recommended cabinet design can accommodate 1, 2 or 3 units thus allowing a max. peak power of 30 watts per complete cabinet assembly. If a total power greater than 30 watts is required then a number of complete cabinets can be employed placed on the rostrum in the hall to simulate the layout of the orchestra.

The amplifier : quality

With a metal cone speaker, it has been found that an experienced listener can distinguish between an amplifier having 0·1% and one having 0·4% total harmonic content. If full advantage is to be taken of this loudspeaker it is necessary to keep distortion to an exceptionally low value.

The amplifier: impedance

The output impedance of the amplifier should be as low as possible, preferably not more than ⅛th of the loudspeaker impedance.

Sources of programmes

Any programme of sufficiently high quality is suitable for reproduction by the metal cone loudspeaker, but in fact the term " high quality " is often purely relative, since the aim of both the broadcasting authority and the recording company must be to give enjoyment to the average listener, who will not always put the quality of reproduction before every other requirement.

Radio programmes

The experimental B.B.C. transmissions from Wrotham* on the 3 metre band are capable of giving a quality which is indistinguishable from that obtained by a line direct to the studio. The only problem is that of 3 metre reception which is absolutely free from local interference. Reception of programmes on the medium wave band, on the other hand, calls for a number of special precautions. The frequency response of the whole system must be wide, but this will often give rise to a 9 kc/s whistle from adjacent stations. A compromise between wide band-width and adjacent channel interference reached by day will seldom hold by night. Even when great care is taken in the design of the tuned circuits of the receiver, there is apt to be some falling off at the highest frequencies. This loss can only be compensated to a very limited degree because if considerable " top boost " is used it will also boost high frequency components of distortion. It is therefore, important to keep the high frequency losses as small as possible, but it is even more important to avoid a " double humped " response which, in effect reduces the size of the carrier in relation to the side bands and will produce all the symptoms of over-modulation in the detector circuits. Where conditions are not ideal and there is considerable interference and background noise it is generally advantageous to reduce the effective band width of the receiving system. This usually reduces the amount of interference but degrades the programme quality as well. It is for the listener to decide on that compromise which gives him most enjoyment. It is often simpler to cut high frequency reproduction in the pre-amplifier than to make an elaborate radio receiver with variable band width.

One of the principal sources of distortion in radio receivers is the detector. It is necessary to make the A.C. load exceed 90% of the D.C. load and to maintain that ratio to the highest frequencies.

*The experimental transmission from Wrotham is radiated on 91·4 Mc/s F.M. and 93·8 Mc/s A.M.

Programme times (Wrotham)

Time.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.	Sun.	
11–12 noon ...	L	L	L	L	—	—	—	L = Light
1–2 p.m.	L	L	L	L	—	—	—	H = Home
2.30–4.30 p.m. ...	L	L	L	L	—	—	—	T = Third
6.0 p.m. to close ...	T	T	H	T	—	H	T	

Disc records : general

Since the quality of reproduction obtainable from records is not limited by wavelength plans, but by tools and materials, a much greater advance has been made in recording than in broadcasting during the last 30 years. For this very reason, a much wider range in quality is to be expected from records of various ages, all of which may be found in a collector's library. It is the duty of the reproducing equipment to give the best results possible from any particular record. This implies correcting circuits in the pre-amplifier which can be varied over a wide range to suit the occasion.

Disc records : pickups

The design of a satisfactory pickup to take advantage of the latest recording techniques is very difficult. It must cover the whole frequency range with no resonance peaks, have low record wear, and be able to follow the groove in the record over the whole frequency range, and at the amplitudes used in recording. It is this last requirement which is perhaps the most difficult to meet. If this is not done the higher frequencies will be marred by a " fizz " or " buzz " which is most objectionable. In general it can be said that this is due to insufficient vertical compliance, often accompanied by vertical resonance at the wrong frequency. Its effects are enhanced by the modern tendency to use high frequency "pre-emphasis." This failure can easily result in excessive record wear, particularly at high frequencies where it can do more harm than a pick-up weighing twice as much, but having adequate vertical compliance.

Disc records : reproduction from worn discs

It is sometimes necessary to play worn records in those cases where the programme value justifies the lower quality of reproduction. In these cases it is often possible to increase the enjoyment given by the reproduction by reducing the frequency range of the system. First, remove all frequencies in the reproducer range not actually present on the record. This can best be done by a sharp cut filter which can be switched to cut at a suitable frequency. Second, use a gradual roll off of 6db per octave in addition to that required for record correction, commencing at a lower frequency.

Magnetic tape

Records made on a magnetic tape are capable of giving an exceptionally high standard of quality, but since they are not readily duplicated, they have to be recorded by the listener himself. If they are recorded from the radio programmes or from disc records, the same precautions should be taken as when reproducing these sources of programmes direct. When live recordings with a microphone are made, the quality of the microphone and the surrounding room will usually set a limit on quality which is far below that obtainable from either the B.B.C. or from disc records. A bald statement of the frequency response of the tape recorder and microphone gives little information as to its constancy of speed, harmonic content etc. and certainly gives no indication whatever of the suitability of the room as a studio.

In conclusion

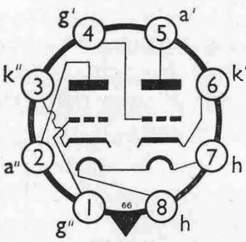
Finally, therefore, the listener is referred back to the introductory section of this publication and by the development of the art of listening supplementing the correct scientific design and construction of the listening equipment it is hoped that he may obtain enhanced pleasure from the wealth of sound programme material available at the present day.

ACKNOWLEDGMENTS

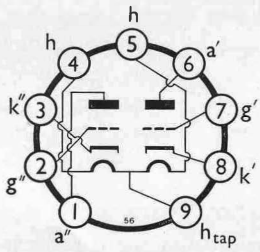
Acknowledgments are made by the author for the valuable assistance in preparing this publication to The M.O. Valve Co. Ltd., Applications Laboratory ; Research Laboratories of The General Electric Co. Ltd. ; and to the technical section of the Osram Valve and Electronics Department, Magnet House, Kingsway, London, W.C.2, under whose auspices this book is published.

BASE DIAGRAMS

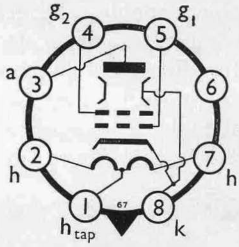
of all Osram Valves specified for equipment described in this publication.



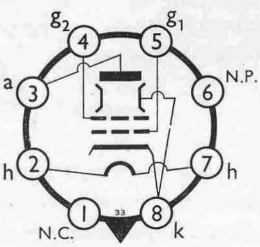
B65



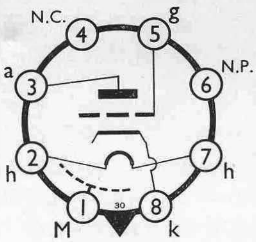
B309



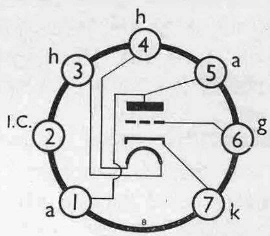
KT33C



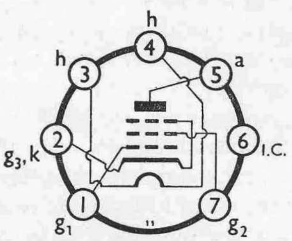
KT66



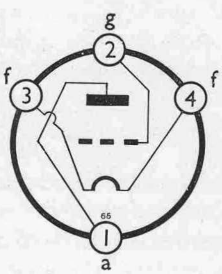
L63



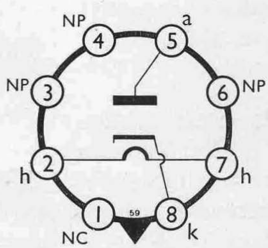
L77



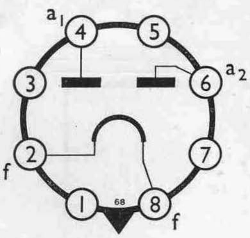
N78



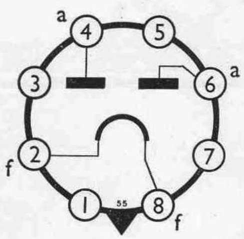
PX4



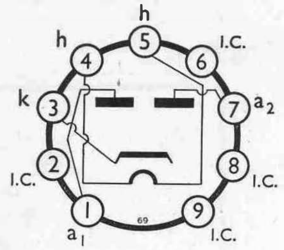
U31



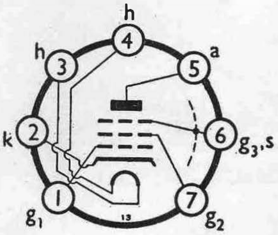
U50



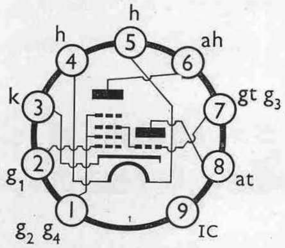
U52



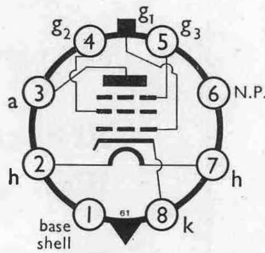
U709



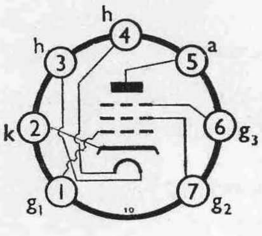
W77



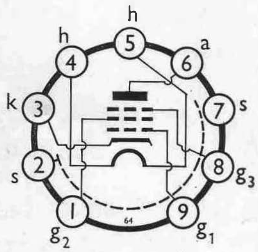
X79



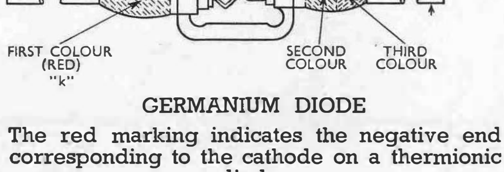
Z63



Z77



Z729



GERMANIUM DIODE

The red marking indicates the negative end corresponding to the cathode on a thermionic diode.

OV2139 8/53 Printed in England by Cheney & Sons Ltd., Banbury, Oxon.