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A. K. Box's

AUDIO AMPLIFIER HANDBOOK

IT is a long step from the primitive signal drum of the savage to the modern public address system, but the principle of sound propagation remains the same, whether we think of the signal drum or the P.A. amplifier.

The beating of the drum resulted in the generation of sound waves, which set up a chain of disturbances in the surrounding air. Fluctuating air pressures caused by these sound waves impinged upon the ear of the listener, and passed through the aural canal until they made contact with its inner membrane.

Vibration of this membrane in accordance with the sound disturbances set up by the beating of the drum caused pulsations of the fluid contained in the inner ear, and these pulsations, acting upon delicate nerve centres, carried the sensation of hearing to the brain.

In passing, it is interesting to note that centuries before Lord Rayleigh's famous treatise on sound was published some knowledge of acoustics — as witness the "flares" often given to signal drums—existed. The signal drum, however well it might serve as a means of communication between primitive peoples, lacked the faculty of transmitting vocal intelligence. In this respect it can be compared to the radio telegraph transmitter.

The next major development in sound was the employment of the megaphone to extend the distance over which the human voice could be heard. It was purely an acoustical device, however, and merely increased the amount of work a vocal system could accomplish. With Reisz's invention of the microphone and Bell's application of it to the telephone we entered upon a new era, but it was not until DeForest perfected his triode valve that things began really to move.

To-day, thanks to the impetus given to sound by the introduction of radio broadcasting, we find it possible to build simple and economical equipment which is capable of amazing results.

Preface

THE purpose of this manual on audio frequency amplifiers and public address systems is to cater for the needs of the average service-man, dealer, or experimenter in a field which is growing in importance—the application of electronic principles to the amplification and distribution of speech or music.

Our aim throughout will be to avoid involved technicalities, and to confine our remarks to the practical application of each of the components which go to make a sound system.

The outcome of our efforts, we hope, will be a manual of real use to the average technician, who usually is concerned more with the ultimate result rather than in the sometimes abstruse principles which are responsible for it.

Modern Sound Equipment.

The basis of the modern sound amplifier is its capability of reproducing without distortion, but with a magnification of up to 100 million fold, every cadence of the speaker's voice or the musician's instrument. This is accomplished by the combination of three units.

The first is the microphone, which is an electro-mechanical device capable of changing the sound pressures impressed on its diaphragm into minute electrical impulses. Next comes the amplifier, which, operating upon electronic principles, magnifies these impulses to such a degree that they are capable of actuating the third unit in the apparatus—the loud speaker.

The latter operates inversely to the microphone in that the electrical impulses fed to it by the amplifier are caused to operate some form of atmospheric piston, which, disturbing the surrounding air, sets up a train of impulses which are a replica of those which actuated the microphone, but, depending upon the design of the amplifier and the conditions under which it operates, may be more or less loud than the former.

We come now to the practical consideration of modern valve amplifiers. With the most recent types of radio valves and the application of them in improved circuits, the potential user of sound equipment has a choice of power outputs ranging all the way from 300 milliwatts to some 60 watts. It is quite easy to go much higher in power output, but we are considering the subject from the viewpoint of the average user, and a 60-watt output will be the very most he will normally need or find economically practicable.

The chief thing to consider in designing an amplifier, even before the question of its output power is to be considered, is its frequency response —i.e., the degree of amplification which will take place as tones of different pitch are picked up by the microphone.

Frequency Response.

Theoretically, the amplification of the system should be equal for high, low, or intermediate tones, but this does not occur in practice unless particular care is taken. The three units of the sound system, each possesses inherent distortions — discriminations for one range of frequencies. Of the three, the well-designed amplifier is the least culpable.

The modern microphone is almost as free from serious frequency discrimination as the amplifier, but so far we have not learned how to make loud speakers which are reasonably cheap, yet are acoustically faithful. Nevertheless, the accommodating properties of the human ear make the properly designed sound system capable of extremely fine reproduction, in spite of the fact that our physicists and research workers tell us that its frequency response is not linear.

Glance at the diagram showing the musical and speech range of frequencies which can be heard by the human ear. This extends in the normal case between 16 and 20,000 cycles per second. Vibrations lower than 16 per second do not sound as one tone, but separate into sixteen different impulses. Those above 20,000 per second are so rapid that the ear's membrane cannot follow them.

This response to sound varies in individuals and with their age. It is narrowed as the amount of sound is reduced and by advancing age. Some people are unable to hear tones above 10,000 cycles. The range of frequencies used in average speech lies between 200 and 3000 cycles. Musical instruments produce tones ranging from 16 cycles to over 8000 cycles per second, but overtones or upper harmonics extend this range to the previously mentioned upper limit of hearing.

Musical Sound Production.

The various musical instruments produce sounds in different ways. The violin, 'cello, piano and banjo produce sound by vibrating strings.

Wood-wind instruments, such as the flute, piccolo and oboe, and brass-wind types, such as the cornet, trumpet and saxophone, produce their sounds by the vibration of air in hollow tubes controlled either by reeds or by the lips of the player.

Percussion instruments, such as the drums, xylophone and bells produce their sounds as a result of their being beaten, rattled or jingled.

The piano is both a stringed and a percussion instrument, whilst the pipe organ is both a wood-wind and a percussion instrument. The human voice belongs to the vibrating air column type.

Timbre is the distinctive quality possessed by each of the musical instruments, and, in fact, by every generator of audible sound. It is due to the fact that most sounding bodies vibrate sectionally as well as wholly.

Loudness or intensity depends upon the violence with which the air surrounding the sound generator is set in motion. The degree of loudness is determined by the intensity of the sound sensation set up in the brain as the result of the pressure exerted by the aural membrane.

The actual pressure variations of sound waves are quite small. The person of average hearing can detect a sound which has exerted a pressure variation of only .000,000,015 pounds per square inch. A painfully loud sound might impose a pressure variation of .015 pounds per square inch on the aural membrane.

The lower level of sound is referred to as the "threshold of audibility," whilst the upper level is known as the "threshold of feeling." Both vary considerably with the frequency of the sound.

Planning Frequency Range.

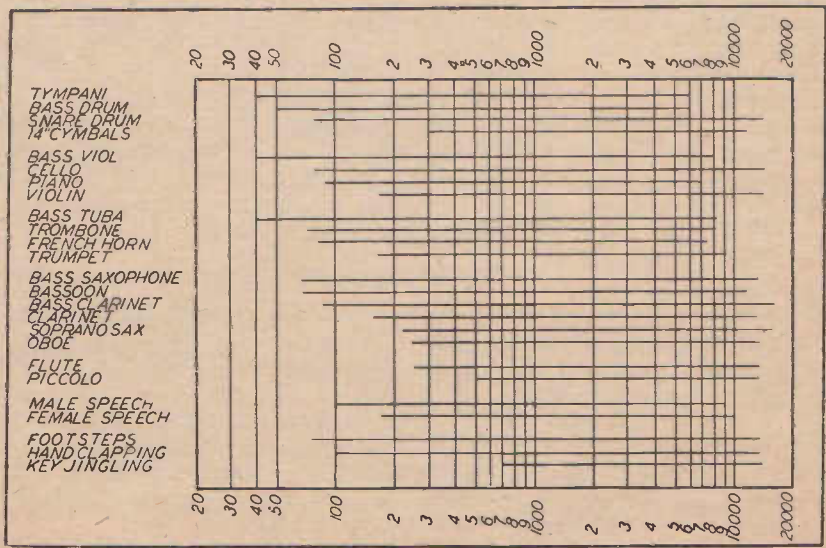
In designing an amplifier system for any particular application we have to consider carefully the frequency range we require. Fortunately, it is possible by circuit adjustments so to control the amplification of any unit that desired frequencies can be accepted or rejected at will.

For reproduction of music, particularly that provided by a "live" orchestra and fed to the amplifier by the microphone, it is desirable that the frequency range should be made as great as possible and should extend at least from 20 cycles per second to 15,000 cycles or above. Such a requirement will necessitate careful planning of the amplifier and speaker installation. The standard type of dynamic speaker, which does not cover frequencies above 7500 cycles without considerable loss, will need to be reinforced with a high frequency "tweeter." The result, however, will be well worth while, for, providing other factors of design have been looked to, the reproduction will lack nothing in naturalness.

For reproduction of gramophone records it is unnecessary to plan for a higher frequency range than 10,000 or a lower one than 50 cycles. With standard recordings we find that seldom are notes higher in frequency than 8000 present. With high fidelity recordings, such as the 33 r.p.m. "inside start" type used for broadcast purposes, the desirable frequency range of the amplifier lies between 25 and 10,000 cycles per second.

There are amplifier applications, however, where still further restriction of the frequency range is desirable. This is particularly so in industrial applications where, due to a high noise level, it is essential that the upper register should be eliminated. Here we find it very useful to so "cut" the amplifier's frequency response that tones below 30 cycles and above 3000 cycles are excluded.

Naturally, such an amplifier would not be of much use as a reproducer of music.



This diagram shows clearly the frequency range necessary to provide full rendition of the various musical and vocal sounds.

AMPLIFIER TYPES SUMMARISED

Types of Amplifier Service—Class A, AB1, AB2, and B Amplifiers—Relative Plate Efficiencies—Necessity for Good Power Regulation—Low Level Distortion—Inverse Feedback Explained.

BEFORE we can touch upon output power requirements we first must deal with the basic types of amplifiers available, their application, and their peculiar advantages.

There are four classes of amplifier service recognised. These are known as Class A, Class AB, Class B, and Class C. The latter has its practical application only in transmitting circuits, so will not be dealt with here.

Briefly, the characteristics of the three types in which we are interested are:—

Class A.—In this form of amplifier care is taken to see that grid current does not flow during any part of the amplifier's cycle of operation. Under these conditions there should be no plate current change during the variation from zero to full output. The Class A amplifier possesses excellent fidelity characteristics, but is relatively inefficient. An output valve in a Class A amplifier is used to supply relatively large amounts of power to the speaker.

The average Class A power amplifier tube has a relatively low "power-sensitivity"—i.e., requires a comparatively large signal input voltage to deliver its output voltage and power. However, its distortion factor is low. These remarks apply in the main to the triode type of Class A tube. The pentode may be operated as a Class A tube, but although its power-sensitivity is greater than the triode, its harmonic distortion is much higher.

"Beam" tubes of the 6L6 type may be used as Class A amplifiers with still further increased power-sensitivity and much better plate efficiency than even the pentode. Its harmonic distortion, however, ranges from 9 to 11 per cent. and is higher than the pentode's.

A Class A power amplifier, usually a triode, also is used to drive a push-pull Class AB or Class B output stage.

Push-Pull Operation.

Class A power amplifiers may be connected in either push-pull or parallel. In the latter connection they are capable of providing twice the output of a single tube with only the same input voltage requirement.

In push-pull operation double the signal input voltage is required, but this disability is offset by several important advantages. First, the even harmonics are cancelled out and an important contribution to distortion is thus eliminated. Secondly, hum emanating in the final stage, although this should not be serious with a well-designed filter system, is bucked out. Finally, the reduction of second harmonic distortion permits more power than the normal amount for the two tubes to be obtained by an increase in the load resistance.

Voltage amplifiers usually are operated only as Class A amplifiers. Their purpose is to combine high gain with linearity of frequency response, the latter factor being looked after by correct design of the coupling medium.

The modern tendency is to use sharp cut-off pentodes as Class A audio voltage amplifiers, because, when the couplings, usually resistive, are correctly proportioned, these tubes provide a much better frequency response than the conventional triode. In addition, they are capable of gains running up to the 100 mark.

Such tubes are almost essential when low level microphones are to be used for, at most, only two amplifying stages, against the three to four if triodes were used, are necessary in front of the driver stage.

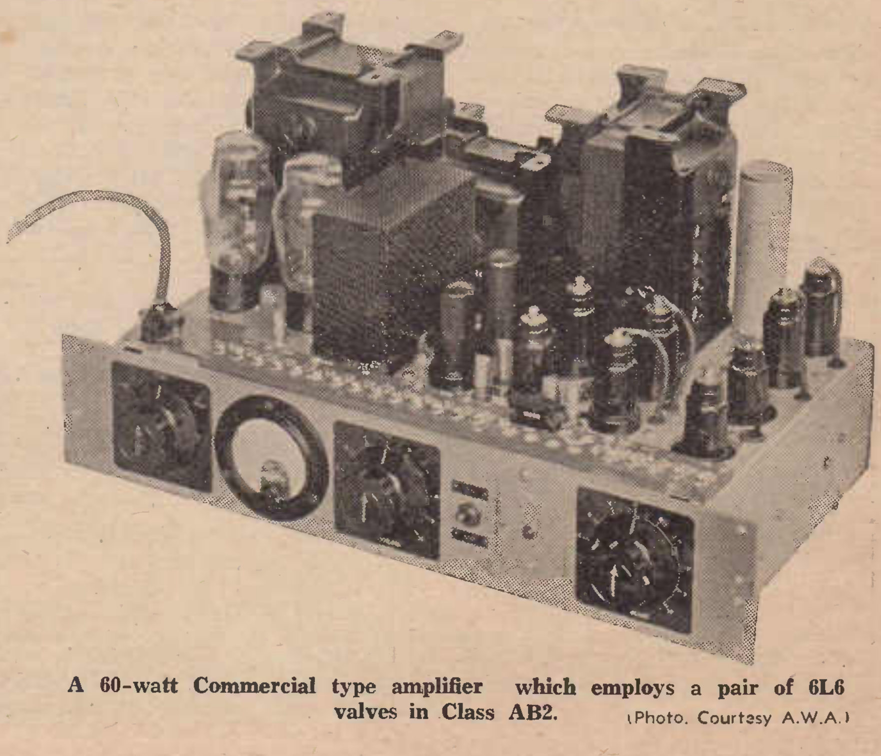
Grid Current Amplifiers.

Next we come to the grid current drawing type of amplifier.

In this category fall the Class AB and the Class B amplifiers. For **Class AB** the operation is so planned that a higher negative bias prevents dangerous rises in the plate current, although this varies with the input signal.

Actually, there is a sub-division of the Class AB amplifiers into AB1 and AB2. In the **AB1** operation the bias is merely raised above that required for **Class A** operation.

The increase in bias permits a rise in the plate and screen voltages without affecting the internal dissipation, but allows the rated power output to be increased. As no grid current is drawn, a standard voltage amplifier may be used ahead of the power stage and conventional coupling methods may be employed.



A 60-watt Commercial type amplifier which employs a pair of 6L6 valves in Class AB2. (Photo. Courtesy A.W.A.)

In spite of the fact that this inverse feedback amplifier is capable of an undistorted output of 50 watts, it is extremely compact.

(Photo. Courtesy Philips Radio.)

High Plate Efficiencies.

In **Class AB2** operation the applied signal voltage is greater than the grid bias, so that grid current flows during portion of the operating cycle. It is essential for AB2 operation that two tubes be used in push-pull. As grid current is drawn by the AB2 tubes there is a loss of power in the grid circuit, and thus must be made up by employing a driver valve capable of supplying sufficient power to overcome the deficiency.

Unlike the voltage amplifier, which delivers voltage rather than power, the driver valve in a Class AB2 or Class B amplifier must deliver powers ranging between 260 and 625 milliwatts for amplifiers ranging between 2 and 60 watts. (These figures depend on the selection of particular tube types and are not to be considered final. Each AB2 amplifier will require individual treatment, but full details will be found in the circuit section of this manual.)

The advantage of AB2 operation is that the plate power efficiencies are very high, but the drawback is that considerable care has to be taken with power supply regulation, and in most cases a fixed bias system in which the bias voltage is held constant irrespective of plate current variation must be used.

Both a choke input filter system and a mercury vapor type of rectifier tube should be used in the power pack of Class AB2 and Class B amplifiers.

Distortion at Low Levels.

The **Class B** amplifier is a further development of the Class AB2, but with it the plate current is cut off for a larger portion of the negative grid swing. Like the Class AB2 amplifier, it is essential that two tubes be used. Several types in which two sets of elements have been included in the single envelope have been developed for this service.

The advantage of the Class B stage is similar to that of the Class AB2 stage, but it is more subject to low level distortion than the AB2 type.

Because a Class B amplifier tube is usually operated at zero bias each grid draws considerable current during the positive half cycle of its signal swing. Thus, similar provision for power output from the driver tube to that made with the AB2 amplifier must be made with the Class B stage.

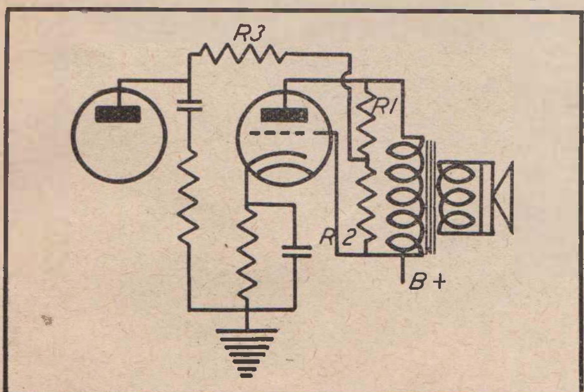
Provided that this tube is capable of delivering considerably more power than required for operation of the Class B stage, the distortion will be low at high levels but will progressively increase at low levels. In this respect the AB2 type amplifier scores, for, at low levels, it operates as a Class A amplifier.

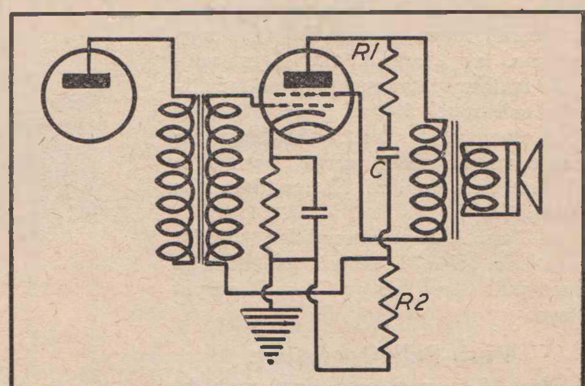
Since the plate current excursions in a Class B amplifier are extremely large, it is essential that a well-regulated power supply, similar to that used for the AB2 amplifier, be employed.

To-day, with the improved operating conditions for AB2 amplifiers and the introduction of the beam power tetrode the Class B stage is being neglected in most audio amplifier work. Its main application today lies in the transmitter modulator field.

Corrective Filters.

We come next to means for overcoming distortion in the output stage. Two systems are in general use. The first is the inclusion of filters across



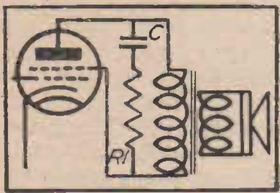


Two conventional Inverse-Feedback circuits are shown. The left-hand one depicts the method used to apply feedback when the driver stage is resistance coupled, whilst the right-hand circuit shows how the feedback is applied to a transformer-coupled amplifier.

the output circuits of pentodes, whilst the second is the application of Inverse Feedback to these and the beam tubes.

The necessity for these additions is due to the fact that the impedance of the loudspeaker does not remain constant over the amplifier's frequency range; consequently the load impedance on the valve varies with frequency changes.

The filter consists of a condenser and resistor connected between plate



An output filter circuit.

and screen grid of the pentode or beam tube. Note that no filter is required, except possibly for adjustment of frequency response, when a triode is employed in the output stage.

The value of the resistance to be used in the filter should be 1.3 times the recommended plate load resistance for the tube, or 1.3 times the plate to plate load resistance for push-pull tubes. The capacity of the condenser used in the filter will usually range between .02 mfd. and .05 mfd. Its correct value is one which results in equal voltage outputs when 400 and 1000 cycle signals of similar amplitude are fed to the input of the amplifier.

Inverse Feedback Applications.

With Inverse Feedback a proportion of the voltage available at the output circuit of the amplifier is tapped off and fed to its grid circuit. This is done by means of a potential dividing system, consisting of the resistors R1 and R2. In single-ended resistance coupled amplifiers this is done by connecting the divider, R1, R2, across the primary of the output transformer and feeding the plate of the driver tube, V, through the customary plate resistor, R3, which is connected to the midpoint of the R1, R2 divider.

With transformer coupling we interpose a blocking condenser, C, between R1 and R2, earth one side of R2 and join its high side to the grid return of the coupling transformer.

The same condition is duplicated in the case of the push-pull stage, but here we must use a transformer having separate secondary windings.

It is undesirable that inverse feedback be applied to Class AB2 or Class B amplifiers because of the resistance introduced into the grid circuit.

Practical Details.

The amount of inverse feedback which can be usefully applied to an amplifier will seldom exceed 20 per cent. More usual percentages range between 10 and 16. The approximate feedback voltage is determined from the expression:

$$\frac{Ep \times R2}{R1 + R2}$$

Where Ep is the audio output voltage of the tube and R1 and R2 are the resistors in the feedback potential divider.

Percentage then is obtained by dividing the feedback voltage by the audio output voltage and multiplying the result by 100.

The audio output voltage may be obtained by measurement. For this a high resistance a.c. voltmeter—20,000 ohms or more, or a valve voltmeter, should be connected across the primary of the output transformer, but isolated from the d.c. by means of a large capacity condenser. A 4 mfd. paper condenser will do.

For extreme accuracy it is necessary that the measurement be taken at the reference frequency of 400 cycles, at which the output transformer impedance was calculated. The voltage can be determined with a fair degree of accuracy with the aid of the following formula:

$$\text{Out voltage} = \frac{Mu \times Eg\ (\text{eff.}) \times R1}{Rp \times R1.}$$

Where MU is the amplification factor of the output tube.

Eg (eff.) is the rated vias voltage divided by .707.

R1 is the load impedance of the output circuit.

Rp is the plate impedance of the output tube (half the plate-to-plate impedance if two tubes are used in push-pull).

The application of a negative signal voltage to the grid of the valve which is to be operated under Inverse Feedback conditions results in the bucking of the input signal voltages to this tube. We might consider the negative feedback voltage as constituting an addition to the bias on the tube. This, of course, would result in the reduction of its output.

Input Voltage and Output Power.

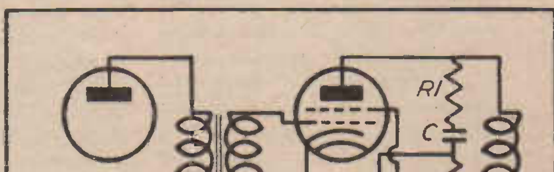
Suppose in the circuit diagram the voltage developed across R2 is 10 per cent. of the output voltage. In other words, words, the resistance of cent. of that of the combination R1-R2. Furthermore, let us assume that there is a one-volt input to the grid of the output valve, and that this valve has an amplification factor of 10.

Then the voltage across the primary of the output transformer will be 1 × 10 or 10 volts. Now, if 10 per cent. of this output voltage, i.e., 1 volt, is fed back to the grid circuit of the tube, it will cancel out the one-volt signal input and no output will be available.

Suppose, however, that we increase the signal input to the final tube to two volts. It will still be bucked by the one-volt negative feedback voltage, but the output tube will then operate under the same conditions of power output as it did before we attempted to apply feedback.

Thus, it will be seen that in planning an inverse feedback system it is necessary to ensure that there is ample voltage available from the preceding stage to energise the final stage tube to full output, even when the bucking effects of the feedback voltage are present. This increase in output may be available in the amplifier's original design.

If not, it must be provided for by increasing the voltage amplification of the driver stage or by adding an additional stage. The advantages of Inverse Feedback are that it reduces both frequency and amplitude distortion, and helps to eliminate hum, noise, or any other component of the output.



When Inverse Feedback is applied to a push-pull output stage, it is desirable that the coupling transformer be fitted with completely separate secondary windings.

OUTPUT POWER REQUIREMENTS

Output Power Needs—Overcoming High Noise Levels—Directional and Baffled Loud Speakers—Audio A.V.C.

THE question often asked by the prospective user of sound equipment is: "What power do I require to cover this job?"

Here we are faced with something of a poser, for the requirements of each individual installation vary. Different acoustic conditions, different ideas of the amount of volume required, and different local noise levels all combine to give the equipment designer a headache.

He is fortunate to-day, however, in that he can solve most of his problems by building an amplifier of sufficient capacity to cover even the biggest job with ease. It will not be unduly expensive—modern tube designers have seen to that, and, after all, there is always a gain control available.

Outdoor and Industrial Installations.

Probably the two most difficult coverages to estimate are the outdoor one and the industrial one where local noise levels are likely to be extremely high.

Outdoor jobs will usually be covered with groups of loud speakers. These will be the flared-horned type and their directional characteristics will help materially in getting economical sound coverage. The arrangement of indoor speakers will depend upon acoustic problems and the likelihood or otherwise of acoustic feedback taking place.

As a rough guide, however, we may assume that the average factory job will require an amplifier having an output of between 30 and 60 watts. A pair of 6L6's in Class AB1 or AB2 will meet either of these requirements.

Provided that due care is given to the placing of the directional type speakers, which should be energised to the tune of about 5 watts each, the biggest stadiums or football grounds we have in Australia could be satisfactorily covered with a 60-watt amplifier and from 8 to 10 horn-type speakers.

It is worthy of note that for greatest acoustic efficiency in high powered amplifier systems, particularly those employed in outdoor work, the diaphragm type dynamic speaker, used in conjunction with a horn of suitable design, should be used.

These diaphragm units are extremely efficient, and can handle audio powers of 10 watts and more without trouble.

Some of the diaphragm units require an exciting voltage, but the latest types are permanent magnet units so that the problem of running high voltage lines for field excitation or of providing a separate exciting battery for each bank of loud speakers is eliminated.

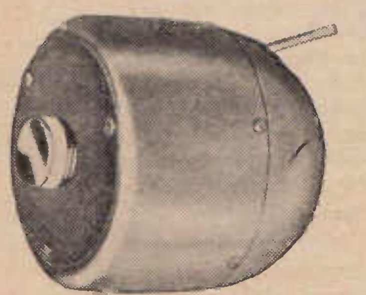
Indoor P.A. Systems.

For indoor work we find that much lower powers are required. For the average small dance hall, say of 50,000 cubic feet content, a 5-watt amplifier will be adequate. Below this we can use 2 or 3½ watt amplifiers.

Halls or theatres holding from 600 to 1200 people, and having a cubic content between 70 and 100,000 cubic feet, will be adequately served with a pair of speakers and an 8-watt amplifier.

In 1200 to 3000 seat group, with cubic contents between 150,000 and 300,000 feet, an 18-watt amplifier will be required, whilst for the largest jobs, 3000 to 5000 seats and 500,000 to a million cubic feet content, a 30-watt amplifier will do all that is needed.

It is desirable, where practicable, in indoor installations to use some form of directional radiator, whether it be a directional baffle or a horn. This will obviate most of the possibilities of acoustic feedback, and will permit the speakers to be placed close enough to the microphone to avoid echo effects.



For high powered outdoor installations diaphragm type permanent magnet speakers, such as this, are almost essential.

(Photo. Courtesy Philips Radio.)

However, modern amplifiers fitted with automatic volume control are free from acoustic feedback problems, so that the speaker placement really comes down to a question of the acoustic properties of the building in which the equipment is installed.

We have touched upon the ease with which high output powers can be obtained from modern amplifiers. There is a reservation to this statement, however. With A.C., A.C.-D.C., or D.C. amplifiers, it is quite easy to obtain adequate, yet economical, power.

Battery Amplifier Problems.

With battery amplifiers large power outputs are expensive. Fortunately, however, little two-watt Class B battery amplifiers can be built to give excellent service in the ordinary small hall. We have discussed this matter with a large number of country dealers, experimenters, and service men, who all have agreed that for the average country dance hall a two-watt Class B amplifier and two or three permanent magnet speakers provide first-class results.

For those who wish to go in for something bigger, there are the vibrator and genemotor forms of power supply. Mark this, though, neither of these supply systems can be used with a grid current drawing amplifier because their poor voltage regulation would introduce serious distortion.

For Class A work it is practicable to use one or two 300-volt 100 milliampere vibrator units to provide powers up to 15 watts. The catch would be the necessity for frequent recharging of the "A" batteries, but at least, this system would permit comparatively large powers to be obtained.

A thought worthy of attention in connection with these vibrator units is the possibility of using one of the old BH 85 milliampere Raytheon gaseous type rectifiers or one of the new 75 m.a. OZ4 tubes now manufactured by this concern.

The advantage of these gaseous type rectifiers is that they do not require any filament excitation. Elimination of the synchronous vibrator rectifier would improve the wave form of the a.c. power supply output, give better current regulation, and produce less hash in the output.

LOUD SPEAKERS

Acoustic Power Levels—Transient and Harmonic Distortion—Installation Details—Multi Speaker Systems—Impedance Matching—High Frequency Speakers.

THE ultimate aim of the amplifier builder is to feed the output of the microphone or pick-up through the amplifier to the loud speaker in such a way as to obtain the best tonal fidelity possible as well as the greatest coverage for a given electrical out-put power.

Most amplifier designers are fairly conversant with electrical, or what we term "audio" out-put powers, but when it comes to translating these into acoustic powers it is an entirely different matter.

Quite recently, a well-known English technician, who apparently had devoted considerable study to the subject, set out a thesis which upset all preconceived ideas of electrical watts input for acoustic watts output. His figures showed that our generally accepted audio output power calculations were grossly over-stated. However, no clue was given in his discussion to the practical application of his ideas which, after all, are based primarily upon the translation efficiency of the electro-acoustic device we term the loud speaker.

The lower priced types of loud speaker used in radio receivers, have a translation efficiency ranging from 5 to 6 per cent. The auditorium, or so-called high fidelity speakers, range as high as 15 to 20 per cent., and one American manufacturer claims to have reached the remarkable figure of 35 per cent.

These figures set a limit to the coverage obtainable with a given electrical power.

In any audio system four major requirements exist.

These are:—

Good Frequency Response.
Good Transient Response.
Freedom from Harmonic Distortion.
Adequate Power Range.

We might as well make it clear that from a practical viewpoint, the loud speaker response curve doesn't mean very much. It is practicable to run response curves on lines, microphones, amplifiers, or pick-ups, but when we come to the loud speaker, with its complications of electrical and acoustic effects, we are helplessly at sea. The performance of a loud speaker in a sound damped room, or under the ideal "free air" conditions, is totally different from that experienced in any one of the numberless situations in which it is expected to operate.

Transient Response.

Of far more importance is the loud speaker's Transient Response, for upon this hinges its capability of handling those nuances which lend intelligibility to speech and "life" to music.

A rough indication of the possibilities of a loud speaker from the Transient Response viewpoint is its efficiency of design. The more efficient the loud speaker and the more aurally "flat" is its overall response, the better its Transient Response is likely to be. "Mass," as represented by heavy, moving parts, and low flux, due to lack of field excitation, are enemies of Transient Response.

Where a loud speaker is fitted with a badly designed horn, the frequency characteristic of which is "peaky," the transients will suffer. With permanent magnet type speakers we can lay down a general rule that the bigger and more effective the magnet the better the loud speaker's reaction to transients.

The 12-inch Auditorium type dynamic speaker is now accepted as a standard for high fidelity reproduction.
(Photo. Courtesy the Rola Co.)

As far as Harmonic Distortion is concerned we cannot do better than quote the statement made by Rudd, in his paper to the I.R.E. (Aust.). He says, inter alia: ". . . it is interesting to note that more distortion is usually introduced by the valve operating upon the speaker load, which is variable with frequency, and is usually reactive, than is inherent in the speaker itself."

Distortion in the speaker is due, in the main, to poor acoustic loading at the lower frequencies. This may be caused by ineffectively designed baffles or, in rarer instances, by fundamentally unsound loud speaker design. In the design of the amplifier, provision should be made for a large power reserve, because the efficient loud speaker has a good operating load characteristic.

Frequency Ranges Compared.

The question of power range is easily settled, provided that the exciting amplifier is carefully planned. The experience of radio set and talkie equipment manufacturers shows that a power range of 30 db. is necessary for satisfactory rendition of music.

Before we leave the subject of the speaker itself we might recapitulate slightly, and discuss the working frequency response of the two main types.

With the lower priced speakers we find that the frequency range seldom extends below 90 cycles or above 5000 cycles. Most cut off seriously in the 4500 cycle region. With the auditorium type speaker, such as the Rola G12, we find that the lower frequency spectrum has been extended to 50 cycles, whilst the upper register embraces a frequency of 7500 cycles without serious acoustic loss.

Where horns are used with speakers, it may be found that, whilst their resonance may affect the overall response, the intelligibility will not necessarily suffer. From a frequency response viewpoint the flat baffle may be superior. However, a horn with a small throat—i.e., the section facing the speaker, will have a higher efficiency than the baffle, because of its better air loading and the acoustic transformer effect it possesses by reason of the area expansion from diaphragm to throat.

The horn is directional, but its characteristics follow definite acoustic laws.

The directional characteristics of any radiator of sound are governed by the size of the diaphragm. In the case of the horn, this means the size of the bell or mouth. The smaller the diaphragm the higher must be the frequency before the directional effect becomes marked.

In the flat baffle a form of directional effect exists. Radiation takes place from the front and rear of the baffle but not from its sides, for at this point the front and rear sound waves cancel out.

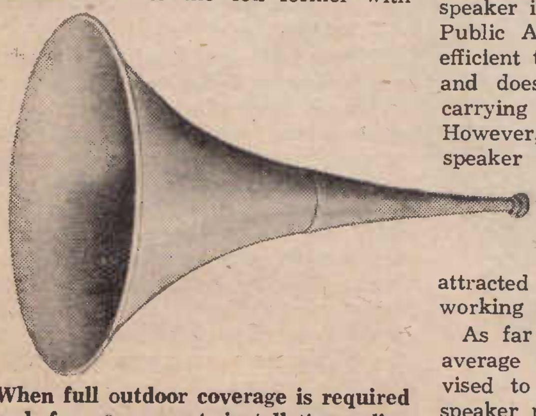
Picture Theatre Baffles.

Recent developments in reproducing equipment for picture theatres involve the use of a new type horn, so designed that the middle and high frequencies are radiated directly from the loud speaker, which is mounted above, but acoustically connected to a folded horn, designed to reproduce frequencies as low as 32 cycles.

The back radiation from the loud speaker is fed through this horn, the system being so arranged that no front radiation at low frequencies takes place from the speaker unit. With a single Rola G12 for medium sized installations, and two similar type speakers for large theatres, the efficiency of the new system is claimed to be high, and its frequency response considerably better than that normally obtained.

The chief barriers to the handling of high audio powers by loud speakers are stress on the spider and heating of the voice coil. The lower priced speakers may handle audio powers of 10 watts on peaks, but their normal operating power lies in the 4 to 6 watt region. The auditorium types handle 15 watts normally, and up to 20 watts on peaks, but, as their efficiencies are some 300 per cent. greater than the standard type speakers, the resultant acoustic output is similarly improved.

Power overload on a loud speaker will result in heating of the voice coil winding. The result will be that, despite the fact that the windings are cemented on to the coil former with special heat resisting cement, this will be unable to withstand the temperature rise, and the voice coil winding will slip, and will jam in the air gap.

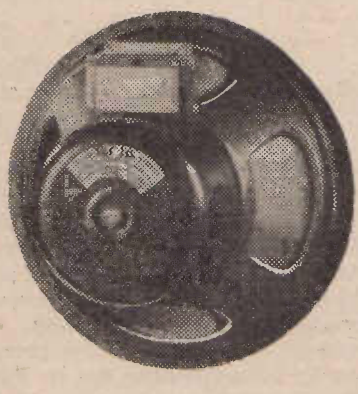


When full outdoor coverage is required and for permanent installations diaphragm type speakers, fitted with long metal horns such as this are employed.
(Photo. Courtesy Philips Radio.)

Practical Details.

Now for some practical operating data. First, it is desirable, wherever possible, to use a push-pull output stage to keep the d.c. from flowing through the output transformer winding. Care in this regard will be repaid by a considerably better low frequency response.

Remember, that for Public Address installations, where a number of speakers are to be used, there is nothing to beat the better class Permanent Magnet types. In the larger P.M. speakers more flux exists than it would be possible to get in a corresponding type d.c. excited speaker—and flux means efficiency. For example, with one of the modern 21 oz. magnet type Permanent Magnet speakers, a flux equivalent to a field excitation of 15 watts is obtained.

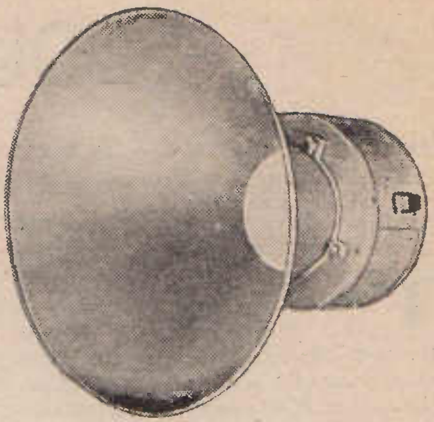


Recent developments have made it possible to obtain 12-inch high fidelity permanent magnet type loud speakers, such as the one depicted above.
(Photo: Courtesy the Rola Co.)

A good quality Permanent Magnet speaker is the best investment for the Public Address operator. It is more efficient than the electro-magnet type, and does not require special power carrying leads for its field excitation. However, it is essential that the P.M. speaker be dust-proofed. Even the minor operation of screwing the speaker to a baffle will result in fine metallic particles being attracted to the magnet, and finally working their way into the air gap.

As far as service is concerned, the average technician will be well advised to leave this job to the loud speaker manufacturer.

In the rather rare case of the voice coil getting out of centre, a satisfactory adjustment may be made by cutting four thin strips of 10/1000th inch thick celluloid, slackening the speaker cone, slipping the strips down equidistantly around the pole piece, and carefully tightening up the cone unit whilst the strips are in place.



For directional coverage, speakers fitted with short metal horns such as this are desirable.
(Photo. Courtesy Philips Radio.)

Impedance Matching.

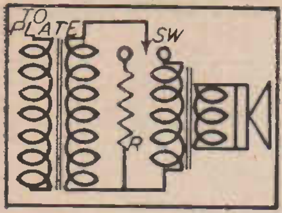
The next point of interest in loud speaker operation is that of line matching. This is essential where one or more loud speakers are to be used at some distance from the amplifier. Three things enter into this matter—i.e., the d.c. resistance, the capacity, and the inductance, of the line. For short runs, the speaker voice coil leads may be connected directly to the line, provided the latter consists of standard V.I.R. cable of such a wire gauge that its total resistance—both lines—is not more 10% of the voice coil resistance.

Thus, for a 2.3 ohm. voice coil, the line resistance should not be more than .115 ohms. per side. Don't attempt to connect a number of different type speakers in series. Even if they have the same voice coil resistance, the design of the different types will be such that varying electro-acoustic reflections will result in distorted reproduction.

Sometimes, for instance, when the length of line in great, it may be desirable to connect the voice coils of two of the SAME TYPE speakers in series. It is not good practice, however, and should be avoided whenever possible.

Occasionally it may be necessary to arrange matters so that one loud speaker gets more power than another. For example, take the case where a 5-watt output is being fed into a line. Speaker A is to receive 4 watts and speaker B is to receive 1 watt. Both are connected in parallel, so their combined impedances should equal the impedance of the line.

This in turn must be matched by the



A simple muting circuit for multi-speaker systems.

secondary of the amplifier output transformer. Let speaker A be fitted with an input transformer having a primary impedance of 3000 ohms. Speaker B, which is to get only quarter the available output power, must have an impedance of 750 ohms.

$$\text{From the formula } \frac{Z1 \times Z2}{Z1 + Z2}$$

$$\text{we get } \frac{3{,}000 \times 750}{3{,}750}$$

or 600 ohms.

This, pre-supposing we are using a pair of 42's in Class A push-pull, the amplifier output transformer will have a step down ration of 14,000 ohms. plate to plate to the 600 ohm. impedance of the line.

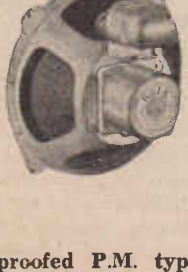
If a number of speakers is to be used in parallel, we use this formula for the calculation of the amplifier output transformer:—

ZL × No. of speakers = Impedance of each speaker.

ZL being the line impedance.

Thus, if we desire to use ten speakers in parallel on a 500 ohm. line, each speaker must be fitted with an input transformer having an impedance of 5000 ohms. Note, though, that the amplifier output transformer must have an impedance step-down from the load resistance of the output tube to the line impedance, 500 ohms. in this case.

Although accurate measurements will quickly show up the disturbance to frequency response caused by mis-matched impedances, it will be found in practice that mis-matches, with ratios as high as 4-1, can be tolerated by the ear. Besides affecting the frequency response, impedance mis-matching will result in power wastage, and for this reason, if for no other, it should be avoided.



This dust-proofed P.M. type speaker has wide application in P.A. work.
(Photo. Courtesy the Rola Co.)

Speaker Volume Control.

In Fig. 1 we see a form of volume control which can be applied to each loud speaker. R1 and R2 are ganged potentiometers, R2, nearest the speaker transformer, is the higher resistance one.

The resistance of R2 should approximately equal the combination of the impedance of the loud speaker input transformer and the resistance of R1. R1 itself should have a resistance at least five times as high as the input impedance of the speaker. For a 5000 ohm speaker we might select a value of 25,000 ohms for R1.

In these circumstances the resistance of R2 should be 6000 ohms. From this other impedance and resistor values may be worked out in the same ratio. If the speaker impedance is 2500 ohms, then R1 should be 12,500 ohms., and R2 should be 3000 ohms. The combination works as a series-parallel arrangement, in which R2 cuts in series resistance as the impedance of the speaker input transformer changes with the reduction of the parallel resistance, R1.

Fig. 2 shows a system of "muting" a speaker without disturbing the balance of the line. The resistor, R, should be approximately 25 per cent. higher in resistance than the speaker impedance, and so arranged that either it or the loud speaker may be switched into circuit at will.

Loud Speaker Requirements.

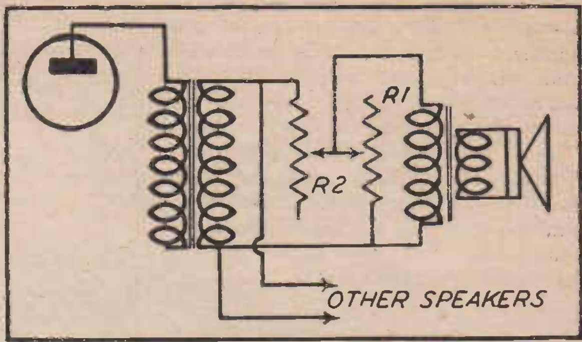
Some idea of the number of loud speakers necessary to cover a given area may be obtained from the following:—

For theatre work, we find that three auditorium type speakers, such as the Rola G12, will adequately cover a 1500-seat theatre. A single speaker is quite enough during the actual screening of a picture, when the audience is absolutely quiet, but at intervals and before the show, the noise of speech is such as to make the additional speakers necessary. Another advantage of the trio is that it is possible to diffuse the sound better, and get over acoustic "dead spots" in the hall or theatre.

For 300 to 500 seat theatres, a pair of seven-inch speakers may be used.

Many country halls have exceptionally large and deep stages.

If the speaker, or speakers, are mounted behind the movie screen in such locations, reverberation will take place, and impart a "boominess" and lack of intelligibility to speech. In these circumstances, the only thing to do is to bring the speakers out in front of the screen, and arrange them in baffles of such a design that no sound is directed rearwards towards the stage.



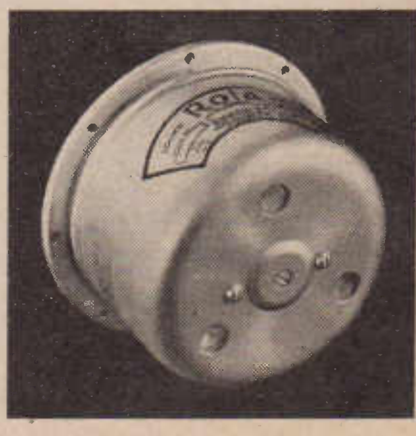
Matched impedances and independent volume control is possible with this multi-speaker system.

The Tweeter.

A recent development, so far as Australia is concerned, is the high frequency speaker, or "Tweeter." This type of loud speaker has a frequency response ranging from 4000 cycles up to 10,000 or 15,000 cycles.

To understand why it is necessary to use this adjunct to the standard type of speaker, we first must remember that, although the high fidelity type speaker is capable of responding to tones as high as 7500 cycles per second, its operation is such that these tones are generated mainly at the outer periphery of the cone.

The tendency of all high frequency tones is to concentrate into a sound beam. As the angle of projection is fairly wide from a standard 12 inch loud speaker, the listener to it must stand almost directly in front of it to hear the high frequency tones. If he



A modern dynamic type high frequency "tweeter."
(Photo. Courtesy the Rola Co.)

stands more than a few degrees off centre, the fact that radiation from opposite side of the cone will reach him out of phase will result in the cancellation of these tones, as far as the ear is concerned.

With the tweeter's smaller diaphragm the beam is made far more compact, with the result, paradoxically enough, that it is not necessary to stand directly in line with the beam to obtain an aural impression of the higher frequency tones. Besides helping matters from this viewpoint, the Tweeter, being light in mass, can respond to much higher frequencies than the standard type speaker.

There are catches, however, to the use of Tweeters. The first is that the amplifier must really be 100 per cent. and free from all traces of harmonic distortion. Most of this distortion manifests itself at the higher frequencies, and, when a Tweeter is used, harmonic distortion is heard in the form of a rattly hash.

It is in only a few cases that the Tweeter can be used to full advantage. Harmonic distortion, electrical and side band noise, where the amplifier is connected to a radio receiver, and when the input signal is a broadcast one, the same forms of harmonic distortion in any of the links connecting the studio with the loud speaker, all militate against full use of the Tweeter.

However, it is possible, whilst restricting the frequency response of the Tweeter, to still obtain an extension, and a reinforcement of the higher frequency range covered by a standard type dynamic speaker.

A mobile P.A. unit.
(Photo. Courtesy A.W.A.)

LOUD SPEAKER CHARACTERISTICS

Model.	Impedance.	Field Watts.	Output Watts.
Amplion.			
Electro-Magnet.			
M	3.25	6	3
F	1.75	9	—
Q	1.25	9	5
RM	1.25	9	7.5
S	13	12	10
"SA"	13	12	10
"T"	7.8	15	12
Permanent-Magnet.			
K	3.25	—	3
G	1.75	—	—
O1M	1.25	—	5
O1	1.25	—	5
L1	12.5	—	6
O5x	13	—	7.5
L5x	13	—	7.5
Cine.			
O1	13	—	5
L5x	13	—	7.5
Public Address (Complete Speakers).			
P.S.17	1.25	—	—
P.S.19	13	—	—
P.S.21	15	15	10
P.S.25	7	—	12
Public Address (Unit Only).			
A108	15	15	12
SU6	7	—	12
Hartley-Turner.			
Electro-Magnet.			
Duode De Luxe	4	40	12
Permanent Magnet.			
Standard Cone	4	—	12
Twin Cone	4	—	12

Model.	Impedance.	Field Watts.	Output Watts.
Jensen.			
Electro-Magnet.			
A12	8	14	10
"M"	6.5	—	15
Philips			
Permanent Magnet			
9803	—	—	6
9800	—	—	10
2257	—	—	20
*9802	—		

*This is a diaphragm type unit and should be used with the Philips type 9812 31-inch Exponential Horn. The 2234/39 type horn may be used with other Philips speakers.

Model.	Impedance.	Field Watts.	Output Watts.
Rola.			
Electro-Magnet.			
DP5B	3	6	5
F4	3	6	5
F10	2.3	8	5
K10	2.3	9	5
K8	2.3	8	5
K12	2.3	9	7
G12	8	18	15
Permanent Magnet.			
5-6 P.M.	3	—	4
6-6 P.M.	3	—	4
8-8 P.M.	2.3	—	5
8-20 P.M.	2.3	—	5
8-21 P.M.	2.3	—	7
10-21 P.M.	2.3	—	7

Controlling Tweeter Response.

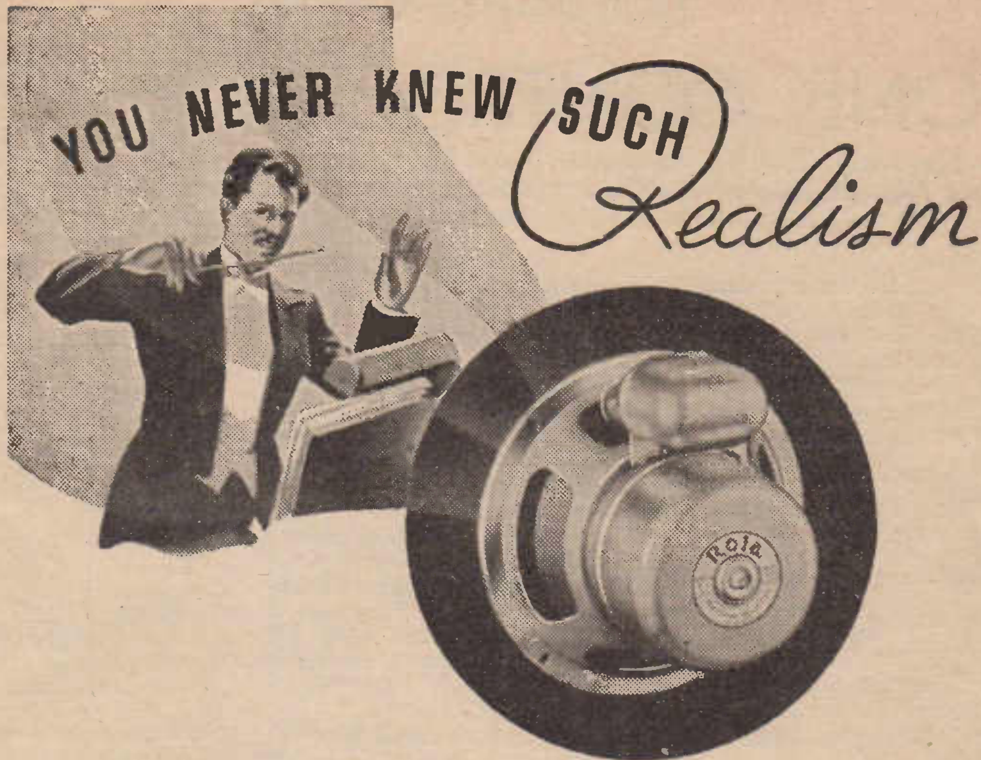
This is achieved in the following way:—The tweeter must be connected to the primary of the main speaker output transformer through its own output transformer. This output transformer in the tweeter has a series condenser in one of its connection leads. Adjustment to the capacity of this condenser will restrict the range over which the tweeter will respond, and by this means its upper cut-off can be fixed.

Undoubtedly, the tweeter is necessary for high fidelity reproduction, but unless it is used properly, it will introduce more apparent distortion than was present when only a standard speaker was used.

As we have explained, however, this is due either to distortion in the amplifier or to incorrect operation of the tweeter. The high frequency speaker itself is free from major distortions, and, when properly employed, will give excellent transient response.

Incidentally, it is impracticable to use a tweeter with any type of standard loud speaker. It must be employed with the dynamic speaker for which it is designed, and must be installed strictly in accordance with the manufacturer's instructions.

The correct method of mounting the tweeter is to place it on the same baffle as the standard speaker, above the latter, and as near to it as possible.



8-20—An 8 in. permanent magnet model. Patented dust-proof acoustic filter assembly. New type moulded diaphragms permit greater power handling capacity without loss of sensitivity. Also features the new insulated transformer.

K-12—A de luxe 12 in. wide range reproducer of the electro-dynamic type. Designed for those who are supplying the best in radio.

The rich, powerful tones of the golden-voiced virtuoso; the softest shades of glowing patterns woven by strings, woodwinds and brasses; the slightest sound during tense moments on packed playing fields . . . these things the Rola Reproducer brings you as though the artist, the actors of each drama, stood at your very elbow, or were grouped about your armchair.

Rola Reproducers have earned for themselves a reputation of efficiency and reliability in all parts of the world. Their greater electro-acoustic efficiency, fidelity of reproduction, and sturdy construction enable Rola Reproducers to give outstanding performance and thrilling realism.

NOW ROLA INTRODUCES A NEW RANGE OF SPEAKERS,

incorporating the best features of former models, and presenting new revolutionary features, chief of which is the Rola Isocore Transformer, which includes electrical and mechanical principles entirely new to loud speaker Transformers, and is designed to eliminate electrolysis. This valuable feature makes these models especially suitable for humid climates, where efficient, trouble-free performance depends so much upon protection of such vital parts from moist atmospheric conditions.

In addition, Rola manufactures a range of Permanent Magnet Speakers particularly adaptable to multiple public address installations or for use in Car Radios and Battery Sets. Particular features of these Reproducers are the Rola patented dust-proof and acoustic filter assembly, high-efficiency, and complete freedom from the inconvenience of providing separate Speaker-field excitation.

Rola

THE WORLD'S FINEST SOUND REPRODUCER

Manufactured by: ROLA CO. (Aust.) PTY. LTD., The Boulevard, Richmond, Victoria, Telephone J5351.

TONE CONTROL

Desirable Frequency Cut-offs—Condenser Tone Control—Increased Low Frequency Gain—High and Low Note Compensation.

FOR high-fidelity operation there should be no need for any tone compensating circuits provided that the amplifier and its associate equipment has been properly designed. However, in certain public address amplifier applications, particularly in those cases where the sound system is to be operated in areas in which a high noise level exists, some form of tone control is essential if speech is to cut cleanly through the prevailing noise.

As a general rule we can take it that any p.a. amplifier used solely for the reproduction of music requires as flat and as extensive a frequency range as possible.

Where both speech and music are to be handled, then we can cut the amplifier's upper register somewhere around 5000 cycles.

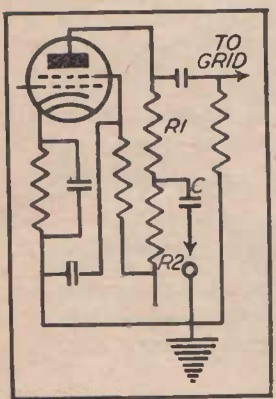


Fig. 1. Bass Boosting Circuit.

For purely speech applications, however, it is desirable that only the middle register, say from 300 to 3000 cycles, be passed.

Low Frequency Cut-Off.

Now, to get a complete cut-off of the lower frequencies is fairly easy. Either a simple low pass filter may be used, or if the amplifier be resistance coupled, we can easily control the low frequency response by selecting suitable values of coupling condensers. For example, where ordinarily a .01 to .05 mfd. grid coupling condenser is used in a high fidelity amplifier, we can reduce this capacity to .002 mfd. or even lower, and thus provide quite a smooth cut-off of the lower frequencies.

It is interesting to note that reduction of the capacity of the coupling condenser and the resistance of the grid leak of the following tube will readily combine to restrict the low frequency characteristics of the amplifier. Grid resistors as low as 50,000 ohms can be used in place of the conventional .25 or .5 megohm resistors.

Whilst it is unnecessary to aim at a sharp cut-off, i.e., complete elimination of all frequencies below the selected one, at the low frequency end of the scale, it is desirable at the high frequency end that the cut-off be quite sharp.

This is impossible if condensers connected between plate and ground are used as tone controls, because the impedance factor of the condenser is such that the tone control effect will increase with an increase in frequency and will have a linear rather than a sharp cut-off effect.

Probably the best simple way out of this difficulty is to combine an inductance with a condenser, connecting the two in series to form a resonant circuit across the output of the controlled valve.

As in all forms of control of amplifier circuits, it is desirable that the tone control be obtained in the early stages of the amplifier. We come next to the consideration of another form of tone control—i.e., one which compensates for the apparent loss of high and low frequencies as the output level of the amplifier is reduced.

This effect is due to the ear's response to tones of different frequencies. The greatest audible effect for a given volume takes place in the 300 to 3000 cycle range, so that if we reduce the output of an amplifier we find an apparent loss of both high and low notes.

Two simple circuits to overcome this difficulty have been developed by the engineers of the A.W. Valve Co. for application to broadcast receivers. They can be applied with equal satisfaction to P.A. amplifiers.

Bass Boosting Circuit.

In Fig. 1 we see a convenient audio frequency pentode hooked up to the grid of the following tube. Resistor R1 is a 50,000 ohm resistor, whilst the standard 250,000 ohm plate load for the 6C6 tube is made up with the 200,000 ohm resistor, R2. The grid resistor for the following tube is a 1 megohm one.

Condenser C is connected between earth and midpoint of the plate resistors, R1 and R2.

Like the grid coupling condenser, C has a capacity of .02 mfd. When the switch is closed, resistance R2 is short-circuited as far as the higher audio frequencies are concerned, with the result that the amplification curve of what was previously a "flat" amplifier shows a rise from 100 cycles downwards with a peak 7 db. above the normal level at about 50 cycles. If C has its capacity reduced to .01 mfd., the capacity of the grid coupling condenser remaining at .02 mfd., then the 50 cycle peak is increased to 9 db.,

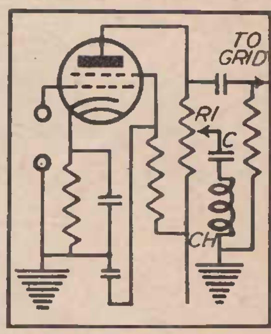


Fig. 2. High and Low Frequency Tone Compensating Circuit.

there being a corresponding rise in amplification all the way from 1000 cycles. This is purely a bass boosting circuit, which should be switched on only at low volume levels if over-accentuation of the lower frequencies and consequent distortion is to be avoided.

Tone Compensating.

In Fig. 2 we find a variation which employs a tuned circuit resonating at 1000 cycles. With this circuit both the bass and the treble are boosted at low volume. The same 6C6 type pentode is used as audio amplifier tube, and is connected to the following tubes grid through the customary .02 mfd. condenser. Condenser C has a capacity of .01 mfd. whilst the choke coil, CH, has an inductance of 2.5 henries.

When the arm of the potentiometer, R1, is set at the "B" plus end of this resistor, the amplifier performs normally.

When the arm is at the midpoint of the potentiometer it will be found that the output level has dropped 5 db., from 1000 to 2000 cycles. However, at the low frequency end there is less than 1 db. loss at 100 cycles, and some 2 db. loss at 10,000 cycles.

When the arm is moved to the plate end of the potentiometer a severe trough is introduced in the response curve, which then shows a 12 db. drop from the original level at 1000 cycles, but a fall of only 4 db. at 100 cycles and 2.5 db. at 10,000 cycles.

The foregoing information on tone control systems is brief, but it will indicate to amplifier users the general principles upon which the boosting or attenuation of different frequencies are based.

MICROPHONES

Various Types Analysed—Direction and Non-Directional Characteristics —Selecting the Right Microphone — Loud Speaker as Substitute.

THE best P.A. amplifier and loudspeaker system is no better than the microphone associated with it. In this section we propose to review briefly the various types of microphones, deal with their advantages and disadvantages and give hints on their usage.

There are five distinct types of microphones—the Carbon, the Velocity or Ribbon type, the Crystal, the Condenser, and the Dynamic.

The Carbon Microphone consists of a stretched diaphragm across the centre of which rests a pile of loosely-packed carbon granules mounted in a carbon cup. Sound pressure waves on striking the diaphragm increase or decrease the pressure on the granules,

A direct current is applied to the granules by an external source of supply. The varying pressure on the granules cause them to change their resistance and thus convert the direct current passing through them into a series of variations, the amplitude of which changes in accordance with the amplitude and frequency of the sound waves impinging on the diaphragm.

Advantages: The carbon microphone is cheap and effective. It is a low impedance type and thus can be connected to the amplifier through unshielded cables running for 1000 to 2000 feet without giving trouble from hum pick-up. There are both single and double button type carbon microphones, but the latter is more generally used.

A variation of the standard carbon microphone is the Reiss type in which a sheet of very thin rubber or mica is used for the diaphragm.

The Carbon microphone has a relatively high output being only 32 db. down.

Disadvantages: The frequency response of the carbon microphone is limited, the noise level is high, and increases with age, and an exciting current is required for its operation. Furthermore, it is not linear in pick-up characteristics, the response falling off badly as the angle between the microphone and the sound source is increased.

Points of Operation: The current flowing through a carbon microphone should be kept to a maximum of 10 m.a. to prevent "frying" and similar background noises. The finer the Carbon granules used in the microphone the lower should be the exciting current. This should be read with a milliammeter and not calculated with the aid of a voltmeter. If desired, the 10 m.a. exciting current may be drawn from the voltage divider in an a.c. or a.c.-d.c. receiver.

Crystal Microphones are of two types. One employs a sound cell with a diaphragm attached to some point on it. In this type the sound waves strike the diaphragm and cause it to vibrate the sound cell which is so constructed that feeble currents are generated in proportion to both the frequency and the amplitude of the sound pressure waves which strike the diaphragm.

The diaphragm is usually of duralumin. This type of crystal microphone has a comparatively high output but has not nearly so good a frequency response as the multi-cell type.

In the **multi-cell type** the diaphragm is eliminated, and various series and series parallel connections of crystal slaps, depending upon special service requirements, and the ideas of the different manufacturers are used. The multi-cell type has a much better frequency response than the diaphragm type.

One type of Crystal microphone combines a Ribbon type mike in the same housing as the Crystal unit.

Advantages: The Crystal microphone is rugged and is suitable for both indoor and outdoor work. It has the excellent attribute of being free from blasting and is usually lower in cost than Ribbon types.

Its high frequency response depends on the methods used to couple it to the amplifier input circuits but with normal care is quite good. It can be designed as a really non-directional type.

Disadvantages: The gain is low, being from 65 to 70 db. down. Its high impedance necessitates the use of a very high impedance line to couple it to the amplifier. Matching transformers can be used but are rather expensive. The line losses affect output at all frequencies but the higher frequencies are particularly affected.

Operating Points: For short lengths of cable, up to 30 feet, the crystal mike may be connected directly into the grid circuit of the input stage. However, a parallel resistance of not less than 5 megohms should be shunted across the tube input and, where there is any possibility of grid current flowing, the microphone should be isolated by means of a .02 mfd. condenser.

Where strong R.F. fields exist the microphone cable should be kept as short as possible. If transformer matching is employed for long line work the winding to which the microphone is connected should have an impedance around 100,000 ohms.

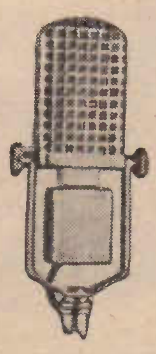
The Condenser Microphone operates on the principle of changing capacity between two electrodes. A stretched metallic diaphragm, usually duralumin, is insulated and separated a very small distance from a flat electrode. Sound pressure waves cause the flexing of the diaphragm and thus the changing of the capacity existing between it and the flat electrode.

The two electrodes, the diaphragm, and the stationary electrode usually operated with a potential difference of 90 volts or more between each other.

Advantages: The frequency response of the Condenser microphone usually is excellent, and the noise level is extremely low. However, the fidelity often is affected seriously by what is termed "cavity resonance"—the air columns which exists in the 1/1000th inch gap between the diaphragm and the stationary electrode. The aim of Condenser microphone designers is to keep the capacity high and the cavity resonance low.

Disadvantages: The Condenser microphone has a fairly low output, being about 70 db. down. In this it compares with the crystal and the dynamic types. Another disadvantage is that due to the capacity effects which exist in a cable the pre-amplifier has to be mounted in the microphone housing. Another drawback is the necessity of providing a polarising potential.

The Condenser microphone has been



A Modern Velocity Microphone, the Philips Type 9514.

(Photo. Courtesy Philips Radio.)

superseded by the Ribbon, the Dyna, mic, and the Crystal types.

The Velocity or Ribbon Microphone does not employ a diaphragm but uses a loosely suspended ribbon maintained in an intense magnetic field. Sound waves striking the ribbon cause it to vibrate, cutting the magnetic field, and thus producing varying potentials across the ribbon.

Advantages: The greatest advantage of the Ribbon mike is that it posseses marked directional properties which permit it to be used under bad acoustic conditions without fear of trouble from feedback. No polarising voltages are required with the modern Ribbon which is robust in construction and designed for use on both high and low impedance lines.

This latter feature makes for economy in mixer circuits and transmission line matching equipment. Noise level is at a minimum and the frequency response is practically only limited by the design of the coupling transformer.

Disadvantages: The Ribbon is subject to blasting troubles and is not suitable for work in noisy locations.

The Dynamic Microphone is a fairly recent development in the field of electro-acoustic devices. It is a completely self-contained unit and does not need any form of excitation. It consists of an extremely light voice coil mounted on a diaphragm. The voice coil is maintained in an extremely strong magnetic field supplied by a permanent magnet.

Advantages: The Dynamic microphone has an extremely good frequency response. No polarising voltages are required and the matching transformer which can be wound for either high or low impedance lines is mounted in the microphone housing. Most types of Dynamic mikes are non-blasting. Their noise level is extremely low.

Disadvantages: The Dynamic is relatively insensitive being between 75 and 90 db. down. Furthermore, it is rather heavy and so not suitable for mobile work. Its construction is such that it must be handled with extreme care.

The R.C.A. Model 74B Velocity Microphone.
(Photo. Courtesy A.W.A.)

* * *

Selection and Use of Mikes.

HAVING dealt with individual types of microphones we come now to a general survey of the field and a brief discussion on the selection and use of microphones.

The first thing to be considered is Frequency Response. As we have mentioned earlier this is governed to a large extent by the type of service. For music it is desirable that the microphone shall have as wide a range as possible. In this application the Crystal, the Ribbon, and the Dynamic type microphones stand out.

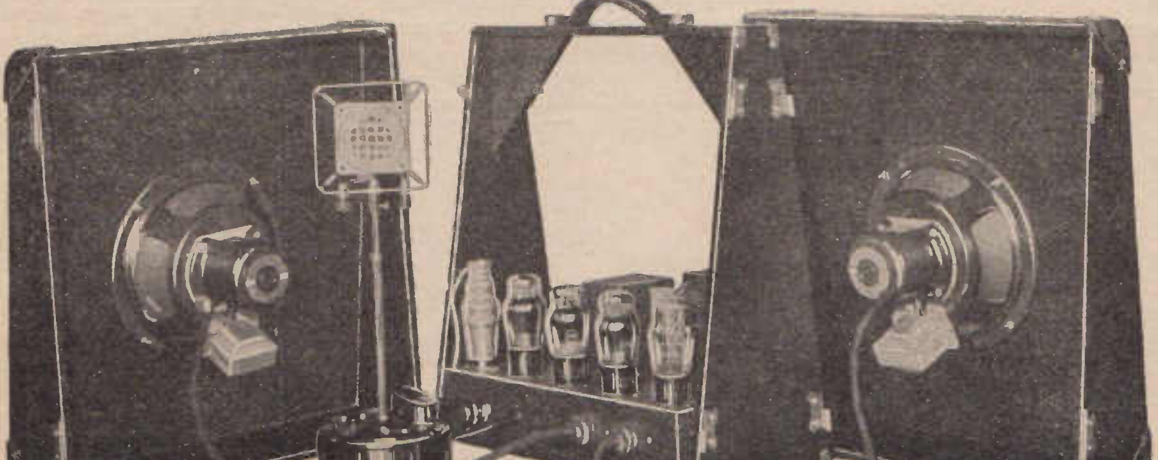
For speech, particularly in noisy locations, it is desirable that the lower frequencies be eliminated, and the high frequencies boosted. It is easy to eliminate the former by reducing the values of coupling condensers, but the boosting of the latter may call for some form of filter system in the amplifier. It is interesting to note, however, that some types of Crystal and Dynamic microphones have a definitely rising characteristic at the high frequency end. For best "break through" of speech it is desirable that this response hump should take place between 1000 and 4000 cycles. Above this frequency the lift will have little practical effect.

The rising characteristic should be sought in the microphone and not in the amplifier. For general outdoor p.a. work the length of microphone cables, with their resultant attenuation of the high frequencies does not matter much for the diffusion of high frequency sounds is such that the majority of those listening to a p.a. system wouldn't be able to hear them in any case.

* * *

Directional Characteristics.

FOR indoor work it is sometimes desirable to employ microphones which possess a marked directional characteristic, but this expedient, to prevent trouble from acoustic feedback, is rapidly passing, due to the in-



This suitcase type portable p.a. amplifier is extremely compact, yet is capable of especially good coverage. Although a carbon type microphone is shown, it is also adapted for use with crystal and similar low gain mikes.
(Photo. Courtesy A. J. Veall Pty. Ltd.)

creasing use of audio automatic volume control.

Blasting is one of the bugbears of microphone operation. This occurs when a mike is being operated in a high noise level area and it is necessary to speak right into it in order to over-ride the outside noise. It is a fault experienced most with Ribbon mikes and least with the Crystal and double button Carbon types.

Wind effects are another bugbear of the outdoor p.a. worker. The action of the wind on the Diaphragm of Condenser, Carbon, and Crystal types, on the ribbon of the Velocity type, and on the cone of the Dynamic type places a stress on these driving mediums which causes severe displacement. This in turn affects the effective sound pressure on the driving unit and the frequency response of the microphone suffers.

A simple but none-the-less effective method of minimising wind effects is to tie a handkerchief over the microphone diaphragm.

Another point worthy of attention, particularly in mobile systems which have, by virtue of their application, to be compact in design is the placing of the microphone transformer on the same chassis as the amplifier power unit. Unless care is taken, both in the careful shielding of the microphone transformer and in its orientation with respect to the power transformer and filter chokes, a high hum level will be introduced. It is worthy of note that at least one Australian P.A. equipment manufacturer makes a doubly shielded microphone transformer.

* * *

Substitute Microphones.

THE design of the dynamic microphone leads one to think of P.M. type dynamic speakers as substitutes for microphones. They are used fairly extensively for intercommunication systems where "tall-back" is provided for and have proved quite satisfactory in this regard. Some dynamics, however, seem to have a tendency to blast.

Their gain is high, and usually they can be connected straight into the first audio stage of a standard radio receiver, and will provide an output approximately equal to that of a pick-up.

Local speaker manufacturers can design their speakers in such a way as to avoid the bass resonances which usually are present in speakers for reproduction work and this results in the limination of that "woofiness" often encountered when a standard dynamic speaker is used as a mike.

MICROPHONE CHARACTERISTICS

BELOW is listed information on those types of commercially-made microphones which are readily available and are priced within the reach of the average P.A. operator.

Make and Model.	Type.	Gain.	Freq. Range.	Other Details.
Amplion				
190 & 192	Car.	——	——	Transverse current type. Voltage, 2-40. Current, 3 to 60 m.a. Resistance 600 ohms.
Amperite				
SR80	Rib.	-65db.	40-15,000	Studio Type Output. Impedance 50-200 ohms.
SR80H	Rib.	-65db.	40-15,000	
RBSN	Vel.	-68db.	60-8,000	
RSHN	Vel.	-68db.	60-8,000	
RAL				
RAH		-68db.	60-7,500	
7J				
7JH		-70db.	60-7,500	
HDL				
HDH		-68db.	60-7,500	
KTH				
KTL		-40db.		Contact microphones.
Electro-Voice				
V2	Vel.	-68db.	40-14,000	Gain taken with 20 feet cable.
V3	Vel.	-66db.	40-14,000	High gain P.A. type.
V4	Vel.	-66db.	40-14,000	Calibrated recording and studio type. All designed for 500 ohm. line.
Comet	Carb.	——	50-4,500	Low hiss level but not recommended for music. Resistance, 200 ohms per button.
201S	Carb.	——	50-5,000	Hand mike. Rising freq. characteristic.
Piezo-Astatic.				
D104	Crystal	-65db.	——	Impedance 80,000 ohms at 60 c.p.s.
Shure				
70H	Crystal	-48db.	50-7,000	High gain p.a. type.
720A	Crystal	-63db.	40-7,500	Also uni-directional -63db. and bi-directional -68db.
700A	Crystal	-52db.	50-7,500	Compact type.
701A	Crystal	-52lb.	30-10,000	
702A	Crystal	-52db.	30-10,000	Non-directional.
85A	Crystal	-68db.	30-10,000	Non-directional.
American				
D7T	Dynamic	—56	70—8500	Semi-dir.
C5	Crystal	—54	40—9000	Non. Dir.
AG	Crystal	—52	40—8700	Semi-dir.
A1	Carb.	—38	50—8800	Semi-dir.
CD4	Carb.	—35	70—6600	Semi-dir.
EL4	Carb.	—32	70—6000	Semi-dir.
Bruno				
SK4	Vel.	—64	50—12,000	Dir.
SK2	Vel.	—78	60—10,000	Dir.
Philips				
4210	Carb.	—	—	—
9514	Rib.	—	—	Dir.
R.C.A.				
74B	Rib.	—66	70—8000	Bi-Dir.

In selecting microphones for specific service four things must be considered. These are Frequency Response, Mobility, Robustness, and Cost. The first we have already dealt with. Mobility is essential with portable equipment and for this reason any type which requires an exciting voltage must be ruled out. Robustness is an essential in all but permanent installations for, if a mike is to be moved around, it must be of such construction as to require only normal care. In this regard the crystal is probably best of all, having regard to other requirements.

From a cost versus performance viewpoint, there is not much to choose between the Crystal and the Ribbon.

PICK-UPS AND GRAMO. MOTORS

Crystal or Magnetic Pick-ups—Record Wear—Correct Tracking Methods—Frequency Response Juggling—Care of Motors.

FEW amplifier components are productive of so many arguments as the gramo. pick-up. One amplifier user will swear by a pick-up, which others only swear at, whilst the types which HE dismisses with a wave of the hand may give excellent service to many of his confreres.

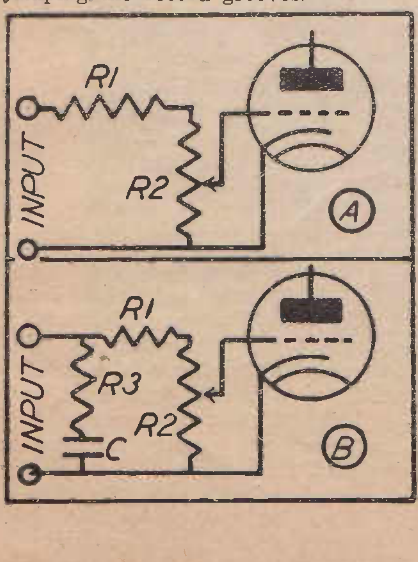
For all general applications we find pick-ups divided into two major classes—the Magnetic and the Crystal. The magnetic was the earliest type of gramo. pick-up available, and the fact that to-day it still is widely used says much for its general performance.

Proponents of the crystal pick-up will demonstrate that it possesses an extremely wide frequency range, and does not begin to drop until frequencies as low as 50 cycles or as high as 8 to 10,000 cycles are reached. The average magnetic speaker cannot approach this wide range, but where reproduction over the 100 to 5000 cycle range is all that is required, the generally robust characteristics of the magnetic pick-up plead urgently for its employment.

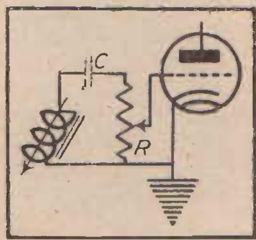
Although we do not advise rough usage of any pick-up, there is no doubt that the magnetic types will stand far more man-handling than even the most robust crystal type.

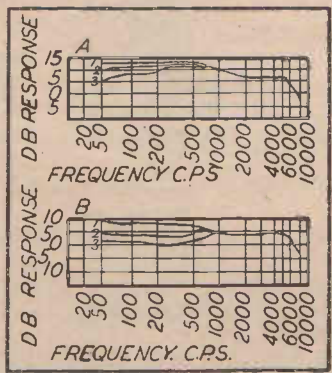
Scratch Filters.

A point which should be watched in selecting a gramo pick-up is its weight. The actual weight of the pick-up head does not matter if this is counterbalanced, but, where no compensation is provided, the aim should be to keep the weight down to just that amount necessary to prevent the needle from jumping the record grooves.



Whilst on the subject of frequency response it might be as well to touch briefly on that often discussed question of scratch filters. In reality, when high fidelity recording is required, a scratch filter should never be incorporated because its very function is to restrict the high frequency response.





Above is shown the conventional method of connecting a piezo pick-up into circuit. Below are the response curves resulting from the circuit variations shown in Figs. A and B.

However, where worn recordings are used or where in large installations it is necessary to keep surface noise down to a minimum, simple scratch filters may be made up with resistors. For crystal pick-ups merely connect a half megohm resistor between the pick-up and the grid of the input tube. For magnetic pick-ups parallel a resistance equal to the impedance of the pick-up across the latter's output leads.

Fig. 1 shows a simple input circuit recommended for use wth crystal pick-ups. The potentiometer should have a minimum resistance of 500,000 ohms. Lower values will attenuate the low frequency response. It is undesirable to apply any polarising voltage to the crystal element, and for this reason the condenser, C, shown in the dotted line, should be connected in circuit where such a voltage is likely to be present. C may have a capacity of from .02 to .1 mfd.

The two sets of response curves show how the frequency characteristic of a crystal pick-up may be altered by judicious rearrangement of the input circuit resistances and capacities.

In Fig. A the greatest cut-off at the low frequencies is obtained when R1 and R2 total 5 megohms. The intermediate curve is obtained when R1 and R2 total 1 megohm, whilst the top curve is obtained when R1 and R2 total 2 megohms. In each case the resistance of R1 equals that of R2.

In Fig. B and Circuit B we find the top curve is obtained when R1 and R2 total 2 megohms, R3 is 50,000 ohms and C is .002 mfd. The middle curve results when R1 and R2 total 500,000 ohms, .005 mfd. For the lower curve, R1 and R2 total 500,000 ohms, R3 is 50,000 ohms, and C is .01 mfd. In each of the three cases given for Fig. B, R1 is equal to R2.

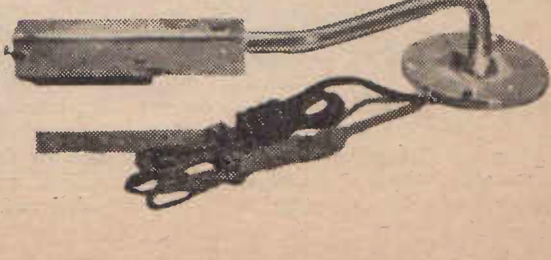
Mounting the Pick-up.

Considerable care must be taken in mounting the pick-up on the motor board, because if any inaccuracy exists here, both the reproduction and the record wear will be affected.

Two general types of pick-up arms, the bent and the straight, are available. The bent arm generally will be found to provide more correct tracking.

In any case, follow this procedure in mounting a pick-up. Taking the centre spindle of the motor shaft, draw a line at right angles out towards the edge of the turntable. Now, taking the inner and outer circles of the start and finish of the record, describe an arc A to B, on this line. Next bisect this arc at its midpoint, and project a line from the bisection at right angles. Project two more lines from the inner and outer terminations of the arc to

At the left are shown the compensating circuits responsible for the curves above. The illustration at the right is of a typical "bent arm" crystal pick-up.



(Photo. Courtesy A. J. Veall Pty. Ltd.)

form an isoceles triangle, and at the apex of this mount the pick-up.

Selection of Needles.

Needles require just as much care in their selection as was given to the purchasing of the pick-up itself. Most pick-up manufacturers specify a particular type of needle for their units. Stick to these. Use a new needle with each record, and don't try to economise by turning a needle after it has been played once. Full tone needles should always be used.

This provision against departing from the manufacturer's needle specification applies particularly to needle armature types of pick-ups.

With magnetic pick-ups hold the needle in such a way as to take up the torque imposed on it during tightening, otherwise the pick-up armature will be forced against the pole-piece. Any attempt to fit new rubbers to a pick-up will usually be fraught with disappointment.

It is worthy of note, too, that with magnetic pick-ups it is essential that pains be taken to keep them away from metallic dust.

With high gain amplifiers it is desirable that the pick-up connecting leads be run in braided cable, the braid of which should be earthed to the motor frame and the main earth point.

These braided leads, however, should not be so stiff as to impose drag on the movement of the pick-up arm.

The Stroboscope.

Another essential to good quality reproduction is the speed at which the record is played. To-day the general standard is 78 or 33 r.p.m. Not many of the slower speed recordings will come the average amplifier user's way, but the same provision for accurate running must be observed with them as with the 78 r.p.m. discs.

The simplest method of accurately determining the speed of a record is by means of a stroboscope. A stroboscope disc can easily be made up from a sheet of paper or light cardboard. It consists merely of a number of black lines on a white background. The lines are set out in the form of spokes, but, unlike spokes, should not converge towards the centre.

The exact number of lines may be determined from the following formulae

$$\frac{2F \times 60}{\text{R.p.m.}}$$

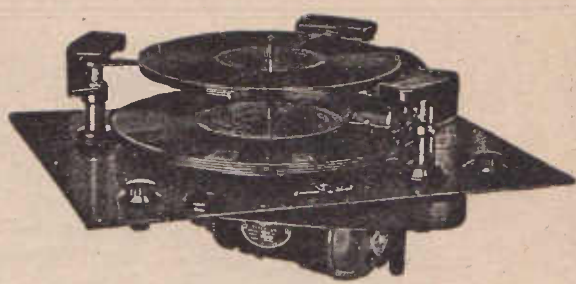
Where F = the frequency of the alternating current supply mains.

R.P.M. = the speed at which the record revolves.

For a 78 r.p.m. record on a 50 cycle supply system the stroboscope should have 77 black spokes. The disc might be six inches in diameter, and the spokes one inch in length and one-eighth of an inch in width. They should be separated from one another by approximately an eighth of an inch. The stroboscope cannot be used on direct current supply line.

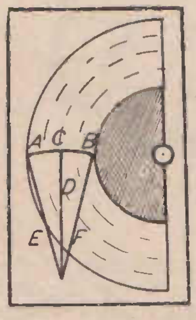
To use it, place the record on the turntable and the stroboscope on top of the record, so that the hole in the centre of the former passes over the motor shaft. Start the gramo motor and place the pick-up on the record.

Hold a 50 cycle light source above the gramo turntable and adjust the speed of the gramo until the black spokes on the stroboscope appear motionless.



The Garrard R.C.1A Automatic Record Changer.

(Photo. Courtesy Howard Radio Pty. Ltd.)



Method of ensuring correct pick-up tracking.

Motor Units.

We have two general types of electric gramo motors, and a spring driven unit to select from. The particular type will depend upon the power supply available, although it is of interest to note that a new portable gramo motor designed for both A.C./D.C. and spring operation has now been produced.

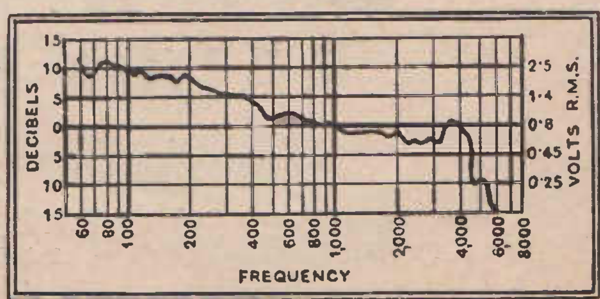
In selecting any gramo motor try and pick one with a heavy turntable, preferably one of the cast type. Maintenance of gramo motors mainly depends on commonsense attention to lubrication, and to the selection of brushes for the Universal type motors. In replacing the latter, err rather on the side of soft carbon, because too hard carbon brushes will cut up the commutator.

Speed control of the motors is confined to friction systems in the Universal and spring types, and to line frequency in the squirrel cage types. With friction type speed controls it is desirable to keep flexible the rubber, felt or leather, the latter by means of sparse lubrication with fine machine oil.

Another type of gramo motor—although it is something more than that—is the automatic record changer. Modern units capable of handling up to eight records, playing or rejecting them as desired, can be obtained at reasonable prices, and should prove a boon to the operator of dance hall p.a. systems.

Finally, be prepared to attack sparking and hum troubles by conventional suppression methods, including the shielding of all "hot" leads in the final stages of the amplifier, and by filtering the gramo motor itself should this be necessary.

One other point worthy of attention is the selection of records. When purchasing new discs, pay attention to the punching of the central hole. Sometimes this may be as much as 1/16th of an inch off centre, a fault which will gave particular trouble when crystal pick-ups are used.



The response Curve of a typical high grade Magnetic Pick-up.

(Graph Courtesy Howard Radio Pty. Ltd.)

MIXERS

Single and Multi Channel Mixers—Advantages of Electronic Method—High and Low Level Inputs.

PROPERLY designed mixer systems are essential in modern public address equipment. The day when the change-over from one pick-up to another or from a pick-up to a microphone could be effected with the accompanying "bang," as a change-over switch was thrown, is gone. To-day the change-over must be noiseless, the output of one microphone or pick-up being faded in as the first one is faded out.

Again, we find many applications where it is desirable to superimpose music on the speech running through the amplifier. We must be able to control the relative levels of the two sources of sound input, and this mixing must be variable over a wide range to provide for all applications.

Probably the simplest type of mixer system is that shown in Fig. 1, but minus the series resistors, R3 and R4, between the control potentiometers and the grid of the input tube. However, such an arrangement would result in the partial short-circuiting of the two potentiometers at anything above intermediate settings of the controls, so cannot be tolerated in practical use.

Connection of the two series resistors makes the system practical, as shown in Fig. 1. These resistors, however, must be selected with due regard to the permissible grid resistance and the input capacity of the tube into which they feed. If the input capacity of this valve is high the resistance of R3 and R4 must not exceed 250,000 ohms, otherwise there will be considerable loss at the higher audio frequencies.

It is desirable, however, that their resistance shall not exceed that of the potentiometers with which they are used. Thus, with crystal pick-ups working into low input capacity tubes, the control potentiometers should have a resistance of 500,000 ohms, so that the two series resistors then should equal R1 and R2 in value.

It is important to remember, however, that where a low impedance line is being coupled into the input circuit through an impedance matching transformer that R1, for example, in Fig. 1, must still be included across the secondary of this transformer. The usual line to grid transformer has an "infinite impedance" secondary winding, so for all practical purposes we can connect a 500,000 ohm resistor or potentiometer across the secondary and still maintain a reasonably accurate impedance match.

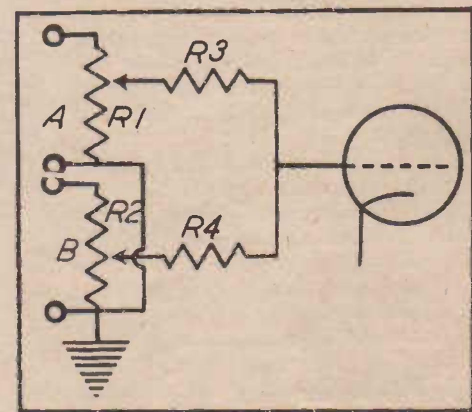


Fig. 1. A simple form of two-channel mixer.

With crystal and similar high impedance pick-ups the same procedure holds good, except that in most cases the crystal pick-up is connected directly into the grid circuit without the aid of the coupling transformer.

Interaction Troubles.

The single tube input type of mixer system is not particularly satisfactory because, try as we may, there will always be a certain amount of interaction between the two input circuits. This disability has been overcome by the development of the so-called "electronic system" of mixing, in which the inputs from two separate channels are fed separately to the grids of a pair of tubes whose plates are connected in parallel. The isolation provided in the input circuits permits each of the volume controls to be set and maintained at a level entirely independent of the other whilst the "electronic mix" which takes place in the plate circuit of the combined tubes remains in direct proportion to that of the input signals fed to the separate grids.

In Fig. 2 we find this form of electronic mixing applied to one of the twin triode tubes, such as the 6A6. Here we already have a common cathode and separate plates and grids. The input circuit A is connected to the No. 1 grid of the tube, whilst input circuit B is connected to the other grid. Separate plate resistors, R4 and R8, are connected to the "B" supply line from the two plates. Unless some step is taken to avoid it, we find that the output voltage of the mixer tube is limited if we want to keep distortion within reasonable bounds.

This is caused by the fact that each of the triode plates is in parallel. To overcome this disability series resistors R5 and R6 are connected between each plate and the grid coupling condenser for the succeeding tube.

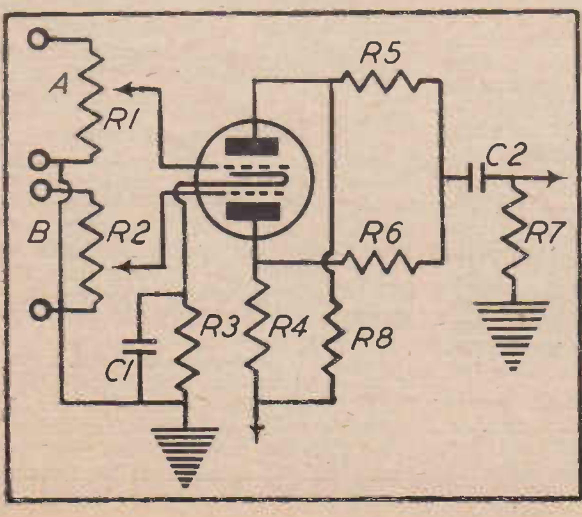


Fig. 2. In this two-channel mixer we find a twin element 6A6 type tube has been employed.

Stage Gain Figures.

According to the A.W. Valve Co., to whom credit must be given for developmental work on this and the mixer circuit shown in Fig. 3, the resistors should be 500,000 ohm ones, and under this condition a stage gain of 10 may be obtained and a peak output voltage of 35 handled without serious distortion.

Of course, for most practical applications, we will find that the input voltage is not greater, and is usually much less than a volt. The Valve Co. suggests that a further improvement of this mixer circuit can be obtained by replacing the single 6A6 with a pair of high-mu pentodes, such as 6C6's. In this case the isolating resistors, R5 and R6, are not needed, and very nearly the full gain of the pentode stage, around 120, can be realised.

The advantage of such an arrangement is obvious, for the mixer unit combines its specific function with that of a really high gain audio stage, and thus economises on the equipment necessary to raise the microphone input level to the degree necessary to get maximum output from the final stage tubes.

It is pointed out that more linear frequency response may be obtained by eliminating the cathode by-pass condenser on this stage, but that its omission will reduce the gain of the stage to approximately half.

Full details of the circuit valves for this twin 6C6 mixer can be obtained on study of the circuiting of V2 and V3 in Fig. 3. Details of the plate and cathode resistor valves will be given when we refer to the elaborate mixer circuit shown in this latter diagram.

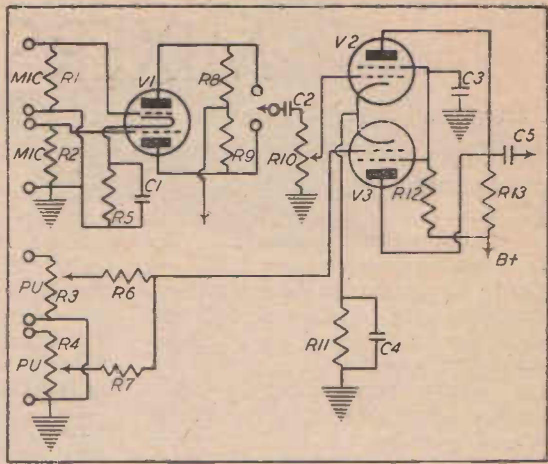


Fig. 3. An advanced form of electronic mixer, having two high level and two low level channels.

Four-Channel Mixer.

This four-channel mixer is provided with independent mixing circuits for the two microphones, another pair of mixers for the two pick-ups, and a three position switch which allows either of the microphone outputs to be combined with either of the pick-up outputs or to be used separately if desired.

Such an arrangements could be practically applied for large dance hall installations.

The reason for the inclusion of the twin triode tube, V1, is to provide the necessary gain for the operation of a low level microphone, as it is desirable that the inputs from either microphone or pick-up be approximately equal, so that too much monitoring of the controls will not be necessary, and so that conditions may be adjusted to a point where equal settings of individual controls will provide substantially the same sound output.

Going over the circuit diagram we find that with a 6A6 input tube, V1, the cathode resistor, R5, should have a resistance of 2000 ohms, and should be by-passed by a 25 mfd. condenser. The two plate resistors, R8 and R9, should be .25 megohm ones, whilst the following grid resistor, R10, should be a .5 megohm one.

The screen resistor, R12, is a one megohm one, and the plate resistor, R13, has a resistance of .25 megohms. C5 is the conventional audio coupling condenser. R1, R2, R3, and R4 are potentiometers whose values are governed by the impedances of the input circuit, as already explained. R6 and R7 are 500,000 ohm resistors, whilst the screen by-pass, C3, is a .5 mfd. one.

Going back to the circuit of Fig. 2, we find that R3 is a 1500 ohm resistor, R4 and R8 are 100,000 ohm resistors, and R5 and R6 are 500,000 ohm resistances. R7 is a 1 megohm resistance. C2 has a capacity of .02 mfd., whilst C1 is a 25 mfd. electrolytic.

MULTI POWER RATIO TRANSFORMERS

THERE are many applications in public address operation, particularly with indoor installations, where it is desirable to feed a number of loud speakers each at a different power level.

Where the transmission lines connecting the loud speakers to the amplifier all have the same impedance, the difficulty can be overcome with suitable loss networks. However, with speaker terminations such as might be encountered if some speakers were to have their voice coils connected to the line, whilst others were operated through impedance matching transformers, the problem is likely to become quite complex.

In any case, loss networks are to be avoided if possible, because, even if amplifier equipment is reasonable in price, no p.a. operator likes to think that he is wasting audio watts in non-productive resistors.

The solution to this difficulty, as expounded by Mr. J. G. Parr, manufacturer of Parco P.A. equipment, lies in the use of Multiple Power Ratio transformers. From a study of the operation characteristics of this type of transformer it would seem that their inclusion in complex sound distribution systems is almost essential.

The Multiple Power Ratio transformer is so designed that a number of lines of the same or different impedances may be fed with different ratios of power. For example, take the case of an 18 watt amplifier using a pair of 42's to feed three 500 ohm lines. Line No. 1 is to take 10 watts, Line No. 2 is to take 6 watts, and Line No. 3 is to take 2 watts. In the Multiple Power Ratio transformer we find a primary winding having an impedance of 8000 ohms to match the AB Class 42's and three secondary windings.

Each has an impedance of 500 ohms. The first feeds the required power to the No. 1 line, the second to Line No. 2, and the third to Line No. 3. Another point of interest is that the ratio of power distributed to each line will hold from zero to the full amplifier output.

The above information was obtained from experiments with Parco Multiple Power Ratio transformers. It is understood that transformers of this type are specially designed by Parco and no stock lines are manufactured.

AUTOMATIC VOLUME EXPANSION

Advantages of Expansion—How Circuit Operates—Operation Data—Faults to be Guarded Against.

ONE of the most difficult problems encountered by gramophone record manufacturers is the maintenance of the original ratio between the lowest and the highest levels of the recorded sound. This is impossible in the case of a symphony orchestra, so that the sound picked up by the recording amplifier system must be monitored in such a way that the loud passages for music are amplified to a lesser degree than the soft ones. The result, of course, is a form of distortion because the true tonal perspective has been lost.

To overcome this difficulty the Volume Expander has been developed. In this Expander the amplifier tube, a 6L7, has a variable gain, which is greater for a high than a low amplitude signal. Thus the Expander amplifies the loud signal more than the soft one, and can thus restore the volume range of the original to the music reproduced from a record.

P.A. Application.

The Expander has considerable application to public address equipment, but at the present time, not because of inherent technical faults, but rather due to the failings of broadcast stations, is not very suitable for use in radio receivers. One point which should be borne in mind before attempting to use Volume Expansion is that sufficient power reserve must exist in the output stage to take full advantage of the Expander's capabilities. Broadly, we may say that no amplifier having an output power lower than 12 watts should be fitted with an expansion system.

The heart of the Volume Expander shown in the circuit diagram on this page is the 6L7 Injector Type mixer tube, V1. This valve possesses the useful characteristic of providing an amplification varying with the bias on its No. 3, or injector, grid.

How System Works.

As the bias on this grid becomes less negative, so the amplification of the Expander valve increases. In the circuit shown the input signal is applied to the No. 1 grid on the 6L7 and to the control grid of the Expansion Amplifier tube, the 6C5 valve, V2.

The signal is amplified separately by each of these tubes and the output of V2 is fed to the diode plates of the 6H6 tube, V3, where it is rectified. The d.c. potential developed across the load resistor, R7, as a result of this rectification, is fed through the de-coupling resistor, R9, to the injector grid of the 6L7, on which it appears as a positive bias.

Thus, when the input signal to the control grids of both the 6L7 and the 6C5 increases so the rectified voltage developed across the diode load resistor increases and the positive bias on the 6L7 injector grid is raised still further.

This increase in the positive bias on the No. 3 grid of the 6L7 results in an increase in this tube's amplification, with resultant expansion in the volume of the signal.

Time Constant.

One thing which must be given careful attention is the time constant of the rectifier load circuit. If this is made too low considerable distortion will take place. Time constants between .025 and .5 of a second have proved satisfactory, and the values of C6 and R7 have been selected on this basis.

Component Values.

C1, C4, C5.—.1 mfd. Tubular Condensers.
C2, C3, C6.—.5 mfd. Tubular Condensers.
R1, R2.—1 megohm Potentiometer.
R3.—10,000 ohm Carbon Resistor.
R4.—1 megohm Carbon Resistor.
R5, R6, R8.—100,000 ohm Carbon Resistors.
R7.—250,000 ohm Carbon Resistor.
R9.—500,000 ohm Carbon Resistor.
R10.—15,000 ohm Voltage Divider.
VALVES.—One each, 6L7 (V1), 6C5 (V2), and 6H6 (V3).

Referring to the circuit diagram, we find that the tap on R10, to which R6 and R7 have been returned, should be about 13 volts negative with respect to the cathode tap for the 6L7. Under these conditions the 6L7 plate current should be .15 m.a. for no signal.

Note, too, that the 6L7 No. 1 grid returns to a point on R10, which is 10 volts more negative than that to which the 6L7 cathode was returned. The 6L7 screen should be returned to the positive 100 volt tap on the divider. (With the present circuit arrangement this will mean the tap measuring 100 volts to the 6L7 cathode tap.)

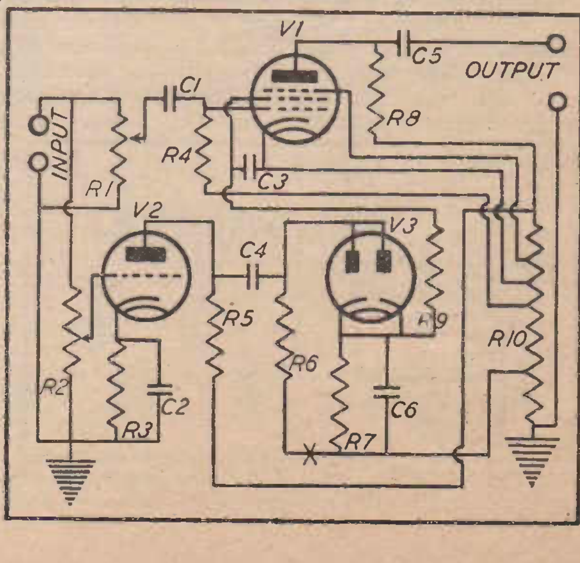
The high side of the resistance, R10, must be capable of providing 250 volts to the 6L7 cathode tap. Plenty of bypassing should be used on each of these voltage divider taps. Suggested capacities are 4 to 8 mfd. For delay purposes, where it is desired to eliminate the expansion until the signal reaches a certain amplitude, a negative voltage may be introduced on the 6H6 plates at the point X. The value of this potential will depend upon the output characteristics of the amplifier and upon the settings of R1 and R2.

Input Voltage Restriction.

It is essential that the 6L7 be operated from peak signals greater than one volt. For this reason it should be connected into the first stage of the amplifier and, when high level pickups are used, the volume control, R1, should be used to keep the input signal within the 1 volt peak limit.

When properly used in conjunction with an amplifier of suitable power rating the Volume Expansion unit will be found fully to justify its inclusion. Indeed, we shall go farther and say that anyone who has once used a Volume Expander on good quality recordings will never want to build an amplifier in which this aid to tonal realism is absent.

The circuit diagram at the right shows a practical A.V.E. circuit, in which a 6L7 tube is used as the expansion valve. The circuit is key-lettered to agree with the list of components.



POWER EQUIPMENT

Summary of Available Supply Methods—High Powered Vibrator Units—Filter Systems—Voltage Regulators—Input V Output Voltage.

THE question of amplifier power supply is one which must be considered coincidently with that of the design of the amplifier itself.

The four generally available methods of power supply are:—Batteries, Vibrator Units, A.C. or D.C. Lighting systems, and Genemotors and Converters.

Battery Power Units.

Here we have two sources of battery supply, Primary and Secondary batteries. Under the first class come dry cell "A" and "B" batteries, whilst accumulators and air cells fall in the second division. As far as "B" supply systems are concerned, we can practically rule out accumulator batteries for p.a. work. For filament supply we are forced to use either accumulator batteries or the recently developed Air Cell.

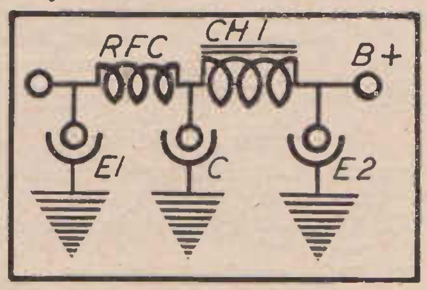
The former suffer from the same disabilities as the accumulator "B" batteries. The Air Cell also is bulky, but possesses the advantage that it will provide many hours' service before needing replacement.

The filament drain imposed on the Air Cell must be carefully studied. It must not exceed 600 m.a. at 2 volts. It is also necessary to connect a fixed resistor in series with the filament circuits to compensate for the abnormal voltage present during the first hours of the Air Cell's working life.

For small installations, delivering powers up to two or three watts, we certainly advise the use of battery power supply both for filaments and plates. Whenever possible, use the Air Cell as the filament source, because the necessity for regular recharging of an accumulator is eliminated. Unless the amplifier builder is prepared to go to the trouble and expense of building a voltage regulator unit, it is essential that class AB and B amplifiers be powered from batteries or the supply lines, and not from genemotors or vibrator units.

A thought well worthy of attention is the practicability of using batteries as a source of bias supply for a.c. operated amplifiers. Where fixed bias is required, as in some of the large AB1 and AB2 amplifiers, it is often more economical to employ light duty batteries rather than to go to the trouble and expense of special power transformers.

Whilst on the subject of battery ratings the following rule should always be observed. When purchasing batteries for either plate or filament use, always select those whose current rating are well in excess of the maximum current likely to be drawn.



A standard Vibrator Power Supply filter system.

The Light Duty type battery is capable of economically supplying a current of only 6 m.a. The heavy duty type may be used on currents around the 12 m.a. mark. The triple capacity battery, on the other hand, may be used with fair economy on amplifiers drawing plate currents up to 25 m.a., although its optimum working drain is around the 16 m.a. mark.

We come next to the latest form of power supply unit, the Vibrator. We have two general types of vibrators—the Synchronous and the Non-Synchronous. In the synchronous vibrator a second set of contacts is used to rectify the pulsating current produced in the secondary of the vibrator power transformer through the rapid making and breaking of the primary vibrator contacts.

Vibrator Power System.

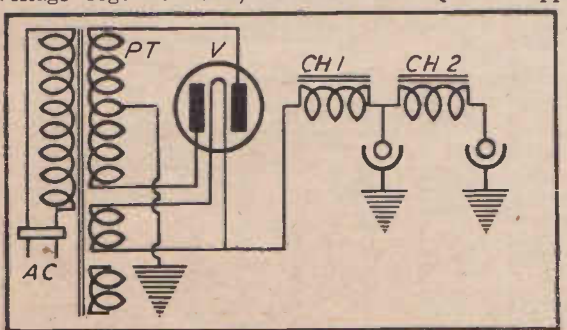
In the non-synchronous type valve rectification is used. The most useful type of valve rectifier for this purpose is the cold cathode type, such as the Raytheon OZ4, although some of the old BA and BH type rectifiers could be pressed into service. The important advantage of this type of rectifier is that it requires no filament voltage or current.

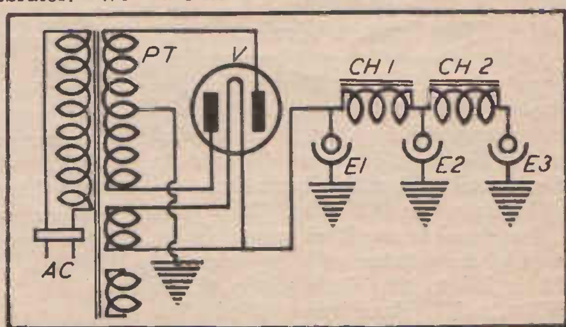
The standard type of vibrator, such as those used for batteryless receivers, will deliver about 150 volts at 20 m.a., but special heavy duty types, capable of providing 300 volts at 100 m.a.. are available in Australia. The smaller units draw about 1 ampere from the six volt battery used for their operation, whilst the large types operate with currents of from 6 to 8 amperes. To this current drain, of course, must be added the filament drain of the valves in the amplifier.

With a 300 volt vibrator it would be quite easy to obtain an audio power output of something around 10 watts from a pair of class AB operated tubes. The total current drain on the battery would not exceed 8 to 10 amperes for the whole amplifier.

One catch with the vibrator form of power supply is that even when good filter circuits are used, its voltage regulation is poor, so that unless a voltage regulator is used, it is impossible to use the vibrator form of power supply for the operation of grid current drawing amplifiers, such as the AB1 and AB2 types.

Mechanical and electrical troubles are not serious with vibrator units, and





At the left is a circuit of a choke input filter system, whilst a condenser input system is shown at the right.

reasonably long life can be expected from them. It is essential to remember, however, that the vibrator unit must be operated with a specially designed transformer and filter system, for the wave form of the alternating current developed by it is vastly different from the sine wave encountered with standard types of a.c. generators.

It is better to purchase the complete power pack rather than to attempt to build up a power unit around the vibrator.

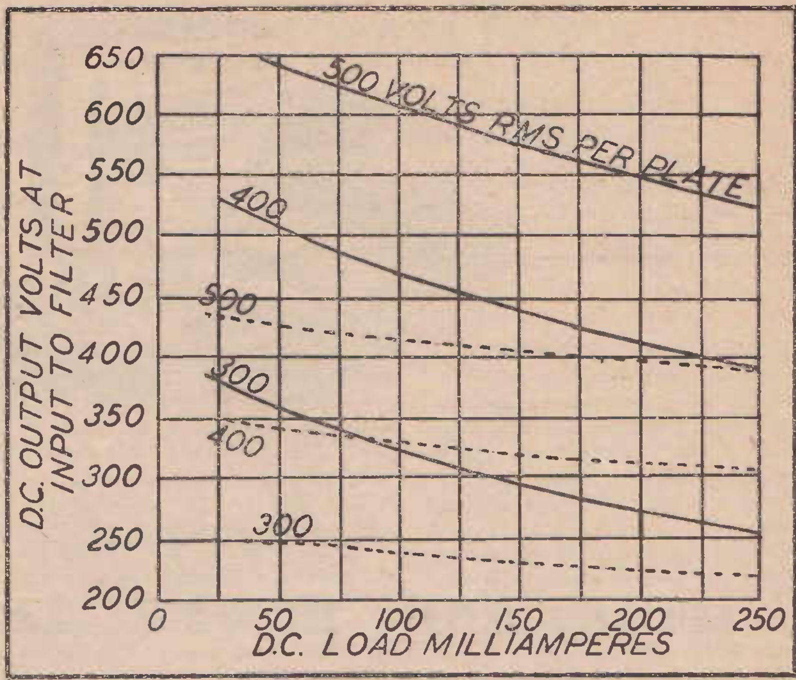
Genemotors and Converters.

In the next class of power supply units we find the genemotor and the rotary converter. The genemotor is a direct current generator, which is designed as a single unit machine and driven from a d.c. source, such as a six or twelve volt battery. Standard types include 135 volt at 30 m.a., 240 volt at 400 m.a., and 500 volt at 150 m.a. machines.

Their power efficiency is not as high as that of the vibrator units, but they are an excellent mechanical job, and will run for extremely long periods without other than lubrication attention. The current drains of the three units specified are 1.8, 12, and 7 amperes respectively, the first being at 6 volts and the other two at 12 volts. Filter units are required for these machines, and can be supplied by the manufacturers.

The operating characteristics of the genemotors are similar to those of the vibrator, inasmuch as voltage regulation is required if the units are used with grid current drawing amplifiers.

A variation of the genemotor is the rotary converter, which is energised with direct current, but delivers alternating current at a frequency of 50 cycles per second. Their application to p.a. work is greater than the genemotor, for they permit the use of standard a.c. type amplifiers on portable set-ups.



This chart shows graphically the resultant output voltages obtained at different input voltages and output currents when either choke or condenser input is used. The dotted lines represent the choke input condition.

Representative a.c. units deliver 240 volts a.c. at a current of .4 amperes, and require an input of either 12 volts at 17 amperes or 240 volts d.c. at .9 amperes.

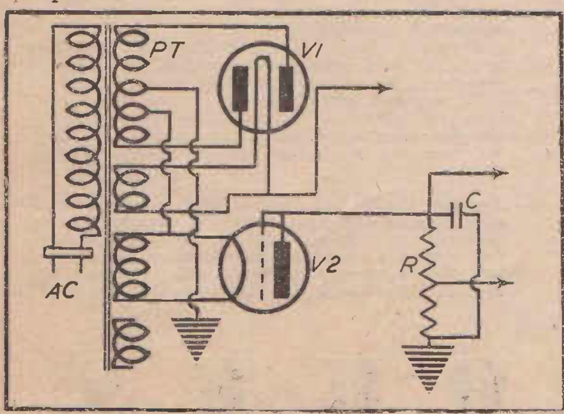
The problem of regulation is not quite so serious because there is a power transformer interposed between the amplifier and the source of supply. However, voltage regulation is still desirable. The greatest application of these rotating forms of power supply appears to lie in portable and mobile p.a. equipment.

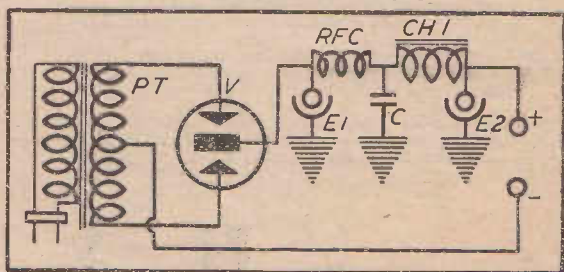
Mains Power Units.

We come finally to the most generally used forms of power supply, those derived from the A.C. or D.C. mains. With d.c. supply systems we merely interpose a suitable filter choke and a pair of filter condensers between the power line and the amplifier plate supply circuits. The choke should have an inductance of from 10 to 30 henries, but must have an extremely low d.c. resistance in order that the voltage drop across its windings shall not be great. D.C. resistances up to a maximum of 100 ohms should be looked for in filter chokes for operation on direct current supply circuits. The filters may be the conventional 8 mfd. capacity.

For a.c. work, always select transformers which have a current rating in excess of that actually required. Furthermore, make sure that the transformer possesses good load regulation characteristics. Large cores and a large number of turns per volt are used in commercially made transformers to secure this regulation characteristic.

(Continued on page 56.)





The circuit at the left shows a method of obtaining fixed bias for large power amplifiers. A tap is made at some suitable point on the power transformer secondary, and the voltage resulting from this is rectified by a directly heated tube. At the left is shown a cold cathode rectifier in a vibrator power system.

CIRCUIT SECTION

ON this and the following pages will be found a representative collection of amplifier circuits. Battery, Vibrator, A.C./D.C., and A.C. types of various power ratings have been included, and both transformer and resistance coupled amplifiers are represented.

The power ratings range from the milliwatt class to the 55 watt AB2 amplifier, using the 6L6 beam power tubes.

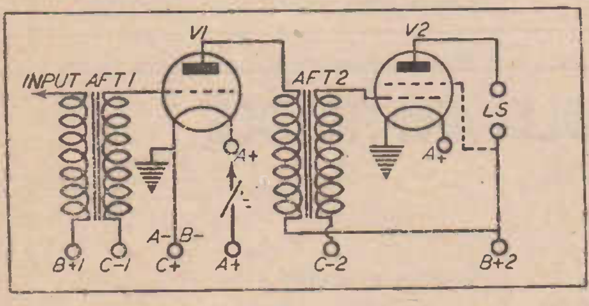
All component values have been carefully worked out and should be followed closely by the constructor.

The output transformer impedances are expressed as plate loads for single ended amplifiers and plate to plate loads for push-pull output stages. Input transformer rations are expressed as the ratio between primary and secondary windings.

All condenser voltage ratings are expressed in terms of "working voltage."

Acknowledgment is made of the courtesy of the A.W. Valve Co. and Philips Radio for permission to reprint amplifiers designed by the technicians of these organisations.

TRANSFORMER COUPLED AMPLIFIER



NOTES.

THE two amplifiers shown on this page represent the "baby" class of battery amplifiers. They may be built up from any given combination of valves and coupling transformers.

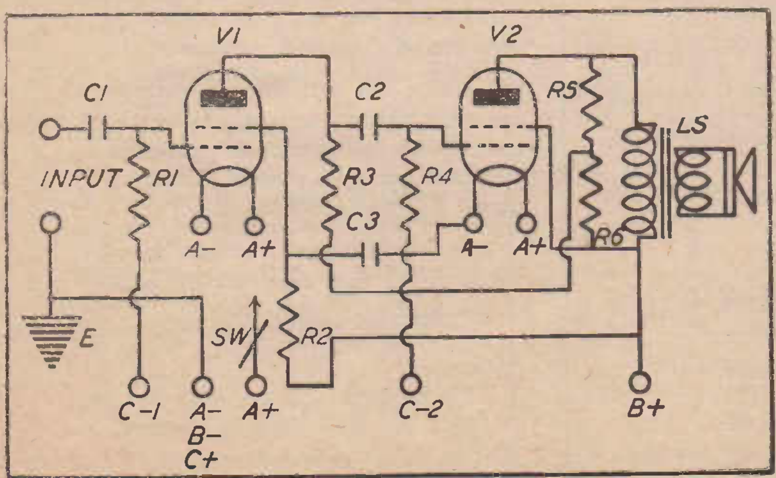
The power outputs will, of course, depend upon the valves selected and the plate voltage conditions under which they are operated.

The top circuit is that of a two-stage transformer-coupled amplifier, which may, or may not, employ a pentode in its output stage. If a triode output tube is to be used disregard the connections shown in the dotted line portion of the diagram.

The coupling transformers should be good quality ones, having a step-up ratio not greater than 1 to 3. Study of the valve data sheets on pages 69 et. seq. will provide full details as to correct plate and bias voltages.

In the lower circuit we have a resistance-coupled amplifier, in which Inverse Feedback is applied to the output tube. This amplifier possesses reasonably high gain, and when operated with correct plate and bias potentials, will be found to have excellent tonal quality.

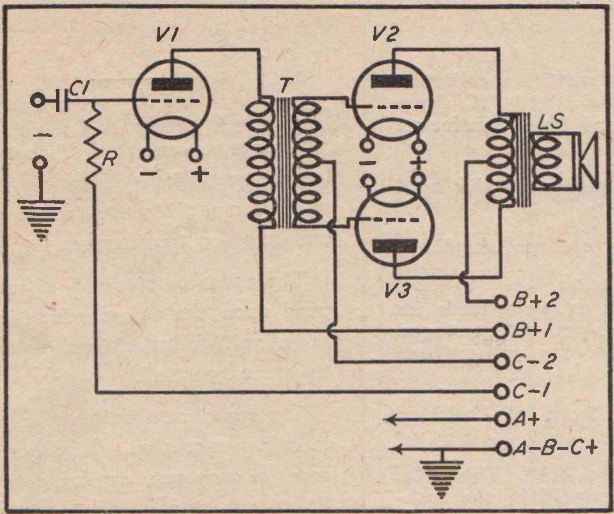
INVERSE FEEDBACK BATTERY AMPLIFIER



COMPONENT VALUES.

C1, C2—.02 mfd. Mica Condensers.
C3—.1 mfd. Tubular Condenser.
LS—P.M. Type Dynamic Speaker. Load to suit selected output valve.
R1, R4—.5 megohm Carbon Resistors.
R2—1.5 megohm Carbon Resistor.
R3—.25 megohm Carbon Resistor.
R5—.1 megohm Carbon Resistor.
R6—10,000 ohm Carbon Resistor.
SW—Battery Switch.
VALVES—See Valve Charts for suitable types.

CLASS B BATTERY AMPLIFIER



COMPONENT VALUES.

C1—.02 mfd. Mica Condenser.
LS—P.M. Type Dynamic Speaker. Load to match Class B Valves.
R—.5 megohm Carbon Resistor.
T—Class B Audio Transformer. (For correct ratio, see valve data sheets.)
VALVES—Select from Data Sheets.

NOTES.

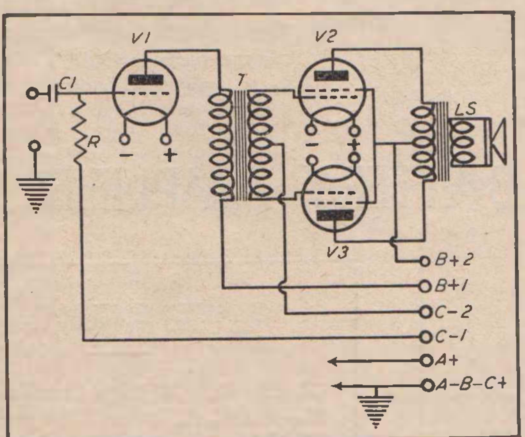
HERE is another perfectly straightforward type of battery amplifer. This one is a Class B push-pull amplifier, in which any combination of driver and output valves selected from the valve data sheets at the end of this handbook may be used.

Be sure, however, after selecting the driver and output valves, to couple them with a transformer of correct ratio and of suitable design for Class B operation. Furthermore, operate the valves with the rated plate and bias potentials specified in the valve data sheets.

In some cases it will be found that no bias is required on the Class B output stage. This same circuit may be applied to the twin type of Class B valve, such as the KDD1 and the 19. All that it is necessary to remember is to wire Grid No. 1 and Plate No. 1 to the same input and output sides of the circuit, and Grid 2 and Plate 2 to the corresponding opposite points.

Power outputs of two watts and greater may be obtained from this Class B amplifier if judicious selection of the valves is made and the correct operoting potentials are applied.

CLASS A PUSH PULL PENTODES



COMPONENT VALUES.

C1—.02 mfd. Mica Condenser.
LS—P.M. Type Dynamic Speaker. Load to suit valves selected.
R—.5 megohm Carbon Resistor.
T—Class A Push-Pull Transformer. Ratio, 1:3½.
VALVES—See data sheets for full details.

NOTES.

THIS push-pull pentode amplifier is capable of quite a good power output, but will not be so economical in operation as a Class B amplifier.

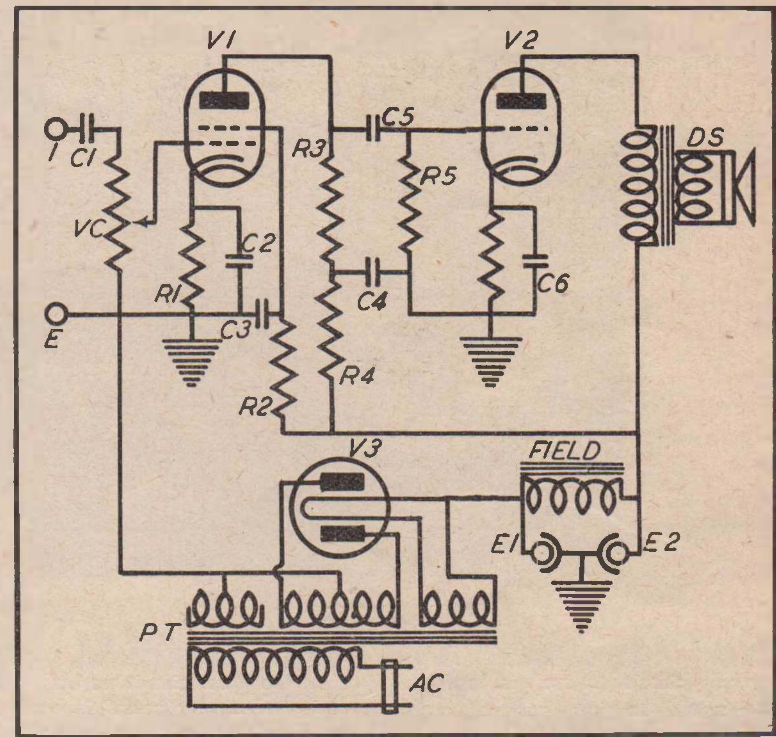
However, the fact that it does not require a special coupling transformer, and, further, may be operated from either a vibrator or a genemotor source of supply will commend it to many.

Suitable valve types should be selected from the data sheets at the back of this book.

3½ WATT TRIODE AMPLIFIER

COMPONENT VALUES.

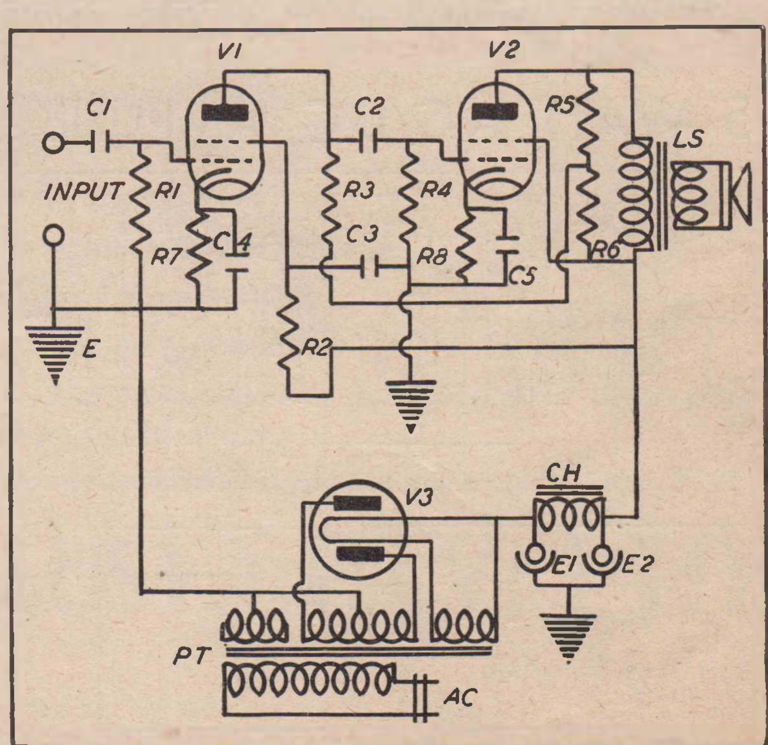
C1, C5.—.05 mfd. Tubular Condensers.
C2.—25 mfd. 25 volt Electrolytic Condenser.
C3.—.1 mfd. Tubular Condenser.
C4.—10 mfd. 300 volt Electrolytic Condenser.
C6.—25 mfd. 75 volt Electrolytic Condenser.
DS.—Field Type Dynamic Speaker, 2,000 ohm Field and 2.500 ohm Load.
E1, E2.—8 mfd. 500 volt Electrolytic Condensers.
FIELD.—Speaker Field, 2,000 ohms.
PT.—Power Transformer, 385-0-385 v. at 80 m.a., 2.5 v. at 2.5 a., 2.5 v. at 2 a., and 5 v. at 2 a.
R1.—2,000 ohm 10 m.a. W.W. Resistor.
R2.—1.5 megohm Carbon Resistor.
R3.—.25 megohm Carbon Resistor.
R4.—50,000 ohm Carbon Resistor.
R5.—.5 megohm Carbon Resistor.
R6.—750 ohm 100 m.a. W.W. Resistor.
V.C.—500,000 ohm Potentiometer.
VALVES.—One each 57, 2A3, and 80.



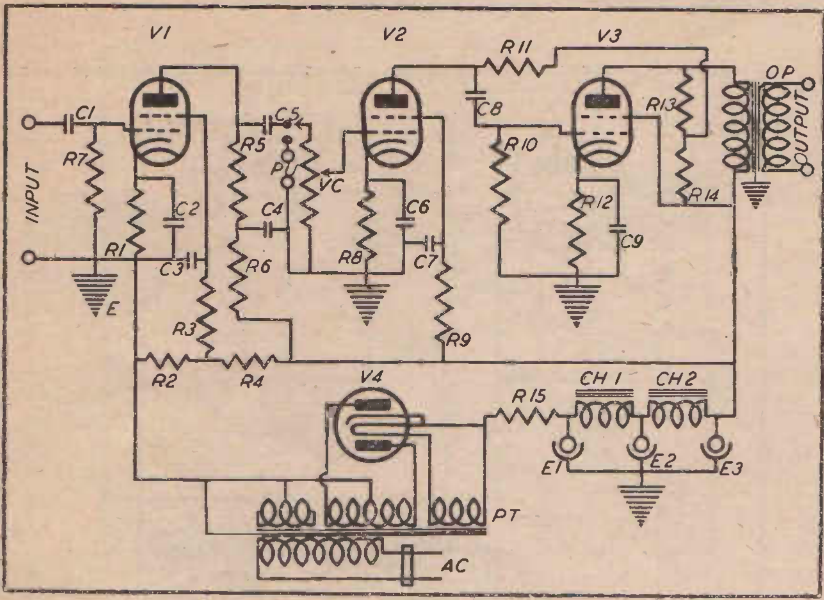
3½ WATT PENTODE AMPLIFIER

COMPONENT VALUES.

C1, C2.—.02 mfd. Mica Condensers.
C3.—.1 mfd. Tubular Condenser.
C4, C5.—25 mfd. 25 volt Electrolytic Condensers.
CH.—150 m.a. 30 Henry Filter Choke.
E1, E2.—8 mfd. 500 volt Electrolytic Condensers.
LS.—Permanent Magnet Type Dynamic Speaker, 7,000 ohm load.
PT.—Power Transformer, 385 v. at 60 m.a., two 6.3 v. at 2 a. and one 5 v. at 2 a.
R1.—.5 megohm Carbon Resistor.
R2.—1.5 megohm Carbon Resistor.
R3.—.25 megohm Carbon Resistor.
R4.—1 megohm Carbon Resistor.
R5.—100,000 ohm Carbon Resistor.
R6.—10,000 ohm Carbon Resistor.
R7.—2,000 ohm 10 m.a. W.W. Resistor.
R8.—400 ohm 100 m.a. Resistor.
VALVES.—One each 6C6, 42, and 80.



4½ WATT HIGH GAIN AMPLIFIER



COMPONENT VALUES.

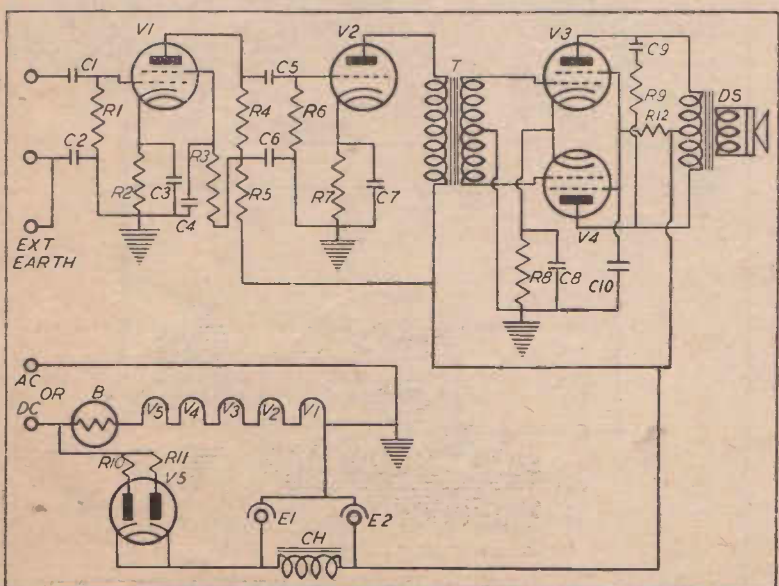
CH1, CH2.—30 Henry 100 m.a. Filter Chokes.
C1, C5, C8.—.05 mfd. Tubular.
C2, C6, C9.—25 mfd. 25 volt Electrolytic Condensers.
C3, C7.—.1 mfd. Tubular
C4.—8 mfd. 300 volt Electrolytic.
E1, E3.—8 mfd. 500 volt Electrolytic.
E2.—16 mfd. 500 volt Electrolytic.
OP.—Plate to Line Output Transformer, 6,000 to 500 ohms.
PT.—Power Transformer, 385-0-385 v. at 80 m.a., two 6.3 v. at 2 a. and one 5 v. at 2 a.
R1, R8.—2,000 ohm 10 m.a. W.W.
R2, R3, R14.—10,000 ohm Carbon.
R4.—30,000 ohm Carbon Resistor.
R5, R11.—250,000 ohm Carbon.
R6.—50,000 ohm Carbon Resistor.
R7.—5 megohm Carbon Resistor.
R9.—1.5 megohm Carbon Resistor.
R10.—.5 megohm Carbon Resistor.
R12.—250 ohm 100 m.a. W.W.
R13.—100,000 ohm Carbon Resistor.
R15.—1,500 ohm 100 m.a. W.W.
VC.—500,000 ohm Potentiometer.
VALVES.—Two 6J7G, one each 6V6G and 5Y3G.

NOTES.

THE circuit above is particularly suited to low powered amplifier use where sufficient overall gain to permit the use of a microphone is required. A feature of the design is the complete filtration of the "B" supply to the first stage of the amplifier, a desirable thing if hum is to be eliminated.

In the lower circuit we have the basic design of a very useful type of universal amplifier, capable of delivering a valuable amount of power, yet of being built compactly enough for portable use. The use of American 6.3 volt series valves in the design is a valuable feature, because of the ease with which replacement tubes can be obtained.

5 WATT A.C./D.C. AMPLIFIER

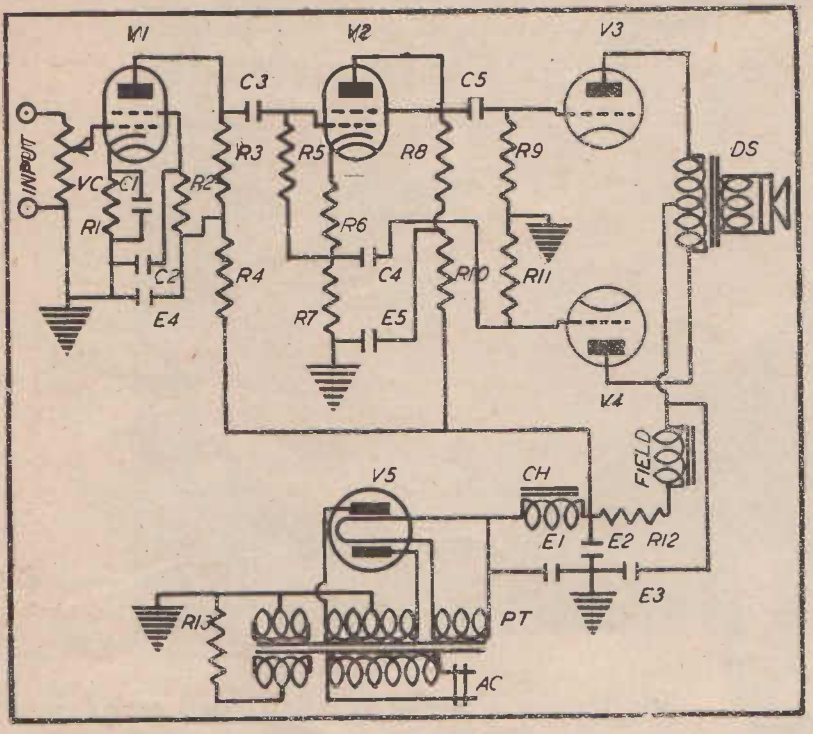


COMPONENT VALUES.

CH.—30 Henry 100 m.a. Filter Choke.
C1, C2, C9.—.02 mfd. Mica Condensers.
C3, C7, C8.—25 mfd. 25 volt Electrolytic ondenser.
C5.—.05 mfd. Tubular Condenser.
C6.—8 mfd. 350 volt Electrolytic.
DS.—Dynamic Speaker, P.M. Type, 8,000 ohm Load.
E1.—16 mfd. 350 volt Electrolytic.
E2.—8 mfd. 350 volt Electrolytic.
R1, R6.—.5 megohm Carbon
R2.—2,000 ohm 10 m.a. W.W.
R3.—1.5 megohm Carbon Resistor.
R4.—.25 megohm Carbon Resistor.
R5.—50,000 ohm Carbon Resistor.
R7.—2,700 ohm 50 m.a. W.W.
R8.—225 ohm 150 m.a. W.W.
R9.—15,000 ohm Carbon Resistor.
R10, R11.—100 ohm 150 m.a. W.W.
R12.—3,000 ohm 25 m.a. W.W.
T.—Class A. Coupling Transformer Ratio (Pri. to Sec.), 1 to 3.
VALVES.—One 6C6, one 76, two 43's and one 25Z5.


Mullard
VALVE
CHARTS
1938 EDITION-
FREE!

7 WATT PUSH PULL AMPLIFIER



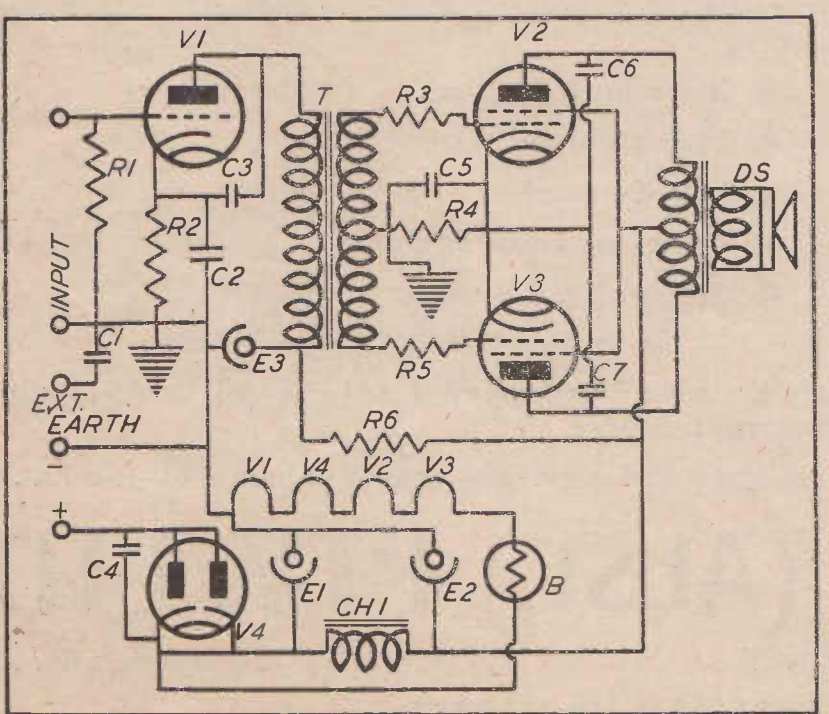
Radiotron Circuit No. A115.

COMPONENT VALUES.

CH.—30 Henry 150 m.a. 275 ohm Filter Choke.
C1.—25 mfd. 25 volt Electrolytic Condenser.
C2.—.5 mfd. Tubular Condenser.
C3.—.05 mfd. Tubular Condenser.
C4, C5.—.1 mfd. Tubular Condensers.
DS.—Dynamic Speaker, 750 ohm field and 7,000 ohm load.
E1, E2, E3, E4, E5.—8 mfd. 500 volt Electrolytic Condensers.
PT.—Power Transformer, 385-0-385 v. at 150 m.a., 6.3 v. at 2 a., 5 v. at 2 a., and 2.5 v. at 5 a.
R1.—2,000 ohm 10 m.a. W.W. Resistor.
R2.—1.5 megohm Carbon Resistor.
R3.—.25 megohm Carbon Resistor.
R4, R7, R8.—50,000 ohm Carbon Resistors.
R5.—1 megohm Carbon Resistor.
R6.—4,000 ohm W.W. Resistor.
R9, R11.—.5 megohm Carbon Resistors.
R10.—20,000 ohm Carbon Resistor.
R12.—225 ohm 150 m.a. W.W. Resistor.
R13.—375 ohm 120 m.a. W.W. Resistor.
VC.—500,000 ohm Potentiometer.
VALVES.—Two 6C6's, two 2A3's, and one 83V.

8.5 WATT A.C./D.C. AMPLIFIER

(See page 40 for further details.)

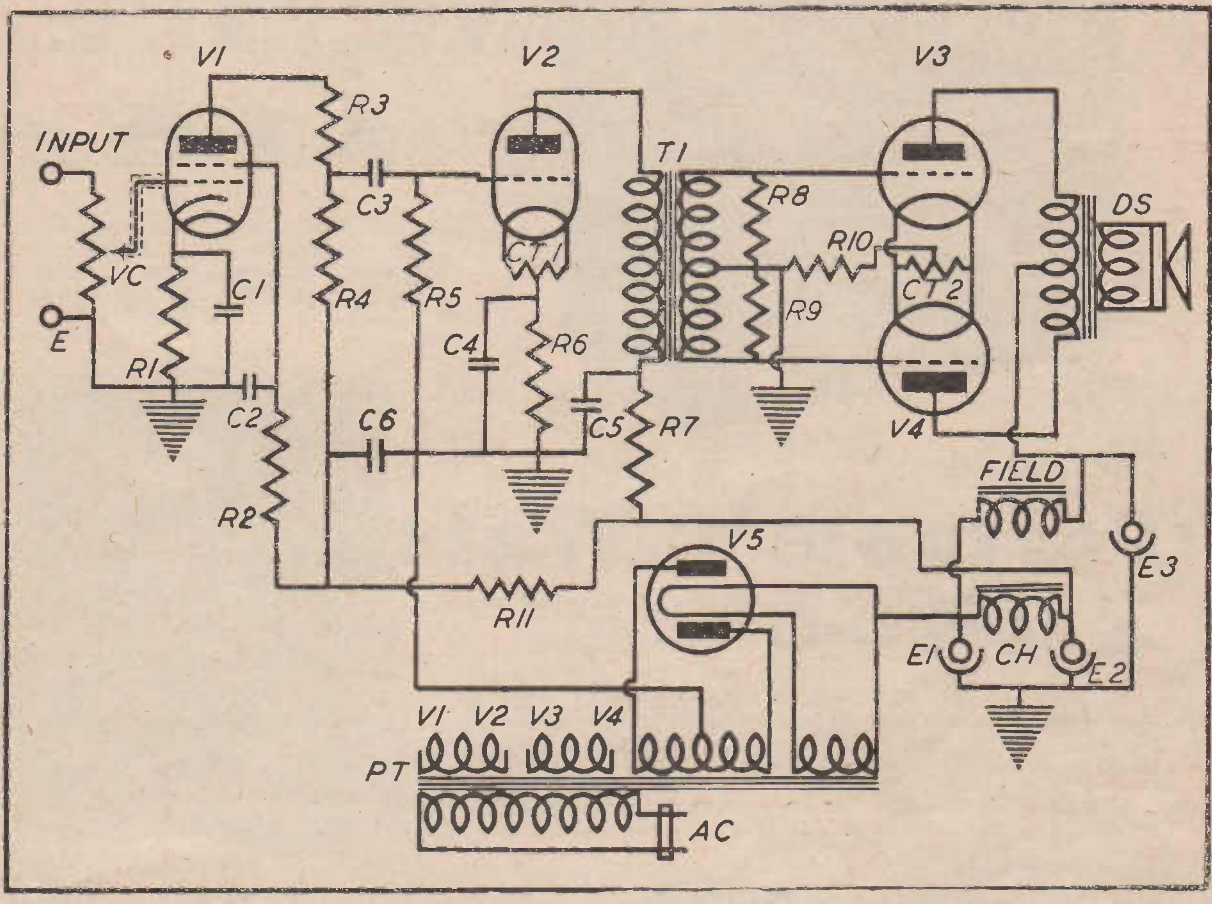


[Courtesy Philips Radio.]

COMPONENT VALUES.

B.—Mullard or Philips CY2 Barretter.
CH1.—30 Henry Filter Choke.
C1.—.02 mfd. Mica Condenser.
C2, C5.—25 mfd. 25 volt Electrolytic Condensers.
C3.—.001 mfd. Mica Condenser.
C4.—.01 mfd. Mica Condenser.
C6, C7.—.005 mfd. Mica Condensers.
DS.—Permanent Magnet Type Dynamic Speaker to match 4,500 ohm. load.
E1, E2, E3.—8 mfd. 500 volt Electrolytic Condensers.
R1.—500,000 ohm Carbon Resistor.
R2.—1,250 ohm 10 m.a. W.W. Resistor.
R3, R5.—1,000 ohm Carbon Resistors.
R4.—140 ohm 150 m.a. W.W. Resistor.
R6.—2,000 ohm 50 m.a. W.W. Resistor.
T.—Class AB Audio Transformer Ratio Primary to half Sec., 1 to 2.
VALVES.—One CBC1, two CL4's, and one CY2.

9 WATT PUSH PULL AMPLIFIER



Components List and Operating Data

C1.—25 mfd. 35 volt Electrolytic Condenser.

C2.—1 mfd. 400 volt Paper Condenser.

C3.—.1 mfd. Tubular Condenser.

C4.—25 mfd. 50 volt Electrolytic Condenser.

C5.—4 mfd. 500 volt Paper Condenser.

C6.—.5 mfd. Tubular Condenser.

CT1, CT2.—30 ohm Centre-tap Resistors.

CH.—30 Henry 50 m.a. 900 ohm Filter Choke.

DS.—Dynamic Speaker, 1,500 ohm Field and 9,600 ohm Load.

E1, E2, E3.—8 mfd. 500 volt Electrolytic Condensers.

PT.—Power Transformer, 500-0-500 v. at 120 m.a., one 5 v. at 3 a., and one 2.5 v. at 10 a.

NOTES.

HERE we find our old friend the 45 in a new guise. Modern circuiting has made it possible to obtain an audio output of 9 watts from a pair of 45's used in Class AB1 and driven by a third of these highly popular valves.

It is interesting to note that in this circuit the loud speaker field winding has been used as that section of the filter system from which the final stage valves' supply is drawn. The higher voltage required from the pre-amplifier stage is tapped off the first section of the filter.

R1.—2,000 ohm 25 m.a. W.W. Resistor.

R2.—300,000 ohm Carbon Resistor.

R3.—25,000 ohm Carbon Resistor.

R4.—75,000 ohm Carbon Resistor.

R5.—500,000 ohm Carbon Resistor.

R6.—1,470 ohm 50 m.a. W.W. Resistor.

R7.—3,500 ohm 50 m.a. W.W. Resistor.

R8, R9, R11.—10,000 ohm Carbon Resistors.

R10.—775 ohm 200 m.a. W.W. Resistor.

T1.—Coupling Transformer Ratio (Pri. to ½ Sec.), 2-1.

VC.—10,000 ohm Potentiometer.

VALVES.—One 57, three 45's, and one 5Z3.

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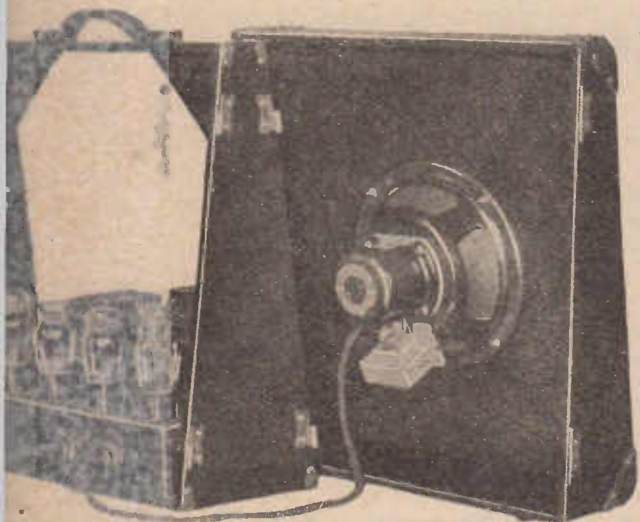

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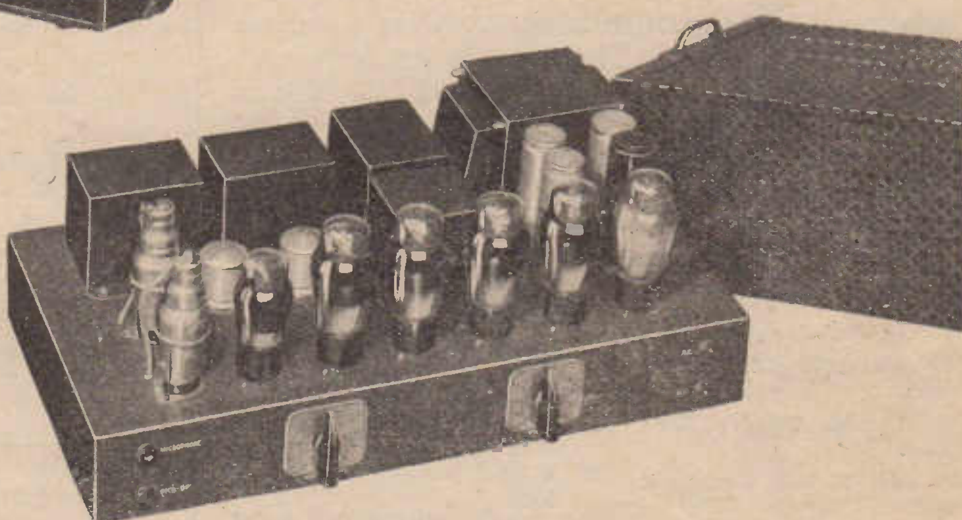

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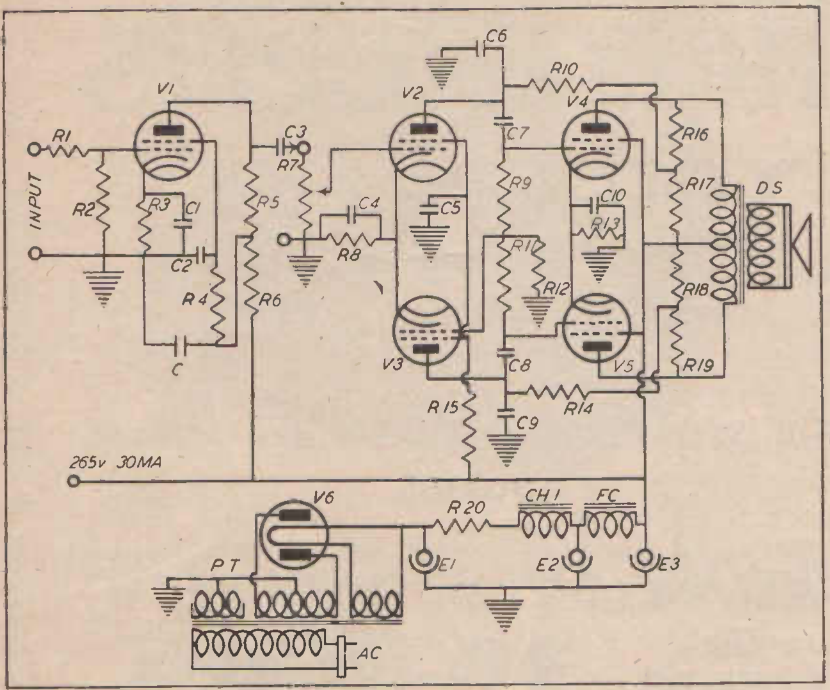
8.5 WATT PUSH PULL AMPLIFIER



Radiotron Circuit, No. A130.

NOTES.

HERE is an intermediate amplifier, its power output lying between that of the low level class—$3\frac{1}{2}$ to 5 watts—and the medium powered 12 to 20 watt amplifiers. Note that separate input levels are provided for the microphone and the pick-up.

The resistance of R20 will be governed by that of the filter choke, CH1. The combined resistances of these components should total 750 ohms. R20 should be able to carry 150 m.a. with safety.

Components List

CH1.—Filter Choke, 30 Henries at 150 m.a.

C.—8 mfd. 300 volt Electrolytic Condenser.

C1, C4.—25 mfd. 25 volt Electrolytic Condensers.

C2, C5.—.5 mfd. Tubular Condensers.

C3.—.05 mfd. Tubular Condenser.

C6, C9.—.0001 mfd. Mica Condensers.

C7, C8.—.1 mfd. Tubular Condensers.

C10.—50 mfd. 25 volt Electrolytic Condenser.

DS.—Dynamic Speaker, 750 ohm Field and 10,000 ohm Load.

E1, E2.—8 mfd. 500 volt Electrolytic Condenser.

E3.—16 mfd, 350 volt Electrolytic Condenser.

FC.—750 ohm Loudspeaker Field Winding.

PT.—Power Transformer, 385-0-385 v. at 125 m.a., 5 v. at 3 a., and 6.3 v. at 2 a.

R1.—3 megohm Carbon Resistor.

R2.—2 megohm Carbon Resistor.

R3.—2,000 ohm 10 m.a. W.W. Resistor.

R4, R15.—1.5 megohm Carbon Resistors.

R5.—.25 megohm Carbon Resistor.

R6, R16, R19.—50,000 ohm Carbon Resistors.

R7.—.5 megohm Potentiometer.

R8.—1,000 ohm 50 m.a. W.W. Resistor.

R9, R11.—.2 megohm Carbon Resistors.

R10, R14.—.1 megohm Carbon Resistors.

R12.—.3 megohm Carbon Resistor.

R13.—165 ohm 200 m.a. W.W. Resistor.

R17, R18.—9,000 ohm Carbon Resistors.

VALVES.—Three 6J7G, two 6V6G, and one 5V4G.

8.5 WATT AC/DC AMPLIFIER.

(See page 36.)

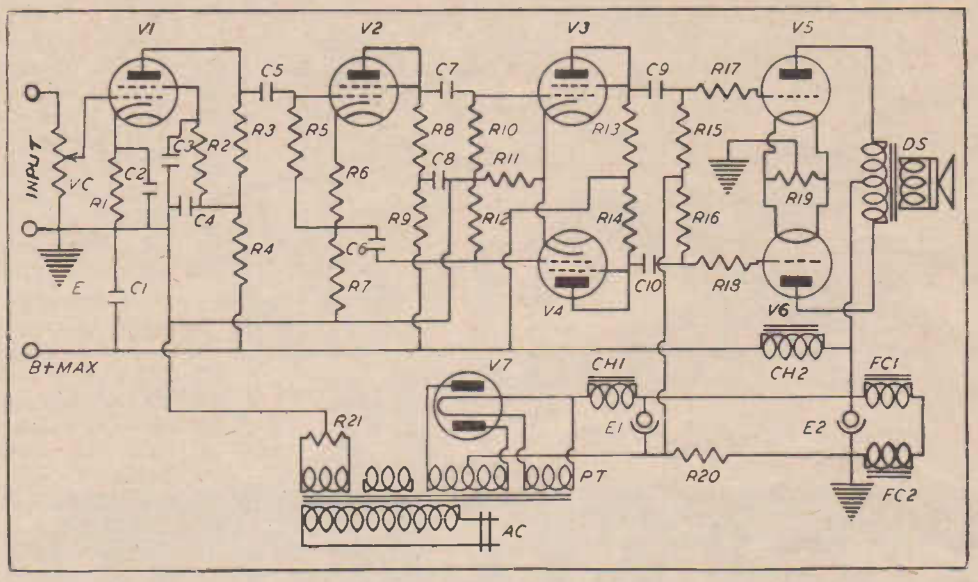
NOTES.

THIS A.C./D.C. amplifier will provide adequate power for the majority of small hall jobs, and can be built up in a compact and portable form. The rating of 8 watts is based on the expectation of a maximum of 200 volts being available from the filter circuit.

However, if the amplifier is to be used under conditions where a plate supply voltage of 250 will be available, the bias resistor, R4, should be increased to 180 ohms. and the amplifier then will deliver over 10 watts of audio at 1.6% distortion, or 13.5 watts at 5.7% distortion.

For operation on the high voltage condition, the recommended plate load should be raised to 6,000 ohms.

13 WATT P.P. AMPLIFIER



Radiotron Circuit, No. A120.

Components List and Operating Data

CH1.—12 Henry 250 m.a. 60 ohm Filter Choke.

CH2.—30 Henry 60 m.a. 200 ohm Filter Choke.

C1.—16 mfd. 350 volt Electrolytic Condenser.

C2.— 25 mfd. 25 volt Electrolytic Condenser.

C3, C9, C10.—.5 mfd. Tubular Condensers.

C4, C8.—8 mfd. 500 volt Electrolytic Condensers.

C5.—.02 mfd. Mica Condenser.

C6, C7.—.1 mfd. Tubular Condensers.

DS.—Dual Dynamic Speakers, 4,000 ohm load.

E1, E2.—16 mfd. 500 volt Electrolytic Condensers.

FC1, FC2.—2,500 ohm Field Windings of Loud Speakers.

PT.—Power Transformer, 500-0-500 v. at 250 m.a., 2.5 v. at 5 a., 6.3 v. at 4 a., and 5 v. at 3 a.

R1.—2,000 ohm 10 m.a. W.W. Resistor.

NOTES.

IN this amplifier a triode-connected 6C6 has been used as a phase inverter tube. Particular attention should be paid to the inductance and resistance values specified for the filter chokes, as these will have a large bearing upon the amplifier's ultimate performance.

Care also should be taken to see that the resistances used in the push-pull stages are matched with within 2% or less.

Although two speakers are shown in the circuit diagram, these may be replaced with a single auditorium type speaker designed to operate with a field excitation of 18 watts. In this case the field resistance of the single speaker must be 5000 ohms.

R2.—1.5 megohm Carbon Resistor.

R3, R10, R12.—.25 megohm Carbon Resistors.

R4, R7, R8, R9, R15, R16.—50,000 ohm Carbon Resistors.

R5.—1 megohm Carbon Resistor.

R6.—3,000 ohm 10 m.a. W.W. Resistor.

R11.—550 ohm 100 m.a. W.W. Resistor.

R13, R14.—10,000 ohm Carbon Resistors.

R17, R18.—1,000 ohm Carbon Resistors.

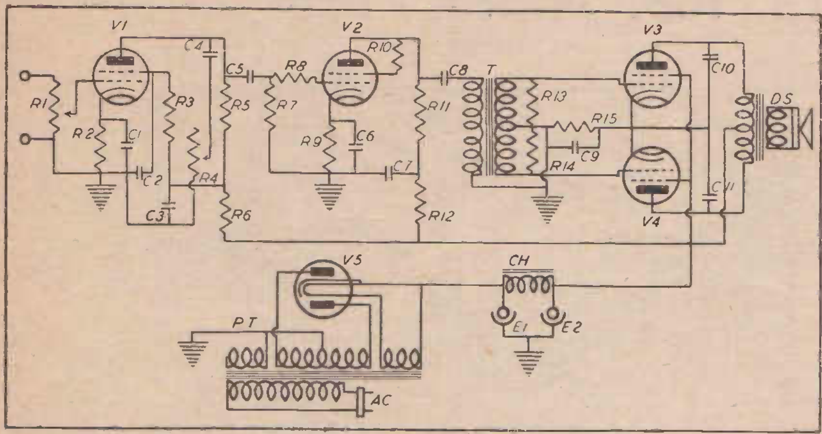
R19, R21.—30 ohm Centre Tap Resistors.

R20.—315 ohm 250 m.a. W.W. Resistor.

VC.—500,000 ohm Potentiometer.

VALVES.—Two 6C6's, two 42's, two 2A3's and one 5Z3.

15 WATT PUSH PULL AMPLIFIER



[Courtesy Philips Radio.]

NOTES.

EMPLOYING a pair of EL3 pentodes in the output stage, this Class AB amplifier combines a reasonably high audio output with excellent tonal quality. Particular attention should be paid to the resistance of the filter choke, CH, which should be kept as low as possible, and should not exceed 200 ohms.

Complete de-coupling of the first stage and driver plate circuits has been employed in order to keep the hum level at the lowest.

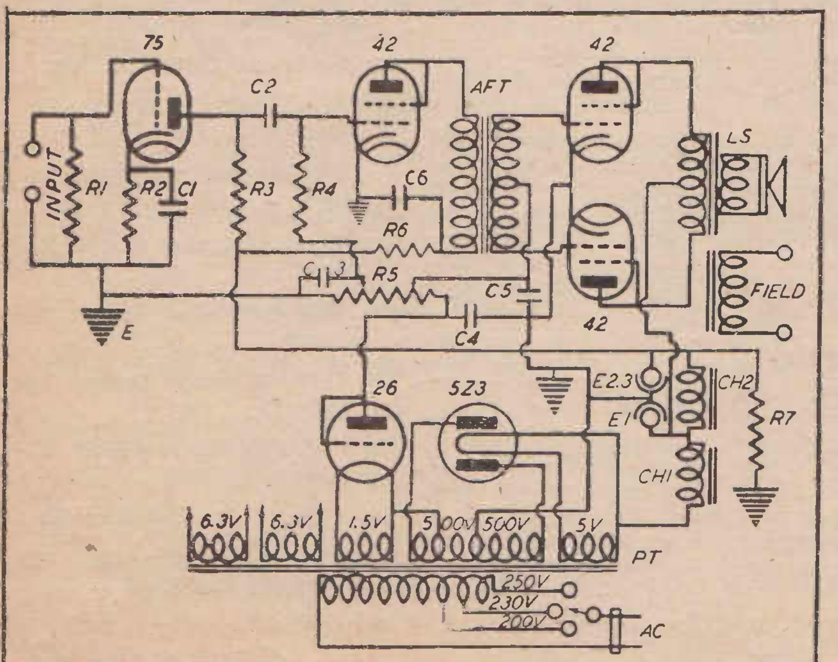
The overall gain of the amplifier is reasonably high, but it is desirable that an additional pre-amplifier stage be used if low gain microphones are to be employed.

COMPONENTS LIST.

- CH: 30 Henry, 150 m.a., 200 ohm Filter Choke.
- C1, C6, C9: 25 mfd. 25 volt Electrolytic Condensers.
- C2, C3, C7: .5 mfd. Tubular Condensers.
- C4: .1 mfd. Tubular Condenser.
- C5: .02 mfd, Tubular Condenser.
- C8: 1 mfd. Paper Condenser.
- C10, C11: .005 mfd. Mica Condensers
- DS: Dynamic Speaker P.M. Type to suit 4000 ohm Load.
- E1, E2: 16 mfd. 500 volt Electrolytic Condensers.
- PT: Power Transformer. 300-0-300 v. at 200 m.a., 6.3 v. at 4 a., and 6.3 v. at .9 a.
- R1: 1 megohm Potentiometer.
- R2: 1600 ohm 10 m.a. W.W. Resistor.
- R3: .25 megohm Carbon Resistor.
- R4: 50,000 ohm Potentiometer.
- R5, R12: 5000 ohm 50 m.a. W.W. Resistors.
- R6, R8, R13, R14: 50,000 ohm Carbon Resistors.
- R7: 1 megohm Carbon Resistor.
- R9: 800 ohm 10 m.a. W.W. Resistor.
- R10: 100 ohm 50 m.a. W.W. Resistor.
- R11: 30,000 Carbon Resistor.
- R15: 160 ohm 200 m.a. W W. Resistor.
- VALVES: One EF6, Three EL3's and one EZ4.

18 WATT CLASS AB AMPLIFIER

(See page 44 for further details.)



COMPONENTS LIST.

- AFT.—Class AB Transformer, 6F6 triode to 6F6 triodes.
- C1.—25 mfd. 25 volt Electrolytic
- C2.—.1 mfd. Tubular Condenser.
- C3, C4, C5, C6.—4 mfd. 250 volt Paper Condensers.
- CH1.—Filter Choke. 10 Henries, 150 m.a. 100 ohms.
- CH2.—Filter Choke. 30 Henries, 70 m.a., 300 ohms.
- E1, E2, E3.—8 mfd. 500 volt Electrolytic Condensers.
- LS.—Dynamic Speaker to match 8,000 ohm load. Field to suit, or may be P.M. type.
- PT.—Power Transformer, 500-0-500 v. at 150 m.a., 5 v. at 2 a., 1.5 v. at 1 a., and two 6.3 at 2 a. (See Notes on page 44.)
- R1, R4.—.5 megohm Carbon
- R2.—10,000 ohm Carbon Resistor.
- R3.—.1 megohm Carbon Resistor.
- R5.—30,000 ohm 10 m.a. W.W.
- R6.—3,000 ohm 100 m.a. W.W.
- R7.—15,000 ohm 25 m.a. Voltage Divider.
- VALVES.—One 75, three 42's, one 26 and one 5Z3.

25 WATT CLASS A PUSH PULL AMPLIFIER

NOTES.

DESIGNED for medium powered outdoor systems, this Class "A" pentode amplifier will be found particularly effective. It requires an input of .8 volts to load the output stage fully, so will need a pre-amplifier stage for microphone work.

The total current drain of the amplifier is approximately 180 m.a., and is derived from two full wave rectifiers, which are used with their plates paralleled as separate half-wave rectifiers.

COMPONENTS LIST.

CH.—30 Henry 200 m.a. Filter Choke.

C1.—25 mfd. 25 volt Electrolytic Condensers.

C2, C4.—.5 mfd. Tubular Condensers.

C3.—.02 mfd. Mica Condenser.

C5, C6.—16 mfd. 300 volt Electrolytic Condensers.

DS.—Dynamic Speaker 7,000 ohm Load.

E1.—4 mfd. 1,000 volt Paper Condenser.

E2.—8 mfd. 500 volt Electrolytic Condenser.

PT.—Power Transformer, 400-0-400 v. at 200 m.a., two 4 v. at 2 a., and one 4 v. at 4 a.

R1.—500,000 ohm Potentiometer.

R2.—1,750 ohm 10 m.a. W.W. Resistor.

R3.—30,000 ohm Carbon Resistor.

R4, R5.—10,000 ohm Carbon Resistors.

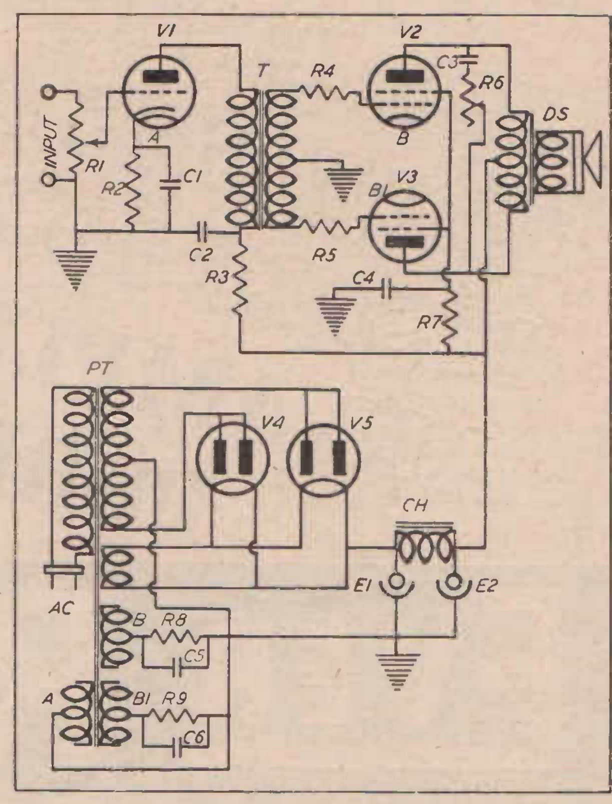
R6.—15,000 ohm Potentiometer.

R7.—5,000 ohm 50 m.a. W.W. Resistor.

R8, R9.—460 ohm 200 m.a. W.W. Resistors.

T.—Audio Transformer, Class A. Ratio, 1 to 3.

VALVES.—One ABC1, two F443N's and two 1561's.



[Courtesy Philips Radio.]

NOTES ON 18 WATT CLASS AB AMPLIFIER

(See page 42.)

THIS is an extremely fine amplifier, which, except for the power transformer, is built up from absolutely standard parts.

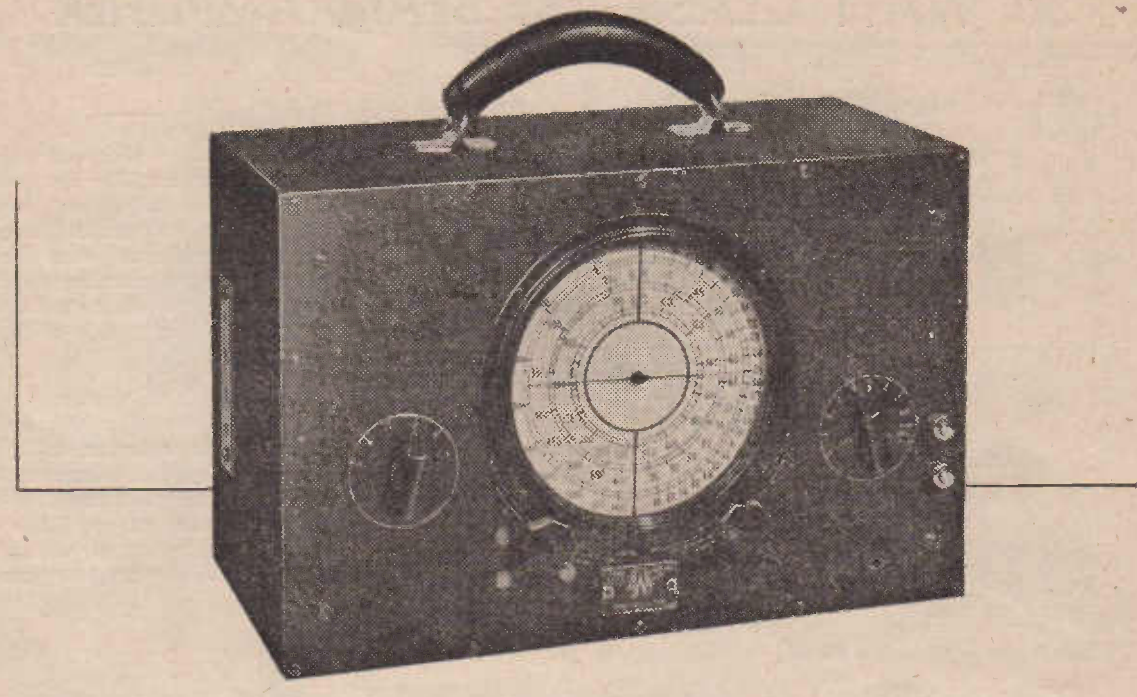
The power transformer should have a tap on the high voltage secondary capable of delivering 100 volts to centre tap. This is for the purpose of obtaining the fixed bias for the driver and output tubes.

Condensers C3, C4, C5, and C6 should NOT be replaced with electrolytic types.

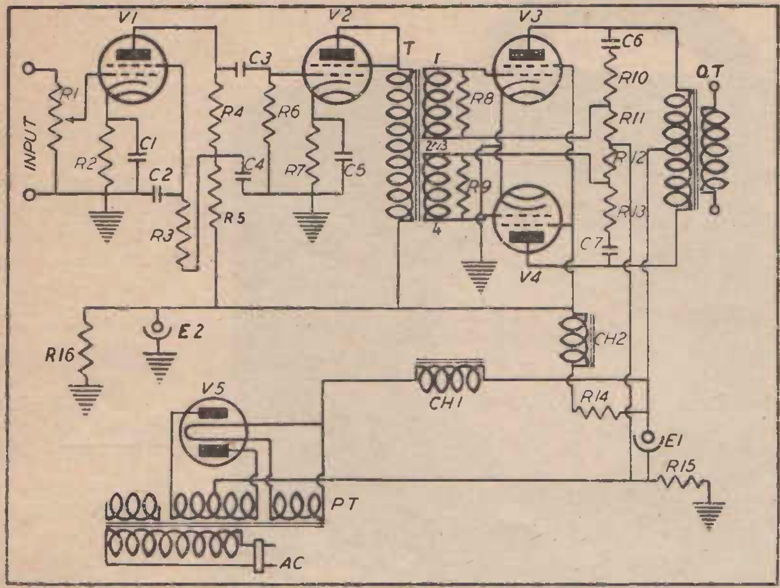
If desired, the 75 may be replaced with a 6C6 pentode.

In that case the following resistor valves will be changed:—R3 will become 250,000 ohms, and R2 will become 2,000 ohms. In addition a 1.5 megohm resistor should be connected between the 6C6 screen and the "B" supply line. The screen of the 6C6 should be bypassed to chassis with a .1 mfd. condenser. This alteration will provide adequate gain for microphone operation.

Don't attempt to replace the 26 with an indirectly heated valve.



30 WATT CLASS AB1 BEAM AMPLIFIER



Radiotron Circuit No. A111.

NOTES.

THE application of inverse feedback to this Beam amplifier necessitates the use of a triode driver transformer coupled to the output stage. The coupling transformer must have two entirely separate secondary windings, so that the degree of feedback may be made the same for each of the output tubes.

As it is essential that the voltage regulation of the power pack be as good as possible, it is impracticable, without greatly raising the voltage and output current of the power unit, to attempt to energise the speaker field from this source. Either separately excited speakers or permanent magnet types should be used.

Components List

C1, C5.—25 mfd. 25 volt Electrolytic Condensers.

C2.—.5 mfd. Tubular Condenser.

C3.—.02 mfd. Mica Condenser.

C4.—8 mfd. 300 volt Electrolytic Condenser.

C6, C7.—.25 mfd. Tubular Condensers.

CH1.—10 Henry 200 m.a. Filter Choke.

CH2.—30 Henry 100 m.a. Filter Choke.

E1.—24 mfd. 500 volt Electrolytic Condenser.

E.2—8 mfd. 600 volt Electrolytic Condenser.

OT.—Output Transformer, 6,600 ohms load impedance.

PT.—Power Transformer, 475-0-475, v. at 250 m.a., 5 v. at 3 a., and 6.3 v. at 4 a.

R1.—500,000 ohm Potentiometer.

R2.—2,000 ohm 10 m.a. W.W. Resistor.

R3.—1.5 megohm Carbon Resistor.

R4.—.25 megohm Carbon Resistor.

R5.—50,000 ohm Carbon Resistor.

R6.—1 megohm Carbon Resistor.

R7.—1,600 ohm 10 m.a. W.W. Resistor.

R8, R9, R10, R13.—100,000 ohm Carbon Resistors.

R14.—100 m.a. W.W. Resistor (to total 1,600 ohms with resistance of CH2).

R15.—120 ohm 500 m.a. W.W. Resistor.

R16.—4,800 ohm. 100 m.a. W.W. Resistor.

VALVES.—Two 6C6's, two 6L6's and one 83.

HINTS ON AMPLIFIER CONSTRUCTION

IT'S all very well to sit down and design an amplifier, but if it is not constructed along reasonably sound lines the builder will almost certainly find himself in bother.

Two of the greatest problems encountered by the amplifier constructor are hum and instability. The first, usually, is caused by failure properly to separate the input stages from the power circuits, and by the neglect of such an ordinary precaution as shielded leads to the grids of screen grid tubes.

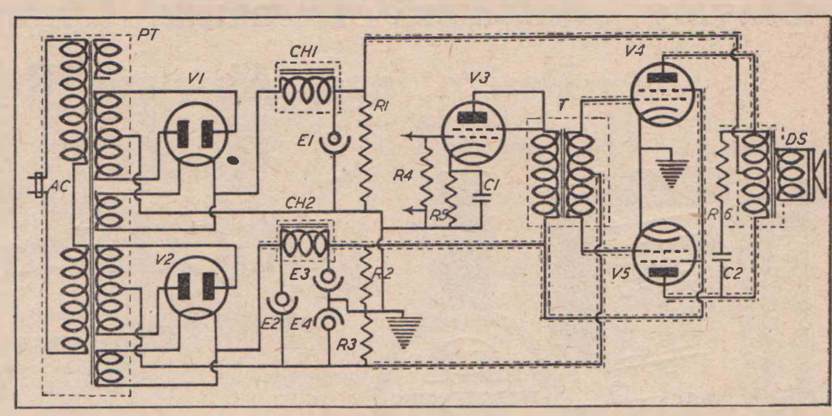
Another common source of hum is inter-action between the power transformer and filter choke and any audio coupling transformer which may be used. This means line input transformers as well as inter-stage ones.

It is a wise precaution when constructing an amplifier so to mount the audio transformer and the filter choke, if one is used, that it may be swivelled around through a 90 degree arc before finally being mounted firmly to the chassis. It will be found that many otherwise obdurate hums can be eliminated by selection of the right angle between the fields of the audio transformer and the power choke or transformer.

Another thing overlooked in the present-day craze for compactness is the correct method of amplifier lay-out. It is better, from a practical viewpoint, to have a long narrow chassis on which the components are laid out, so that successive stages progress along the chassis instead of being folded back on themselves, as they would be in a square chassis.

Next time you lay out a high gain chassis, arrange it so that, say, from left to right, there is a gradual progression from the input to the output, and finally the power supply stages. This will save you considerable bother from hum and audio instability.

55 WATT AB2 AMPLIFIER



NOTES.

IT is essential that the regulation of the power supply circuits be beyond reproach or the amplifier's fidelity will suffer.

All leads shown surrounded by dotted lines should be run in braided cable, the braiding being earthed. Similarly, the transformers should be fitted with electrostatic shields, and the filter chokes, as well as the power and audio transformer, enclosed in heavy metal cases, which also must be earthed.

Before plugging the 83 rectifier into its socket or withdrawing it from the socket, make sure that the line supply is disconnected.

The pre-amplifying unit should be connected between the grid and ground of the 6F6 driver tube, as shown by the arrows. Condenser E4 should have its negative terminal connected to the centre tap of PT2 and its positive lead taken to earth. The diagram shows these leads reversed.

COMPONENTS LIST.

C1.—25 mfd. 25 volt Electrolytic Condenser.

C2.—.035 mfd. Mica Condenser.

CH1.—5 Henry 50 ohm 220 m.a. Filter Choke.

CH2.—20 Henry 100 ohm 150 m.a. Filter Choke.

DS.—P.M. Type Dynamics. Output Transformer Primary Impedance 3,800 ohms.

E1.—16 mfd. 500 volt Electrolytic Condenser.

E2, E3.—8 mfd. 500 volt Electrolytic Condensers.

E4.—25 mfd. 25 volt Electrolytic Condenser.

PT1.—(6L6 Supply.) 450-0-450 v. at 250 m.a., 6.3 v. at 2 a., and 5 v. at 3 a.

PT2.—(6L6 screens and rest of amplifier.) 385 v. at 200 m.a., 6.3 v. at 2 a., and 5 v. at 3 a.

R1.—50,000 ohm 10 m.a. W.W. Resistor.

R2.—2,500 ohm 150 m.a. W.W. Resistor.

R3.—200 ohm 150 m.a. W.W. Resistor.

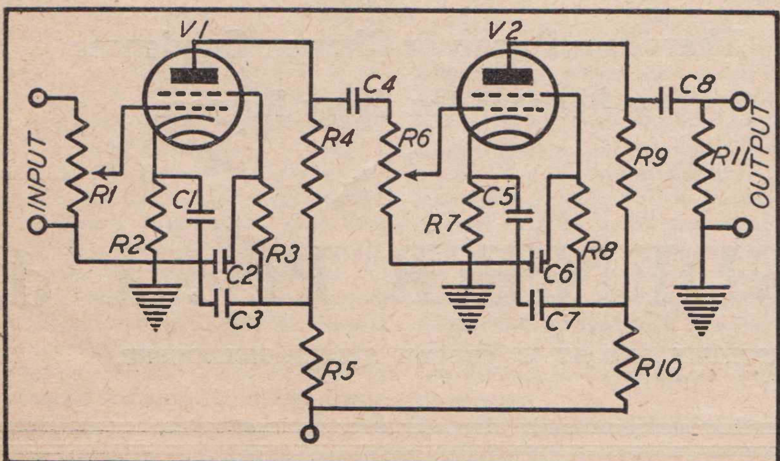
R4.—.5 megohm Carbon Resistor.

R5.—650 ohm 100 m.a. W.W. Resistor.

R6.—5,000 ohm 100 m.a. W.W. Resistor.

VALVES.—V1, 83; V2, 5Z3; V3, 6F6; V4 and V5, 6L6's.

RESISTANCE COUPLED PRE-AMPLIFIER



COMPONENTS LIST.

C1, C5.—25 mfd. 25 volt Electrolytic Condensers.

C2, C6.—.5 mfd. Tubular Condensers.

C3, C7.—8 mfd. 350 volt Electrolytic Condensers.

C4, C8.—.05 mfd. Tubular Condensers.

R1, R6.—500,000 ohm Potentiometers.

R2, R7.—2,000 ohm 10 m.a. W.W. Resistors.

R3, R8.—1.5 megohm Carbon Resistors.

R4, R9.—25 megohm Carbon Resistors.

R5, R10.—50,000 ohm Carbon Resistors.

VALVES.—Two 6J7's or equivalent types.

AUDIO A.V.C.

Advantages of A.V.C.—Elimination of Acoustic Feedback.

FROM time to time throughout this manual reference has been made to the possibilities of Audio Automatic Volume Control in overcoming that bugbear of the Public Address operator—acoustic feedback. However, the application of A.V.C. at audio levels can perform an equally valuable service in the operation of the amplifier under normal conditions —i.e., those conditions where acoustic feedback is absent, but where some form of output volume control is essential.

Such applications nearly always relate to the handling of speech. Even the best microphone-trained orator is liable to let his enthusiasm lure him into the besetting sin—for the p.a. man —of wandering away from the microphone. No sooner has the gain been raised to counteract this drop in the pick-up level than the orator steps back in front of the mike, and, in his loudest and most impassioned tones, drives home his point.

The result is disastrous, even if acoustic feedback is absent, for the blasting and overload which invariably results not only makes the speech unintelligible, but in so doing reflects unfavourably on the efficiency of the p.a. system.

With this in mind, one can appreciate how the development of audio automatic volume control, rationalised wth the introduction of the 6L7 tube, has made easier the path of the sound man. With its aid the output of the p.a. system can be held constant within reasonable limits, and distortion, due to overload, almost entirely eliminated. In fact, with the system detailed in the circuit diagram below we can practically say that distortion is confined only to that caused by microphone blasting. This in turn can be eliminated, or at least reduced, by judicious selection of microphones.

In employing an audio a.v.c. system, we must be prepared to provide adequate microphone amplification to permit the mike to be operated at the lowest sound levels and yet provide sufficient signal voltage for full output. This does not necessarily mean that there shall be a large signal voltage output from the microphone itself. It is desirable, indeed, that the mike output shall be low, but that succeeding amplifier stages will have sufficient reserve of gain to build this up to the level necessary for adequate driving of the output stages.

Converse of A.V.C.

The audio a.v.c. system set out below is the basically exact opposite of the Automatic Volume Expansion circuit shown earlier in this manual. Where the A.V.E. system depended upon the application of an increasingly positive bias on the injector grid of the 6L7 to provide a greater amplification and consequently a greater output volume, the A.V.C. system feeds to the 6L7 injector grid a negative bias which increases with any increase in the strength of the input sound, and those of the microphone's voltage output. The increased bias cuts down the amplification of the 6L7, and so reduces the final output volume. As we explained in the A.V.E. article, it is essential that the expander tube be operated well below the overload level. For this reason the expansion tube was introduced into the front part of the amplifier circuit.

As the gain from the standard p.a. microphone is extremely low, this is not necessary with the A.V.C. tube, which may be preceded with one, or even two, pre-amplifier stages.

However, in both these applications of the 6L7 it is desirable that expansion or "contraction" — a.v.c. — should be obtained early in the amplifying chain, so do not use more than two pre-amplifier stages ahead of the control tube.

The circuit diagram will show that except for minor changes, the basic expansion circuit has been applied to a.v.c. The major change is that for a.v.c. the 6L7 is supplied with a negative instead of a positive bias from the 6H6.

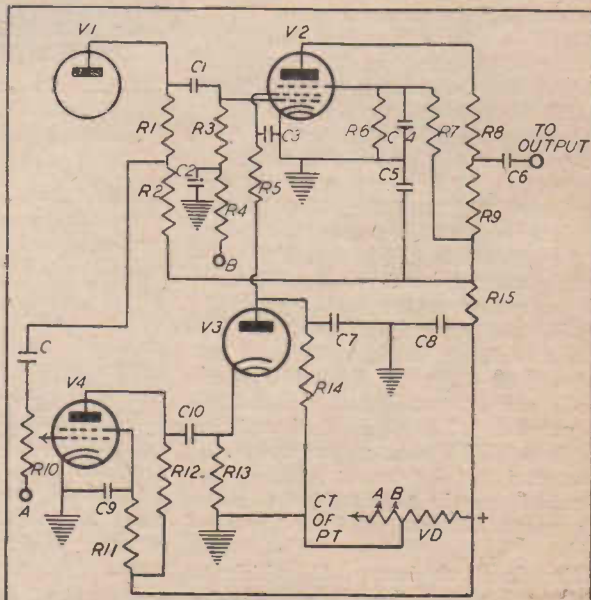
Time Constant.

One thing which must be watched is the time constant to the rectifier tube. If this is too low it will result in all expression being taken from speech, and could quite easily be low enough to seriously impair reproduction. If it is too high, then the delay will be such that an appreciable time will exist between the necessity for the application of control and its

(Continued over leof.)

PARTS LIST AND CIRCUIT DIAGRAM

C—.01 mfd. Mica Condenser.
C1, C2, C7, C9, C10—.1 mfd. Tubular Condensers.
C3, C6—.5 mfd. Tubular Condensers.
C4—1 mfd. Paper Condenser.
C5, C8—8 mfd. 500 volt Electrolytic Condensers.
R1, R8, R9—50,000 ohm Carbon Resistors.
R2, R7—20,000 ohm Carbon Resistors.
R3, R4, R5, R14—500,000 ohm Carbon Resistors.
R6—25,000 ohm Carbon Resistor.
R10—500.000 ohm Potentiometer.
R11—1 megohm Carbon Resistor.
R12—.25 megohm Carbon Resistor.
VD—Voltage Divider. (Resistance in accord with permissible power pack drain.)
VALVES—V1, triode in pre-amplifier stage; V2, 6L7, V3, 6H6, V4, 6J7.



LEVEL INDICATORS

Advantages of Visual Indication — Simple Circuiting for Magic Eye Unit — Calibration in Power or Decibels.

SOME means of indicating visually the output volume at which an amplifier is being operated is a desirable refinement to any p.a. system. With the aid of such a device it is possible visually to set the gain controls to meet any given set of conditions without having to run backwards and forwards from the amplifier to the loud-speaker system.

Visual level indicators can be broadly divided into two classes, those in which a meter is used and those in which some form of indicating light is employed. In the former class we have watt meters and d.b. meters. The d.b. meter usually consists of a rectifier unit in series with suitably calibrated direct current milliammeter.

In the second class we have the neon lamp and, more recently, the Magic Eye cathode ray tuning tube. Much is to be said for the simple neon lamp, but the more definite adjustment of the level indicator made up from the magic eye tube makes this type of indicator the most satisfactory for general use.

One feature of the Magic Eye tube is that the deflection of the beam follows an approximate logarithmic law, so that it becomes possible readily to calibrate the tube deflection in terms of decibels. For most applications, however, it will suffice merely to use the eye as an overload indicator.

Indicator Circuit.

Referring to the schematic circuit diagram, it will be seen that the Magic Eye Level Indicator consists of a diode rectifier tube connected in the output circuit of the amplifier, and having its own output fed to the tuning indicator tube. Incidentally, this circuit was developed by the A.W. Valve Co. Engineers, and was described in one of their technical manuals. In practical operation it will be found to perform extremely well, and will save the amplifier operator considerable trouble and many heartburnings.

In the circuit diagram V1 is a 6H6 twin diode tube which has its two plates and its two cathodes connected in parallel. The diode load resistor, R1, is a 500,000 ohm potentiometer so connected that the output voltage from the diode may be adjusted just to close the eye at full output from the amplifier.

The fixed condenser, C, which is connected across the diode load resistor, should be large enough to result in a time constant which will prevent the eye fluttering rapidly, yet will permit definite indication of overload conditions. It has been found that a capacity of .25 mfd. will meet most requirements.

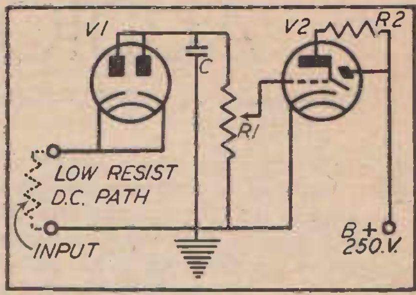
The 6G5 tube, V2, is a conventional Magic Eye tube operated with zero bias, and with a 250 volt target supply. Plate voltage for this tube is obtained from the 250 volt line through the dropping resistor R2, which has assigned to it a value of 1 megohm.

Calibrating the Unit.

Under these conditions the voltage required fully to close the eye is approximately 25 volts R.M.S. It is desirable to connect the input of the tuning indicator across a low resistance source that is low with regard to the 500,000 ohm input to the 6H6. When 500 ohm speaker lines are used, the indicator may be connected directly across them, or it may be wired across the secondary of the output transformer.

When it is desired to calibrate the indicator in terms of power or decibels the resistance, R1, should be of the taper type and preferably one with a true logarithmic taper. To calibrate the unit for full output merely connect an a.c. voltmeter across the primary of the output transformer, but with a large capacity condenser in series with its high potential side.

Run the amplifier to full output—i.e., run to a point where the voltage read by the a.c. meter is equal to the product of the bias voltage for the output tube or tubes and the tube amplification factor. Adjust the potentiometer R1 till the eye ust closes, but fails to overlap.



The Schematic Circuit of the Magic Eye Level Indicator.

Calculation of the output power at this stage is effected by use of the formula.

$$\frac{E^2}{R}$$

Where E^2 = the A.C. Output Voltage (R.M.S.).
R = the load impedance in ohms.

The product of this calculation should be doubled for push pull tubes.

Then, with lower inputs, the actual power output of which can be calculated in a similar manner and reduced to decibel levels if desired, calibrate the angle of the eye.

Another and more satisfactory way is to calibrate the potentiometer, R1, so that it can be adjusted to close the eye fully at various power outputs.

In this application, of course, R1 would be ganged with the amplifier volume control.

In operation the eye is adjusted so that the shadow angle is nil at any given power setting. Overlap of the eye will produce a bright line which is the danger signal indicating overload.

AUDIO A.V.C.

(Continued from preceding page.)

actual application. The values provided for the diode load resistor and condenser set a happy medium, and should result in generally satisfactory performance. The points A and B on the voltage divider are the points to which the grid return of the a.v.c. amplifier tube and the control grid of the 6L7 should be returned. Their voltages will be the same as that set out for the A.V.E. system described on page 27.

However, suitable amendments to meet individual needs may be made. It may be found necessary to delay the a.v.c. action, although this will to some extent defeat its object. However, should delay be required, then it is necessary only to introduce a suitable voltage between the load resistor for the a.v.c. rectifier and earth.

For general applications, however, the circuit shown will prove eminently satisfactory, and, in addition to providing adequate control of wide signal levels, will eliminate the greater percentage of those troubles caused by acoustic feedbacks. In conclusion, it should be pointed out that the a.v.c. system is indeed only for speech applications, and should not be used with recorded music.

Incidentally, the remaining cathode and plate of the 6H6 rectifier may be used to actuate the level indicator dealt with above.

METERS AND SERVICE EQUIPMENT

Value of Volt-Ohm-Milliammeter—Add-On Analysers—Overlaad Safeguards — Frequency Response Measurements —Producing a Response Curve.

A Combination Valve and Circuit Tester is of inestimable value to the Amplifier user.
[Photo Courtesy Homecrofts Pty. Ltd.]

WE shall confine this discussion of service equipment to that necessary for the electrical servicing of amplifiers. Mechanical servicing and routine overhauls such as battery recharging and replacement, etc., check-ups of the mechanical condition of portable amplifiers, and the maintenance of indoor and outdoor loud speaker systems, are fairly well understood.

Most amplifier service must be carried out under rush conditions, and usually away from the workshop. The service man's main aim is to find out QUICKLY the fault which is causing unsatisfactory operation. Once found, he usually will be able speedily to rectify it.

To find faults quickly, we must have good equipment. No longer will the rule-of-thumb and low resistance voltmeter system work out. Fortunately, modern set analysers and valve checkers are both accurate and well designed. In addition, they are comparatively cheap, so that there is little excuse for the sound man who takes his job seriously to be hampered by lack of test equipment.

General Purpose Meters.

For general checks there is little to beat the combined volt-ohm-milliammeter. With this instrument it is possible rapidly to check all operating potentials and currents, and to determine whether correct resistance conditions exist in the various circuits.

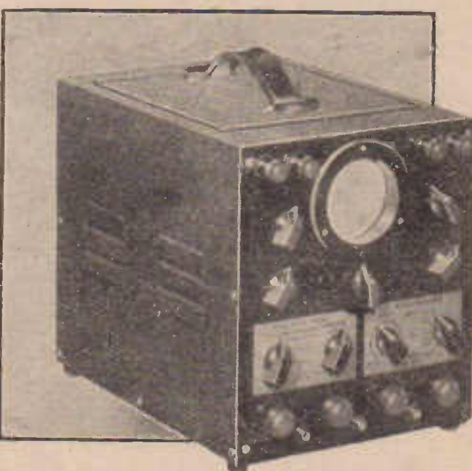
It seems almost superfluous to state that the voltmeter should be of the high resistance type, but even in these enlightened days we still see service men trying to muddle along with low resistance meters which register serious discrepancies in circuits having resistances above two or three thousand ohms.

Let us understand, then, that the resistance possessed by the voltmeter must be at least 1000 ohms per volt. Recently it has become possible to obtain really high resistance metres—up to 20,000 ohms per volt. These, of course, provide much more accurate measurements in high resistance circuits, but for general amplifier use, where reasonably accurate measurements will suffice, the 1000 ohms per volt type meter will prove more robust and will be generally satisfactory.

In selecting test set, look for one which combines both A.C. and D.C. voltage ranges. The a.c. current range is not necessary, as it will have only a very limited application. On the D.C. volts scale it should be possible to select full scale voltages of 10, 100, and 1000 volts, and an intermediate scale of 500 volts is an advantage.

The 10 and 100 volt scales will give accurate indication of bias potentials, whilst the 500 and 1000 volt scales will serve for plate voltage and rectifier output voltage readings. Similar ranges should be present on the A.C. volt scale of the meter.

It also is desirable that the A.C. scale should be equipped for output voltage readings. This necessitates the connection of a large capacity condenser in series with one side of the meter in order to keep direct current from flowing through the meter whilst output voltages are being read.



The Cathode Ray Oscillograph permits Visual Study of Amplifier Characteristics.
[Photo Courtesy Homecrofts Pty. Ltd.]

Current and Resistance Scales.

On the D.C. current side we should look for full scale ranges of 1, 10, 100, and 250 m.a. in order that all current requirements will be met. The ohms scale should extend from zero to 1000 or 2000 ohms on the "Low Ohms" scale, through an intermediate range of 100,000 or 200,000 ohms to a "High Ohms" scale of 1 or 2 megohms. It is probable, however, that the highest scale will necessitate the use of an external battery, unless the scale readings are made so cramped as to be practically useless.

In its fundamental form such a test instrument usually is provided only with a pair of test prods, so that for current or resistance measurements it is necessary to open the circuit to be tested and to connect the meter in series with it for current readings, and in parallel with the resistor for resistance measurements.

Such a system is hardly conducive to speedy testing, but this difficulty has been overcome by the provision of selector units which connect to the meter.

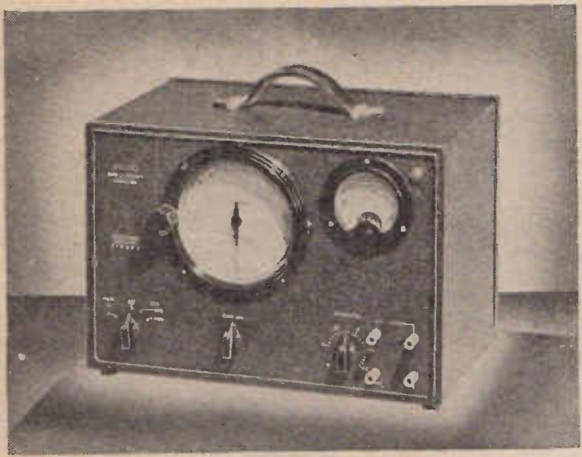
These selector units are provided with a number of sockets to suit the different types of valves. When connected to the meter the unit permits the various current and voltage readings to be taken under operating conditions, the valve being tested merely being plugged into its correct socket on the selector.

A more elaborate type of test unit is that which incorporates a valve checker in addition to the conventional voltage and current ranges. Such a unit is of inestimable advantage in outdoor service work where very often valve faults are responsible for non-operation. The latest types of these units possess the further advantage in that being fitted with a vibrator unit they may be operated either from the a.c. mains or from a 6 volt d.c. supply source.

Laboratory Type Equipment.

Still more elaborate are the general purpose testers which provide for the determination of the characteristics of condensers and inductances. These units are more for the workshop and the laboratory, although it cannot be denied that, were they fitted with vibrator power supply units, they would be extremely valuable in the field.

However, it is an old axiom that the best test equipment is no better than the man who uses it. In tracking down



The Beat Frequency Oscillator is an essential piece of equipment for measuring Amplifier Response Curves. This one covers the range from 10 to 12,000 cycles.

[Photo Courtesy Homecrafts Pty. Ltd.]

faults, progress stage by stage—use your common sense in looking for the possible trouble—and, above all, be careful when using the motors to see that they are not subjected to voltage or current overloads.

The best safeguard against the latter is to set the instrument to the maximum voltage or current scale, **even if you know that only a small voltage or current is flowing, for the initial test reading.**

In the next class of test instruments comes that used in amplifier construction, and in the more involved problems of servicing.

Probably the most valuable instruments in this regard are the Beat Frequency Oscillator and the Output Meter. With these two instruments it is possible speedily to determine the frequency response characteristics of any amplifier, to determine the reasons, for distortion and uneven response, and to discover the overall gain under working conditions.

However, the mere use of a Beat Frequency oscillator and an Output Meter will not provide a true picture of the amplifier's performance. These instruments must be combined with a heavy duty audio choke and a suitable load resistor. For push pull operation the choke should be centre tapped. The resistor should be of the wire-wound type and robust enough to handle considerable power.

In the diagram below will be seen the schematic set-up for measuring amplifier response. The beat frequency oscillator is connected to the input amplifier. No loud speaker is used at the output of the amplifier. Its place is taken by the heavy duty audio choke CH, and the parallel resistance, R. The choke should possess an inductance between 30 and 50 henries at the maximum current likely to be passed through it. Resistance R will have a value equal to the rated load resistance for the valve or valves with which it is to be used.

When push pull stages are being used R will be connected from plate to plate. CH also will connect between these points, and the "B" supply fed to the tubes through the centre tap on CH. The output meter should be of the high resistance type and, of course, must be an a.c. meter or a d.c. instrument fitted with a rectifier. Between the high potential side of the meter and the choke, CH, a 4 mfd. condenser should be connected to prevent d.c. flowing through the instrument.

From this it can be seen that quite a simple form of output meter will give satisfactory results. For laboratory work it is usual to employ meters which are calibrated directly in decibles, and are fitted with impedance matching transformers. However, providing the specifications set out for the simple meter are followed, this high grade, and consequently costly, type may be dispensed with.

Running a Response Curve.

Assuming that the equipment is set up as shown in the diagram, a frequency curve may be plotted as follows:—

Adjust the beat frequency oscillator to generate a frequency of 400 c.p.s. Set the output voltage control on the instrument to a point adequate to give good output from the amplifier. This may be checked by connecting the speaker and listening to the tone or by increasing the voltage control on the B.F.O. until the rated output voltage (grid voltage by amplification factor of the output valve) is read at the output meter.

Usually the test is run at full output, half output, and quarter output, but matters are simplified from the viewpoint of later calculations if the output meter can be set at some whole number (say 150 volts for the average 3 watt amplifier).

Now, assume that for this output the B.F.O. was delivering an input of 1 volt. This input voltage must be maintained at all subsequent frequency checks.

The 400 c.p.s. output voltage reading is noted and the B.F.O. turned to 20 c.p.s. With the same input to the amplifier, i.e., the one mentioned previously, the output voltage reading is noted. Probably it will be lower. Subsequent readings are taken at every 10 cycles to 100 cycles, every 100 cycles to 1000 cycles, and every 1000 cycles to the upper frequency limit of the B.F.O.

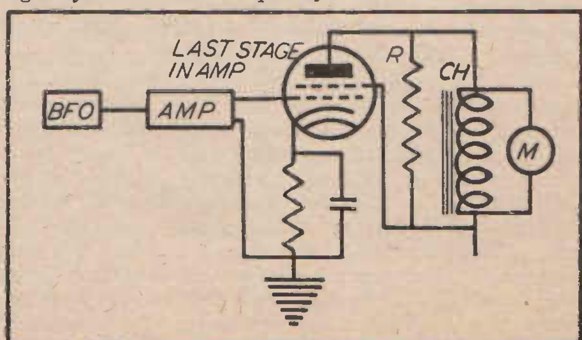
Remember, it is essential that the output voltage from the B.F.O. be the same for all these frequencies, so that slight readjustments of the output voltage control should be made at each test frequency.

The amplifiers output response in d.b. is determined by establishing the ratio between the 400 cycles standard voltage (150 in the present case), and the output voltages at the various test frequencies.

The logarithm of the ratio will be the number of d.b. above and below the reference frequency. Thus, if the 150 volt reference at 400 cycles increased to 168 volts at 300 cycles the ratio—168 divided by 150—would equal 1.12 or a gain of 1 decibel. On the other hand, if at 500 cycles the 150 volts output had dropped to 133.5 volts, the ratio would be 133.5 divided by 150 or .89, which would equal a loss of 1 decibel.

The results of these computations are then graphed on a sheet of logarithmic paper, the result being a visual indication of the amplifiers frequency response.

Modern practice is to hold the amplifiers response within plus or minus 2 decibels of the output at the 400 cycles test frequency.



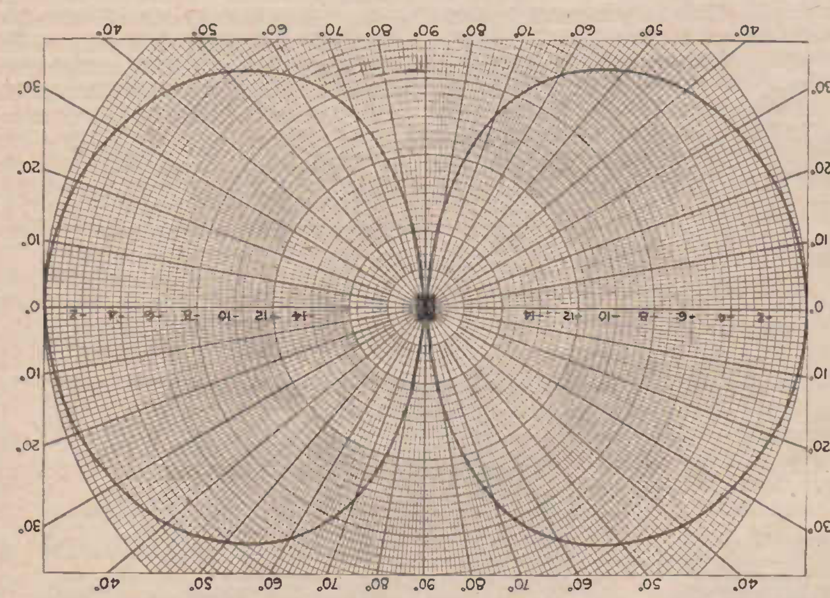
This block diagram illustrates the method of combining a Beat Oscillator with an Output Meter to measure an Amplifier's Frequency Response.

VELOCITY MICROPHONE PLACEMENT

Guide to Modern Microphone Technique—Avoid Solid Reflecting Surfaces—Direct Pick-up Preferable—Microphone Placement Diagrams.

IN order to realise fully the inherent advantages of any microphone, it is essential that it be placed properly with respect to the source of sound.

For this reason the following instructions, originally provided in the instruction manual accompanying the R.C.A. Model 74B Junior Velocity Microphone, and now reprinted through the courtesy of A.W.A., should be carefully studied.



This polar diagram shows the pick-up characteristics of the Model 74B microphone. The two solid line lobes indicate the angle over which sound can be collected, and the central figures show the loss in db. for various angles.
(Illustration Courtesy A.W.A.)

Close attention also should be paid to the results obtained from the use of any special technique of microphone placement. The present instructions should be used only as a guide. A study of the effects met with in different locations and under different pickup circumstances, will soon result in the P.A. operator becoming accustomed to the principles underlying correct microphone placement.

The source of sound, whether it be a speaker or a musical instrument, should not be closer than two feet to the microphone. A distance of between three and four feet is desirable.

At shorter distances there is a tendency towards accentuation of the lower frequencies, which may result in making voices sound "boomy."

The placement of the speaker or musical instrument off from the centre line of the microphone will not affect the quality of pick-up, but will attentuate the direct sound pick-up, thereby raising the ratio of reverberation to direct pick-up.

With bi-directional mircrophones speakers, instruments, or players may be placed on either or both sides of the microphone with equal effect. The placement diagrams on this page will serve as examples of the advantages arising from this bi-directional characteristic.

For the most satisfactory results, avoid placing the microphone closer than three feet to any solid reflecting surface. This provision, of course, is general, and specific conditions, such as in footlight mounting, may require the rule to be disregarded.

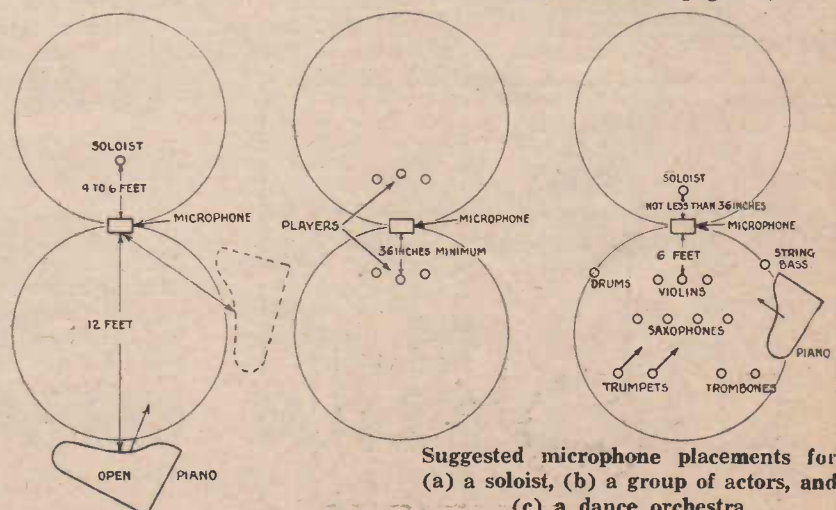
The diagrams referred to and the discussion concerning them can serve only to indicate some of the possible placements under particular conditions. The final decision as to what constitutes the proper placement must rest with someone who is competent to judge the quality of the results as reproduced by a monitor speaker.

Interesting effects may be obtained by changing the angle of the microphone with respect to the piano, thus altering the ratio of reverberation to direct pick-up. The distance between the soloist and microphone should be determined by the strength of his (or her) voice, and the piano should be placed accordingly. The general arrangement is shown in the diagram. Under no conditions should the soloist be less than two feet from the microphone.

In plays the bi-directional characteristic of the microphone may be used to its fullest advantage in broadcasting, by grouping the players about the microphone at such positions that their voice levels match to form the desired composite. With such an arrangement, considerable if not all of the moving and dodging back and forth of the characters seeking positions advantageous to the presentation may be avoided.

When the microphone is used by a speaker located at a table or desk, the microphone should be so placed that it picks up direct sound from the speaker rather than reflected

(Continued on page 55.)



Suggested microphone placements for (a) a soloist, (b) a group of actors, and (c) a dance orchestra.
(Illustration Courtesy A.W.A.)

PHASE INVERSION

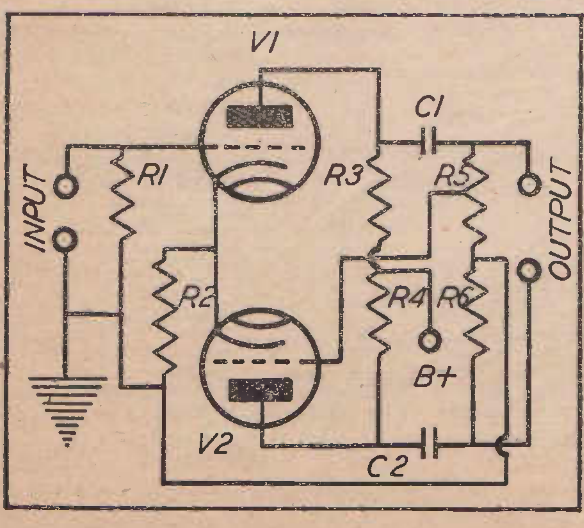
Why Phase Inversion is Used—Advantages and Disadvantages —Necessity for Matched Resistors—Frequency Characteristics.

DEVELOPED as a means of permitting push-pull operation of resistance, coupled with amplifier circuits, Phase Inversion has passed through its experimental days, and is now looked on with considerable favour by designers of high fidelity amplifying equipment.

To understand the necessity for Phase Inversion it is essential to realise the signal voltage input to each of the grids of a push pull amplifier stage must be equal in amplitude, but 180 degrees out of phase at any given moment. Thus, when one grid is swung positive by the input signal, the other one should be swung negative to an equal degree.

To obtain this out-of phase condition with transformer coupled amplifiers, a coupling transformer having a centre tapped secondary winding is used. Such an expedient is impossible with resistance coupling, so we are forced to use something along the lines shown in the basic circuits of Figs. 1 and 2.

The circuit opposite represents an attempt to get over some of the early difficulties of Phase Inverters, and is known as a Signal Divider circuit. Below is shown a standard Phase Inverter circuit of modern design. Let us analyse its operation before we touch upon signal division.



The accepted version of Phase Inversion coupling, as developed by the R.C.A. engineers.

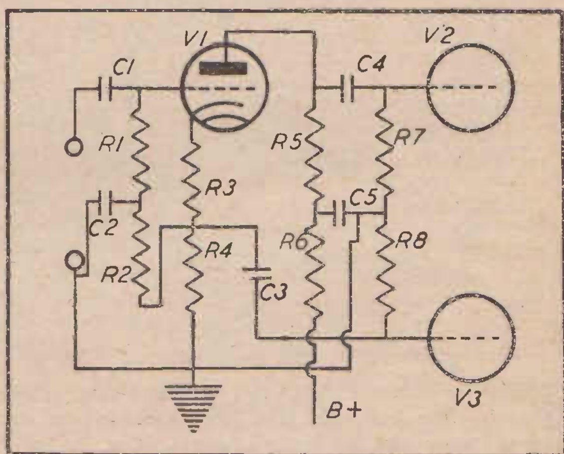
How It Functions.

Phase Inversion in this circuit is provided by V2, which is the second section of a twin triode tube such as at 6A6. The voltage output from V1 is applied to one of the push pull grids through the coupling condenser, C1, which may have asigned it to any value between .02 and .1 mfd. However, the grid resistor, R5, is tapped in such a manner that portion of the signal voltage developed across it by the action of V1 is applied to the grid of V2, the Phase Inverter valve. The voltage output from V2 is applied to the second of the push pull grids through the coupling condenser, C2, which should have the same capacity at C1.

When the output voltage from V1 swings the control grid of V2 positive, the plate current for this valve increases. Thus, there is an increase in the voltage drop across the plate resistor, R4, and the output from this valve becomes negative. In other words, there is a 180 degrees phase difference between the outputs from V1 and V2. It is necessary, however, for the output voltages from V1 and V2 to be the same. Suppose each valve has the same amplification factor—20 in this case. Such a state of affairs would be present if two valves of the same type were used and similarly so if the two sections of a twin valve were employed.

Assuming this amplification factor of 20 to exist, it then becomes necessary so to tap R5 that one-twentieth of the audio voltage developed across this resistor is applied to the control grid of V2. By doing this the voltage appearing across R5 will be equalled by that appearing across R6.

Following are circuit values for Fig. 2:—R1; 1 megohm. R2; 1150 ohms. R3, R4; .1 megohms. R5; .1 megohms tapped at 20,000 ohms. from earth end R6; .1 megohms C1 and C2 .03 mfd. V1 and V2 6A6 twin triode valve operated from 250 volts plate supply.



A variation of the standard Phase Inversial circuit, this system is known as "Signal Division."

Single Valve System.

There is a single valve method of Phase Inversion in which only the Phase Inverter tube is used ahead of the push pull grids, but this method has the weakness that not only is there not signal amplification in the phase inversion stage, but there is actually a slight loss of gain. The circuit dealt with above, does not suffer from this disability and, in fact, has a stage gain of around 20 in addition to provding Phase Inversion.

It is essential in these Phase Inversion circuits that the values of the grid and plate resistances be kept properly balanced. For this reason, the resistors should not have a greater tolerance than 1 per cent., and even closer tolerances are desirable.

Voltage Division.

In the voltage divider system we see in Fig. 2 an ordinary triode with a resistor, R5, connected between its plate and the "B" plus de-coupling net work comprising R6 and C5. R4 is a similar value resistor connected between the bias resistor and earth. R1 is the grid return resistor, for this tube connected to the normal bias point (negative end of the cathode resistor) through another de-coupling network made up of R2 and C2.

If a signal now be applied between the grid and cathode of the valve V1 it will be amplified and appear across the load resistors R1 and R2, with equal amplitude, but in exactly opposite phase. Thus, it becomes possible to feed this amplified signal off through the coupling condensers C3 and C4 to the grids of the succeeding push pull amplifier stage.

It is claimed by the sponsors of this system that it is far less critical in operation than the phase inversion system previously dealt with, and that it is capable of giving a better approach to true push pull operation than the straight phase inversion schemes. Still, we have found that this circuit is not nearly so satisfactory in operation as the standard phase inversion system.

For those interested in its operation, however, we provide the following circuit values: C1, C4, C3; .1 mfd. C5; 8 mfd. C2; 1 mfd. R1, R7, R8; .5 megohms. R2; .25 megohms, R3; 4000 ohms. R4, R5; 50,000 ohms. R6, 15,000 ohms. V1 Type 76 valve.

Whilst there is little doubt that high fidelity push pull transformers will give equally as good frequency response with fewer worries than phase inverted resistance coupling systems, the latter are particularly useful when cheap and compact construction must be combined with wide range frequency response.

VELOCITY MICROPHONE PLACEMENT

(Continued from page 53.)

sound from the surface of the table, desk, or manuscript.

The diagram also shows the placement of a dance orchestra. The only precaution necessary is to keep the soloist at least two feet, and preferably three feet, from the microphone.

Due to the fact that artists and announcers cannot work close to the microphone, some difficulty may be experienced in obtaining the proper balance between the artist or announcer and the orchestra. This difficulty can be overcome quite satisfactorily by using two microphones, one to pick up the orchestra and the other to pick up the artist or announcer. The artist's microphone should be located so that its "dead zone" is toward the orchestra. By a proper setting of the mixing controls, the level of the orchestra can be controlled so that a satisfactory background accompaniment of music is obtained.

In locating the microphone with respect to an orchestra, care should be taken to avoid reflected pick-up from hard surfaced floors. Such reflections can be avoided by the use of carpets or similar material on the floor.

For public address use, the microphone can usually be placed near the speaker (within three or four feet). It is important to see that the direction of minimum pick-up is toward the loud-speaker system to prevent acoustic feed-back. If the speaker must have latitude of movement on the stage, it may be necessary to have a microphone installed at each side to obtain satisfactory pick-up.

Microphones used for sound reinforcing purposes must generally be concealed and may be placed and successfully operated in the wings, footlights, flys, etc., of the stage. When the microphone is placed in a footlight trough, heavy sound-absorbing felt should be placed behind the microphone to prevent undesirable reflection effects. Such a system usually requires a number of microphones and the detailed location of these microphones is largely determined by the exact use of the microphone, constructional details of the stage, and other conditions so numerous as to preclude any definite statement of rules or methods of application.

The plane of zero sound may be utilised to great advantage in eliminating undesirable resonance, reflection, and diffraction effects usually encountered when a microphone is located in a cavity. This fact accounts for the highly successful application of this microphone to footlight trough mounting.

POWER EQUIPMENT

(Continued from page 30.)

A point which is worthy of attention is the checking of the valve filament voltages under operating conditions. If the transformer filament lighting windings are too lightly loaded, a voltage rise, which will lower the working life of the amplifier tubes, will take place. Measure the voltages with a good a.c. voltmeter whilst the valves are in circuit, and if the available voltage is more than 10 to 15 per cent. higher than that for which the tubes are rated, connect resistance in parallel with the filament winding until the voltage falls to the desired level. In most amplifiers it is possible to use standard transformers, which usually are made to deliver 385 to 400 volts at currents ranging from 60 to 150 m.a.

It is worth while remembering that by replacing the loud speaker field with a low resistance filter choke, it is often practicable to employ a standard type transformer on an amplifier normally calling for a special job. The speaker then would be of the P.M. type, which requires no field excitation.

Below is listed a representative collection of standard Radiokes transformers, showing the secondary voltages and currents available from each type. The primaries of all may be obtained with taps permitting operation on lines supplies ranging from 200 to 260 volts.

Filter Circuits.

We come next to the most important part of the power pack. On looking at the diagrams on page 30 it will be seen that two basic forms of filter circuits exist. These are the Condenser Input type of filter and the Choke Input type. Selection of either type will be governed by the operating conditions of the amplifier. The choke input type of filter is noted for its good regulation, and so is particularly suited to use with AB1 and AB2 amplifiers.

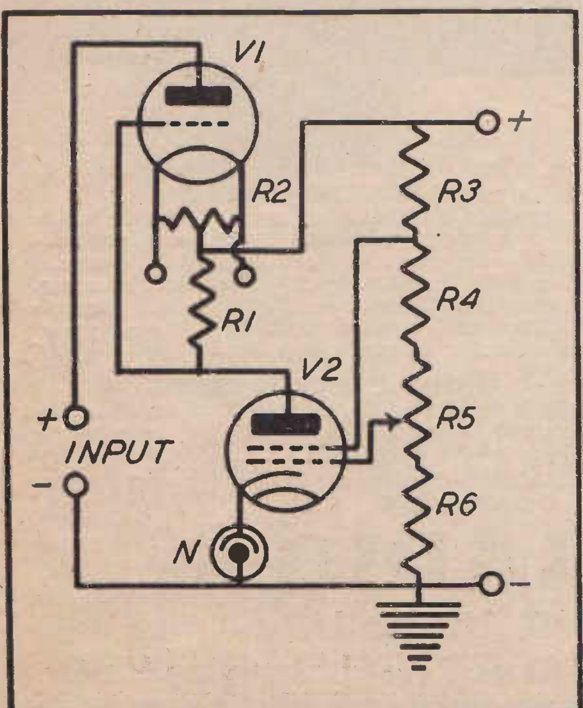
However, as will be seen from the graph on Page 30, there may be up to a 200 volt drop in the output when a choke instead of a condenser filter is used.

In the condenser input type of filter the first condenser should have a quite large capacity—from 8 to 16 mfd.—in order that a sufficient reservoir of power will be available to meet sudden peak demands by the amplifier. It this is not done distortion, due to starvation of the power tubes, will be introduced during the rendition of heavy low note passages.

Filter chokes themselves should be rated in terms of inductance for the current which is to flow through them, and have their d.c. resistance specified. Low resistance chokes, the values of which usually are specified by the circuit designers, are essential in Class AB and B amplifiers. In any amplifiers of this class it is undesirable to attempt to reduce the voltage to the tube plates by means of additional series resistance in any part of the plate supply circuits.

If the transformer will stand the additional current drain, then attempt the voltage reduction by means of a parallel resistance between the filter input and earth.

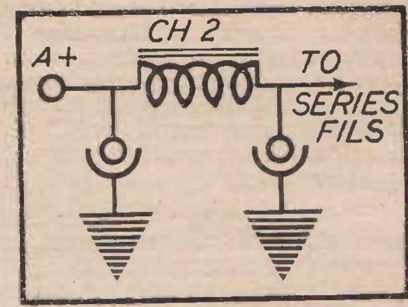
Glancing at the filter diagrams of Page 28, we see that a radio frequency choke coil is used in the vibrator filter circuit. This is by-passed by a small mica condenser, C, which may have a capacity of from .00025 to .001 mfd.. E1 and E 2 are standard electrolytics. It will generally be found, however, that the plate supply filter circuit is already built into the commercial vibrator power pack.



Circuit diagram of the voltage regulator unit.

Voltage Regulation.

Finally, let us deal with a simple, but effective, form of voltage regulator. The one shown uses a 2A3 and a 57, and is connected between the filtered output of the power unit and the amplifier with which it is intended to be used. With the circuit constants given the regulator will deliver some 250 volts at a current of 70 m.a. when the power unit feeding into it delivers around 400 volts at this current.



The filament filter circuit used in vibrator amplifiers.

It must be realised that the power transformer and associated filter circuit must be capable of delivering more voltage to the input of the regulator than is desired at the output. Adjustment of the output voltage is obtained through the 10,000 ohm potentiometer, R5. The degree of control ranges from about 175 to 375 volts, but the current available at the higher voltage will be only about half that available at 250 volts.

The neon tube, N, is a standard ½ watt Osram tube.

The power pack with which the regulator unit is employed, must have a separate filament winding for the 2A5. The 57, or 6C6 tube, if the transformer is fitted with a 6.3 volt filament winding, may be connected to the filament winding used for any of the tubes in the amplifier.

One other thing which should be touched on in this consideration of power equipment is the selection of the rectifier tube. For heavy duty applications in Class AB2 amplifiers tubes of the mercury vapour type should be used, because their regulation characteristics are considerably better than those of the filament or cathode type tubes.

COMPONENT VALUES FOR REGULATOR UNIT.

N—½ watt Osram Neon Lamp.
R1—.5 megohm Carbon Resistor.
R2—30 ohm Centre Tap Resistor.
R3—10,000 ohm Carbon Resistor.
R4—25,000 ohm Carbon Resistor.
R5—10,000 ohm Potentiometer.
R6.—5,000 ohm Carbon Resistor.
VALVES—One each, 2A3 and 57 (or 6C6).

ACOUSTICS

Correct Damping—Reverberation Period Explained—Sound Absorption Coefficients—Practical Applications—Eliminating Feedback.

ANYTHING approaching a full treatment of the science of Acoustics would call for infinitely more knowledge than the present writer possesses, and would require far more space than is available in the whole of this handbook. However, with the object of aiding those P.A. men whose business brings them into contact with indoor sound installations and their varying acoustic problems, we shall endeavour to give some outline of the subject.

First, we must understand that all sounds, no matter how produced, cause a tangible atmospheric disturbance. Sound, like light, can be reflected and from particularly good sound reflections the loss of sound may be only 2 per cent. against light's 5 per cent. minimum from the best light reflector.

Reflections of sound waves can cause distortion of speech or music, cancellation of some frequencies, and reinforcements of others, depending upon how the reflection takes place.

Effect of Over-Damping.

The elimination of reflections by heavy drapings can reduce the acoustic efficiency of a given hall or auditorium to a very low level; but this may be necessary in cases where extremely large volumes of sound, for example from a symphony orchestra, are to be radiated in the hall. However, too much damping gives a "flat" effect, whilst too little makes for reverberation.

An echo effect will take place if the total distance travelled by the reflected wave to the listeners' ear is 60 feet greater than the distance travelled by the direct sound.

Reverberation takes place when, due to the reflections back and forth between various hard surfaces, certain frequencies continue to be heard for some time after the original sound source has been silenced.

However, some degree of reverberation is desirable in any system in order to give naturalness to speech and music.

Testing Reverberation Time.

Considerable experiment on this subject has resulted in the drawing up of quite complete tables setting out the Optimum Reverberation Periods of halls of various sizes. A rough, but reasonably accurate guide to the Reverberation Period can be obtained by operating a 512 cycle source of sound (a whistle, pipe, or audio oscillator and loud speaker) for a sufficient length of time to fill the hall in which the test is being conducted (this latter condition will be readily recognised with a little practice), then shutting off the source of sound and measuring with a stop watch the time elapsing before the sound dies out completely.

Tests such as this should be carried out at a number of points around the hall, and should be repeated at each point. The Reverberation time for each test should be noted. The total time divided by the number of tests will give the average Reverberation Period for the hall.

Such a procedure would only be worth while on a big job or on a permanent installation. Where a temporary installation is being put in, the P.A. man's best procedure is to operate a number of scattered loud speakers at low sound levels, and thus obtain good coverage without troublesome echo or reverberatory effects.

For reference purpose, however, we include below tables of the Optimum Periods of Reverberation and the Sound Absorption Coefficients of various materials at the frequency, 512 c.p.s., for which the reverberation figures were calculated.

Table I.

Optimum Periods of Reverberation.

Cubic Feet.	Seconds
Below 7,000	1.0
7,000 to 20,000	1.1
20,000 to 45,000	1.2
45,000 to 85,000	1.3
85,000 to 145,000	1.4
145,000 to 225,000	1.5
225,000 to 330,000	1.6
330,000 to 465,000	1.7
465,000 to 630,000	1.8
630,000 to 835,000	1.9
835,000 to 1,100,000	2.0

The various factors involved and their bearing upon "time of reverberation" is expressed in

Sabine's formula: $T = \frac{.05V}{A}$

Where T equals time of reverberations in seconds, V equals volume of room in cubic feet, and A equals total number of absorption units in room. A is obtained by totalling the obsorption units of all materials in the room, and then measuring the square footage of all the materials employed in the surface construction of the room and multiplying the resulting figures by their respective coefficients of absorption.

Practical Application.

These coefficients of sound absorption have been determined for practically all materials, and each square foot is rated by comparison with one square foot of open window space, which is accepted as 100 per cent. absorptive, and therefore, has a coefficient of unity or 1.00. Thus if a square foot of curtain material absorbs $\frac{3}{4}$ as much sound as 1 square ft. of open window, the **coefficient of absorption** of the curtain is said to be 0.75. Table II. gives the coefficient of absorption units of different materials and individual objects at a standard pitch of 512 vibrations per second.

It is customary to subtract the absorption factor of the chair from that of a person to obtain the net absorption units brought in by each person. This is because the person covers the chair when seated. It is also assumed that the chair covers three-fourths of the floor space it occupies. It is evident that the size of an audience will affect the time of reverberation; therefore, T should be calculated for conditions such as (1) empty, (2) $\frac{1}{2}$-full, and (3) full.

Then, by transposing Sabine's formula and solving for A, we find the total number of the absorption units required.

$$A = \frac{.05V}{T}$$

Subtracting the actual number of absorption units from the required number, we obtain the number that must be added for ideal conditions.

Acoustic Requirements.

The amplifier installation should have a sufficient power reserve to meet the requirements of unfavourable conditions, for example, when the absorption is high, due to the presence of a capacity house in a theatre. It should not be run at full output when the house or hall was one or two-thirds full. Too much sound can be as unpleasant as too little, so that it is necessary to keep adjusting the amplifier's sound output with each major change in the acoustical conditions.

Remember that dance hall installations require more average output than would be required in similar sized halls devoted to lectures to a seated audience.

Where acoustic treatment is necessary, start at the rear wall of the hall. In most cases a few drapes here will often clear up troublesome echoes and reverberatory effects.

Directional type speakers, whether they be standard dynamics in directional baffles, square mouthed exponential horns, or the popular "Morning Glory" type of metal horn, will aid in keeping sound off hard reflecting surfaces and thus in reducing reverberation.

Acoustic feedback can be eliminated in three ways. The first and most uneconomic is to reduce the output of the amplifier to a point where the level of the sound waves fed back to the microphone is too low to actuate the latter. The second is to use directional type radiators and to keep the sound emitting points of these facing away from and ahead of the microphone. The third, and one which is coming into rapid use, is the employment of audio automatic volume control. Information on the application of this to Public Address Amplifiers will be found elsewhere in this handbook.

TABLE II.

Sound Absorbing Coefficients for Pitch of 512 C.P.S.

Material	Coeff. per Sq. ft.
Open window	1.00
Brick wall—plain, set in plaster	0.082
—painted	0.017
—plain, set in cement	0.025
—unlined 0.15 to	0.20
Carpets	
—lined with thin padding 0.20 to	0.30
—lined $\frac{1}{2}$-in. felt	0.25
Celotex—unperforated $\frac{7}{8}$-in thick	0.20
Acousti-Celotex—type BB, painted or unpainted, $1\frac{1}{4}$-in. thick	0.70
Cork Tile	0.06
Acoustic Tile—$\frac{1}{2}$-in. thick, with metal screen	0.42
Cement—top dressing on concrete	0.025
Concrete	0.015
Cocoa Matting—lined	0.17
Curtains—cretonne	0.15
—chenille	0.23
—velour, heavy folds	0.75
—hung straight, against wall	0.40
—cotton fabric, 10 ozs. per sp. yd.	0.11
Draperies—velour, hung same way,, 18 oz. per sq. yd.	0.35
Felt—all hair, 1 in. thick, 75 lbs. per sq. ft.	0.58
Glass—single thickness	0.027
Linoleum	0.03
Marble	0.01
Oil Painting—per sq. ft.	0.28
Plaster—on wood lath	0.034
Stage Opening—depending on furnishings 0.25 to	0.40
Ventilators 0.50 to	0.75
Wood—plain	0.06
—varnished	0.03
Individual Objects.	
Adult Person	4.7
Church Pews—per seat	0.2
Seat Cushions 1.00 to	2.00
Chairs—padded seat and back covered with imitation leather	1.6
—various padding, covered with velour or mohair 2.3 to	3.5
—opera plywood seat and back, plain	0.24
Piano	0.6
Table	0.2

A TRANSVERSE CURRENT MICROPHONE

Full Details Enable Its Building by the Experimenter.

FROM our earlier remarks on microphones, it will have been appreciated that we do not altogether favour the Carbon type. There is no doubt that this form of microphone has been outmoded by the Crystal, the Ribbon, and the Dynamic types. Unfortunately, the latter cost real money, whilst a really effective Carbon type microphone can be made by the experimenter easily, and at a comparatively small cost.

Another big advantage of the Carbon microphone is that, although it requires an exciting voltage, it is much more sensitive than the crystal and other types, so requires much less pre-amplification to drive the output stage.

The disability of "packing" of the carbon granules can be largely avoided by selecting good quality carbon and by operating the microphone at reasonable current levels.

Having briefly given the advantages and disadvantages of the home built microphone, let us now see how the intending constructor should go about the job of making a Transverse Current microphone.

The container should consist of some acoustically dead material. Marble is ideal, but is difficult to machine. The next best thing is much less expensive, and is easily handled by anyone possessing woodworking knowledge. It is common hardwood. Jarrah is the most generally used wood for microphone purposes.

The block should measure 3 inches by 2 inches by 1½ inches. On one three-inch face mark out a rectangle measuring 2¼ inches in length and 1¼ inches in width. This should now be carefully chiselled out to a depth of ⅛ inch, care being taken to keep the depth as uniform as possible over the whole area of the rectangle.

Next mark out two smaller rectangles inside the one which has been chiselled out. The smaller ones should measure 5/16th of an inch in width and 1⅛ inches in length. They should be 1½ inches apart. When they have been marked, chisel them out to a depth of a quarter of an inch. These troughs are to take the polished copper pole pieces.

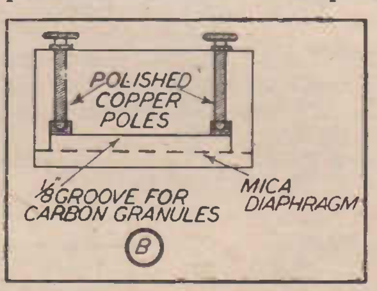
The pole pieces themselves should consist of 5/16th inch diameter copper rod which has been split longitudinally to form a "D." The length of each pole piece should be 1⅛ inches. These should be polished and then either nickel, silver, or gold plated.

Before the pole pieces are plated each should be drilled and tapped to take a piece of ⅛-inch threaded brass rod. These rods should be sweated on to the pole pieces after they have been screwed in. The rods must be long enough to extend from the pole pieces through the case of the microphone to take lock nuts and connection terminals.

Before going ahead with the construction and assembly of the microphone diaphragm it is necessary to drill a ⅛ inch diameter hole slantwise from the back of the microphone case to the top of the ⅛ inch deep slot provided for the Carbon. The purpose of this hole is to fill the recess with Carbon when once the diaphragm is in place.

When the carbon has been poured into the recess the hole is plugged with wax or some similar compound. Sufficient carbon should be poured into the recess fully to fill the space between the diaphragm and the back of the recess, but no attempt should be made to pack it into place, although judicious bumping of the case, to ensure that no gaps exist, is permissible.

However, before the Carbon is poured into the microphone we must make the diaphragm. With microphones of this type we may use either thin rubber or mica for the diaphragm. The latter is preferable because it will not perish,



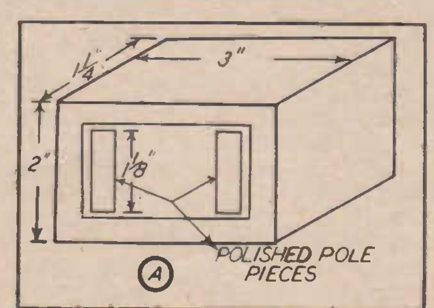


Fig. A shows the general details of the hardwood block, whilst Fig. B indicates the method to be followed in hollowing it out to take the pole pieces and to provide accommodation for the carbon granules.

but it needs to be protected by a grill of some sort, because it is liable to fracture if subjected to severe mechanical stress.

Assuming that mica is used, we shall want a sheet measuring 3 inches by 2 inches and .001 inch (1/1,000th of an inch) thick. This is mounted on the face of the microphone, and is secured in place by first coating the microphone case with seccotine or fish glue. However, the adhesive will not hold the diaphragm in place permanently, so it is necessary to construct some sort of a bezel.

This may consist of a 1/16th inch thick piece of brass or a ⅛ inch thickness of bakelite. It should measure 3 inches by 2 inches, and have rectangle measuring 2⅛ inches by 1⅛ inches cut out of it. This will permit an overlap of 7/16th of an inch all the way round the mica.

The bezel should be screwed to the face of the wooden block with four or six small round-headed wood screws. These should be nickelled to enhance the appearance of the finished job. A further improvement to the appearance of the microphone is the interposition of a fine brass or copper mesh between the bezel and the diaphragm. Mesh such as that of ordinary household flywire will be sufficiently fine.

However, in order that the mesh will not foul the diaphragm, it will be necessary to interpose a sheet of thin strawboard, cut to the same dimensions as the bezel, between the mesh and the mica diaphragm. The mesh could also be plated to ensure that its finish was in keeping with that of the rest of the michophone.

This completes the assembly of the microphone and all that is necessary now is to fill it with carbon. Good quality, polished carbon granules are necessary for best results, and carbon having a "screen" or 120 is recommended. About half an ounce of carbon will be required. In operation the microphone will have an impedance around 500 ohms, so for correct matching should be coupled to the input circuit through a 500 ohm line to grid transformer. The exciting voltage required for the microphone's operation ranges from 2½ to 8 volts, while the maximum permissible current flow through the microphone is around 10 m.a. This should be measured with a milliammeter connected in series with the microphone, and the source of the exciting voltage. For general work a mike such as this will be found fully satisfactory, and the fact that it is low in cost will appeal to many.

RESISTORS AND CONDENSERS

Watt Ratings and Colour Code Tables—Grid Circuit Resistances—Electrolytic, Mica and Paper Dielectric Condensers—By-Pass Capacities—Safe Operating Ratings.

THE two most universally employed components in amplifiers are Resistors and Condensers. The first are used as means of reducing voltage, preventing feed-back and aiding filtration, whilst the second find application as means of coupling at audio frequencies, as frequency acceptors and by-passes, and as filters in power supply units.

Our resistors are divided broadly into two classes—Carbon or Metalized types and Wire-Wound types. We have other inductive type resistors such as chokes and loud speaker field windings, but these possess, in addition to their direct current resistance, an a.c. resistance, or, as it is usually termed, a Reactance. We shall deal with the direct current resistors first.

The Carbon and Metalized type resistors range in value from 100 ohms to 5 or 10 megohms. They are characterised mainly by small physical dimensions and low current carrying capacity.

Wattage Ratings.

However, as the table shows, the question of resistor rating is bound up not only in the current carrying capacity but in the potential which may be applied between the resistor and the unit which it feeds.

Typical values are shown for One Watt rating resistors. Carbon and Metalized resistors are made in quarter watt, one-third watt, half watt, one watt, two watt, and three watt types, although the latter is not readily obtainable in Australia.

The chief requirements of these small resistors are noiseless operation and stability of resistance, both of which are obtainable in the better grade resistors.

From the Load Characteristic Table it will be seen that as the value of the resistance rises so the permissible current passing through it falls.

On the other hand, the permissible voltage which may be applied between the resistor and the load, assuming that it is being connected in series, rises with an increase in resistance.

Where the operating conditions call for an increase in either of these figures for a given resistor it is necessary to employ a resistor of greater wattage rating.

The main thing to watch in employing Carbon or Metalized resistors is to keep soldering flux from coming in contact with the body of the resistor, and to be careful when soldering them into circuit to keep the soldering iron from making contact with the metal seals at the ends of the resistor. Failure to observe either precaution will result in noisy operation and in variation of resistance from the specified value.

Wire Wound Resistors.

For heavier current carrying applications but where high resistances are not required we have wire-wound types. These are rated to carry currents up to 300 or 500 m.a. depending upon the particular type and upon the actual resistance of the unit. Most amplifier type wire-wound resistances will have current carrying capacities ranging between 10 and 250 m.a.

Resistor Colour Codes.

First Colour: Body or Label—represents first figure.
Second Colour: End—represents second figure.
Third Colour: Dot—represents number of following noughts.

0—Black	5—Green
1—Brown	6—Blue
2—Red	7—Violet
3—Orange	8—Grey
4—Yellow	9—White

Thus:

Value.	Body.	End.	Dot.
10,000 ohms.	Brown	Black	Orange
15,000 „	Brown	Green	Orange
20,000 „	Red	Black	Orange
25,000 „	Red	Green	Orange
30,000 „	Orange	Black	Orange
50,000 „	Green	Black	Orange
100,000 „	Brown	Black	Yellow
150,000 „	Brown	Green	Yellow
200,000 „	Red	Black	Yellow
250,000 „	Red	Green	Yellow
300,000 „	Orange	Black	Yellow
500,000 „	Green	Black	Yellow
1 meg.	Brown	Black	Green
2 „	Red	Black	Green

The lower values will be suitable for voltage amplifier tubes such as the high gain r.f. pentodes and for certain triodes. For Class AB2 or Class B driver triodes we will require resistors having a current carrying capacity around 50 m.a. whilst for the output stages the capacity will range from 50 m.a. upwards.

We have always found it a good practice in designing an amplifier **to employ wire-wound resistors at least 100% higher in rating than are actually called** for in the circuit. Thus, a valve whose total cathode current, plate and screen in the case of a pentode, was 50 m.a., should always be provided with a bias resistor of suitable ohmage, but rated to carry, not 50, but 100 m.a. Remember, too, in calculating bias resistors, that where two valves are used in push-pull, the value of the bias resistor is half that of one required for a single tube, but its current carrying capacity **must be twice as great.**

From our previous suggestion, then, we see that the 1500 ohm 50 m.a. resistor for a single tube would become a 750 ohm 200 m.a. resistor for push-pull tubes.

After all, a resistor is much cheaper than one or a pair of new output tubes, so it pays to see that it is safeguarded against all reasonable possibility of overload.

Cathode resistor breakdown could quite easily occur in such a way that the supply might be completed, yet the cathode bias be removed. The result would be the wrecking of the output tubes, particularly if these were working under AB1 or AB2 conditions.

The cardinal rule in selecting resistors for amplifiers is to buy the best. The price difference between first class and inferior types is small yet the performance difference and general reliability is as divergent as the poles.

Amplifier Grid Resistors.

For amplifier work we cannot afford to use grid resistors of too high a value. The grid circuit resistance should be kept as low as possible, so that there shall be no tendency towards signal "choking" or, in more serious cases, for the amplifier to sound distorted or to cut out entirely.

These effects are far more likely to be met where high value grid resistors are associated with large power tubes.

The maximum resistance permissible in the grid circuit of any valve is one megohm, but this high value should be used only with extreme caution.

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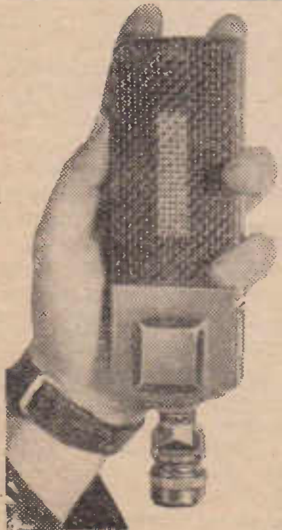
Stedipower Paper Moulded Condensers up to and including .1 mfd.		1/-
.00005 mfd.—.00025 mfd.	Type M Mica	1/-
.0003 mfd.—.0005 mfd.	"	1/1
.0006 mfd.—.0009 mfd.	"	1/3
.001 mfd.—.003 mfd.	"	1/6
.004 mfd.—.006 mfd.	"	1/7
.007 mfd.—.009 mfd.	"	1/9
.01 mfd	"	2/1
.02 mfd	"	3/6



"BRUNO" VELOCITY MICROPHONE

The Bruno Velocity Mike, being actuated by the Velocity component of the sound wave, rather than by its kinetic energy, eliminates the resonant peak inherent in the diaphragm type microphone.

SK4 MODEL.
Output Level — 64 db.
Freq. ± 1 db 50-12,000 cycles.
Equipped with 10 feet Shielded Cable.
£15/15/-.

SK2 MODEL.
Output Level — 78 db.
Freq. Response ± 2db.
60-10,000 cycles.
£10/10/-.

TRANSVERSE CURRENT MICROPHONE

To Builders of this excellent Microphone we offer a complete kit of parts necessary for the building thereof. The Kit contains Block, Plated Contacts, Terminals, Mica Diaphragm, and Polished Carbon Granules, etc.

THE COMPLETE KIT OF PARTS COSTS 17/6.

Wooden Block	4/6
Polished Carbon Granules	7/6
Pair Plated Contacts	1/6
Mica Diaphragm	6d.
Gauze Cover	1/6
Cover Plate	2/6

Complete Microphone, 25/-. Transformer to suit, 15/6.

AUSTRALASIAN ENGINEERING EQUIPMENT CO.
370 Little Collins Street, Melbourne. MU 2315

Normally .25 or .5 megohm grid resistors should be used.

Triodes such as the 2A3 should not be fitted with grid resistors higher than 10,000 ohms when fixed bias is used, but when the valve is automatically biassed, then the grid resistor may be increased to between 250,000 and 500,000 ohms.

Condensers.

Now for condensers. Here we have three types—Electrolytic, Paper, and Mica dielectric condensers. The former are most widely used in cases were large capacities are called for. For filter condensers, large audio by-passes, and de-coupling condensers the electrolytic type has ousted the paper dielectric condenser although the latter has definite advantages which seem to have been overlooked in the prevailing quest for lowered constructional costs.

Electrolytic condensers are of two types—the wet and the dry. In the former, the electrolyte is a definite liquid, which is in direct contact with the plates of the condenser. In the dry type, electrolytic, the electrolyte is mixed with a form of porous binder, and does not "slosh" around in the container, although it functions similarly to the truly liquid electrolyte.

Many arguments have been advanced both for and against each type of electrolytic condenser, but in point of fact we find that modern manufacturing technique has left little margin of selection between either.

Electrolytic condensers should not be used in circuits where alternating current is flowing because their very construction is in the nature of a "valve" in which current may pass easily in one direction, but be retarded from flowing in another. The action of alternating current is such that the polarity of current flow is changed rapidly with resultant ill effects on the condenser. However, in practice we find electrolytics widely used as by-passes on the cathodes of audio tubes without apparent ill effects.

Polarity Essential.

On power supply circuits, however, where the voltages are high it is essential for the condenser to be connected in correct polarity. Failure to observe this will result in the breakdown of the condenser, an occurrence sometimes attended with a wide scale spraying of the electrolyte through the breather holes in the can.

All electrolytic condensers have a "leakage current." This current increases with an increase in the potential applied to the condenser but most good quality electrolytics will not have a leakage current in excess of .1 m.a. per micro-farad.

In selecting electrolytic condensers for specific service (this remark applies to all condensers), bear in mind that in circuits which are carrying rectified a.c. or straight a.c., there is always a peak voltage value to be considered. This is 1.4 times the normal or R.M.S. voltage, so the condenser must be adequately rated if it is not to break down.

For example, the first filter condenser—i.e., nearest the rectifier, in a power pack delivering 400 volts must be able to withstand the 400 x 1.4 or 560 volts which will be applied to it on peaks. Failure to observe this fact is the reason for so many disappointments with filter condenser units.

Paper and Mica Type Condensers.

Paper condensers ranging in capacity from .0001 mfd. to .5 mfd. are to-day usually of the tubular type. There are still many of the old "block" type paper dielectric condensers available, and, providing their voltage ratings are within the limits demanded in any particular circuit application, these may be used with equal satisfaction.

The newer tubular type condensers are usually of the so-called non-inductive type but this feature has not very much application to audio work. However, just by way of standard practice, connect the outer foil or "grounded end" of the tubular condensers to the low potential side of the circuit.

Paper type condensers find wide application as plate and screen supply by-passes and as tone compensating condensers. In all cases where high audio voltages are likely to be present we still prefer the mica dielectric type of condenser. Modern manufacturing methods have improved the dielectric strength of the paper type condensers considerably but the higher safety factor of the mica types make their use desirable, where capacity factors do not impose a barrier.

For all small coupling condensers—up to .02 mfd.—for tone compensating by-passes, and for hum-bucking condensers in power packs, the mica dielectric type condenser still, in our opinion, is unbeaten.

Application Details.

Now for details of the practical application of condensers. The Reactance Chart shows the reactances or opposition to the flow of alternating current possessed by various capacity condensers. Unlisted capacities can be calculated on a pro rata basis. From this chart it will be seen that the higher the capacity of the condenser the less opposition it will offer to the passage of alternating currents. The higher the frequency of the current the easier it will pass through a given capacity condenser.

From this we can understand that for hum suppression reasons or because we wish to by-pass some particular frequency the higher the capacity of the condenser the more it will eliminate this frequency. Of course that's all right where we want to eliminate one frequency, but, remember that although a condenser may offer an easy path to one particular frequency, it will offer only a slightly less easy path to other higher and lower frequencies.

In order to get a true elimination of any particular frequency we have to combine capacity with reactance in the form of complicated filter systems. From the angle that we want to provide a reactance—free passage for audio frequency currents, we find that we require an increasingly large capacity condenser as the frequency of the lowest current is increased.

Thus whilst a condenser of, say, .1 mfd. would offer a reactance (or in a practical sense a resistance) of 31,800 ohms to the passage of a 50 cycle current a 1 mfd. condenser would offer only one tenth this reactance.

Correct selection of the by-pass condenser across a cathode resistor is necessary, otherwise the gain of the amplifier will be reduced. Furthermore, the use of too small capacities as by-passes, will result in a lowering of the bass response.

LOAD CHARACTERISTICS

One Watt Metallised Resistors.

Resistance Ohms.	Current m/A.	Volts.
4,000	15.8	63.4
5,000	14.2	71.0
6,000	12.9	77.5
7,000	12.0	84
8,000	11.2	89.5
9,000	10.5	95.0
10,000	10	100
15,000	8.1	122
20,000	7	141
25,000	6.3	158
30,000	5.8	173
40,000	5.0	200
50,000	4.5	224
60,000	4.1	245
70,000	3.8	264
80,000	3.5	283
90,000	3.3	300
100,000	3.16	316
150,000	2.6	388
200,000	2.23	447
250,000	2.0	500
500,000	1.4	707
1,000,000	1	1000
2,000,000	0.7	1410
4,000,000	0.5	2000

LOUD SPEAKER BAFFLES

Why Baffle is Necessary—Directional Radiators—Infinite Baffles—Avoidance of Resonances.

DESPITE its widespread use in aiding the reproduction of the low frequency tones fed to the loud speaker, the action of the Baffle is very imperfectly understood by the majority of people who use it.

To make clear the functioning of the Baffle, which is by no means the "sounding board" which many believe, the following summary has been prepared:

A dynamic cone loud speaker functions over most of the audio range as a piston, driven by the A.F. output of any amplifier through the agency of its voice coil, which may best be considered as a "motor" driving the piston (cone). When the cone is so driven by an audio-frequency signal, it moves forward and backward, thus displacing surrounding air both in front of as well as behind the cone. It is this displaced air which the ear perceives as sound.

In such operation, the air pushed out in front by the cone moving forward must go somewhere. As a partial vacuum is created at the rear of the cone as it moves forward, the displaced air in front finds it most easy to flow toward the partial vacuum at the rear, because the space at the rear of the cone needs new air to fill the semi-vacuum left by the forward movement of the speaker cone.

The net result of this action in theory is the generation of sound waves in only the air very near the cone.

This is true for very low frequencies, but not for high frequencies. Thus, in practice, an unbaffled speaker will reproduce high tones, but will lack almost entirely all low tones, due to this cancellation described above. (See Fig. 1A.)

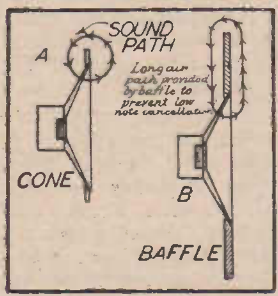
Defining the Term.

A baffle is any means at all placed between the cone front and the cone rear which lengthens the distance the air must travel from front to rear to cause cancellation of front pressure by rear vacuum, as the cone moves forward in its reproducing cycle.

For high frequencies, the "baffle" provided by the size of the cone itself is sufficient to prevent cancellation. The low-tone reproduction range is dependent upon the size of the baffle, or more exactly, the length of the air path from the centre of the cone in front to the centre of the cone at the rear. (See Fig. 2.)

The purpose of the baffle is to so lengthen the front-to-back air path so that air displaced by the forward movement of the cone cannot reach the near-vacuum at the rear until the "vacuum" has ceased to exist, by virtue of the cone having had time to pull backward.

The baffle should be made of some acoustically "dead" (non-vibratory) material, such as softwood, celotex, or the like. If it is hard and stiff (or thin) it will vibrate in itself, which it should never do, for, if the baffle vibrates, it contributes tones to reproduction which were not intended to be in it, thereby causing distortion.



Showing how the sound path is lengthened by the use of a baffle.

Baffle Board Sizes.

There is a simple rule for figuring sizes of baffles to reproduce down to any desired frequency, below which, however, they will cut off rapidly. It is based upon the speed of sound travelling in air (1130 feet per second, approx.), and its frequency per second.

By this same "rule of thumb," we get the path lengths, for different low-frequency cut-offs below which our speaker will not reproduce, shown in Table 1.

TABLE 1.

*Cut-Off Frequency (in Cycles)	**Length of Path (in Feet)
100	5.65
60	9.416
40	14.125
30	18.83
20	28.25

(*Lowest frequency to be reproduced. **Measured from front-of-cone centre to rear-of-cone centre.)

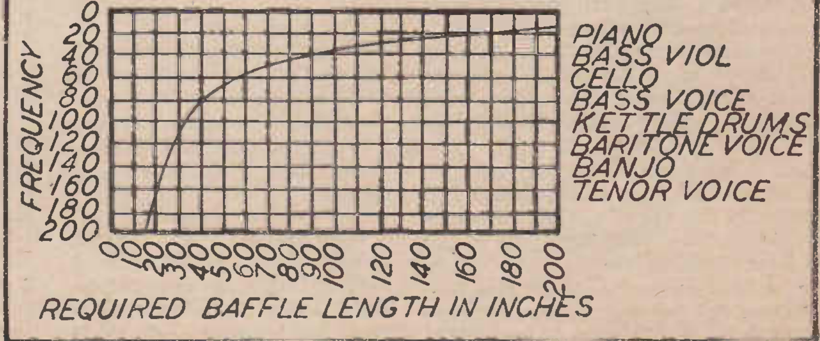
Remember that these are figures in feet for the shortest distance from the cone centre at front to the cone centre at rear. If our baffle is to be a flat, soft board 1 to 1½ ins. thick, we will need the air path lengths given in the table in order to reproduce down to the frequencies given. If the baffle is a square, flat board with the reproducer at the centre, then these figures are for size of the square baffle, since, if the speaker is at the centre, sound must travel half of each figure from front to baffle edge, and again this same distance around to the cone rear.

Acoustic Labyrinths.

So far we have dealt entirely with the "flat" baffle. There are other forms of baffles which are more complex in structure, but which operate with the fundamental idea of presenting the longest possible path between the front and the rear of the speaker itself, to those tones which lie in the low frequency region below, say, 100 cycles per second.

Each of these special types has its adherents, but usually their design depends upon highly technical knowledge of the acoustic characteristics of the speaker with which they are to be used.

The Acoustic Labyrinth consists of an enclosed box, in which the loud



From this chart the required baffle size, considered as the width and length of a flat board when the loud speaker is centrally mounted, can be computed for given frequency responses.

speaker is mounted. Inside this box are a number of interleaved plates of acoustically "dead" material, such as celotex. Alternate sheets are spaced at predetermined distances from each side of the box and a pre-determined air gap is provided between adjacent plates. At the rear of the labyrinth is provided an opening designed to reduce air pressure effects.

The idea of the labryinth is that the sound wave from the rear of the loud speaker dissipates its whole energy in traversing the air path provided around the baffle plates.

This system has been used with success by radio manufacturers and by those sound equipment manufacturers who have the fullest technical knowledge both of baffle design and of the loud speaker with which the baffle is to be used. However, for the average man, the Acoustic Labyrinth is a snare and a delusion. If he does obtain an increase in apparent bass note reproduction he will probably find that this is due to cabinet resonance, an undesirable condition, rather than to the true baffling effect of the labyrinth.

The Infinite Baffle.

A variation of the baffle plate labyrinth consists of what is known as the Infinite Baffle. This is less critical in design and has been found to give first-class results under a wide range of conditions.

It consists of a box measuring 24 inches in height, 21 inches in width, and 13 inches from front to rear, and is designed to house both a low frequency speaker and a tweeter. The low frequency speaker should be mounted at a point eight inches down and eight inches in from the top left-front corner of the baffle. The tweeter should similarly be mounted eight inches down from the top of the baffle, but four inches in from the top right-hand corner of the baffle.

Inside the baffle two wooden boards, measuring 18 inches in length and 11½ inches in width (the complete unit is made of ¾ inch thick wood) are screwed in place. The lower one is mounted at a distance three inches up from the floor of the box, and has one of its ends screwed to the tweeter, right-hand side of the box. The upper one is three inches above the first, and has its end screwed to the left hand side of the box.

When these have been put in place, a slot measuring nine inches in length and one inch in width is cut in the side wall of the box, just below the lower baffle plate.

Next the whole inside of the box, including the top and bottom of each baffle plate and the rear cover (which may be a hinged door if desired), is covered with "hair wool," which can be obtained in rolls measuring up to one inch in thickness.

This is glued on and cut out where it covers the openings for the two loud speakers, and the pressure release slot. This baffle will be found quite effective for indoor P.A. work. It is practically undirectional, and thus is nearly free from acoustic feedback effects. At the same time, it will aid the low frequency response without introducing cabinet resonances. For portable work the unit can be fitted with handles. The dimensions given are the minimum for a 12-inch speaker, and could be increased with advantage.

Exponential Horns.

We come next to the Exponential and other type loud speaker horns. These are particularly advantageous for outdoor work and for talkie theatre reproduction, for they are quite directional, and, when properly designed, are highly efficient.

The length of the horn is important, for the large air-column load which exists in a long trumpet imposes a desirable acoustic load on the loudspeaker diaphragm.

The low frequency cut-off of a horn is governed by the area of the bell or mouth. The larger this is, the lower the frequency to which the horn will respond. From this it can be seen that, given equal diameter, the square-mouthed horn is to be preferred to the bell-mouthed type for low frequency response, although the latter is much easier to handle.

Some loud speaker manufacturers make speaker units intended to be mounted directly to a small-throated trumpet. This type of unit is to be preferred for portable work, and will give very satisfactory results in all outdoor applications. The exponential horn is so called because its cross section area doubles for equal increases in length. If the area doubles for every foot in length the area would be two square inches at one foot from the throat; four square inches at two feet; eight square inches at three feet; 16 square inches at four feet; and so on. This increase is called Expansion Ratio. From this it can be seen that we can design either a long, narrow exponential of slow expansion, or a short, wide one of rapid expansion.

When correctly designed, an exponential horn radiates a wide frequency range uniformly.

Low Frequency Coverage.

The low frequency cut-off is determined by the expansion ratio. A horn which doubles its area in each foot of length will reproduce down to 64 cycles per second, whilst one doubling only half as rapidly, each two feet of length, will respond to 32 c.p.s.

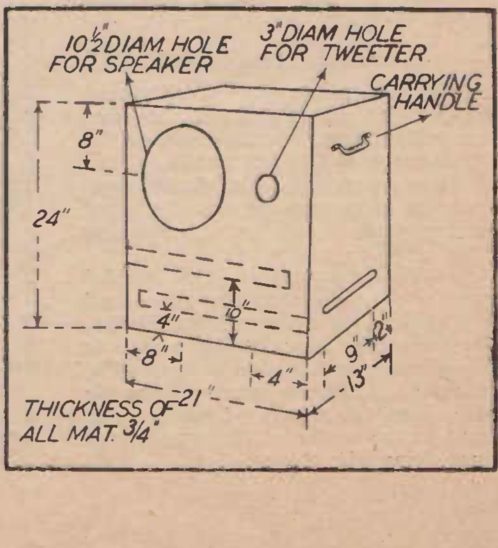
Points in the construction of exponential horns are:

The horn must be free from noticeable resonance, and for this reason the mouth diameter should be made equal to one-quarter of the wavelength of the cut-off frequency. The latter is determined by the expansion rate.

If the cross section of the horn is square, the side measurements should equal the diameter. Thus, if we were working on calculations involving a four-feet diameter circle, then each side of the square horn mouth should measure about four feet.

The horn may be built of celotex sheets, which are drilled and laced together with strong cord. Before assembly, the inside of the celotex should be coated with shellac or some similar varnish, to make its surface as smooth as possible. Papier mache is sometimes used, but its handling calls for some skill.

As in all cases where the acoustic loading is good and the cancellation of the rear and front sound waves from the loud speaker is eliminated, the efficiency of the exponential horn is high. This, added to its directional properties, makes it a valuable aid to the P.A. man.



This dimensional sketch of the Infinite Baffle gives all the information necessary for its construction. Note that provision has been made to house a tweeter as well as a conventional low frequency loud speaker.

The dotted lines indicate the two baffle plates screwed to the inside of the cabinet. Note that a three-inch gap is provided between each baffle plate and one side of the cabinet.

AN ACOUSTIC LABYRINTH

Full Building Instructions.

ALTHOUGH, as we have emphasised in the previous section, the building of Acoustic ltbyrinths is hardly a matter to be undertaken without foreknowledge of the acoustic properties of both the loud speaker and the baffle unit itself, the following details are provided for those who wish to experiment.

As will be seen from the scale drawings of the labyrinth it consists essentially of a wooden box measuring 24 inches in depth (all inside dimensions). Inside the box are placed 12 baffles of half-inch thickness Celotex or similar sound absorbing material. The box is provided with a screwed lid and floor, the latter being two inches shorter at the back end of the box to provide an air outlet.

Were no air outlet provided the inequality in pressure between the front and back of the cone would seriously affect the loud speaker's performance. The Celotex baffles are located half an inch apart and alternatively run from one side of the box to within half an inch of the other side. The actual construction of the box is not very difficult, but requires some knowledge of joinery.

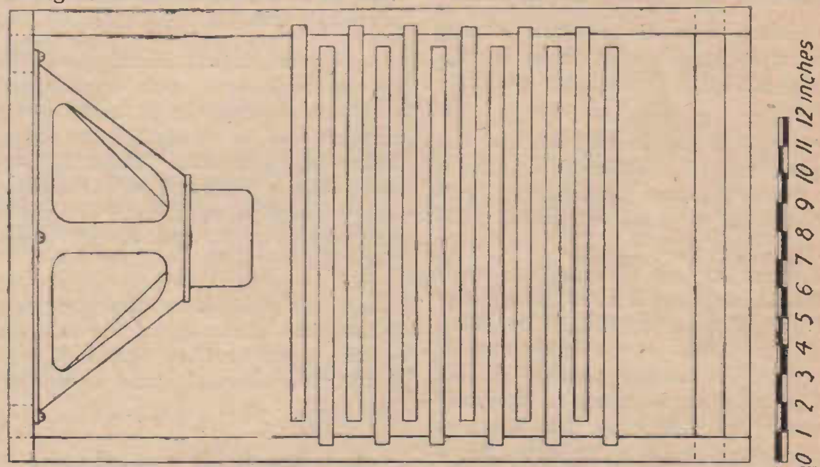
When the sides, ends, top and bottom have been cut to size, the sides and ends are "halved," as indicated in the heading illustration. Then the bottom and two sides are set up and marked out for the 12 baffle plates. Each side is trenched for six baffle plates whilst the bottom is trenched for the whole 12 baffles. The trenches are half an inch in width and from ¼-in. to 5-16 in. deep. Those in the sides of the box run right through from one side to the other, while those in the bottom terminate half an inch from each side of the board.

Be very careful when laying out the trenches that they are dead square, otherwise it will be impossible to fit the Celotex baffles when the labyrinth is being assembled. The lid of the box is not trenched. It and the other sections of the assembly are screwed together and the baffle plates then are forced into the trenches.

These baffle plates will measure 14¾ inches or 14 and 5-16th inches in height (depending upon the depth of the trenches) and 13¾ inches or 13 and 3-16th inches (again depending upon trench depth) in width.

Each alternate baffle is half an inch from the left-hand side of the box, the other alternates being separated a similar distance from the right-hand side. The front side of the first baffle is located 9 inches from the front inside of the box.

Don't be afraid to use plenty of screws when screwing the assembly together. Air leakages and warping of the timber will affect both the efficiency of the labyrinth and its freedom from resonance. Both can be materially reduced by careful screw placement.



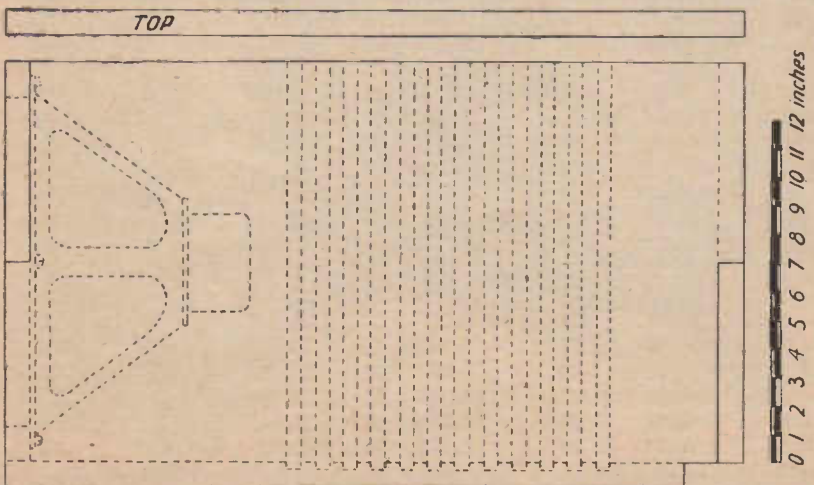
A plan view diagram which shows clearly the alterations of the baffle plates in the box. Like the other diagram this one is to scale.

The front of the box has a circular hole cut out in it to take the loud speaker, the latter being screwed to the inside of the front and also to the bottom of the box.

A small hole drilled in the side of the cabinet in the loud speaker compartment, and just large enough to take the speaker leads, will be necessary.

With the speaker in place and the lid screwed on, the labyrinth is ready to operate. Although it will give very good results when used at floor level, there is some tendency to over-emphasise some notes in the lower register. For this reason the labyrinth should be mounted, either on a stand or in the received cabinet, so that it is some distance up from the floor.

Although the dimensions given in this article are for a labyrinth which will effectively baffle a 12-inch loud speaker of the High Fidelity type, there is no reason why the dimensions should not be proportionately reduced to take a smaller speaker. The main thing is to ensure that as great an air path as possible, as arranged by a large number of baffles, is provided. The results with smaller loud speakers will be improved proportionately to those obtainable from the high fidelity types.



A dimensional side view drawing of the labyrinth showing how the baffle plates are trenched into the floor of the box.

THE DECIBEL

Logarithmic Response of Ear—Power and Voltage Ratios—Loud Speaker Ratings—Gain and Output Power Calculations.

THE amplifier designer should have a working knowledge of elementary arithmetic, and be able to use a few simple formulæ. These have been set out in this section.

Another angle of amplifier calculations is the employment of the Decibel as the yardstick of amplifier performance.

Full use of the Decibel involves the employment of a book of logarithms, but for all practical purposes the tables we have set out here will prove sufficient.

Modern practice in rating amplifier performance is to list the power and voltage gains of amplifiers, speakers, and microphones as plus or minus so many db. A simple addition of db. rating indicates whether an amplifier possesses enough gain for a given microphone, or if a pre-amplifier is needed, how much gain the pre-amplifier must have.

If the same amplifier is to be used with both the microphone and the pick-up, it may have enough gain for the one, but too much for the other, and will overload when it is used. The db ratings will indicate how much attenuation or loss must be introduced into the circuit to obviate the possibility of overload.

Use of the DB.

THE db. is used in two ways, and these must be carefully distinguished. An amplifier may, for example, have a gain of 120 db., but a power output of 30 db.

First, let us consider the use of the db. to express gain or amplification. In this connection one of its values is that it can be used to express large, complicated numbers by small and simple ones. Modern amplifiers may amplify 1,000,000,000,000-fold the sound power applied to their input terminals. In the decibel system such an amplification would be expressed merely as 120 db. To determine the db. equivalent of a whole number, such as 1000, simply count the zeros and multiply by 10. There are 3 zeros in 1000, so the db. equivalent (power ratio) is 3 times 10, or 30.

Unfortunately, in actual practice, power ratios do not always come out in round numbers, but the table provided will give the ratios in five db. steps, which is near enough for most practical work.

A very important advantage of the db. in connection with amplification problems is that large and clumsy numbers can be multiplied by adding their db. equivalents. Thus, a thousands time a thousand is one million. One thousand is equal to 30 db. Thirty plus thirty is 60, and 60 db. equals 1,000,000.

However, this only shows up the arithmetical advantage of the db. The decibel is particularly useful in considering the effect of sound on the human ear.

Ear's Response Logarithmic.

IN addition to expressing amplification the db. is used to rate power level, and is a valuable substitute for the watt. Obviously, since the db. is capable of comparing the output power delivered by an amplifier with that fed into it, it can also compare the same output power with any accepted standard or "reference level."

Thus, if the standard chosen were 1 watt, a power of 100 watts would represent 20 db. Actually, the standard chosen is .006 watts, or six milliwatts. Taking .006 watts as a standard, multiply it by 10, bringing it to 60 milliwatts. Reference to the table of power levels, will show that this corresponds to a gain of 10 db.

Similar multiplications of 10 increase the number of db. by 10 each time, and we find that a power of 60 watts (.006 watts by 10,000) equals 40 db.

Now, the human ear can hear only those changes in volume which are proportionate to that already present. If the sound level is 1 watt, an increase to 10 watts will easily be noticed, but an increase from 600 to 610 watts cannot be detected.

The average human ear can detect only 3 db. increases in power, so that, whilst it could hear the 10 db. change from 1 to 10 watts, it could never detect the .043 db. change from 600 to 610 watts.

The ear will detect an increase in volume only if the existing volume is **doubled or more than doubled.** Similarly, a decrease will not be noticed until the existing volume is reduced to one-half or less. If the existing volume

DECIBELS VERSUS WATTS OUTPUT.

D.B.	Watts.	D.B.	Watts.	D.B.	Watts.	D.B.	Watts.
—20	0.00006	0*	0.006	20	0.600	40	60.00
—19	0.000076	1	0.0076	21	0.759	41	75.90
—18	0.000095	2	0.0095	22	0.948	42	94.87
—17	0.00011	3	0.0119	23	1.185	43	118.59
—16	0.00015	4	0.0153	24	1.518	44	151.8
—14	0.00023	6	0.0237	26	2.371	46	237.18
—13	0.000303	7	0.0305	27	3.036	47	303.60
—12	0.000397	8	0.0380	28	3.795	48	379.50
—11	0.000474	9	0.0474	29	4.743	49	474.37
—10	0.0006	10	0.060	30	6.000	50	600.00
— 9	0.00076	11	0.0759	31	7.590	51	759.00
— 8	0.00095	12	0.0948	32	9.487	52	948.75
— 7	0.00119	13	0.1187	33	11.859	53	1185.94
— 6	0.00152	14	0.1518	34	15.180	54	1518.00
— 5	0.00190	15	0.1898	35	18.975	55	1897.50
— 4	0.00237	16	0.2372	36	23.718	56	2371.88
— 3	0.00303	17	0.3037	37	30.360	57	3036.00
— 2	0.00397	18	0.3795	38	37.950	58	3795.00
— 1	0.00474	19	0.4744	39	47.43	59	4743.75
						60	6000.00

* Zero Reference Level.

is 1 watt, an increase to 2 watts will be heard, but an increase from, say, 6 watts to anything less than 12 watts, will make little or no impression.

If a loud-speaker system has an output power of 6 watts, or plus 30 db., the level must be increased to 33 db., or 12 watts, for a volume increase to be noticed.

To use the db. in amplifier calculations, we first must decide upon the output wattage. Suppose this to be 15. Then, from our power level chart, we find this corresponds to approximately 34 db. Now, we propose to use a crystal microphone, whose power level is minus 70 db. By adding the two figures together we find that the over-all power gain must be 104 db., or 25,120,000,000.

SPEAKER RATINGS.

Number of Speakers, at Level Indicated Which Can Be Operated.

Output Level Per Speaker. D.B.	Watts	28DB	33DB	36DB	39DB	42DB
33	11.86	—	1	2	4	8
32	9.49	—	1	2	5	10
31	7.59	—	1	3	6	12
30	6.00	—	2	4	8	16
29	4.74	—	2	5	10	20
28	3.79	1	3	6	12	25
27	3.04	1	4	8	16	32
26	2.37	1	5	10	20	40
25	1.90	2	6	12	25	50
24	1.52	2	8	16	32	64
23	1.19	3	10	20	40	80
22	0.95	4	12	25	50	100
21	0.76	5	16	32	64	128
21	0.60	6	20	40	80	160
19	0.47	8	25	50	100	200
18	0.38	10	32	64	128	256
17	0.30	12	40	80	160	320
16	0.24	16	50	100	200	400
15	0.19	20	64	128	256	512
14	0.15	25	80	160	320	640
13	0.12	32	100	200	400	800
12	0.09	40	128	256	512	1024
11	0.08	50	160	320	640	1280
10	0.06	64	200	400	800	1600
9	0.05	80	256	512	1024	2048
8	0.04	100	320	640	1280	2560
7	0.03	128	400	800	1600	3200

To use this table, proceed as follows: For example, to operate a group of 24 speakers at 19 d.b. level; look in the first column and find 19, then check horizontally until we find the nearest figure to 24 (which is 25) and then check at the top of the column, and obtain the necessary power in d.b. that the amplifier must deliver to operate this group of loudspeakers.

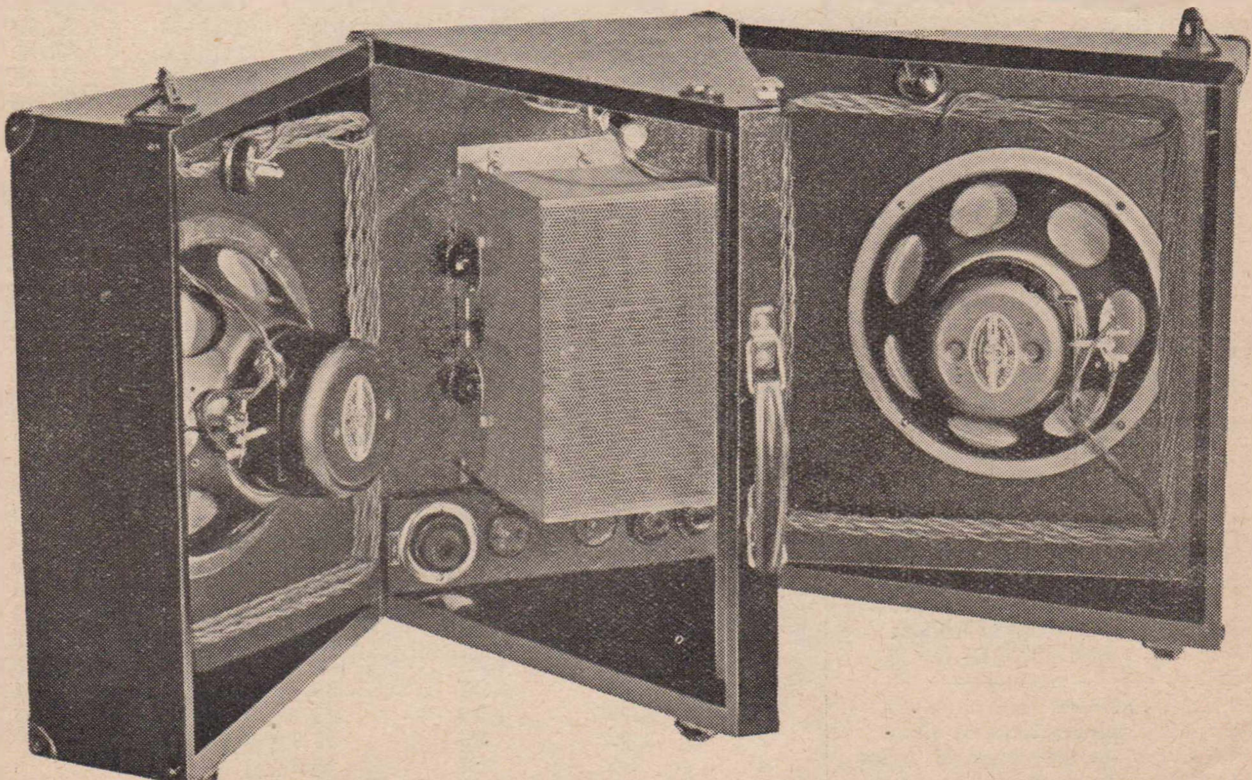
Amplifier Ratings.

FROM this we see that the amplifier rating can be, and often is, expressed in two ways. First, we have the indication of the actual power output, 15 watts in this case; and, secondly, the required power gain to permit a low-level input device to be used, the microphone or pick-up to be used.

There are many other practical applications of the decibel, but to reap their advantages the amplifier designer must have a knowledge of logarithms —a subject beyond the scope of this manual.

DB VOLTAGE AND POWER RATIOS.

No. d.b.	Voltage Ratio	Power Ratio.
1	1.12	1.25
2	1.26	1.59
3	1.41	1.99
4	1.58	2.51
5	1.77	3.16
6	1.99	3.99
7	2.23	5.01
8	2.51	6.31
9	2.81	7.94
10	3.16	10.00
20	10.00	100
25	17.78	316
30	31.62	1,000
35	56.20	3,162
40	100.00	10,000
45	177.81	31,620
50	316.2	100,000
55	562.3	316,200
60	1,000	1,000,000
65	1,778	3,162,000
70	3,162	10,000,000
75	5,623	31,620,000
80	10,000	100,000,000
85	17,781	316,200,000
90	31,620	1,000,000,000
95	56,230	3,162,000,000
100	100,000	—
105	177,800	—
110	316,200	—
115	562,300	—
120	1,000,000	—



This commercial type Public Address amplifier is designed to deliver an output of five watts, and is arranged for operation from either a.c. or d.c. mains. (Photo. Courtesy A.W.A.)

HANDY FORMULAE FOR THE SOUND MAN

Resistance—Capacity—Inductive and Capocitive Reactance —Output Voltage—Resistance Coupling—A.C. Values.

RESISTANCE AND CAPACITY.

Resistance in Series.

$$\text{Total Resistance} = R1 + R2 + R3 + R4$$

Resistance in Parallel.

$$\text{Total Resistance} = \frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}+\frac{1}{R4}}$$

Use the above resistor formula for condenser calculations, but for parallel condensers employ the Series resistor formula, and for series condensers employ the Parallel resistor formula.

POWER FORMULÆ.

$$W = 1^2 \times R$$

$$1 = \frac{W}{R}$$

$$R = \frac{W}{1^2}$$

$$W = \frac{E^2}{R}$$

$$E = R \times W$$

$$R = \frac{E^2}{W}$$

OHMS LAW.

$$C = \frac{E}{R}$$

$$E = C \times R$$

$$R = \frac{E}{C}$$

Where C is the current in amperes,
R is the resistance in ohms,
E is the potential in volts.

CATHODE RESISTOR CALCULATION.

$$R\ \frac{E}{C} \times 1{,}000$$

Where R is the resistance in ohms,
E is the desired bias voltage,
C is the plate current in m.a.

CAPACITIVE RESISTANCE.

$$XC = \frac{6.2832 \times f \times C}{1{,}000{,}000}$$

Where XC is the reactance in ohms.
f is the frequency in cycles per second.
C is the capacity in microfarads.

OUTPUT VOLTAGE.

$$\text{Voltage output} = \frac{Mu \times Eg \times Rl}{Rp + Rl}$$

Where Mu Amplification factor of a single output amplifier tube.
Eg Grid bias for single output tube divided by .707.
Rl Load impedance of single output tube.
Rp Plate impedance of single output tube.

Note.—Double these figures for a push-pull stage.

ALTERNATING CURRENT VALUES.

R.M.S. Volts by 1.414 = Peak Volts.
Peak Volts by .707 = R.M.S. Volts.
Peak Volts by .066 = Average Volts.
Average Volts by 1.57 = Peak Volts.
Average Volts by 1.11 = R.M.S. Volts.
R.M.S. Volts by .9 = Average Volts.

RESISTANCE COUPLED AMPLIFIERS.

$$\text{Amplification} = \frac{3}{4} \times \frac{F \times R}{R + r}$$

Where R is the plate resistor in ohms,
r is the valve plate resistance,
F is the valve amplification factor.

INDUCTIVE AND CAPACITIVE REACTANCES

REACTANCE IN OHMS.

Inductance (Henries)	50 cycles	100 cycles	1000 cycles	5000 cycles	10,000 cycles
250	78,500	157.000	1,570,000	7,850,000	15,700,000
100	31,400	62,800	628,000	3,140,000	6,280,000
50	15,700	31,400	314,000	1,570,000	3,140,000
25	7,850	15,700	157,000	785,000	1,570,000
10	3,140	6,280	62,800	314,000	628,000
5	1,570	3,140	31,400	157,000	314,000
1	314	628	6,280	31,400	62,800
.1	31.4	62.8	628	3,140	6,280
.01	3.14	6.28	62.8	314	628
Micro-H.					
1000	.314	.628	6.28	31.4	62.8
200	.0628	.1257	1.257	6.28	12.57
100	.0314	.0628	0.628	3.14	6.28

REACTANCE IN OHMS.

Capacity Micro-Fds.	50 cycles	100 cycles	1000 cycles	5000 cycles	10,000 cycles
.00003	—	—	—	1,060,000	530,000
.0001	—	—	1,590,000	318,000	159,000
.00025	—	—	637,000	127,000	63,700
.0005	—	—	318,000	63,700	31,800
.001	3,180,000	1,590,000	159,000	31,800	15,900
.006	530,000	265,000	26,500	5,300	2,650
.01	318,000	159,000	15,900	3,180	1,590
.02	159,000	79,500	7,950	1,590	795
.05	63,700	31,850	3,185	637	318
.1	31,800	15,900	1,590	318	159
.25	12,700	6,370	637	127	63.5
.5	6,370	3,180	318	63.7	31.8
1	3,180	1,590	159	31.8	15.9
2	1,590	796	79.6	15.9	7.96
4	796	398	39.8	7.96	3.98
8	398	127	12.7	3.98	1.99
25	127	63.5	6.35	1.27	0.63

PUSH PULL AMPLIFIERS

CLASS AB1, AB2, AND SPECIAL CLASS A AMPLIFIERS English and Continental Series Valves

Courtesy Philips Radio and the Mullard Valve Co.

Type	Application	Plate Volts	Screen Volts	Fixed Grid Bias	Cathode Bias Resist., Ohms	No. Sig. Plate Current, 2 Valves	Max. Sig. Plate Current, 2 Valves	Power Output (Watts)	Distortion, %	Plate-to-plate Load (Ohms)
C243N } PM22A }	Class B, without Grid Current ..	135	135	7V	—	3	15	1.0	10	25,000
KL4	Class B, without Grid Current ..	135	135	9V	—	3	9.8	0.8	8	35,000
B240	Class B. Driver valve B217. Ep = 150v., Eg. = —4.5. Transformer ratio, 3:1	150	—	0	—	3	21	1.6	10	19,000
KDD1	Class B, Driver valve KC3. Ep. = 135v.; Eg. = —2.8v. Transformer ratio, 1:2	135	—	0	—	3	30	2.0	10	10,000
AL2	Class AB1. Driver valve AL2 as triode. Ep. = 250v.; Eg. = —28v. Transformer ratio, 1:3 ..	250	250	—	300	72	83	9.0	0.8	5.100
		375	250	—	540	48	58	14.2	6.0	15,000
		250	250	33V	—	30	81	11.6	2.8	6,600
		375	250	31V	—	40	89	19	1.5	9,000
EL2	Class AB1. Driver valve EL2 as triode. Ep. = 250v.; Eg. = —20v. Transformer ratio, 1:3 ..	200	200	—	300	42	49	5.0	1.3	9,000
		250	250	—	310	55	65	8.0	1.45	8,000
		200	200	20V	—	25	50	5.0	1.65	9,000
		250	250	25V	—	30	66	8.5	1.6	8,000
AL3 }	Class AB1. Driver valve AL2 or EL2 as triode. Rating as above.	250	250	—	65	72	74	7.4	7.7	11,000
EL3 }	Transformer ratio, 1:3	250	250	9.5V	—	25	60	5.8	2.2	6,000
EL5	Class AB1. Driver valve EL2, as triode. Rating as above.	250	250	—	155	109	128	16.4	4.9	4,000
	Transformer ratio, 1:3	250	250	24V	—	50	126	17.3	4.7	4,000
CL4	Class AB1. Driver valve CBC1. Ep. = 250v.; Eg. = —7v. Transformer ratio, 1—2	200	200	—	140	66	80	8.0	1.5	4,500
		250	250	—	180	70	88	13.5	5.7	6,000
		200	200	13V	—	30	82	8.0	1.8	4,500
		250	250	16.5V	—	40	114	14.0	1.8	4,000
E406N	Class AB1.	500	—	70	—	40	74	13	1.0	12,000
	Class AB2. Driver valve E463 as triode. Ep. = 250; Eg. =	400	—	47.5	—	40	90	14.6	4.5	8,000
	—33v. Transformer ratio, 2.5:1	350	—	40	—	40	83	13.6	4.2	8,000

NOTE: Ep. and Eg. are the respective plate and grid voltages of the driver valve.
The transformer ratio is specified as the ratio between the primary winding and each half of the secondary.

American Series Valves.

PUSH PULL AMPLIFIERS.—Continued

(Courtesy The A.W. Valve Co.)

Type	Application	Plate Volts	Screen Volts	Fixed Grid Bias	Cathode Bias Resist., Ohms	No sig. Plate Current, 2 Valves	Max. Sig. Plate Current, 2 Valves	Power Output, Watts	Distortion, %	Plate to Plate Load, Ohms
1E7G*	Overbiased, Class A1	135	135	—7.5	—	6.5	—	0.65	5	24,000
1H4G / 30	Class B. Driver valve, type 30: Ep = 157.5, Eg = —11.3. Transformer ratio, 1.165:1.	157.5	—	—15	—	1.0	—	2.1	6—7	8,000
	Class B. Driver valve type 30: Ep = 135, Eg = —9. Transformer ratio, 1.8:1.	135	—	—12	—	1.6	15.4	1.0	8	20,000
1J6G / 19	Class B	135	—	—4.5	—	1.4	13.8	1.0	5	20,000
	Driver valve type 1K7G (1K6), Ep =135, G2 tied to plate, Eg1 = —4.5. Transformer ratio, 2.2:1.	135	—	—4.5	—	1.4	18.0	1.25	6	15,000
		135	—	—4.5	—	1.4	24.5	1.6	6	10 000
	Class B (zero bias). Driver valve type 31, Ep = 135, Eg = —22.5. Transformer ratio, 1.5:1.	135	—	0	—	10.0	37.4	2.1	6	6,000
49	Class B (Grids 1 and 2 tied)	135	—	0	—	2.6	—	2.3	—	8,000
		180	—	0	—	4.0	—	3.5	—	12,000
2A3	Overbiased Class, A1	300	—	—62	—	80	140	15	2.5	3,000
		300	—	—	780	80	110	10	5.0	5,000
6AC5G	Class B. (Peak driving power, 950 Milliwatts.)	250	—	0	—	5	—	8	—	10,000
6F6G / 42	Special Class A1 Pentodes	315	315	—22	—	84	—	13	5.5	10,000
	Class AB2 Pentodes	375	250	—26	—	34	—	19	5	10,000
	Driver valve, 6F6G triode, Ep = 250, Eg = —20. Transformer ratio. 3.3:1 (fixed); 2.5:1 (self bias).	375	250	—	340	54	—	19	5	10,000
	Class AB2 Triodes	350	—	—38	—	45	—	18	7	6,000
	Driver as above. Transformer ratio, 1.67:1 (fixed); 1.3:1 (self bias).	350	—	—	730	50	—	14	7	10,000
6L6G	Class A1 / Class AB1 } Negative feedback is desirable in all cases	250	250	—16	—	120	140	14.5	2	5,000
		250	250	—	125	120	130	13.8	2	5,000
		400	250	—20	—	88	124	26.5	2	8,500
		400	250	—20	—	88	126	20	1	6,000
		400	300	—25	—	102	152	34	2	6,600
		400	300	—25	—	102	156	23	0.6	3,800
		400	250	—	190	96	110	24	2	8,500
		400	300	—	200	112	128	32	2	6,600
	Class AB2	400	250	—20	—	88	168	40	***	6,000
	Driver may be push-pull 6F6G triodes. Transformer ratio, 2.6:1.	400	300	—25	—	102	230	60	***	3,800

American Series Valves.

PUSH-PULL AMPLIFIERS.—Continued.

(Courtesy the A.W. Valve Co.,

Type	Application	Plate Volts	Screen Volts	Fixed Grid Bias	Cathode Bias Resist. Ohms	No sig. Plate Current, 2 Valves	Max. Sig. Plate Current, 2 Valves	Power Output, Watts	Distortion, %	Plate to Plate Load, Ohms
6N7G	Class B	250	—	0	—	28	54	8	7.5	8,000
6A6	Driver 6J7G triode. Transformer ratio, 5:1.	300	—	0	—	35	—	10	—	10,000
6V6G	Class AB1	250	250	—15	—	70	79	8.5	4	10,000
		300	300	—20	—	78	90	13	4	8,000
45	Class AB2	275	—	—68	—	28	138	18	5	3,200
	Driver 45, 59 or 2A5 triode. Transformer ratio, 1.67:1 (fixed); 1.3:1 (self-bias).	275	—	—	775	72	90	12	5	5,060
46	Class B (Grids 1 and 2 tied)	300	—	0	—	4	124	16	5	3,500
	Driver type 46 (G2 tied to plate). Transformer ratio, 2.2:1.	400	—	0	—	6	—	20	—	5,800
59	Class B triodes (Grids 1 and 2 tied,	400	—	0	—	20	—	15	—	4,600
	Grid 3 connected to plate)	300	—	0	—	26	104	20	5	6,000
79	Class B	180	—	0	—	7.6	—	5.5	—	7,000
	Driving power, 380 mW.	250	—	0	—	10.6	—	8	—	14,000
801	Class B	400	—	—50	—	8	130	27	—	6,000
	Driving power, 3 Watts.	500	—	—60	—	8	130	36	—	8,000
		600	—	—75	—	8	130	45	—	10,000
807	Class AB2 . . .35W.	400	300	—25	—	100	230	60	**	3,800
	Driving power .6W.	500	300	—25	—	100	230	75	**	4,660
	.4W.	600	300	—30	—	60	200	80	**	6,660
809 (2 valves)	Class B	500	—	0	—	40	200	60	**	5,200
		750	—	—5	—	35	200	100	**	8,400

NOTES.

All these types may also be operated as push-pull Class A1 Amplifiers, under similar conditions to single Class A1 amplifiers, with reduced distortion and double the output. The plate-to-plate load for triodes may be twice that for a single valve, while for pentodes it may, with advantage, be reduced to between 1.5 and 2.0 times that for a single valve, the lower loads giving less distortion, but requiring better regulation in the power supply.

The distortion in all push-pull amplifiers is largely third-harmonic, with some fifth and higher add harmonics. On this account it is desirable for the distortion not to exceed 2.5 per cent. for the best fidelity. Pentodes and Tetrodes in Class A1 or AB1 may be used with negative (inverse) feedback, in order to reduce the distortion, approximately 10 per cent. feedback reducing the distortion to one-half, and 15 per cent. to one-third. Class AB2 and Class B amplifiers cannot be used with inverse feedback, unless very elaborate precautions are adopted. For this reason, as well as for the fact that the distortion includes a large proportion of higher order odd (5th, 7th, 11th, etc.) harmonics, amplifiers drawing grid current cannot be used for good fidelity.

*Type 1E7G is practically equivalent to two type 1F5G (1F4).

**The distortion under these conditions depends very largely upon the plate, screen and grid supply regulation, and upon the D.C. resistance, and leakage inductance in the grid circuit.

Class A indicates that the plate current never reaches cutoff. Class AB indicates that the plate current reaches cutoff for a small part of the cycle. Class B indicates that the valve is biased almost to the point of cutoff. The numeral 1 indicates that no grid current flows, while 2 indicates that grid current flows during some part of the cycle. Transformer ratios are given in terms of Primary turns to one-half Secondary turns.

RESISTANCE COUPLED AMPLIFIERS

(Courtesy The A.W. Valve Co., the Mullard Valve Co., and Philips Radio.)

Type	Total Supply Voltage.	Plate Load Resistor (Megohms)	Following Grid Resistor (Megohms)	Cathode Bias Resistor (Ohms)	Screen Dropping Resistor (Megohms)	Voltage Gain	Peak Output Voltage
AF7	250	0.25	0.5	4000	0.75	150	—
	250	0.1	0.5	1500	0.25	90	—
CF1	200	0.3	0.7	6400	90v.	220	58
	100	0.3	0.7	6400	40v.	180	25
EF6	250	0.32	0.7	4000	0.8	180	14
	200	0.2	0.7	2500	0.4	152	14
KF4	135	0.3	1.0	-1.5v.	0.64	72	—
	90	0.2	1.0	-1.5v.	0.25	48	—
6C6 / 6J7 / 57	135	0.25	1	2,000	1.5	116	36
			0.5			96	31
	250	0.25	1	2,000	1.5	150	72
			0.5			125	60
	400	0.25	1	2,000	1.5	175	115
			0.5			145	95
77	135	0.25	1	2,000	1.5	105	34
			0.5			88	29
	250	0.25	1	2,000	1.5	134	60
			0.5			110	50
	400	0.25	1	2,000	1.5	160	96
			0.5			133	80
6C6 / 6J7 / 57	250	0.1	1.0	2,000	0.3	98	85
			0.5			82	78
			0.25			70	67
	400	0.1	1.0	2,000	0.3	105	135
			0.5			92	124
			0.25			80	106
			0.5			92	72
1K4	90	0.25	1		0.75	59	25
			0.5	All		48	20
	135	0.25	1	-1.5v	0.75	75	36
			0.5	Bias		6.25	30
	180	0.25	1		1.0	88.5	48
			0.5			74	40
6L5G (triode)							
	180	0.1	0.5	4790	—	12.3	50
		0.25	0.5	9290	—	12.4	46
			1.0	10950	—	12.5	52
	300	0.1	0.5	4700	—	12.9	89
		0.25	0.5	9100	—	12.9	80
			1.0	10750	—	12.8	88

CLASS "A" AMPLIFIERS

Type	Plate Volts	Screen Volts	Plate Current	Screen Current	Grid Volts, R.M.S.	Cathode Resistor, Ohms.	Bias Volts	Distortion, %	Load Resistance	Power Output Watts
AL2	250	250	36	5	12.6	600	—	11	7,000	4.5
AL3 / EL3	250	250	36	4	3.5	150	—	10	7,000	4.5
EL2	250	250	32	5	10	500	—	10	8,000	3.6
EL5	250	250	72	7.5	11	200	—	10	3,500	7.7
C243N / PM22A	135	135	6	1.4	3.15	—	4.5	10	20,000	0.31
CL2	200	100	40	5	9	450	—	10	5,000	3.0
CL4	250	250	36	4.5	5	320	—	10	7,000	4.0
E406N	250	—	48	—	15.4	450	—	7	3,500	1.6
F443N	300	300	83	4.6	23.5	450	—	10	3,500	12.9
KL4	135	135	7	1.0	3.3	—	5	10	19,000	0.44
43 / 25A6	180	135	38	7.5	14	440	—	10	5,000	2.75
45	275	—	36	—	40	1550	—	7	4,600	2.0
1F4 / 1F5G	135	135	8	2.6	3.2	—	4.5	5	16,000	0.34
1D4	180	180	9.5	2.3	4.5	—	6	10	15,000	0.75
2A3	250	--	60	—	31.5	750	—	5	2,500	3.5
2A5 / 6F6 / 42	315	315	42	8	15.4	440	—	7	7,000	5.0
6L6	375	250	67	6	12 25	—	17.5	14.5	4,000	11 5
6V6G	250	250	45	4.5	8.75	250	—	7	6,000	4.25
25L6	110	110	50	11	5.25	125	—	10	2,000	2.2

RECTIFIER VALVES

NOTE.—I indicates an indirectly-heated filament, and D a directly-heated one. Except where specially indicated, all valves are full-wave rectifiers.

Serial	Type	Fil. Volts	Fil. Amps.	Max. A.C. Plate Volts, R.M.S	Max. D.C. Current, M.A.
AZ3	I	4.0	1.85	385	120
CY2	I	30	.2	250	120
DU2	D	4	1	250	75
DW4	D	4	2	500	120
EZ2	I	6.3	.25	350	60
EZ3	I	6.3	.65	350	100
EZ4	I	6.3	.9	350	175
IW3	I	4	2.4	350	120
1V	D	6.3	.3	350	50
5T4	D	5	2	450	250
5U4G, 5X4G, 5Z3	D	5	3	500	250
5V4G, 83V	I	5	2	400	200
5W4	D	5	1.5	350	110
5Y3G	D	5	2	400	125
5Y4G, 80	D	5	2	400	110
5Z4	I	5	2	400	125
6X5G, 6X5	I	6.3	.6	350	75
6ZY5G	I	6.3	.3	350	35
12Z3	I (½-wave)	12.6	.3	250	60
81	D (½-wave)	7.5	1.25	700	85
82	D (Merc. Vapor)	2.5	3	400	125
83	D	5	3	500	250
84	I	6.3	.5	350	60
866	D (½-wave Merc. Vapor)	2.5	5	2650	125
866A	D (½-wave Merc. Vapor)	2.5	5	3500	125
1561	D	4	2	500	120
1867	I	4	2.4	350	120