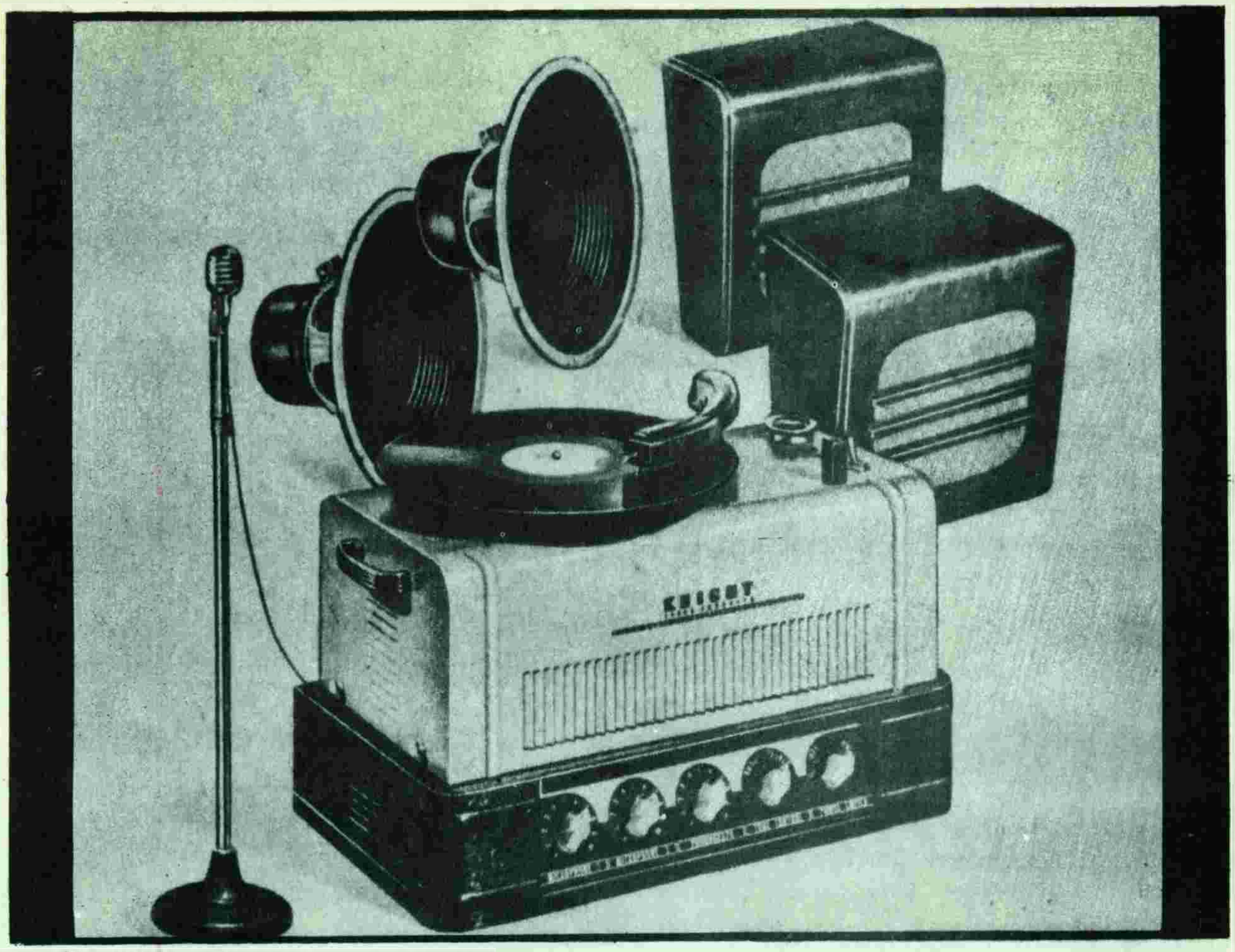

LESSON 57 R

POWER AMPLIFIER METHODS IN P.A. SYSTEMS

RADIO-TELEVISION TRAINING SCHOOL, INC. LOS ANGELES ESTABLISHED 1922

RADIO-TELEVISION TRAINING SCHOOL, INC.

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POWER AMPLIFIER METHODS IN P.A. SYSTEMS

Public address and sound distribution systems consist essentially of three sections: the sound sources with their respective selector switches and input control devices, the main amplifier in which the signal input voltages are suitably amplified according to the power distribution requirements of an installation, and the loud speaker or reproducer system.

The design of the power amplifier, as well as the number and types of tubes used, depend entirely upon the requirements of the reproducer system, that is, the number of loud speakers to be operated and the area and number of people to be served by each speaker. The power amplifiers are really only specially designed audio amplifiers, resistance and transformer coupled, with output stages generally of the push-pull type equipped with tubes of sufficient power handling capacity to satisfy the needs of the reproducer system. In the next several pages are taken up a series of circuit diagrams of various power amplifier designs having signal voltage gain and power output values to meet practically any requirements.

POWER AMPLIFIER SPECIFICATIONS

In order to be able to determine if an available amplifier will meet the requirements of an installation, or to be able to specify to a manufacturer what performance is required of an amplifier, certain operating data must be known. Such amplifier specifications generally include the following seven items:

1. Type of service
2. Kind of circuit
3. Types of tubes used
4. Input -(Nature of input system)-(Strength of input signal needed)
5. Signal gain or amplification
6. Output
   - Power output in watts
   - Nature of output circuit
7. Power supply
   - Kind of operating power
   - Current or watts consumed

The first item, type of service, refers to the purpose for which the amplifier is to be used, whether for an indoor auditorium or central distribution system, for an outdoor installation, as a portable public address system, or as a mobile amplifier on a sound truck. The kind of circuit used, that is, the number of stages and types of tubes employed, will depend upon the amplification gain that is needed and the output power that is desired. The fourth item, input, refers to the kind of input circuit the amplifier has, whether the signal is fed directly to the grid of the tube or whether some special input coupling transformer is employed. The signal gain or amplification depends upon the available signal strength from the sound sources employed and the voltage needed to swing the grids of the output power tubes. This amplification gain is measured in decibels, a new unit that is explained in a later paragraph.

The sixth term, output, indicates the power output in watts that the amplifier delivers and the kind of output system with which the amplifier is equipped, whether the output transformer has a secondary of a specified impedance or whether the secondary is tapped so that different impedance values can be obtained. The last item specifies the kind of power needed for operating the amplifier, for example -- 110-volt or 220-volt alternating or direct current, 6-volt direct current from an auto storage battery, or other kind of electric power. It also indicates the amount of current or power (watts) consumed from the power supply.

Generally there are also some miscellaneous items included, such as the type of volume and tone controls with which the amplifier is equipped, whether the amplifier is designed to supply field excitation current to additional speakers, etc.

THE DECIBEL

The decibel is a unit that offers a means of comparing two quantities of electric power with respect to the effect each produces on the human ear when converted into sound. It aids in establishing a mathematical relation between the power expended in an electric circuit and the sound sensation produced, and is employed in describing the operating characteristics of power amplifiers, transmission lines, and other electrical communication apparatus. It was originally developed in telephone practice, but is now used in connection with public address and sound systems.

The decibel is a comparison unit for denoting a gain or loss ratio, it does not stand for any certain quantity or amount. The original unit as developed in telephone work was the bel; but since this was somewhat too large a unit for practical work, the decibel was adopted, a decibel being 1/10th of a bel. It is commonly abbreviated db.

The decibel system is based on the manner the human ear responds or reacts to changes in the power dissipated in a sound. The sensitivity of the ear is not the same at different noise intensities or sound levels. Under comparatively quiet conditions, that is at low noise levels, the sensitivity is much greater than at higher noise levels or more noisy conditions. In other words, equal amounts of sound power will not effect the ear in the same degree at different sound levels or intensities. For example, in a quiet room it is easy to hear a pin when dropped hit the floor, but if any persons are talking and walking around in the room it cannot be heard, even though the same amount of power is dissipated each time. The reason is that when all is quiet and the noise level is low, the sensitivity of the ear is very high; but when conditions are noisy and the sound level is higher, the ear is less sensitive. In other words, at higher sound levels much greater sound power is required to cause a reaction or attract attention than at low sound levels. This is why a radio set appears to have more volume and better tone in a quiet room than under more noisy conditions, for in a quiet room the ear is more sensitive to slight changes in sound.

POWER DISSIPATION AND SOUND IMPRESSION INTENSITY

The power dissipation represented by the loudest sound the ear can tolerate is several million times as great as that of the faintest sound the ear can detect. The reason the ear can respond to such wide ranges in sound power is that the impression intensity or loudness of the sound is not directly proportional to the sound power reaching the ear. In other words, as the sound level becomes higher, increasingly greater amounts of power must be expended in order to create the same impression of increased loudness or intensity.

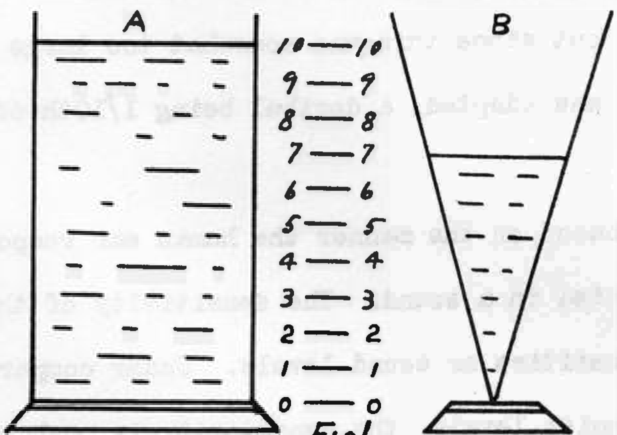


Fig 1

The facts given previously can be more clearly brought out with the aid of the glass vessels shown in Fig. 1. Vessel A has vertical sides while B is conical in shape with a small base and a large opening at the top. For the sake of comparison, let the amount of water contained or poured into each vessel correspond to the amount of power dissipated in a sound, and the height of the water correspond to the sound level or impression intensity produced by the sound.

In the case of vessel A, for each measure of water poured into it the height of the water rises an equal amount; in other words, the rise of the water is directly proportional to the amount of water poured in, irrespective of the height of the water. This corresponds to the condition that would exist in our sense of hearing if the impression intensity of a sound were directly proportional to the power dissipated in the sound. This would mean that at any sound level a certain amount of power dissipated in a sound would always produce the same impression intensity or loudness effect, that is, the ear would have the same sensitiveness at all levels.

In the case of vessel B. however, the effect is different. With the first measure of water poured in, the water will rise to a certain height. With the second measure the height will again rise, but due to the slanting walls the rise will be less than with the first measure. When the third measure is poured in, the increase in height is less than with the second, and with the fourth the increase is less than with the third. In other words, equal volumes of water produce constantly decreasing rises in level. Each rise in height is always the same fractional part of the previous rise for an equal volume of water added. Or, to produce the same rise in height each time, constantly increasing amounts of water must be added. At the bottom of the vessel the rise in height per measure of water will be very great compared to the rise per measure of water at the top of the vessel.

It is a similar case with our sense of hearing, where the sound impression intensity corresponds to the height of the water in the vessel and the sound power to the volume of water added. At low sound levels the sound impression created by a unit or measure of power is very great; but as the sound level rises, the added sound impression per unit of power decreases. To recall the case of the dropped pin — when the room is quiet and the sound level low, the impact of the pin on the floor creates an appreciable impression and is clearly heard. When the room is noisy and the sound level high, even though the same amount of power is dissipated in the sound by the pin hitting the floor, it creates little or no impression in the ear, for due to the higher sound level a great deal more power must be dissipated to create the same impression intensity that was created at the low level. As the sound level rises, a given sound power dissipation creates less and less impression; or in other words, to create the same impression, a constantly increasing amount of power must be dissipated.

MATHEMATICAL MEANING OF THE DECIBEL

Although the decibel is primarily a mathematical term and a thorough handling of it would involve rather complex calculations, its applications in public address work can be readily understood without going into the deeper mathematics. In Fig. 2 is an interesting table of numbers:

Fig. 2

Column A Ratios	Column B Bels	Column C Decibels
1	0	0
10	1	10
100	2	20
1,000	3	30
10,000	4	40
100,000	5	50
1,000,000	6	60

A careful study of this table will reveal that a definite relation exists between the numbers in the three columns. The numbers in column B show how many times the number 10 must be multiplied by itself to produce the larger numbers in column A, while the numbers in column C are equal to 10 times those in column B. Since this definite relation exists between the corresponding numbers in columns B or C and column A, it is evident that by using the smaller numbers in column C, the use of the larger numbers in column A can be avoided. For example, instead of saying that a signal has been strengthened or amplified 10,000 times, we can merely say that the signal amplification was 40 decibels, for 10,000 is equal to 10 multiplied by itself 4 times, and according to the table this is equivalent to 40 decibels.

It was stated in a previous sentence that the decibel is purely a comparison unit for denoting a gain or loss ratio. In this decibel system the number 10 is used as a standard or basis for comparison; and whenever amplification gain or signal loss is referred to, it is expressed by saying that the signal was amplified T times, where T is numerically equal to 10 multiplied by itself a certain number of times, and this T is then translated into decibels. For example, if the specifications of an amplifier state that the signal gain is 60 Db., it means that the signal will be amplified 1,000,000 times in passing through the amplifier (10 multiplied by itself 6 times). Another way of stating it if the gain is 60 Db., is that the ratio of the power output to the input is 1,000,000. If the output is divided by the input, the result is 1,000,000 meaning 60 decibels.

It does not always happen that the gain of an amplifier is expressible in such nice round numbers as 20, 30, 40, 60 or 80 decibels. For example, when an amplifier is said to have a gain of 72 decibels, it means that the power ratio of the output to the input is equal to 10 multiplied by itself 7 2/10 times. But with ordinary arithmetic it is not possible to work out such fractional powers of 10. For such cases logarithms must be used which enables one to work with fractional exponents, but the subject of logarithms goes beyond the scope of this text and will not be taken up here. But the fact should always be kept in mind that decibels denote a ratio of power output to power input.

APPLICATIONS OF THE DECIBEL SYSTEM

The decibel is used in two ways in power amplifier calculations: one is to measure the gain in an amplifier, that is the ratio of the power output to the power input, and the other is to designate the actual power level of the output of a sound source or amplifier or of the input required by an amplifier to produce full rated output. For example, if the power dissipation in one sound is 100 times as great as that of another sound, in the decibel language this would be stated by saying that the first sound is 20 decibels greater than the second. Or if the output of an amplifier is 6 watts and the input is .006 watts, the power ratio would be 6 divided by .006 or 1,000, or translated this would mean a 30 decibel gain. Decibels always denote the value of a ratio with respect to the base 10.

The use of the decibel as a comparison unit for denoting the value of power ratios not only eliminates the use of large numbers as is evident from the table in Fig. 2 and as was demonstrated above, but also simplifies calculations greatly when two power ratios are combined. For example, if two amplifiers are used and the first amplifies the signal power 100 times and the second 1,000 times, the total amplification is 100 x 1,000 or 100,000 times. Expressed in decibels the first amplifier gain is 20 and that of the second 30, while the total amplification is 100,000 times or 50 decibels.

In other words, when two power ratios are to be combined and the decibel system is used, the gain of the two amplifiers expressed in decibels need merely be added together, while if expressed merely as numerical ratios they must be multiplied together. If power ratios were always in whole round numbers as in the illustrated example, calculations would not be so bad; but when uneven numbers are used, such as 79 or 537, then calculations become rather tedious and the advantage of the decibel system in simplifying the work is very readily apparent.

When the decibel is used to designate the actual power level of a sound, it is really a comparison with an understood "zero level" standard. This "zero level" standard has been set by acoustic and communication engineers at 6 milliwatts or .006 watt, and this value forms the basis of comparison for designating actual power level. For example, the output of an amplifier is 6 watts, and compared to this zero level standard 6 divided by .006 would represent a power ratio of 1000. Expressed in decibels this would be 30 decibels. This means that the power output level of the amplifier is 30 decibles above zero level, or simply 30 decibels. Just as one says that the temperature in a room is 70 degrees but actually means that it is 70 degrees above zero, so the expression that the power level of the output of an amplifier is 30 decibels actually means that it is 30 decibels above zero level.

POWER GAIN AND OUTPUT LEVEL

Two terms that should not be confused in regard to the operating characteristics of a power amplifier are "gain" and "output level". Gain, referring of course to the power amplification or gain, is the ratio increase between the amount of power input and the power output, and is denoted in decibels. Thus, if the power input to an amplifier is .06 watt and the power output is 6 watt, the ratio increase is 6 divided by .06 or 100, and expressed in decibels this is 20 decibels. The output level, on the other hand, indicates just how much greater the output of an amplifier is above the standard zero level, which in sound work is .006 watt. It is also denoted in decibles. Thus, in the amplifier illustration used above the output power is 6 watts, and the ratio between this and zero level or .006 watt is 6 divided by .006 or 1000. Expressed in decibels this would be 30 decibels.

The gain in the amplifier illustration above is 20 decibels, but the output level is 30 decibles, meaning of course 30 decibels above zero level. The input to the amplifier was given at .06 watt, and the ratio of this value to zero level is .06 divided by .006 or 10, which expressed in decibels is 10 decibels. In other words, the input power was already at a level of 10 decibels, and adding to this the 20 decibel gain in the amplifier, brings the output level to 30 decibels.

In the table in Fig. 3 are given the approximate power ratios equivalent to decibel gains ranging from 1 to 30 decibels.

Power Ratio	Decibel Gain
1.25	1
1.6	2
2.0	3
2.5	4
3.2	5
4.0	6
5.0	7
6.3	8
8.0	9
10.0	10
100.0	20
1000.	30

There are two interesting relations revealed in this table that are handy to remember when dealing with decibels. The first is that to increase the sound loudness by 3 decibels means doubling the power, or to increase it by 6 decibels means multiplying the power by 4 etc. The second relation is that 10 decibels correspond to a tenfold change in power, 20 decibels to a hundredfold change in power, etc.

POWER LEVEL OF INPUT DEVICES

Power level also indicates how low the power output of a device such as a phonograph pickup, microphone, etc., is below the standard zero level. Values below the zero level are expressed as negative decibels or —db. For example, the level of the average magnetic phonograph pickup is from —15 to —25 db, the average double-button carbon microphone has an output level of from —40 to —50 db, the average crystal microphone an output level of from —55 to —65 db, and the average velocity microphone an output level around —100 db. It is evident that the lower the output level of a sound source is, the more amplification gain is needed in an amplifier to bring it up to the required amplifier level. For example, if a phonograph pickup with a level of —25 db. is operated through an amplifier that has an output level of 35 db, the total amplification the signal must experience is 60 db, 25 db to bring it up to zero level and 35 db. to raise it to the level of the amplifier output.

If the output level of an amplifier is known as well as its amplification gain, it is also known what the lowest level of the input device may be in order to produce maximum output when it is operated through the amplifier. Thus, if an amplifier has an output level of plus 40 db. and a rated power gain of 70 db. it is only necessary to subtract the output level from the rated power gain to obtain the minimum negative power level that an input device may have in order to operate the amplifier at its maximum output. Similarly it is possible to determine the total amplification gain needed if the level of the input device is known and the required output level of the amplifier.

But if the rated power gain of an amplifier is more than that required to bring the level of the input device to the output level of the amplifier, there will be an excess gain and the amplifier will be overloaded. The amplification gain must then be attenuated or retarded somewhat in order to dissipate this excess gain. This is the function of the attenuator or volume controls. It is always desirable to have some reserve gain available, that is, more than is actually required, and to compensate for any changes in level that the input devices may produce under different operating conditions, various types of attenuator controls are employed. Reserve gain of 10 to 15% should always be allowed to take care of any operating emergencies that may arise.

If an amplifier has considerably excess gain and the attenuation required is more than is desirable to introduce with a volume control, then a fixed attenuator can be connected into the system as was explained in an earlier paragraph. On the other hand, if the gain in an amplifier is not sufficient to operate a certain input device and bring its level to the output level of the amplifier, then additional amplification must be provided. It is in such cases that pre-amplifiers are employed to bring the level of the input device to the required input level for the amplifier. Such pre-amplifiers are commonly used with the various types of crystal microphones as well as with dynamic, condenser and velocity microphones.

This completes the elementary discussion of the decibel and its applications. The previous paragraphs should be studied over and over, for each re-reading will bring to light passages and ideas that were completely neglected or overlooked previously.

AUDIO AMPLIFIER SYSTEMS REVIEWED

The various systems of audio amplification employed in power amplifiers for public address and sound systems, differ primarily in the method of coupling used between the successive amplifier tubes, such as transformer coupling, resistance and impedance coupling, direct coupling, etc. Each of these coupling methods has certain individual operating features that render it particularly applicable in certain cases. In many instances, however, the advantages or

superiority claimed for a certain coupling method are largely a matter of personal opinion, for equally satisfactory results can generally be obtained in severalways.

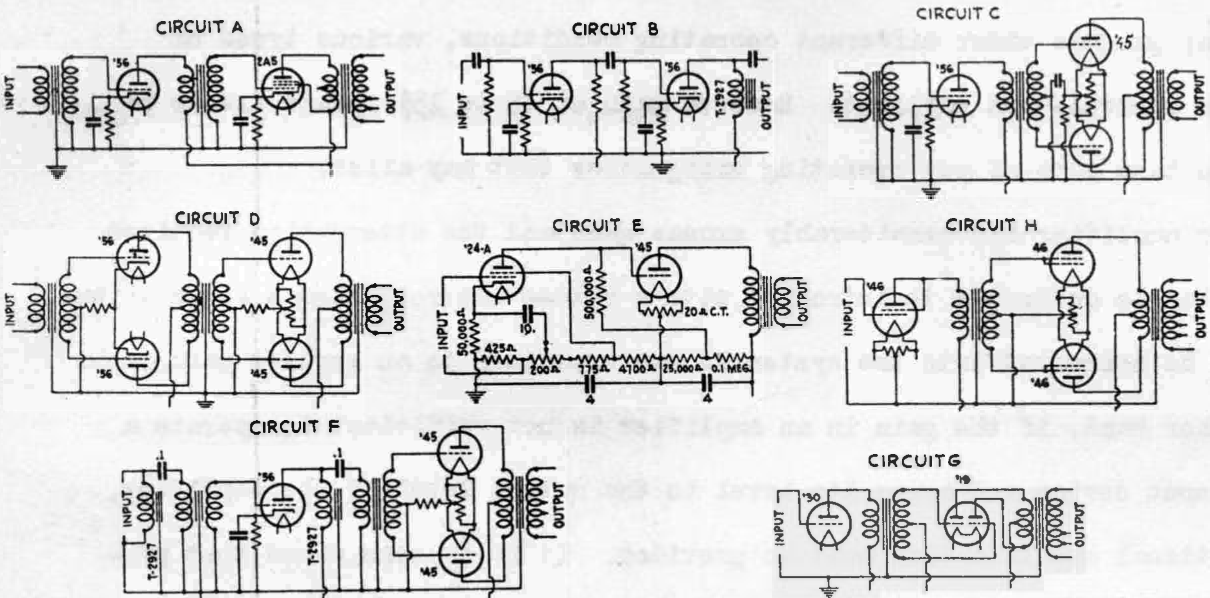


Fig. 4. Skeleton circuit diagrams illustrating the various systems of coupling used in audio amplifiers for public address and sound systems.

In Fig. 4 are illustrated a series of circuit diagrams of the audio systems, commonly used in public address systems. These are reproduced by permission of the Thordarson Electric Manufacturing Company, makers of audio transformers and power amplifier equipment at Chicago, Ill. Circuit A is a straight 2-stage transformer coupled audio amplifier employing a type 56 tube in the 1st stage and a type 2A5 power output pentode in the 2nd stage. A gain of from 45 to 55 db. can be secured from this arrangement with 3 to 4 watts power output and fair quality. Circuit B is a voltage amplifier system for use in pre-amplifiers to bring up the signal voltage from a weak sound source so that it can effectively operate the main power amplifier. As will be explained later, such a voltage amplifier is used with condenser, crystal and ribbon microphones. The amplifier will bring the signal level up 25 to 28 Db.

Circuit C is a typical 2-stage audio amplifier with a 56 tube and two type 45 power tubes in the output stage. A gain of 20 to 25 Db. is secured and a

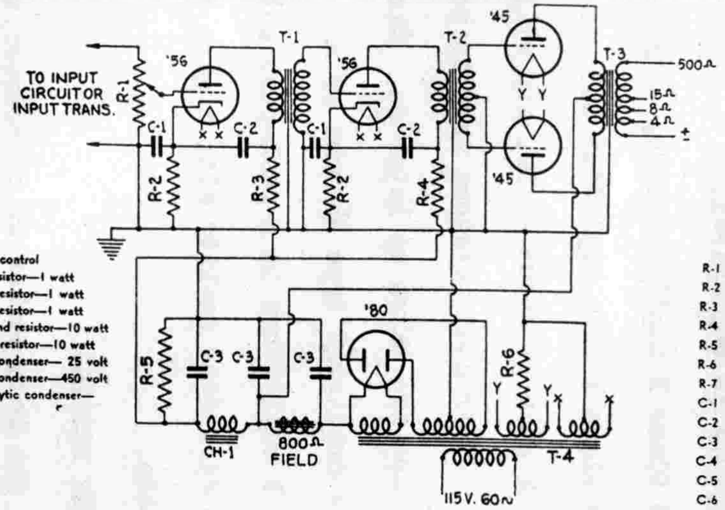
power output of about 4 watts. The tone quality is excellent if good transformers are employed. Circuit D is a double push-pull system with two type 56 and two type 45 power tubes. A 25-Db. gain is available and an output of 4 to 5 watts. It is probably the best of all low-power output amplifiers.

Circuit E is the basic Loftin-White direct coupled amplifier system using a type 24-A and type 45 tube. It affords an excellent gain of about 45 Db., and has a good quality output up to nearly 3 watts. Circuit F is also a 2-stage transformer coupled audio amplifier similar to Circuit C with two type 45 tubes in push-pull in the output stage. However, it employs parallel plate feed which keeps the D.C. component of the plate current out of the transformer primary, and by employing different sizes of coupling condensers the frequency response of the amplifier can be changed. Advantage would be taken of this principle in sound systems using speakers with small baffles, for by increasing the size of the coupling condensers the base note response is emphasized.

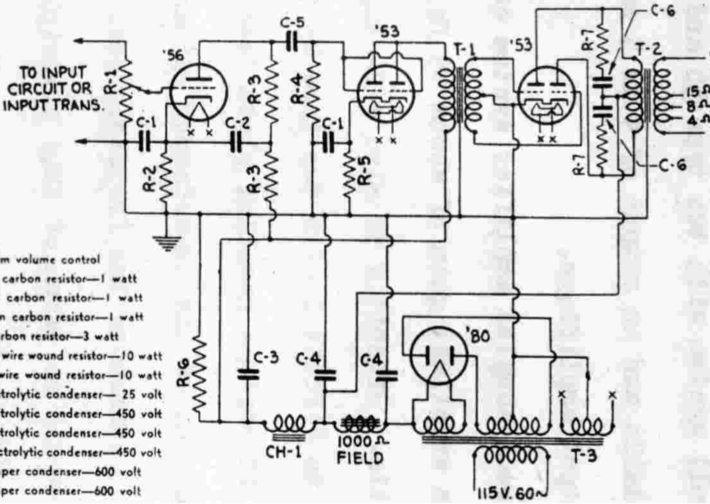
Circuit G is a 2-stage battery-operated Class B amplifier using a type 30 2-volt tube in the 1st stage and a No. 19 Class B twin amplifier tube in the second stage. This amplifier system affords a gain of about 40 Db. and will deliver a good quality output up to 2 watts. Other audio systems used in power amplifiers operating from 6-volt battery sources are taken up later on. Circuit H is a 2-stage Class B amplifier using a dual grid type 46 tube as a triode driver and two similar tubes as Class B amplifiers in a push-push output stage. Such an amplifier affords only a fair tone quality with a gain of about 22 Db., but a power output up to 20 watts.

POWER AMPLIFIER DESIGNS

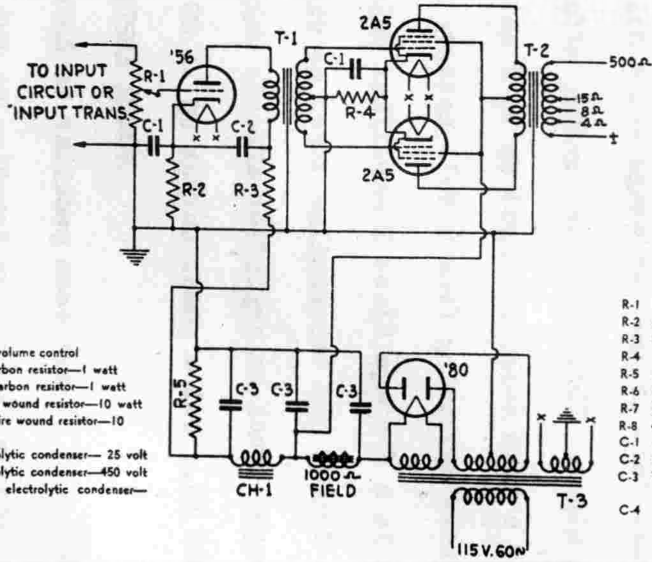
Although it may seem peculiar to do so, the loudspeaker or reproducer system should receive first consideration in the design and layout of a public address or sound system, for it is the reproducers that convey the voice and musical programs to the listening audience. And unless the reproducer system provides



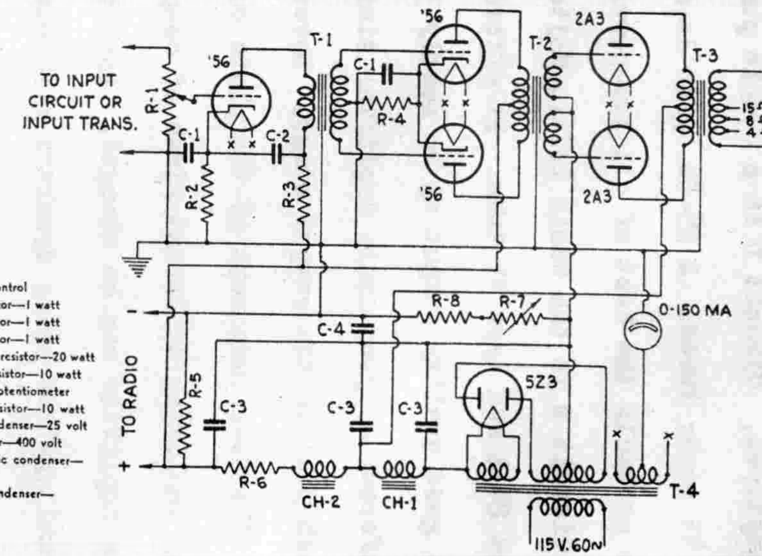
R-1 500,000-ohm volume control
R-2 2,500-ohm carbon resistor—1 watt
R-3 25,000-ohm carbon resistor—1 watt
R-4 15,000-ohm carbon resistor—1 watt
R-5 30,000-ohm wire wound resistor—10 watt
R-6 750-ohm wire wound resistor—10 watt
C-1 4-mfd. electrolytic condenser— 25 volt
C-2 2-mfd. electrolytic condenser—450 volt
C-3 triple 8-mfd. electrolytic condenser—450 volt



R-1 500,000-ohm volume control
R-2 5,000-ohm carbon resistor—1 watt
R-3 50,000-ohm carbon resistor—1 watt
R-4 500,000-ohm carbon resistor—1 watt
R-5 950-ohm carbon resistor—3 watt
R-6 30,000-ohm wire wound resistor—10 watt
R-7 7,500-ohm wire wound resistor—10 watt
C-1 4-mfd. electrolytic condenser— 25 volt
C-2 2-mfd. electrolytic condenser—450 volt
C-3 4-mfd. electrolytic condenser—450 volt
C-4 10-mfd. electrolytic condenser—450 volt
C-5 .01-mfd. paper condenser—600 volt
C-6 .03-mfd. paper condenser—600 volt



R-1 500,000-ohm volume control
R-2 2,500-ohm carbon resistor—1 watt
R-3 10,000-ohm carbon resistor—1 watt
R-4 205-ohm wire wound resistor—10 watt
R-5 25,000-ohm wire wound resistor—10 watt
C-1 4-mfd. electrolytic condenser— 25 volt
C-2 2-mfd. electrolytic condenser—450 volt
C-3 Triple 8-mfd. electrolytic condenser—450 volt



R-1 500,000-ohm volume control
R-2 2,500-ohm carbon resistor—1 watt
R-3 5,000-ohm carbon resistor—1 watt
R-4 1,300-ohm carbon resistor—1 watt
R-5 15,000-ohm wire wound resistor—20 watt
R-6 600-ohm wire wound resistor—10 watt
R-7 200-ohm wire wound potentiometer
R-8 400-ohm wire wound resistor—10 watt
C-1 4-mfd. electrolytic condenser—25 volt
C-2 2-mfd. paper condenser—400 volt
C-3 Triple 8-mfd. electrolytic condenser—450 volt
C-4 10-mfd. electrolytic condenser—100 volt

proper coverage so that a uniform sound distribution is effected, the entire sound system fails in its purpose. The sound sources have definite operating characteristics, and although special equipment could be designed and developed for each installation, the excessive cost would make this prohibitive. Consequently the best and most suitable apparatus available must be selected for a given job.

The nature of the reproducer system, that is the number and size of speakers needed, will determine the amount of electric operating power required. The sound sources, on the other hand, deliver only a certain power output. The connecting link between the sound sources and the reproducer system is the power amplifier. Its duty is to elevate the level of the signal from that at the sound source to that required at the reproducer system and also to release the required amount of power for operating the reproducer system effectively. In other words, there are two characteristics that practically tell the complete story about an amplifier, gain and power output. The other data merely describes the amplifier system as to circuit arrangement and operating quality.

On the accompanying two pages are shown a series of seven circuit diagrams of power amplifier systems that meet the requirements of the majority of installations for which calls will arise. These diagrams were selected from the Sound Manual prepared by the Thordarson Electric Manufacturing Company, at Chicago, and the parts numbers used in the descriptions of the various amplifier designs refer to the Thordarson sound equipment catalog. All of the amplifiers shown are designed for operation from a 110-volt A.C. power line.

TYPE 45 PUSH-PULL CLASS A AMPLIFIER

The first design is a 3-stage type 45 tube push-pull output Class A amplifier having a power output of 5 watts. Type 56 tubes are used in the 1st and 2nd stages, transformer coupled to a pair of type 45 tubes in push-pull in the output stage. Although the type 45 tube is not one of the most recently developed power output tubes, the tube is capable of giving a high quality output at low power. The amplifier is suitable for smaller installations, and can be used to amplify the output of high or low level carbon microphones, phonograph pickups, or the detector output of a radio tuner. The output of the amplifier is coupled through a universal impedance output transformer T-3 having secondary impedances of 4,8,15, and 500 ohms. The 4,8 and 15-ohm taps are for connecting directly to the voice coils of dynamic speakers; while the 500-ohm tap is used either for a magnetic speaker or for connecting to a 500-ohm line, when the speaker is located at a distance of 30 ft. or more.

T-1 is a standard audio coupling transformer having a 3 to 1 ratio, and T-2 is a standard push-pull input transformer also with a 3 to 1 ratio. T-4 is a suitable power transformer having a 720-volt center-tapped high-voltage winding rated at 80 milliamperes, while Ch-1 is a filter choke having a resistance of 400 ohms and an inductance of 20 henries at 35 milliamperes. If it is not convenient to employ the dynamic speaker field as a choke, another 400-ohm filter choke can be used, but this must be rated 15 henries at 85 milliamperes. A 400-ohm 10 watt resistor is connected in series with this choke.

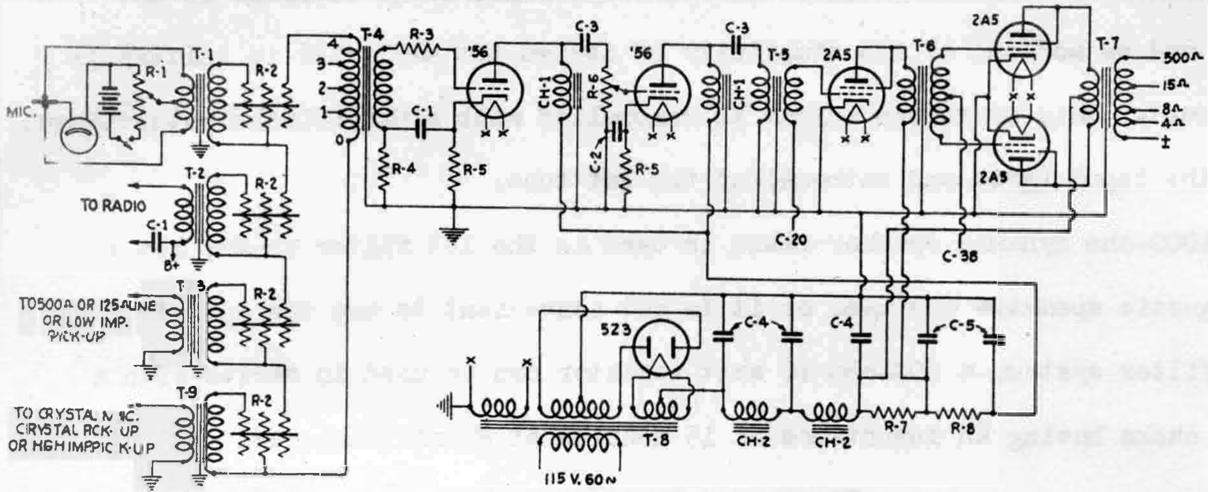
Thordarson Equipment

T-1	T-5733 Interstage transformer.
T-2	T-5741 Interstage transformer.
T-3	T-6748 Output transformer.
T-4	T-6363 Power transformer.
Ch.	T-1892 Filter choke.

TYPE 2A5 PENTODE PUSH-PULL AMPLIFIER

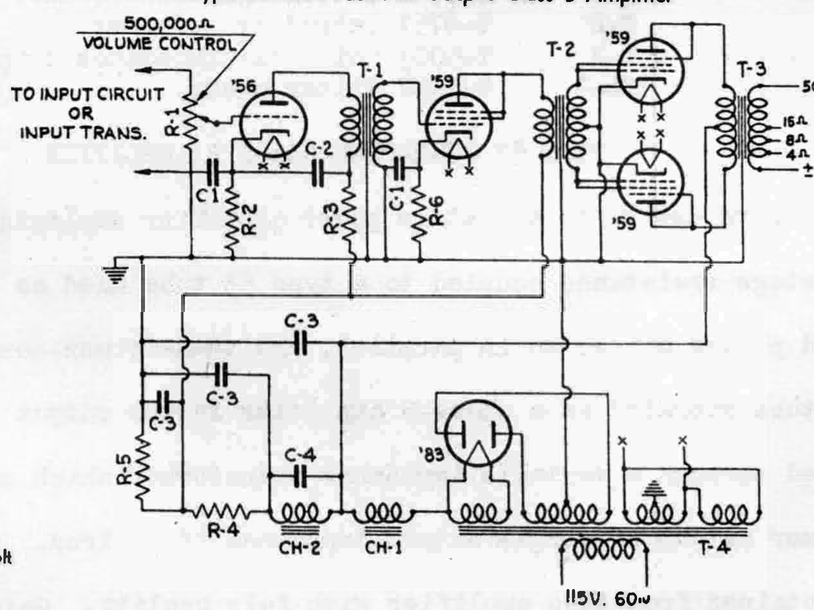
The second design is of a 2-stage power amplifier employing a type 56 tube in the 1st stage, transformer coupled to a pair of type 2A5 power amplifier pentodes in the output stage. Due to the exceptionally high gain of these pentodes only two stages of amplification are needed for the satisfactory reproduction of carbon microphones, magnetic phonograph pickups, radio tuners, etc.

Type 2A5 Tube (Triode) Push-Pull Output Class A Amplifier

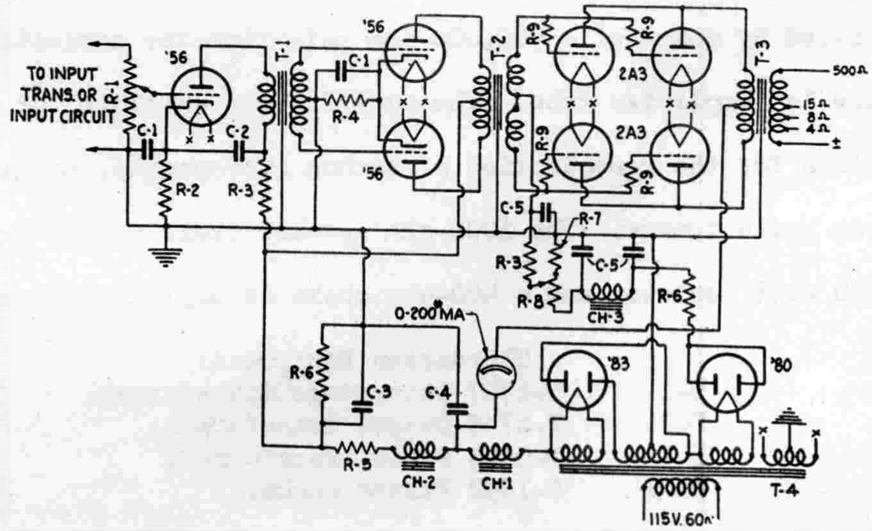


- R-1 400-ohm wire wound potentiometer
- R-2 200-ohm T-pad
- R-3 75,000-ohm carbon resistor—1 watt
- R-4 250,000-ohm carbon resistor—1 watt
- R-5 2,500-ohm carbon resistor—1 watt
- R-6 500,000-ohm volume control
- R-7 3,000-ohm wire wound resistor—20 watt
- R-8 5,000-ohm wire wound resistor—20 watt
- C-1 1-mfd. paper condenser—400 volt
- C-2 2-mfd. paper condenser—200 volt
- C-3 .25-mfd. paper condenser—400 volt
- C-4 8-mfd. electrolytic condenser—450 volt
- C-5 4-mfd. electrolytic condenser—450 volt

Type 59 Tube Push-Pull Output Class B Amplifier



- R-1 500,000-ohm volume control
- R-2 2,500-ohm carbon resistor—1 watt
- R-3 10,000-ohm carbon resistor—1 watt
- R-4 2,500-ohm wire wound resistor—10 watt
- R-5 15,000-ohm wire wound resistor—10 watt
- R-6 1,500-ohm wire wound resistor—10 watt (46 tubes)
- R-6 1,000-ohm wire wound resistor—10 watt (59 tubes)
- C-1 4-mfd. electrolytic condenser— 25 volt
- C-2 2-mfd. electrolytic condenser—450 volt
- C-3 Triple 8-mfd. electrolytic condenser—450 volt
- C-4 .1-mfd. paper condenser—500 volt



- R-1 500,000-ohm volume control
- R-2 2,500-ohm carbon resistor—1 watt
- R-3 10,000-ohm carbon resistor—1 watt
- R-4 1,300-ohm carbon resistor—1 watt
- R-5 2,000-ohm wire wound resistor—20 watt
- R-6 20,000-ohm wire wound resistor—20 watt
- R-7 10,000-ohm wire wound resistor—10 watt
- R-8 5,000-ohm wire wound potentiometer
- R-9 50-ohm carbon resistor—1 watt
- C-1 4-mfd. electrolytic condenser— 25 volt
- C-2 2-mfd. electrolytic condenser—450 volt
- C-3 8-mfd. electrolytic condenser—450 volt
- C-4 16-mfd. electrolytic condenser—450 volt
- C-5 10-mfd. electrolytic condenser—100 volt

An output of 6 watts is available from this amplifier with fair quality. The amplifier is suitable for smaller installations where large coverage is not needed, and on account of its simplicity of design the amplifier is relatively low in cost. Gain or volume output is controlled with a 500,000-ohm potentiometer across the input (grid and cathode) of the 1st tube.

A 1000-ohm dynamic speaker field is used as the 1st filter choke; but if only magnetic speakers are used or it is not convenient to use the speaker field in the filter system, a 600-ohm 10 watt resistor can be used in series with a 400-ohm choke having an inductance of 15 henries at 85 milliamperes.

Thordarson Equipment:

T-1	T-5741 Interstage transformer.
T-2	T-6751 Output transformer.
T-3	T-5003 Universal impedance coupling transformer.
Ch-1	T-1892 Filter choke.

TYPE 53 PUSH-PUSH CLASS B AMPLIFIER

The third design is a 3 stage power amplifier employing a type 56 tube in the 1st stage resistance coupled to a type 53 tube used as a driver with the grids and plates connected in parallel, and transformer-coupled to another type 53 tube operated as a class-B amplifier in the output stage. The output is coupled through a variable impedance transformer which can be replaced by a transformer output of single output impedance if desired. An output of 10 watts can be obtained from this amplifier with fair quality. Gain or volume output is controlled by means of a 500,000-ohm potentiometer connected across the input of the 1st amplifier tube. The amplifier is suitable for a medium sized installation for the reproduction of carbon microphones, magnetic phonograph pickups or radio tuners. The 1000-ohm speaker field can be replaced with a 600-ohm 10 watt resistor and a 400-ohm choke as explained above:

Thordarson Equipment:

T-1	T-6747 Interstage transformer.
T-2	T-6748 Output transformer.
T-3	T-5003 Power transformer.
Ch-1	T-1892 Filter choke.

TYPE 2A3 TUBE PUSH-PULL CLASS A AMPLIFIER

The fourth design is an excellent high quality output amplifier that has an output of 15 watts and a gain of nearly 70 decibels at 1000 cycles. It will fulfill the most exacting requirements of a high grade installation. It has a nearly level frequency response curve from 50 to 8,000 cycles.

Three stages of amplification are employed. The 1st stage uses a type 56 tube with a 500,000-ohm volume control potentiometer connected across the input (grid and cathode). This tube is transformer coupled to two type 56 tubes in push-pull, and these in turn are coupled to two type 2A3 tubes in push-pull, with an output transformer that has secondary impedance taps of 4,8,15 and 500 ohms. The power supply unit is of conventional design and employs the new type 5Z3 rectifier tube.

Bias for the type 2A3 tubes is provided by a 400-ohm resistor in series with a 200-ohm potentiometer in the negative return lead of the power supply. The power supply unit can also be used to furnish plate current to the R.F. section and detector of a radio tuner. The 200-ohm potentiometer is always adjusted until a milliammeter in the plate circuit of the 2A3 tubes indicates a total current of 80 milliamperes drawn by these tubes. The secondary of the push-pull interstage transformer is split so that separate bias control can be provided for each 2A3 tube to balance the tubes for equal plate currents of 40 milliamperes each in order to reduce hum to a minimum. This is done by replacing the 200-ohm potentiometer with two 400-ohm potentiometers connected in parallel and bringing the grid returns from the split secondary to the sliders on these potentiometers. This permits of individual adjustment of each tube by connecting a milliammeter into each plate circuit.

Thordarson Equipment:

T-1	T-5741 Interstage transformer.
T-2	T-5870 Interstage transformer.
T-3	T-6754 Output transformer.

T-4	T-5822 Power transformer.
Ch-1	T-17B Filter Choke.
Ch-2	T-5754 Filter Choke.

TYPE 2A5 TUBE (TRIODE) CLASS A-PRIME AMPLIFIER

The fifth circuit design is a 4-stage amplifier employing two type 2A5 tubes as triodes in Class A-prime push-pull as an output stage. A similar tube is used as driver in the preceding stage. Impedance coupling is used between the 1st and 2nd stages, and parallel plate feed transformer coupling between the 2nd and 3rd stages. This stage arrangement yields a very high gain. The amplifier has an output of 15 watts, sufficient power for a good size installation.

A 4-channel input system is shown with individual T-pad mixers for each circuit. Either sound source can thus be operated at maximum volume, or during announcements a background of music from a radio or phonograph can be imposed upon the voice. The main gain control in the grid circuit of the 2nd type 56 tube is then used to regulate the combined output to meet varying conditions. In the mechanical construction of the amplifier it is good practice to build the power supply system as an individual unit, the amplifier itself as another unit, and the mixer input transformers as a third unit. By building these units on separate chassis of equal size, they can be assembled on a vertical rack and properly shielded from each other. A front panel can also be attached on which the various controls are mounted as well as any meters that may be desired to indicate the various operating conditions.

Thordarson Equipment

T-1	T-6373 Mike to 200-ohm line transformer.
T-2	T-5515 Plate to 200-ohm line transformer.
T-3	T-6196 500-ohm to 200-ohm line transformer.
T-4	T-6371 Input transformer.
T-5	T-5378 Interstage transformer.
T-6	T-6578 Interstage transformer.
T-7	T-6594 Output transformer.
T-8	T-5822 Plate 4 fl. transformer.
T-9	T-7083 Mike to 200-ohm line transformer.
Ch-1	T-2927 Impedance coupling choke.
Ch-2	T-6403 Filter choke.

TYPE 59 TUBE PUSH-PULL OUTPUT CLASS B AMPLIFIER

The sixth circuit design is of a 3-stage amplifier using two type 59 tubes in Class B push-pull, with another type 59 tube as driver in the preceding stage, and a type 56 tube in the 1st stage. Transformer coupling is used, and volume is controlled by means of a 500,000-ohm potentiometer across the input (grid and cathode) of the 1st tube. The amplifier has an output of 20 watts with fair quality, and is suitable for amplifying the output from carbon microphones, magnetic phonograph pickups, radio tuners, or from condenser and velocity microphones with suitable pre-amplifier systems.

	Thordarson Equipment:
T-1	T-5738 Interstage transformer.
T-2	T-6770 Interstage transformer.
T-3	T-6752 Output transformer.
T-4	T-5514 Power transformer.
Ch-1	T-6749 Input choke.
Ch-2	T-5754 Filter choke.

TYPE 2A3 PARALLEL PUSH-PULL AMPLIFIER

The seventh amplifier design is a large capacity high quality 3-stage power amplifier employing four type 2A3 tubes in parallel push-pull in the output stage, two type 56 tubes in push-pull in the preceding stage and a single type 56 tube in the 1st stage. Volume is controlled with a 500,000-ohm potentiometer across the input of the 1st tube. The amplifier has an output of 30 watts, and a practically level response from 50 to 10,000 cycles. It is suitable for the reproduction of voice, music and disc or film recordings. With low level sound sources a suitable pre-amplifier is needed to bring up the signal to the input level required by the amplifier.

An interesting feature of the circuit arrangement is the bias system employed for the 2A3 tubes. A special half-wave rectifier circuit is set up through the type 80 rectifier tube with the two plates tied together. Current flows from the filament of this tube through half of the high voltage winding of the type 83 rectifier to ground, and from ground returns through resistors R-7, R-8 and R-6 to the plate of the tube. The voltage set up across R-7 and part of R-8 then becomes the bias voltage for the four type 2A3 tubes. The potentiometer R-8 is adjusted until the milliammeter shows a total plate current of 160 milliamperes flowing.

Thordarson Equipment:

T-1	T-5741 Interstage transformer
T-2	T-5970 Interstage transformer.
T-3	T-6792 Output transformer.
T-4	T-6793 Power transformer.
Ch-1	T-6749 Input choke.
Ch-2	T-1607 Filter choke.
Ch-3	T-6746 Filter choke.

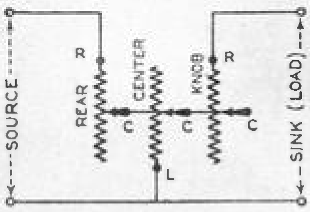


Fig. 1

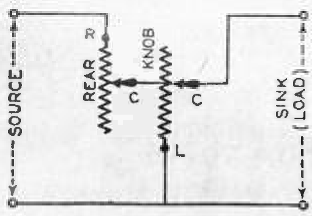


Fig. 3

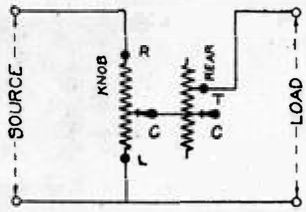


Fig. 5

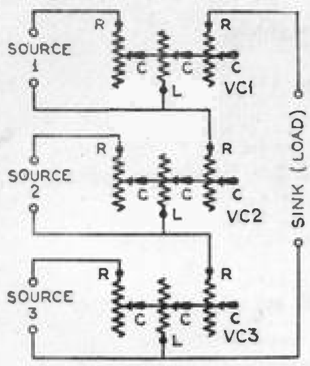


Fig. 2

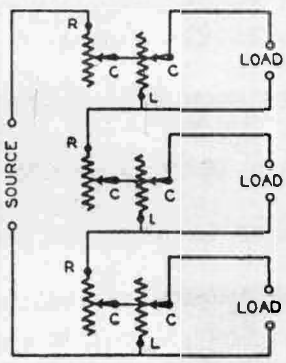


Fig. 4

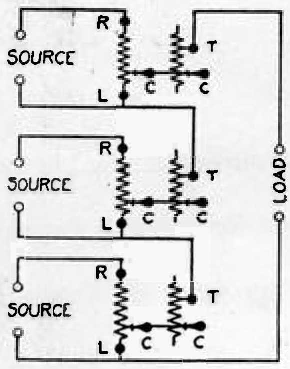


Fig. 6

Fig. 5. Three types of attenuator pads made by Clarostat Mfg. Co. in Brooklyn, New York, are shown here. Fig. 1 is a typical T pad that maintains a constant impedance both at the source and load terminals and is usable as a master level control, mixer control and output control. Fig. 2 shows how to connect a number of sound sources to a common load and maintain a constant impedance across each source and across the load. Fig. 3 illustrates an L pad, which maintains a constant impedance only at the source terminals and is recommended for use as a volume control for individual speakers in multi-speaker installations. Fig. 4 shows how to connect a number of such speakers to a common source (output transformer) and at the same time maintain a constant impedance across the source. Fig. 5 illustrates a type of control that maintains a constant impedance at the load terminals, and is applicable for use as a mixer control. Fig. 6 shows how this control is connected to a number of sound sources so as to maintain a constant impedance across the load. All these controls are available in various resistance values so as to meet the requirements of practically any installation.