High-Fidelity Audio Power Amplifiers

By JOHN G. DODGSON

NRI Consultant

John G. Dodgson

THE amplifier is often considered the heart of a high fidelity system, since the amplifier is in the center of the system between the input signal from the phonograph, tuner, or tape and the loudspeaker. Furthermore, it is in this section of the high fidelity system that we control the tone and loudness of the sound.

The input to a high fidelity amplifier from the signal source, whether it be a cartridge, tuner, or tape, is a very low voltage signal. Since loudspeakers are power-operated devices it is necessary to amplify this low voltage signal to a high voltage level and then to amplify or change this high voltage signal to a sufficient power to operate the loudspeaker.

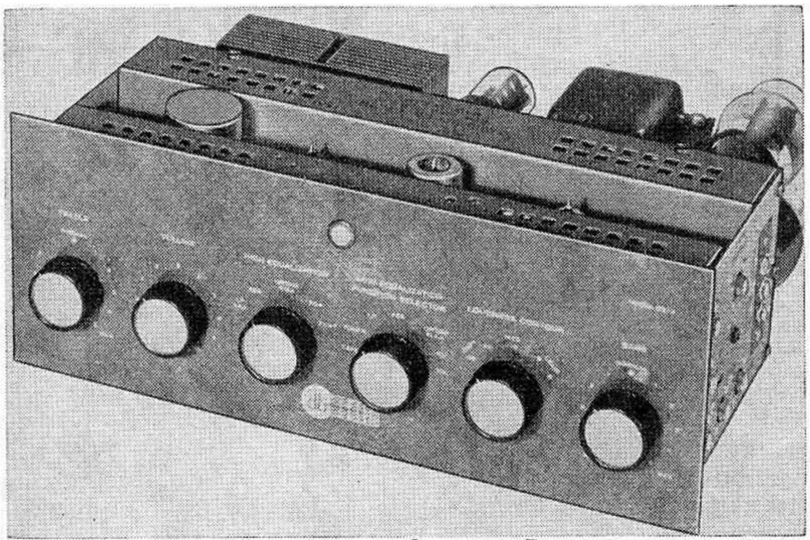
In order to obtain sufficient output power with low distortion it is necessary to use a push-pull output stage in high fidelity amplifiers. A typical push-pull stage with a simple phase inverter transformer is shown in Fig. 3.

Courtesy Newcombe Audio Products Co.

FIG. 1. Many of the highest quality amplifiers such as this Newcombe 2500-R are built in two sections with the power amplifier and power supply on the larger chassis and the preamplifier-control unit on a smaller chassis. Such amplifiers are capable of extraordinary response. This 25-watt amplifier, for example, has a frequency range from 10 to 100,000 cycles at only .01% distortion at 10 watts output which is well above the average playing level.

Phase Inverters

For many years the transformer-driven output stage was used employing triodes or beam power tubes with the addition of negative voltage feedback. The greatest improvement to such a stage was the elimination of the phase inverter input transformer and the use of vacuum tubes as phase inverters. Such a basic stage is shown in Fig. 4. Notice that the driver tube VT1 feeds the grid circuit of power output tube VT2. The grid resistance in this stage is split and a portion of the signal voltage is applied to the grid of VT4. Since this tube inverts the signal 180 degrees (as all amplifier tubes do) the signal fed to VT3 is the same but opposite in phase to that fed to tube VT2 giving push-pull operation. The greatest advantage of the resistance-coupled inverter stage is lower harmonic and intermodulation distortion and a wider frequency range as



Courtesy David Bogen Co., Inc.

FIG. 2. The usual High Fidelity Power Amplifier such as this Bogen DB15 has, on the same chassis, a preamplifier and controls.

while resistors R7 and R6 are the grid resistance for tube VT3. Resistor R6 is then in both grid circuits which are fed the same signal but of opposite phase, causing degeneration.

When a signal is amplified by VT1 a portion of it appears at the R5-R6-R7 junction point and is consequently fed to and amplified by tube VT4. The amplified signal is applied to the grid resistance of VT3-R7-R6. Thus a portion of this amplified signal appears at the R5-R6-R7 junction point and tends to cancel out the first signal. If it does, circuit operation will cease. Therefore resistors R5, R6, and R7 are chosen according to the gain of tube VT4 so that the output voltage of VT4, which is applied to the grid of VT3, is equal to the output of VT1, which is applied to the grid of VT2, achieving balanced

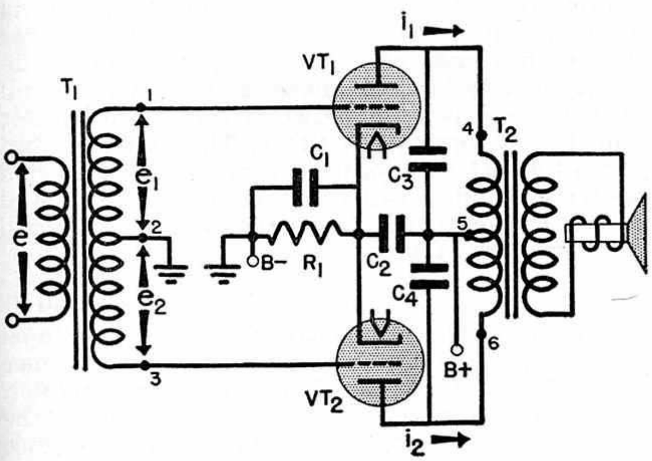


FIG. 3. A simple transformer fed push-pull triode power amplifier.

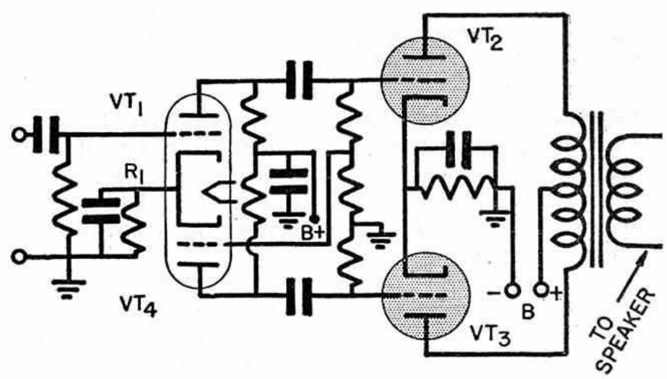


FIG. 4. A vacuum tube phase inverter.

well as reduction of magnetic coupling, hum pickup, weight, cost, etc.

Fig. 5 illustrates a cathode follower, or as it is sometimes called, a cathodyne phase-splitter. In this circuit, equal cathode and plate resistors are used, so the signal voltage in the plate-to-cathode circuit is effectively divided. Output is then obtained from the circuit as shown in the illustration and since the plate and cathode circuits are out of phase equal signals of opposite phase are available to feed the output tubes.

The "floating paraphase" inverter shown in Fig. 6 is very similar to the basic phase inverter shown in Fig. 4. However, the floating paraphase has the additional advantage of self-balancing. In this circuit the phase-inverter grid is fed from the junction of resistors R5, R6, and R7. Resistors R5 and R6 form the grid resistance for tube VT2

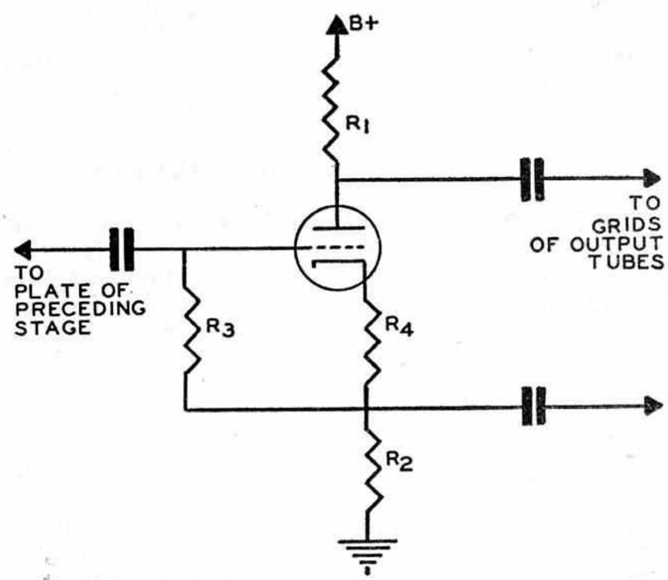


FIG. 5. The cathode-follower or cathodyne phase splitter. R1, R2 Plate and cathode load resistors; R3 Grid resistor; R4 Bias resistor.

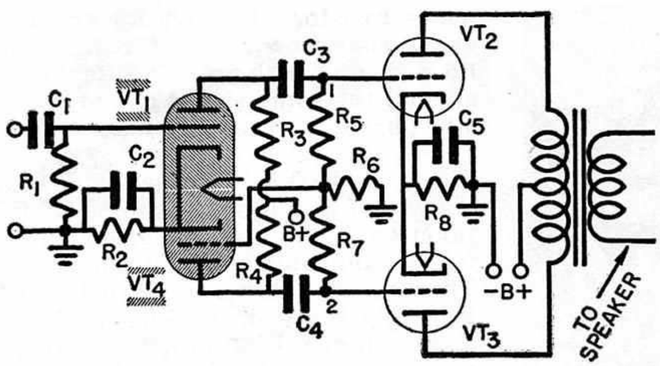


FIG. 6. The Floating-Paraphase phase inverter.

push-pull operation; and so that the portion of the output voltage of VT4 that appears at the R5-R6-R7 junction does not completely cancel out the initial signal.

In practice this isn't too difficult to obtain providing the gain of VT4 is known. The home experimenter, however, will probably have to use the "cut and try" method since resistors R6 and R7 affect the gain of VT4.

All three of these simple phase inverters are now used in high fidelity amplifiers. In addition there are several other versions such as the "long-tailed" pair shown in Fig. 7 and the "Kappler" shown in Fig. 8. Notice the similarity of these circuits.

In the "long-tailed pair" phase inverter the input signal is applied to the grid of VT1 and the amplified output signal of the tube is fed through coupling condenser C2 to one of the output tubes. Tube VT2, a grounded grid amplifier by action of condenser C1, receives its signal from the common cathode resistor R5. Since the grid resistors R3 and R6 are connected to the junction of the two cathode resistors (R4 and R5) only the voltage drop across resistor R4 provides bias for the stage. Resistor R4, causing degeneration, reduces distortion and stabilizes the stage.

The Kappler circuit is a unique combination of other circuits. The first triode VT1 directly feeds the second triode grid. Output can then be taken from the low impedance cathodes and since both cathode resistors R2 and R3 provide degeneration, distortion is negligible.

The Williamson Amplifier

For many years there was little interest in high fidelity reproduction except by a few hobbyists and little was done to improve these basic audio stages or develop new methods. However, five or six years ago a new type of amplifier appeared called the "Williamson" after its inventor, D. T. N. Williamson. A basic Williamson amplifier stage is shown in Fig. 9.

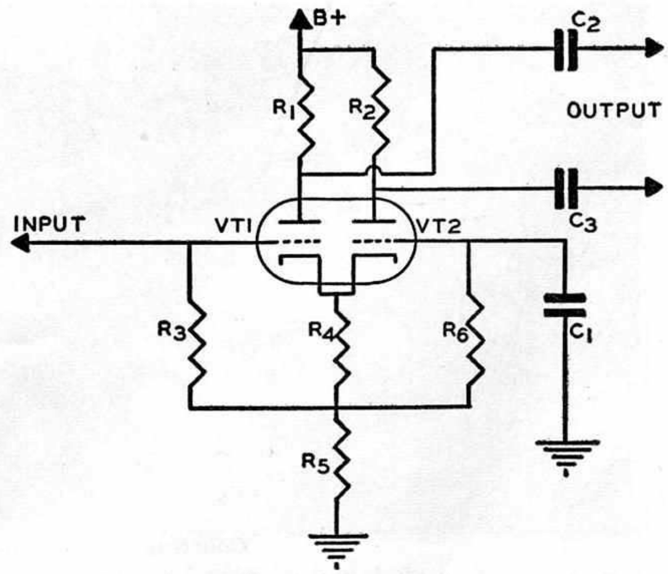


FIG. 7. "Long-Tailed Pair" phase inverter.

Notice the difference between this amplifier and that shown in Fig. 3. A cathode follower type phase splitter is used and the first driver is directly coupled to the phase splitter. A push-pull driver stage is used between the phase splitter and the power output tubes. The power output circuit itself uses beam power tubes connected as triodes and considerable feedback is employed between the output transformer secondary and the first driver stage.

This Williamson amplifier sparked a new interest in high fidelity because of its exceptional qualities of extremely wide frequency response at very low distortion. However, this amplifier, too, had its limitations. For example, due to the cathode follower type phase splitter unbalance was obtained at very high frequencies due to the differences in interelectrode capacities between the grid and plate and the grid and cathode.

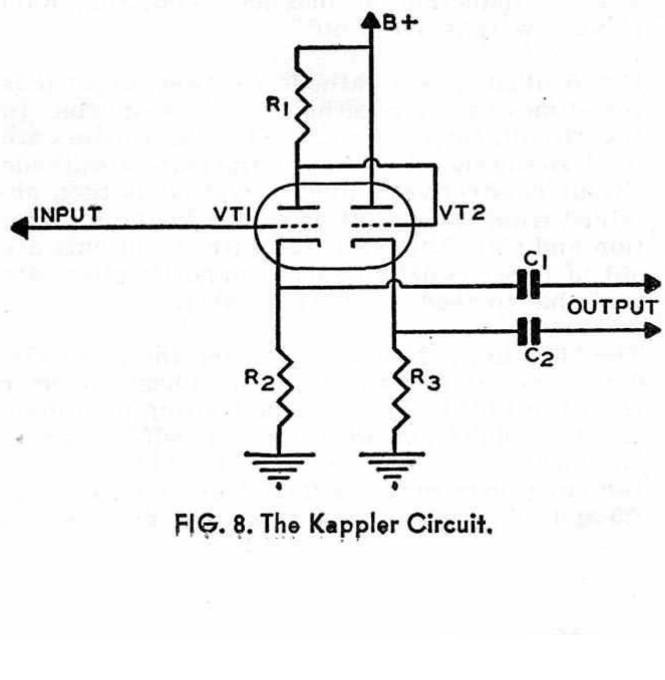


FIG. 8. The Kappler Circuit.

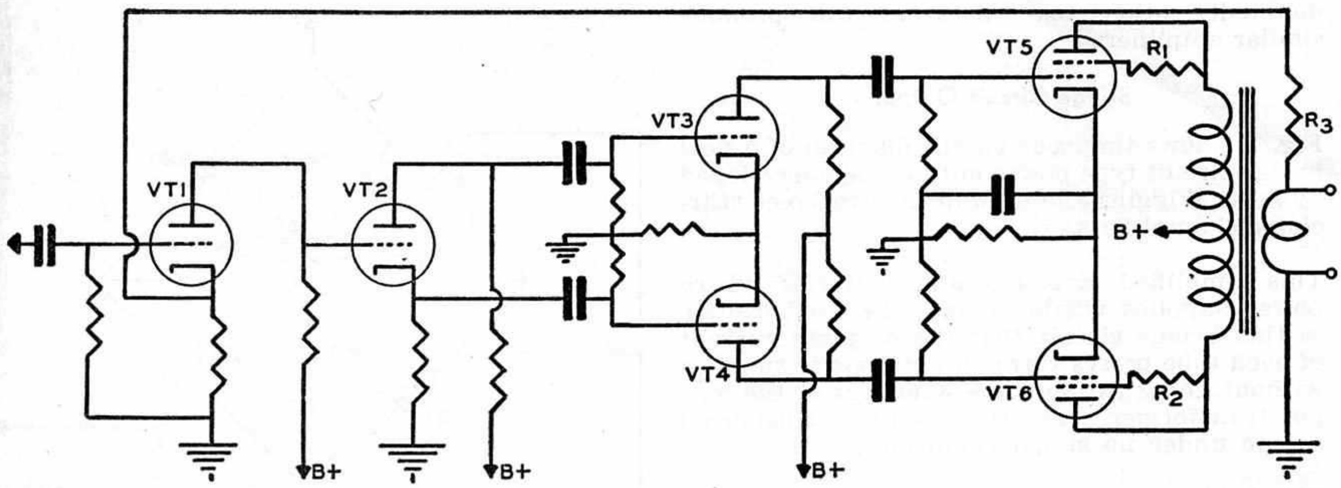


FIG. 9. A basic Williamson circuit. VT1 Voltage Amplifier; VT2 Phase inverter; VT3, VT4 Push-pull drivers; VT5, VT6 Push-pull triode connected power output tubes; R1, R2 Suppressor resistors to prevent parasitic oscillations; R3 Feedback resistor.

Another fault was the limited power output obtained with the triode-coupled tetrode tubes.

Three or four years after the initial announcement of the Williamson amplifier, two audio engineers, D. Hafler and H. I. Keroes, improved the Williamson amplifier as shown in Fig. 10. This improvement in the amplifier somewhat stabilized it and greatly improved the frequency response and power output. This particular type circuit is very popular today partially because of the recent development of high quality output transformers at reasonable prices.

It is not unusual for such an amplifier to have a frequency response from 2 to 200,000 cycles per second ±1 db at normal listening levels with harmonic distortion well below 1%. It should be pointed out that there are many variations of the basic Williamson circuit. The labeling of an audio amplifier as a "Williamson type" does not necessarily indicate high performance. Good response depends on the proper choice of component values and the quality of the output transformer.

Power Output Tubes

Along with the development of amplifier circuits there has also been a redesign of tubes especially built for audio purposes. In modern amplifiers two type tubes seem to be most popular.

In amplifiers up to 12 watts the type 6V6 or its miniature equivalent, type 6AQ5, is generally used. For higher power amplifiers, the type 6L6 is most popular although some amplifiers have used type 1614 and type 807 tubes.

Another very popular type tube, from England, is the type KT66 which is a direct replacement for the type 6L6, This type tube was developed to replace the type 6L6 and has better audio characteristics. After the introduction of this tube the type 5881 was developed in America with similar characteristics. Recently some higher powered tubes, such as the 6550 and the 6CA7, have been developed. These are high-powered versions of the 6L6-KT66 family for use in 50 to 100 watt amplifiers.

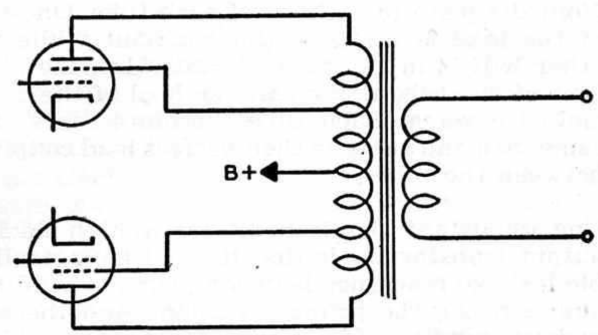


FIG. 10. Ultralinear alteration of Williamson amplifier.

So far we have discussed several different types of amplifiers used today in high fidelity circuits. The basic amplifier shown in Fig. 4 using pentodes or triodes, the Williamson amplifier shown in Fig. 9, and the ultra-linear Williamson type shown in Fig. 10. Actually, the triode type amplifier shown in Fig. 4 is becoming obsolete since recent improvements in audio output transformers enable a beam power type circuit to have extremely low distortion with a more useful power level.

In the last few years several new amplifier circuits have been developed and will now be discussed. In most cases the new circuits have been patented and therefore only the company holding the patent is producing the type amplifier. Of course, when the patent rights run out, undoubtedly other manufacturers will produce similar amplifiers.

Bridge-Circuit Output

Fig. 11 shows the basic circuit diagram of a new bridge-circuit type power output stage developed by A. M. Wiggins and used in Electro-Voice "Circlotron" amplifiers.

This simplified circuit shows batteries where power supplies would actually be used. Notice in this bridge circuit that the dc plate current of each tube passes through both power supplies without going through the windings of the output transformer, since the circuit is a balanced bridge under no signal conditions.

This bridge consists of the two output tubes and the two power supplies, B1 and B2. The output transformer is connected across the bridge between the cathodes of the tubes and is center-tapped to establish the grid-to-cathode circuit through the bias supply B3.

To simplify the circuit, triodes are shown in the diagram although beam power tubes are used in the commercial amplifiers.

As can be seen in the diagram the entire total primary windings are presented as a load to each tube since this winding is essentially connected from the plate to cathode of each tube. One-half of the load is in the cathode circuit while the other half is in the plate circuit. Also, the plate load of one tube is the cathode load of the other and vice versa. Each tube therefore "sees" the same load and there is then perfect load coupling between the tubes.

One important requirement for a high fidelity output transformer is that it must have negligible leakage reactance between primary windings and between the primary winding and the secondary winding. If leakage reactance is high, then transient distortion will occur due to collapsing currents when each tube is driven beyond cutoff. This current, which causes the transient condition, appears as a parasitic oscillation in the waveform at the plate current cutoff points. In addition to this high leakage reactance also causes a tremendous decrease in transformer efficiency at high frequencies resulting in poor high frequency response as well as increased distortion.

This is another great advantage of this balanced bridge circuit. Since both halves of the primary have the same signal current flowing through them no switching transients can occur when either of the tubes are driven past cut-off.

There are several other advantages obtained with this circuit. For example, due to the connections in the output transformer the impedance of the

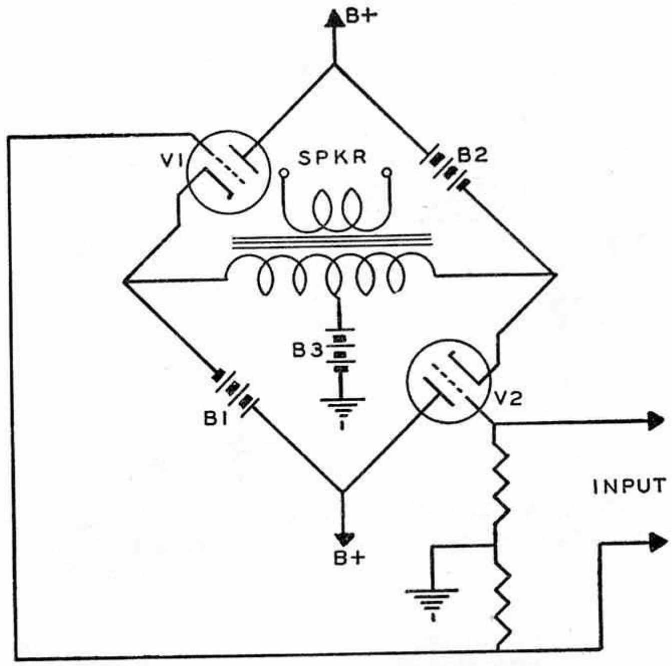


FIG. 11. Wiggins Circlotron circuit.

primary winding need be only one-fourth the impedance of the primary winding of a transformer in the conventional type output circuit with the same tubes. The lower impedance primary permits the transformer to be wound with much less capacitance than would be possible with a higher impedance. Further, the almost perfect coupling between the two tubes allows them to be operated with low quiescent current —very close to class B operation, which gives more power output.

The McIntosh Amplifier

As was discussed previously, several inherent defects are encountered with ordinary output transformers other than the obvious and expected difficulties of frequency response. In modern output transformers, it is not difficult to have a high enough primary inductance to obtain good low frequency response and a low enough leakage inductance to obtain good high frequency response. As was mentioned before, switching transients are encountered when the output tubes reach their cut-off points. These switching transients are a direct result of leakage inductance since not all of the lines of force in one-half of the primary cut the lines of force produced by the other half of the primary. These flux lines that are not coupled produce a counter emf which directly causes switching transients. Obviously, one method of eliminating such switching transients is to obtain perfect coupling and thereby eliminate the leakage inductance.

The McIntosh output transformer and associated circuit is a step in this direction. The elimination of the leakage inductance would result in unity coupling. This is essentially what we have with this McIntosh circuit. The two halves of the primary of the transformer are bifilar-wound. That is, the two wires are laid next to each other and then wound as one wire. The coupling between the primary windings is exceptionally tight since the windings are wound together and the leakage inductance is then insignificant.

As can be seen in the basic McIntosh circuit shown in Fig. 12, the transformer is so wound that the identical winding is in the cathode circuit and the other in the plate circuit. Each winding is center-tapped.

With the circuit set up in this manner, each tube operates as a cathode follower type phase inverter with the power output being developed equally in the plate and cathode windings. Should the input signal make the grid of the top tube more positive, current flows upward from ground to the cathode of this tube and then from its plate through the lower half of the winding to B+. The bottom tube in the circuit operates in a similar manner using the lower half of the cathode winding and the upper half of the plate winding. Since the plate and cathode windings are identical and bifilar-wound, with a coupling factor approaching unity, leakage inductance is effectively eliminated and each tube appears to operate through the full primary.

The load in the secondary windings sees the two primaries as a single winding so the effective turns ratio can be halved and the plate-to-plate impedance reduced to one-quarter the optimum value for the same tubes operated in a push-pull circuit. With the impedance reduced to one-fourth, the effect of distributed capacitance of the windings is reduced by the same factor and the high frequency response of the transformer is increased appreciably.

As you can easily see, the designer of this circuit looked at it in a similar manner as the designer of the Circlotron amplifier. Both circuits accomplish a reduction of leakage inductance and consequent lowering or eliminating switching transients.

Output-Transformer-Less Amplifiers

As was pointed out several times, the output transformer in a high fidelity amplifier can cause considerable trouble. In fact, the previously rather poor quality of the output transformers was perhaps the most important limiting factor of high quality reproduction. As was seen in the discussions of the McIntosh and Circlotron amplifiers, many attempts have been made to improve output transformers in an attempt to obtain high quality reproduction. One method of improving high quality power amplifiers with respect to the output transformer is a natural one—eliminating the output transformer.

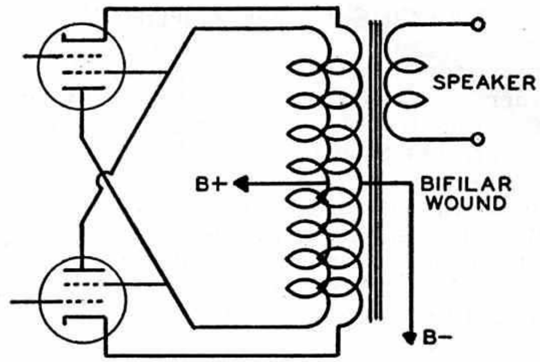


FIG. 12. McIntosh circuit power amplifier.

However, the output transformer in an audio amplifier is necessary to step down the high impedance of the output circuit to the low impedance of the loudspeaker. High fidelity loudspeakers normally have impedances from four to sixteen ohms. However, the plate-to-plate impedance of a high fidelity power amplifier will vary from about 3000 ohms to 10,000 ohms, depending upon the output tubes.

Incidentally, this is the plate-to-plate impedance of the output tubes and the necessary primary impedance of the output transformer. The actual source impedance which the loudspeaker "sees" is lower than this.

In order to eliminate the output transformer it is obviously necessary to change the usual circuit. This has been successfully accomplished by many engineers and hobbyists and descriptions of such circuits appear from time to time in the leading electronic magazines. There is, however, to date, only one commercial amplifier which does not use an output transformer. This is the Stephens "Citadel."

The usual method of eliminating the output transformer is to use a cathode-follower type output circuit. As you know, the output impedance of an amplifier is high. However, by using the cathode circuit of an amplifier for the output (a cathode-follower) the impedance can be made quite low. If the output impedance of the amplifier can be made low and if a loudspeaker can be obtained with a slightly higher than normal impedance then proper matching would result. Many manufacturers will make higher impedance loudspeakers on special order (for additional cost). For example, some very fine Stephens loudspeakers are available with an impedance of 500 ohms for only a slight additional increase in cost.

The omission of any particular high fidelity power amplifier circuit from this discussion should not be taken as a criticism of that circuit. There are just too many to be described in this News article.

SERVICING POWER AMPLIFIERS

The first step in servicing a high fidelity power amplifier is to determine if the amplifier is the cause of the trouble. Power amplifier very obviously are not used by themselves.

The best way to check a power amplifier for a defect is to substitute another one or to substitute for the other components in the system (such as the loudspeaker, preamplifier, record changer, tuner, etc.). If, after doing this, the amplifier is definitely the cause of the trouble, then normal Radio-TV trouble-shooting techniques can be employed with some modification.

Incidentally, whenever I service a power amplifier, my first step, before turning it on, is to make certain that the output transformer is not shorted in any way to B— by components in the output tube plate circuits such as feedback components from the plates of the output tubes. Such a short circuit could, when power is applied, burn out the output transformer, and keep in mind that high quality output transformers cost up to $35. The few minutes needed for such checks have, more than once, prevented the damage of an output transformer.

It is essential to have a load connected to the output transformer secondary whenever power is applied to the amplifier or the output transformer will be damaged. Either a loudspeaker or resistor load can be used depending on the amplifier trouble and what is desired.

The Dead Amplifier

Trouble-shooting a completely dead amplifier, as with similar trouble-shooting in Television and Radio receivers, is generally begun with a test of the tubes and a check of the power supply. Tubes should be checked in a tube tester or by substitution. Then, check the power supply by measuring the B+ voltage. These two steps may lead you directly to the trouble. Of course, if all the tubes are good and the power supply is operating properly then the trouble is somewhere else in the amplifier. To locate this trouble, various methods can be used according to the preferences of the serviceman. Sometimes the characteristics of the amplifier are such that one type of servicing is preferable to another—only experience can show this.

One good method of servicing a dead amplifier is to inject an audio signal. There are several ways of doing this. If you wish you can feed the signal into the first tube in the amplifier and then with a pair of headphones follow the signal through the amplifier from stage to stage. In place of the headphones another amplifier can be used or an ordinary servicing signal tracer. Another method is to feed the signal into the various stages of the amplifier, one at a time, beginning at the loudspeaker end until the defective stage is encountered.

When servicing an amplifier by this signal-injection method keep in mind the characteristics of the phase splitter. In many amplifiers the input of the phase-splitter stage is obtained from the output of the driver stage as shown in Figs. 4, 6, and 8. Because of this a defect in the driver stage will prevent operation of the phase-splitter stage. However, with only a glance at the circuit diagram it may seem that the trouble could be in either stage.

Incidentally, if you would prefer to use the signal injection method of servicing a dead amplifier but you do not have an audio signal generator you can usually use the audio output section of a Radio-TV rf signal generator. Just be sure that the attenuator is set properly so as to have sufficient signal to be fed through the amplifier but yet not too much to overload the first stage of the amplifier.

One other method of servicing by signal injection is to use the oscilloscope as the output indicator. When doing this be sure that the audio generator is set to a medium high frequency range so that any hum in the amplifier is not confused with the output signal that is being traced.

Incidentally, when using the audio portion of the rf generator and an oscilloscope be sure to check the output waveform of the signal generator so as to prevent confusion. Often the waveform of an rf generator is not a perfect sine wave and, if this is not known, some time could be spent in trouble-shooting an amplifier for distortion when it is actually the input signal that is distorted.

Hum

Hum is a very common audio problem. However, most of the time hum troubles occur in the preamplifier and other low level stages of a high fidelity system rather than in the power amplifier. Before trouble-shooting a power amplifier for hum make certain that the hum is actually being caused by the power amplifier and is not being fed into it from the preamplifier.

The oscilloscope is a very handy tool in trouble-shooting for hum in a power amplifier. By going from grid to plate throughout the stages the entrance point of the hum can usually be very easily and quickly located.

As with Radio and TV receivers, hum is generally caused by defective filter condensers and cathode-to-heater leakage in a tube. The output filter condenser can usually be checked by merely bridging a good one across the suspected condenser or by actual substitution. Measuring the ac ripple voltage output of the power supply can sometimes be helpful while at other times it can lead to confusion. Extreme cathode-to-heater leakage in a tube can very often feed this hum voltage into the B+ supply where it could be measured and be suspected as a defect in the power supply.

Hum in a tube can sometimes be detected as leakage in a tube tester test. However, most of the time it is necessary to substitute new tubes that are known to be good. If you do not have any tubes that are known to be good (by being tested in other amplifiers) it is best to try two or three or even more tubes when trouble-shooting for hum. Many tubes will perform properly in Radio and TV receivers and yet will have too much hum for high gain high fidelity circuits.

Hum can also be caused by a defect in the feedback circuits of an amplifier. Normally feedback in an amplifier is used to reduce the low distortion characteristics of an amplifier to an even lower value. Sometimes, however, engineers have used feedback in a poorly designed amplifier to reduce high hum and distortion levels. A defect in such an amplifier feedback network would then result in a higher hum level than would be expected from such a defect.

In the usual push-pull output circuit the B+ voltage for the plates of the ouput tube is fed through the primary of the output transformer through a center tap. If the tubes are properly matched and balanced and the output transformer is of high quality so as to have balanced primary windings any hum voltage in the B+ supply fed to the primary of the transformer would be cancelled in the primary windings. Because of this, B+ voltage for the output tube plates is often obtained at the input filter condenser where there is normally a high ripple voltage. This is not an indication of poor engineering but is perfectly acceptable providing the above conditions are met. However, if a defect should occur which would unbalance the output transformer or the tubes, hum could result. Don't overlook this possibility when trouble-shooting for hum. Common defects are: one of the output tubes being weak or dead, shorted turns in one of the primary windings, etc.

Incidentally, while we are discussing hum, keep in mind that all amplifiers will produce some hum. The hum level is normally too low to be noticed. However, sometimes a customer will increase the volume control to its maximum, turn the bass control to its maximum boost position, and then noticing the hum will complain about it. All amplifiers will produce hum under these conditions and the amount of hum will depend upon the inherent design of the amplifier and the low frequency response of the speaker system. To check for normal hum level feed program material through the system either with a record changer or a tuner and adjust the volume control to a little above the normal playing level. The treble control should then be adjusted to its "flat" position and the bass control should be slightly advanced to a position that might, under some circumstances, be used. This is almost never its maximum position. After the controls have been set remove the source (record or tuner), disconnecting it from the amplifier, and listen critically for hum from the loudspeaker. In very high quality systems hum should not be heard while listening right at the speaker while in medium and low price systems some hum is normal within two or three feet of the speaker. In any case, at normal control positions, the hum should not be loud enough to interfere with the program material nor to be annoying during quiet passages as between bands on an LP record.

Noise

As with hum, noise is generally caused by a defect in the low level amplifier stages rather than in the power amplifier stages. However, an extremely noisy tube in the high level stages can cause this trouble. As indicated previously, a new tube, known to be good, should be substituted.

Noise can often be caused by resistors and substituting new resistors will usually clear up the trouble. It is usually best, in such cases, to replace a noisy resistor with one of higher wattage value (which tends to reduce the noise). Half watt resistors should be replaced with 1-watt resistors, 1-watt resistors with 2-watt resistors, etc. It is generally not feasible to go over 2 watts unless, of course, the original resistor was of higher wattage. That is, replace a 5-watt resistor with a 5-watt resistor but replace a ½-watt resistor with a 1-watt unit.

When trouble-shooting an amplifier for noise it is unsatisfactory to use a radio signal tracer because of its normally high noise level as compared with Hi-Fi equipment. It is usually essential to use a pair of high fidelity headphones or another high fidelity amplifier for such signal tracing.

Distortion

This is the most difficult form of trouble to track down. One of the best methods of tracking down distortion is to feed normal program material such as from a tuner or a record into the input of the amplifier and then trace through the amplifier from stage to stage with a pair of high fidelity headphones or another Hi-Fi amplifier being used as a signal tracer.

There are many types of distortion which can occur in power amplifiers—frequency distortion, harmonic distortion, intermodulation distortion, transient distortion, phase distortion, etc., to name a few. Fortunately, most of these types are peculiar to the design of the amplifier and not to its servicing. The distortions most often encountered by the serviceman are non-linear distortions such as harmonic and intermodulation. Any defect which can cause one of the other types of distortion such as transient or frequency, generally also cause non-linear distortion which, by the way, is the most annoying type.

Non-linearity in any stage will cause both harmonic and intermodulation distortion. Harmonic distortion is the improper amplification of harmonics or the addition of harmonics which are not present in the original signal. Intermodulation distortion is the modulating of the high frequencies by the low frequencies. This causes sum and difference signals to arise.

The harmonics introduced or incorrectly amplified due to harmonic distortion are musically related to the signal but the sum and difference signals produced by intermodulation distortion are not musically related to the signal. Because of this, intermodulation distortion is more annoying than harmonic distortion.

Non-linearity in a stage is generally caused by a change of value of the plate or cathode resistors. Previously described signal tracing methods can be employed to locate the stage causing the distortion and then the defective part can be found with an ohmmeter.

Incidentally, when trouble-shooting for distortion don't overlook the possibility of secondary troubles. For example, a leaky coupling condenser will usually apply a positive voltage to the grid of a tube, upsetting the bias and causing distortion. However, the excessive plate current of that tube resulting from the positive voltage on the grid may increase or decrease the ohmic value of the plate resistor. Replacing the coupling condenser and tube would then still not clear up all of the distortion because of the damaged plate resistor. Remember that the resistor need not be visibly burnt to have changed value.

Harmonic and intermodulation distortion analyzers which are available both factory-built and in kit form can be very useful tools to the high fidelity service man. However, when using these instruments keep in mind that you should not expect all high fidelity power amplifiers to have distortion levels as low as the manufacturer's specifications state. The distortion level given in the specifications should be for a typical power amplifier of that particular model. However, it may not be! First of all, the tolerances of the distortion level are seldom given in the secifications and they can be as much as plus or minus 50%—this is not unusual. Furthermore, the method of measuring the distortion is not given either. Some manufacturers list the distortion level for the over-all amplifier including the preamplifier and control unit. Other manufacturers measure only the distortion of the power amplifier. Other factors can affect such specifications. For example, the distortion with a resistive load connected to the output of the amplifier may be lower than the distortion measured with a loudspeaker load.

Since distortion is greatly affected by the feedback methods in the amplifier, a defect in a feedback loop is a common cause of amplifier distortion.

Some amplifiers use only one loop of inverse voltage feedback which is generally taken from the secondary of the output transformer and fed to the driver tube cathode. However, there are many amplifiers with more than one feedback loop or with different types of feedback. For example, the Bogen DB110 uses a special type of feedback called controlled positive feedback while the UTC amplifier kit employs many feedback loops. In addition to these various types of fixed positive and negative feedback, the current trend in amplifiers is to include variable current feedback which enables the user to adjust the damping factor of the amplifier. Damping factor is a ratio of the load impedance to the output impedance of the amplifier. (The output impedance of the amplifier is the impedance that the loudspeaker "sees"—not the plate-to-plate impedance of the output tubes.) This adjustable damping provision may be known by some other name. Bogen calls it "variable damping factor" while Fisher labels it "Z-Matic."

In conclusion, the servicing of high fidelity power amplifiers does not present any particularly difficult problems. The servicing techniques proven successful in Radio-TV work are usually applicable with some modifications (as explained) providing the serviceman keeps in mind the normally high quality of reproduction to be expected from these amplifiers.

———*n r i*———

The applicant presented his credentials with confidence but the manager read them very dubiously.

"It is certainly a fine thing for you to have these recommendations from your minister and your Sunday School teacher, but I'd like to have at least one recommendation from someone who knows you on week days."

———*n r i*———

"If you want knowledge, you must toil for it; if food, you must toil for it; and if pleasure, you must toil for it. Toil is the law. Pleasure comes through toil, and not by self-indulgence and indolence. When one gets to love work, his life is a happy one."

—*John Ruskin*