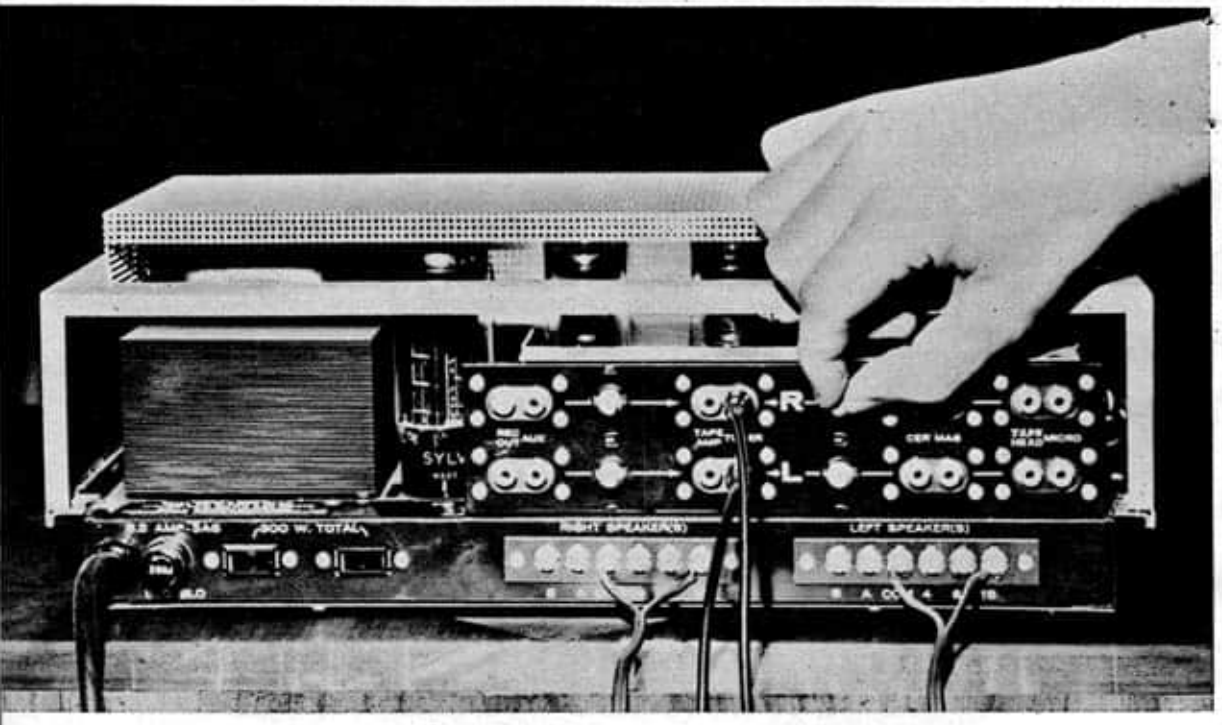
Chapter 8
Power Amplifiers

Rear view of Bell stereo amplifier showing speaker connections, input and output jacks.

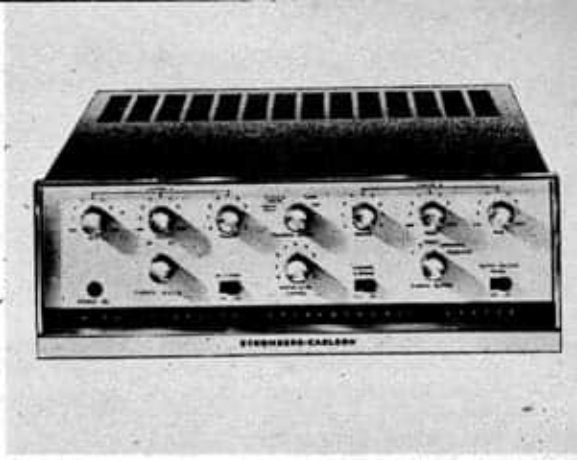


AT the end of the electronic chain in the hi-fi system is the power amplifier, which builds up the tiny voltages from the program sources or preamplifier and sends them as powerful signals into the loudspeaker, where they are to be reconverted to sound. The complexity of the power amplifier will depend upon the number of functions it must perform, and whether any functions are handled by a preamplifier or control amplifier preceding it. The simplest basic amplifier is a fixed-gain device, which sends through in enlarged form whatever signals are fed into it by a control amplifier, the signals being otherwise unchanged. At the other extreme, the hi-fi amplifier may include preamplification, switching and other controls, all within a single unit.

The controls may therefore be an integral part of the main amplifier, or they may precede it. In either event their function is the same, so we will discuss them here, even though they may not always be found as a part of the main power amplifier.

The first control, without which all the others are useless, is the electric power switch. This may be a rotary, toggle, or slide type, but it's still a two-position

Marantz 40-watt power amplifier has hum level of —90 db at 40 watts. Damping is more than 20; 20-20,000 cps; 4, 8, 16 ohm terminals. Price: $219.



Stromberg-Carlson stereo control amp provides 12 watts for each channel, with individual controls for both channels, plus a master gain adjust.

Bell 2-channel stereo unit has a rating of 30 watts for each of its channels, continuously variable loudness control, speaker function lever switch, stereo balance. Response is 15-30,000 cps ± 1 db, hum is —71 db; price: $219.95.

switch, which is turned either on or off. Sometimes it is ganged with the volume or tone control, while in other cases it is entirely separate.

A different type of switch, a selector or function switch, is found at the amplifier input. Since a number of devices from various program sources may be fed to the input, a rotary switch or series of push buttons is necessary for selection of the desired one at any given time. In many cases this switch will also select the phono compensation.

Bear in mind, however, that most compensator design is based on magnetic pick-ups. When such an equalizer is used with piezo type cartridges, an adapter is required. But since crystal and ceramic cartridges are reasonably well equalized internally to the RIAA characteristic, they may be connected directly to any high-level unequalized input jack, such as TV, TUNER, TAPE or AUX. A jack which is specifically designated for the piezo type cartridge may have a little additional equalization and it should certainly be used if available.

There are usually at least two tone controls on the amplifier, one for bass and one for treble. Unlike the simple treble roll-off

control found in home instruments, hi-fi tone controls provide either accentuation or attenuation at both ends of the spectrum. They will thus accommodate almost any personal taste, as well as any acoustical peculiarities of the listening area.

The midrange is not usually controllable, although some amplifiers do feature a "presence" control. Since the human ear is most sensitive in the region between 3,000 and 5,000 cps, it has been found that boosting this range will make solo voices stand out and improve articulation. The change in quality possible with such a control is quite dramatic, but since this form of equalization is now widely used at the source in broadcasting and recording, more fooling around with this range at home is usually overdoing it a bit.

Another form of control over the frequency response is the fixed filter, which may be switched in and out as required. At the low end is the rumble filter, which is used to cut out low frequency noise generated by the turntable, or present in the program source. This filter can't help cutting some bass as well, but it is made as selective as possible.

At the other end of the spectrum are scratch and hiss filters, which are intended to reduce those types of noise to a comfortable volume. There may be several of these each cutting off everything above a specified frequency. They may start as low as 3,000 or 5,000 cps, and go up as high as 10,000 or 12,000 cps.

There are two types of sound level control, one of them actually being a form of tone control as well. The ordinary volume control adjusts the level of all parts of the spectrum equally, but the more elaborate loudness control does not. Since flat response is generally a desirable hi-fi objective, the deliberate distortion introduced by this control must be justified.

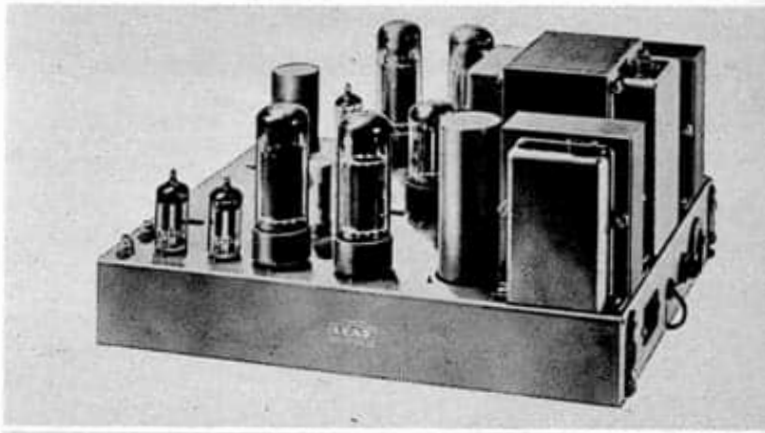
The design of the loudness control is tied in with the peculiar characteristics of the ear already described. The increased sensitivity in the 3,000–5,000 cps range is true at all volume levels, but more so at lower intensities. In other words, the ear is always less sensitive in the bass and treble regions than in the midrange, but as the volume is lowered, the droop at each end becomes even more pronounced. That is, the bass and treble drop even faster than does the middle.

Since most of the time we listen to a hi-fi system at a much lower level than that of the original sound, we are also hearing less treble and bass than originally produced. This can be corrected in a haphazard way simply by tipping up both tone controls, but that is strictly a guesswork method. The loudness control, however, has a characteristic which is just the inverse of the ear, and thus provides the correct aural balance at all listening levels.

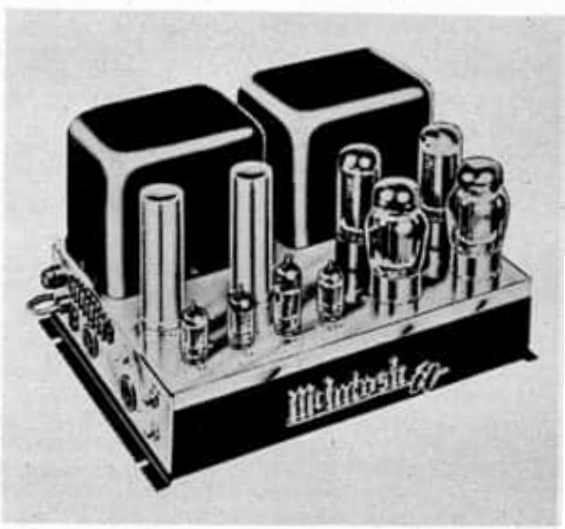
The power rating of an amplifier is supposed to tell the maximum watts it develops in its output load with only a reasonable amount of distortion. But there are dozens of different types of distortion, almost as many ways of measuring it, and

Leak, British 50-watt monaural amp can be used with speakers having impedance of 3 to 20 ohms. Response is 20-20,000 cps ± .5 db; price is $149.

At right are two models by Leak, the 50-watt stereo amplifier and the "Point One" stereo preamp. The power amplifier is rated at 25 watts for each of its two channels, sells for $189; the preamp is $129.



McIntosh 30-watt basic amplifier has frequency range of 15-50,000 cps ± .5 db at 30 watts. The damping factor is 12 for 4, 8, 16 ohms; $143.30.



Continuous 60 watts are obtainable with the MC-60 by McIntosh. Noise and hum: —90 db at 60 watt. Distortion is less than .3% at full power; $198.

Grommes stereo amplifier gives 20 watts for each channel, has ganged controls. The unit is also a complete preamplifier and compensator for tape and phonograph discs.

Basic 60-watt amplifier made by Grommes has 5-50,000 cps ± .5 db frequency response. The power response is 20-20,000 cps ± .5 db at 30 watts. Damping is continuously variable. Hum and noise: —95 db.

some disagreement as to what constitutes a reasonable amount. This all adds up to the fact that the amplifier power rating is not a very useful concept in judging equipment performance.

Since distortion is such an important factor in rating amplifier power, however, it follows that distortion will be less when the system is operated well below its maximum rating. This is the basis of the argument for using amplifiers of upward of fifty watts in home installations when the program content usually is only a fraction of a watt. When a low efficiency loudspeaker is used, of course, the argument takes on even more validity.

The most serious forms of distortion are those which occur when more than a single pure tone is fed into the amplifier simultaneously. Since most hi-fi programs comprise music as the audio signal, and since most music is made up of chords of tones, plus their harmonics, the resultant waveform which must pass through the system is highly complex. A type of distortion which often occurs under these conditions is called *intermodulation*. This occurs when two or more audio frequencies in the amplifier combine to form sum-and-difference tones in the output.

A similar phenomenon actually occurs within the human hearing mechanism, in which case the resultant combinations are called *subjective tones*. But the amplifier is supposed to be completely objective, not subjective. It should not add any coloration of its own at all. As a practical matter, no amplifier is this perfect. All amplifiers will generate some intermodulation, and most listeners are not offended by it, as long as it remains under 5 per cent. Under these conditions, harmonic distortion is no more than 1 or 2 per cent, a negligible amount.

Another important index of amplifier performance is *transient response*. This is the reaction of the system to steep waveforms, attacks and releases. In the case of music, tongueing a mouthpiece, depressing a key, or striking a drumhead or cymbal, all produce sharp sounds which have only a brief instant between the initial impact and the maximum amplitude. At the end of the tone there is a decay period, although the cut-off is less sharp. The system which can accurately reproduce these steep waves is said to have low transient distortion. This distortion is sometimes expressed in terms of the manner in which the shape of a square wave is altered as it passes through the system, the distortion being observed on an oscilloscope.

The human ear is still the best measuring instrument of all, however, and in evaluating any amplifying system you should rate it strictly in terms of what your own ears tell you. Listen carefully to the han-

Dual stereo amp-preamp by Bogen-Presto provides 30 watts for each channel, has phase and channel reverse switch and two hi-lo filter switches.

Harman-Kardon A250 stereo amplifier, 25 watts each channel, has frequency response at 20 w of 20-20,000 ± 1 db, local and remote speaker switch.

dling of program material containing many sharp attacks: staccato, pizzicato and sforzando passages. These should all be perfectly clear, without any "hash" or "ringing."

Any audio power amplifier is really a series of smaller amplifiers in cascade, each of these sub-units being known as a *stage* of amplification. The number of stages in an amplifier indicates the number of multiplication processes the signal goes through between the source and the output.

The means by which the signal is transferred from the output of one stage to the input of the next is known as the *coupling*. Most audio amplifiers are called resistance-coupled, having an arrangement of resistors and capacitors between the plate circuit of the previous stage and the grid circuit of the following tube.

A rather special type of coupling is the *cathode follower*, in which the output signal is taken from the cathode of a tube rather than its plate. When a tube is connected in this way, it isn't really an amplifier at all, but actually a loss device in which the output signal is smaller than the input. The cathode follower is very low in distortion, and an excellent device for coupling a high-impedance source to a low-impedance load. It is therefore some-

A220 stereo amp by Harman-Kardon gives 10 watts at each channel, has 8 and 16 ohm outputs. Inputs include phonograph, tuner and auxiliary. Crosstalk is below 50 db, hum is —70 db at low volume.

Fisher stereo master audio control and 40-watt two-channel amplifier has 8-position input selector, frequency response of 20-20,000 cps; hum and noise are 80 db below rated output; 50 db channel separation.

times used to couple the amplifier output to the loudspeaker, thus eliminating the output transformer.

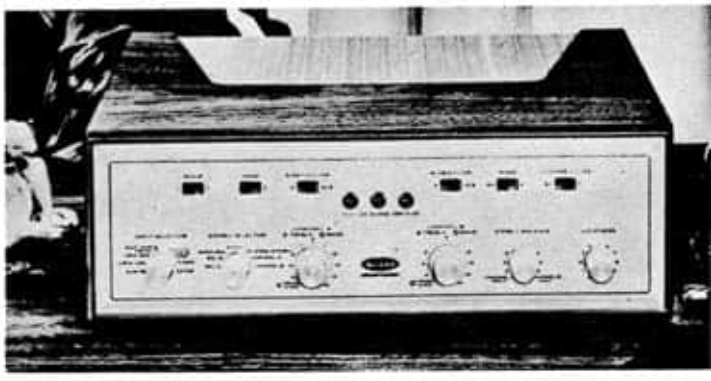
When more than one tube is used in a single amplifier stage, the connection of the tubes is usually in an arrangement called *push-pull.* In this case the signal is fed simultaneously into both tubes, in such a way that a positive peak at the output of one tube coincides with a negative peak at the output of the other. The principle is therefore somewhat analogous to the increased smoothness found in an alternating-fire twin outboard motor. In amplifiers, the advantages are less hum and distortion, and the ability to use smaller and cheaper output transformers.

Between the output of the single-ended amplifier and the push-pull input, there must be a device which can produce, from the single waveform, two output waveforms which are exactly opposite in polarity. The device which does this is called a *phase inverter.* This may be either a center-tapped transformer, or the job may be done electronically by a paraphase (phase-splitting) amplifier. Although the transformer is every bit as much a phase inverter as the paraphase, the term is usually applied only to electronic phase inversion. Paraphase amplifiers have the same advantages as any resistance-coupled amplifiers, namely, better frequency response and the elimination of expensive transformers.

The operation of audio amplifiers often

Three units by H. H. Scott are shown on this page. Right is 99-D monaural 22-watt preamplifier with 20-30,000 cps ± .5 db frequency response.

Dual 12-watt amplifier and stereo preamp, Model 222, has noise and hum of 80 db below full power output; harmonic distortion is .8%. It has a third channel amplifier jack.



Type 229 stereo dual 20-watt amplifier and preamplifier is rated at 17 watt of continuous power for each channel, has a phase reverse and stereo balance control. Outputs include tape and 4, 8 and 16 ohm.

is described as Class A, AB, or B. These designations refer to operating conditions within the tube, which depend upon its basic characteristics and the voltages applied to it. Class A is the least efficient, but it also exhibits the least distortion. All sorts of trick circuitry have been developed for canceling out distortion in the more efficient Class AB and B systems, but the serious audiophile should steer clear of this sort of thing. The best amplifier always has a good, clean Class A design throughout.

In some audio amplifiers, a portion of the output signal is fed back into the input in such a way as to oppose, and therefore reduce, the incoming signal. This action is known as *degeneration*, and the system is called negative—or inverse—feedback.

Negative feedback causes some loss in signal level, but it also causes an even greater reduction in noise and distortion. It should be understood, however, that the feedback only reduces the distortion which is generated within the stages where feedback is used. Any distortion already present in the input signal before the feedback will pass right through unmolested. Generally speaking, negative feedback is desirable in limited amounts, although excessive degeneration will result in instability on peaks and high distortion on overloads.

There are two basic types of vacuum tubes used in audio amplifiers. One of these is the three-element tube known as the triode. The other is the five-element type,

called the pentode. The beam-power tube such as the 6L6, which is often used in the output stages of audio amplifiers, is really a member of the pentode family, although its physical construction is somewhat different from others in the five-electrode group.

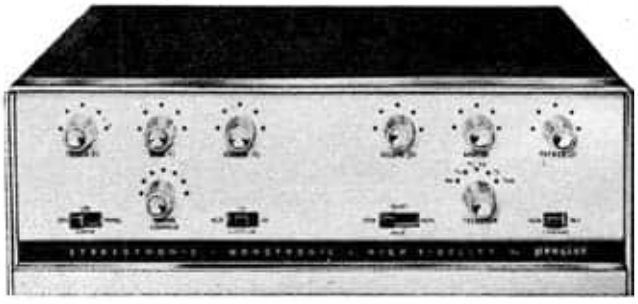
Because pentodes as a group are much more efficient than triodes, they are much more commonly used for audio. But the purist knows that the triode amplifier is still the cleaner of the two. Design engineers may argue that it is theoretically possible to build a pentode amplifier with no more measurable distortion than the triode, but that best measuring instrument of all, the human ear, tells us that the best all-triode amplifier will beat the best pentode rig.

The Stereo Story

The basic power amplifier setup for stereo involves essentially two identical monophonic amplifiers. If you already have a good monophonic system, simply duplicating the power amplifier will take care of that part of the stereo chain. The so-called stereo amplifier is actually two separate amplifiers in one, mounted on a common chassis.

The system which is tailor-made for stereo, however, will have a few convenience features, especially in the way of controls. Since it is fairly difficult to maintain the proper balance between the two stereo channels when volume adjustment of each channel is made separately, most stereo controls have both volume-loudness controls ganged together, so that the out-

H. H. Scott basic 40-watt power amplifier has flat frequency response from 12-40,000 cps. Speaker outputs available are 4, 8, 16 ohms.



Precise stereo amplifier delivers 20 watts for each channel, has Multiplex adaptor built in, includes a speaker phase, and a channel reverse switch.

Pilot 30-watt stereo preamp-amplifier sells for $129.50, has frequency response of 20-20,000 cps ± 1 db. Full output phono sensitivity is 3 mv. Hum and noise is below 80 db.

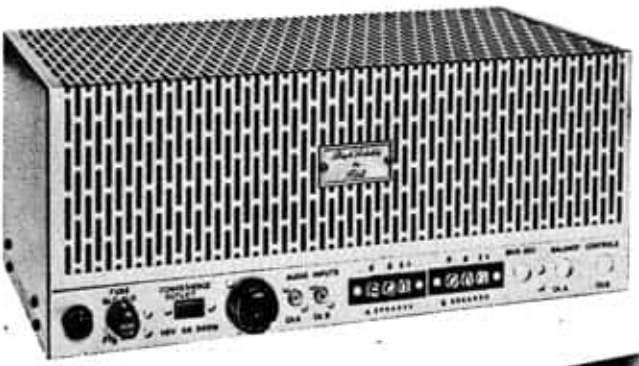
puts of both channels are affected by exactly the same amount.

This is only useful, however, when the two channel outputs have previously been balanced. Ideally, the outputs of the two loudspeakers would be just the same in volume. But differences in recording technique, listening room acoustics, and the location of the listener require some flexibility in this rule. For this reason, stereo systems usually have a *balance control,* which has nothing to do with tonal balance, but merely varies the relative outputs of the two channels.

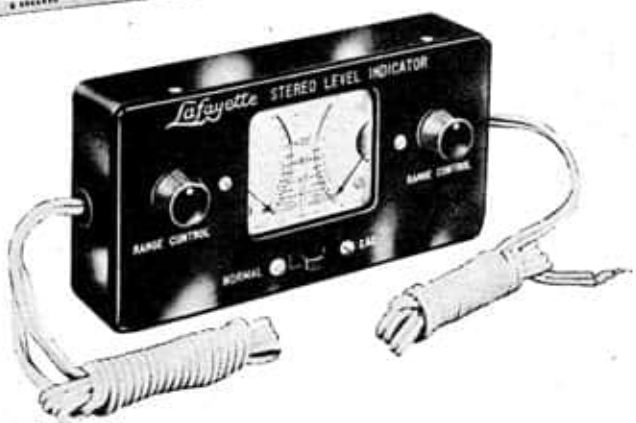
Most stereo systems also have a *reverse* switch, which corrects for any anomaly in the system whereby the left signal appears out of the right speaker, and vice versa. This makes for a rather topsy-turvy

orchestra, but it can be simply corrected by adjustment of the reverse switch. This switch should not be confused with the stereo loudspeaker phasing switch, which will be discussed in the next chapter.

Other switches permit listening to either channel alone for checking purposes, without disturbing the balance, and feeding monophonic program material into either or both loudspeakers. •



Basic 80-watt stereo amp by Pilot gives 40 watts per channel. Hum level is 90 db below full output. Harmonic distortion is .5% at 70 watts. Outputs are 8 and 16 ohms; $139.50.



Lafayette stereo audio output level indicator is used to balance stereo channels. Meter responds to average values of music and speech, lets you compare levels in channels.

Among the many hi-fi units made by Sherwood is this stereo dual preamp-amplifier which gives 20 watts for each channel. It has pushbutton filter and level controls, function indicator lights and phase reverse. Interchannel crosstalk is —50 db at 1 Kc. Frequency response: 20-20,000 cps ± .5 db. Price, less case, $189.