HIGH FIDELITY AMPLIFIER CIRCUITS

This article has been prepared to provide hobbyists, electronic technicians, and others interested in construction of high-fidelity amplifier systems with laboratory-tested circuits, which can provide superior performance at moderate cost. These systems employ valve types designed especially for use in high-fidelity applications, and include the most recent developments in circuit design. The article discusses the performance requirements of a high-fidelity amplifier system, describes the functions of the various amplifiers, preamplifiers, and control units which are usually employed, includes construction hints, and provides voltage charts to facilitate checking the equipment. The article contains circuits for three power amplifiers having power outputs of 15, 30, and 50 watts, a bass-and-treble tone control amplifier, preamplifiers for use with magnetic phonograph pickups, a preamplifier for use with a magnetic-tape pickup head, and a microphone preamplifier. Also included are circuits for a two-channel mixer, and a balancing unit for stereo systems. The tone-control amplifier, preamplifiers, and mixer have matching gain and output characteristics which permit them to be used singly, or in various combinations with any of the three power amplifiers. Each power amplifier circuit includes a power-supply which can be used to supply the heater and B+ requirements of a complete audio system.

PERFORMANCE REQUIREMENTS

The performance capabilities of a high-fidelity amplifier are usually given in terms of its frequency response, total harmonic distortion, intermodulation distortion, maximum power output, and noise level.

To provide high-fidelity reproduction of audio programme material, an amplifier should have a frequency response which does not vary more than 1 db over the entire audio spectrum. General practice is to design the amplifier so that its frequency response is flat within 1 db from a frequency below the lowest to be reproduced to one well above the upper limit of the audible region.

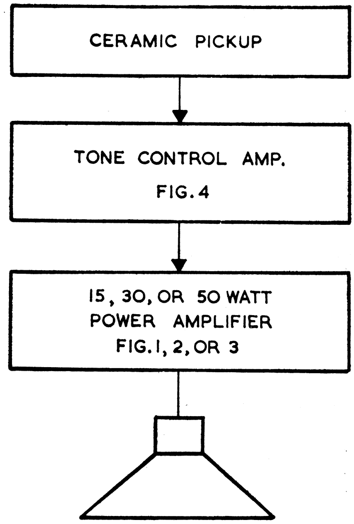
Harmonic distortion and intermodulation distortion produce changes in programme material which may have adverse effects on the quality of the reproduced sound. Harmonic distortion causes a change in the character of an individual tone by the introduction of harmonics which were not originally present in the programme material. Harmonic distortion is expressed as a percentage of the output power. For high-fidelity reproduction total harmonic distortion should not be greater than about 1% at the desired listening level.

Intermodulation distortion is a change in the waveform of an individual tone as a result of interaction with another tone present at the same time in the programme material. This type of distortion not only alters the character of the modulated tone but may also result in the generation of spurious signals at frequencies equal to the sum and difference of the interacting frequencies. Intermodulation distortion, like harmonic distortion, is expressed as a percentage of the output power and should be less than 2 per cent at the desired listening level. In general, any amplifier which has low intermodulation distortion will have very low harmonic distortion.

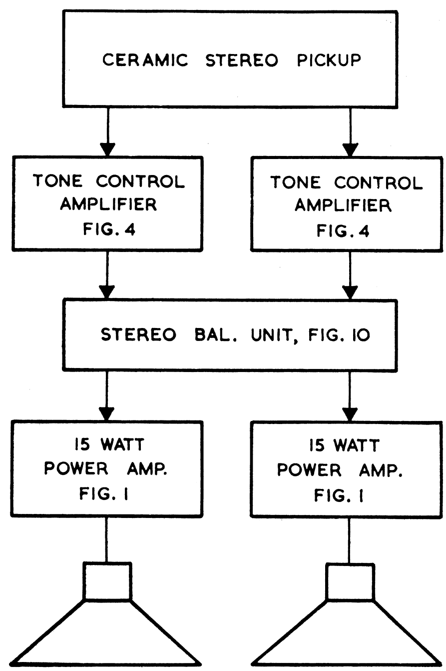
The maximum power output which a high-fidelity amplifier should deliver depends upon a complex relation of several factors, including the size and acoustical characteristics of the listening area, the desired listening level, and the efficiency of the loudspeaker system. Practically, however, it is possible to determine amplifier requirements in terms of room size and loudspeaker efficiency.

The acoustic power required to reproduce the loudest passages of orchestral music at concert-hall level in the average-size living room is about 0.4 watt. Because high-fidelity loudspeakers of the type generally available for home use have an efficiency of only about 5 per cent the amplifier should therefore be able to deliver a power output of at least 8 watts. Since many wide-range loudspeaker systems, particularly those using frequency-divider networks, have efficiencies of less than 5 per cent, amplifiers used with such systems must have correspondingly larger power outputs.

The noise level of a high-fidelity amplifier determines the range of volume the amplifier is able to reproduce — that is, the difference (usually expressed in decibels) between the loudest and softest sounds in programme material. Since the greatest volume range utilized in electrical programme material at the present time is about 60 db, the noise level of a high-fidelity amplifier should be at least 60 db below the signal level at the desired listening level.



SIMPLE HIFI MONAURAL RECORD REPRODUCING SYSTEM

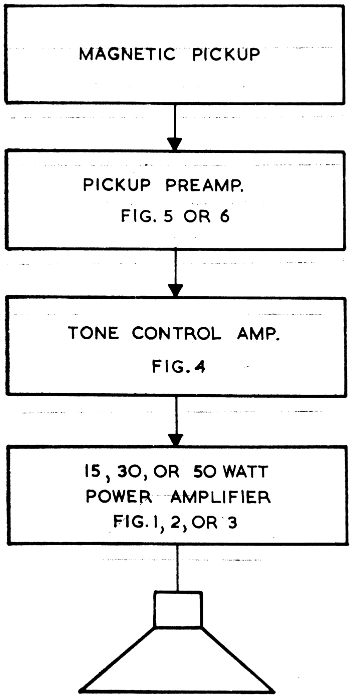


STEREOPHONIC VERSION OF THE SYSTEM SHOWN ABOVE. TONE CONTROLS IN THE TWO CHANNELS MAY BE GANGED.

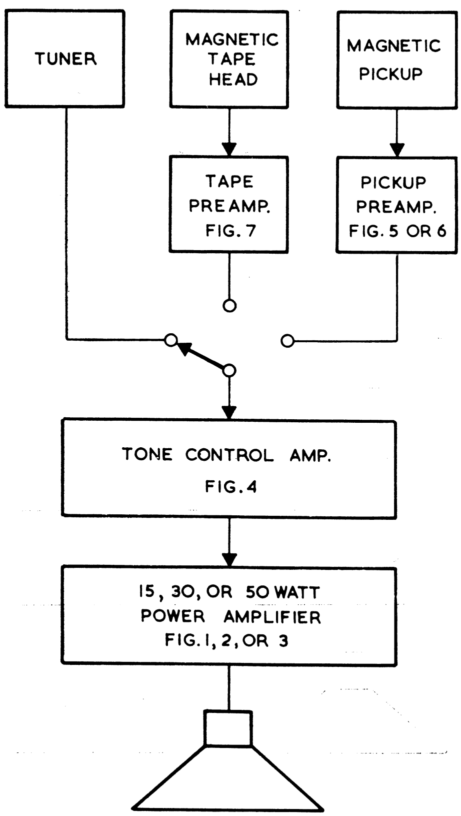
CIRCUITS

FIFTEEN-WATT AMPLIFIER

The high-fidelity power amplifier shown in Fig. 1 can deliver 15 watts with less than 0.4 per cent total harmonic distortion and less than 1.5 per cent intermodulation distortion. It has a frequency response which varies less than + 0.5 db from 20 cps to 60,000 cps, and a sensitivity of 1.2 volts



MONAURAL RECORD REPRODUCING SYSTEM USING MAGNETIC PICKUP.



SYSTEM FOR HIFI REPRODUCTION OF MONAURAL RECORDINGS, TAPE RECORDINGS AND BROADCAST PROGRAMMES.

rms for 15 watts output. Total hum and noise with input shorted is 84 db below 15 watts.

This amplifier incorporates several design features which permit it to provide excellent performance with relatively inexpensive components. Features responsible for the very low hum and noise level are the use of a 7199 low-noise triode-pentode in the input and phase-splitter stages, a choke-capacitor filter in the B-supply circuit, and the application of a positive voltage to the valve heaters to minimize hum due to heater cathode leakage.

The features responsible for the low distortion and excellent frequency-response characteristics of this amplifier are the use of 6973 beam power valves operated under class AB_1 conditions with fixed bias in the output stage, the use of direct coupling between the input and phase-splitter stages, and the use of inverse feedback from the voice-coil winding of the output transformer to the cathode of the input amplifier stage. In addition to its excellent performance capabilities and low cost, this amplifier is extremely compact, and therefore, is particularly suitable for use in stereophonic systems.

THIRTY-WATT AMPLIFIER

The high-fidelity power amplifier shown in Fig. 2 can deliver 30 watts output with less than 0.7 per cent total harmonic distortion and less than 1.5 per cent intermodulation distortion. The frequency response of this amplifier is flat within ± 0.5 db from 15 cps to 40,000 cps. The total hum and noise with the input shorted is 85 db below 30 watts. Sensitivity is 1 volt rms input for 30 watts output. The amplifier is similar in design to the 15-watt amplifier shown in Fig. 1, except that it uses 7027-A beam power valves in the output stage, and a resistive network in the negative leg of the B-supply rather than a separate rectifier to supply the fixed bias voltages for the output valves. The amplifier is also provided with a hum-balancing adjustment in the heater circuit.

FIFTY-WATT AMPLIFIER

The high-fidelity power amplifier shown in Fig. 3 is capable of outstanding performance at moderate cost. This four-stage amplifier can deliver 50 watts output with less than 0.1 per cent total harmonic distortion and less than 1 per cent intermodulation distortion; and has a frequency response flat within ± 0.5 db from 10 cps to 50,000 cps. Sensitivity is 0.4 volt rms input for fifty watts output. The total hum and noise is 70 db below 50 watts.

This amplifier, like the 15-watt and 30-watt high-fidelity amplifiers shown in Figs. 1 and 2 uses a 7199 low-noise triode-pentode as an input amplifier and phase-splitter, but has a push-pull driver stage using 6CB6 sharp-cutoff pentodes, and incorporates several other features which contribute to its superior performance. These features include the use of a 450-volt plate supply and a 400-volt electronically regulated grid-No. 2 supply for the 7027-A beam power valves in the output stage; the use of inverse-feedback loops from the plates to the grids of the output valves, from the plates of the output valves to the cathodes of the driver valves, and from the voice-coil winding of the output transformer to the cathode of the input amplifier.

Additional features are the operation of all heaters at a positive voltage with resect to ground and use of a balancing adjustment (R30) in the heater-supply circuit to minimize hum, a grid-No. 2-voltage adjustment (R39), a grid-No. 1 bias adjustment (R33) for the 7027-A output valves and an ac-balance adjustment (R17) which may be used to balance the outputs of the push-pull stages. Instructions for making the ac-balance adjustment are given adjacent to Fig. 3.

TONE-CONTROL AMPLIFIER

Fig. 4 shows a high-fidelity two-stage tone-control amplifier using a 7025 low-noise twin triode. This amplifier has non-interacting bass and treble controls which can be adjusted to provide up to about 16 db boost or attenuation at 30 cps, and up to about 16 db boost or attenuation at 15,000 cps. With the bass and treble controls set at their mid-range positions, the frequency response of the amplifier is flat within ± 1 db from 30 cps to 15,000 cps. The amplifier has an over-all voltage gain of approximately 2.5, and is designed to be used immediately ahead of any of the power amplifiers shown in Figs. 1, 2, and 3, or any power amplifier having similar characteristics. For operating convenience, the volume control on the power amplifier may be physically located on the tone-control chassis. In this case, it is advisable to insert a 1-megohm resistor in place of the volume control on the power amplifier.

If partial compensation for the reduced high- and low-frequency sensitivity of the ear at low volume levels is desired, the volume-control potentiometer may be replaced by a "loudness control."

REPRODUCTION OF PHONOGRAPH RECORDS AND MAGNETIC-TAPE RECORDINGS

The frequency range and dynamic range which can be recorded on a phonograph record or on magnetic tape depend on a complex relation of several factors, including the composition, mechanical characteristics, and speed of the record or tape, the electrical and mechanical characteristics of the recording equipment, and other factors which are outside the scope of this article. To achieve wide frequency and dynamic ranges, manufacturers of commercial recordings use equipment which introduces a non-uniform relationship between amplitude and frequency. This relationship is known as a "recording characteristic." To assure proper reproduction of a high-fidelity recording, therefore, some part of the reproducing system must have a frequency-response characteristic which is the inverse of the recording characteristic. Most manufacturers of high-fidelity recordings use the RCA "New Orthophonic" (RIAA) characteristic for discs and the NARTB characteristic for magnetic tape.

The location of the frequency-compensating network or "equalizer" in the reproducing system will depend on the types of recordings which are to be reproduced and on the pickup devices used.

A ceramic high-fidelity phonograph pickup is usually designed to provide proper compensation for the RIAA recording characteristic when the pickup is operated into the load resistance specified by its manufacturer. Since this type of pickup also has relatively high output (0.5 volt to 1.5 volts), it does not require the use of either an equalizer network or a preamplifier, and can be connected directly to the input of a tone-control amplifier and/or power amplifier of the type described in this article.

A magnetic high-fidelity phonograph pickup, on the other hand, usually has an essentially flat frequency-response characteristic and very low output (1 millivolt to 10 millivolts). Since a pick-up of this type merely reproduces the recording characteristic, it must be followed by an equalizer network as well as by a preamplifier having sufficient voltage gain to provide the input voltage required by the tone-control amplifier and/or power amplifier. Many current designs include both the equalizing and amplifying circuits in a single unit.

A high-fidelity magnetic-tape pickup head, like a magnetic phonograph pickup, reproduces the recording characteristic and has an output of only a few millivolts. This type of pickup device, therefore, must also be followed by an equalizing network and preamplifier, or by a preamplifier which provides "built-in" equalization for the NARTB characteristic.

PREAMPLIFIERS

Figs. 5 and 6 are circuits of preamplifiers for use with high-fidelity magnetic phonograph pickups.

Both preamplifiers are equalized for the RCA "New Orthophonic" (RIAA) recording characteristic, have similar voltage-gain characteristics, and use valves having exceptionally low hum and noise. These valves are designed especially for use in high-fidelity equipment operating at low signal levels. The two-stage preamplifier circuit shown in Fig 5 uses 7025 twin triode, and has a voltage gain of about 150. This preamplifier has a high-impedance output, and is recommended for use when the preamplifier is constructed on the same chassis as the power amplifier and/or tone-control amplifier. The preamplifier may also be used at distances of up to six feet from the amplifier without effect on its frequency response provided the capacitance of C8 is reduced by approximately 30 $\mu\mu$f for each foot of shielded cable used for the af connection between the preamplifier and the following amplifier.

The three-stage preamplifier circuit shown in Fig. 6 uses a 5879 low-noise sharp-cutoff pentode as an input amplifier, one unit of a 7025 as a voltage amplifier, and the other unit of the 7025 as a cathode-follower output amplifier. This preamplifier has a voltage gain of approximately 180, and low-impedance output. Because of the low impedance output the preamplifier may be installed at distances up to 50 feet from the following amplifier without effect upon its frequency-response characteristics.

Fig. 7 is the circuit of a preamplifier for use with a high-fidelity magnetic-tape-pickup head. This preamplifier is essentially the same as that shown in Fig. 6 except that its frequency response is equalized to provide the NARTB playback characteristic.

Fig. 8 shows the circuit of a one-valve preamplifier for use with a high-fidelity, high-impedance crystal or dynamic microphone. This amplifier uses a 5879 low-noise sharp-cutoff pentode in a conventional circuit with high-impedance output, has a voltage gain of approximately 70, and a flat frequency response over the audio range. Because of its high output impedance this preamplifier should be constructed on the same chassis as the power amplifier and/or tone-control amplifier.

MIXER

Fig. 9 shows the circuit of a high-fidelity mixer which can be used to combine audio-frequency programme material from two sources. In this circuit each mixer control is preceded by a one-stage voltage amplifier using one unit of a 7025 low-noise twin-triode and is separated from the common load resistor by a resistance-capacitance network. These features provide "high-level" mixing to minimize noise during adjustments, a very high degree of isolation between the two signal channels, and more than sufficient voltage gain to overcome the losses in the mixing potentiometers and isolating networks. The common 390,000-ohm load resistor may be used as the input resistor for the following tone-control amplifier or power amplifier.

Each section of the mixer can provide a voltage gain of about 7, and can handle an input signal of about 0.2 volt (200 millivolts) rms without overloading.

AMPLIFIER CONSTRUCTION

The results achieved from any high-fidelity amplifier system depend to a large degree upon the skill and care with which the system is constructed. Improper placement of transformers, other components, and wiring, and attempts to achieve excessive compactness, can easily result in instability, oscillation, hum, and other operating difficulties, as well as in damage to components by overheating. It is important, therefore, that construction of high-fidelity amplifier systems be undertaken only by persons who have had some experience in the layout, mechanical construction, and wiring of audio equipment.

It is impractical to give specific construction data for the various amplifiers and other units described in this article, because the best arrangement for each unit or combination of units will depend upon the requirements of the user. It is possible, however, to list some general considerations which should be observed in the construction of any high-fidelity amplifier system.

Any amplifier having two or more stages should be constructed with a straight-line layout so as to provide maximum separation between the signal input and output circuits and terminals. Power-supply connections, particularly those carrying ac, should be isolated as far as possible from signal connections, especially from the input connection Signal-carrying conductors, even when shielded should not be cabled together with power-supply conductors. Internal wiring for ac-operated valve heaters, switches, pilot-light sockets, and other devices, should be twisted and placed flat against the chassis. All connections to the ground side of the circuit in each unit should be made to a common bus of heavy wire. This bus should be connected to the chassis only at the point of minimum signal voltage—i.e., at the signal-input terminal of the unit, as shown by the ground symbol in the circuit diagrams.

All internal wiring handling signal voltages should be as short as possible, and as far as possible away from the chassis to minimize losses at the higher audio frequencies due to stray shunt capacitance. All connections between units should be made with shielded cable having a capacitance of not more than 30 $\mu\mu$f per foot.

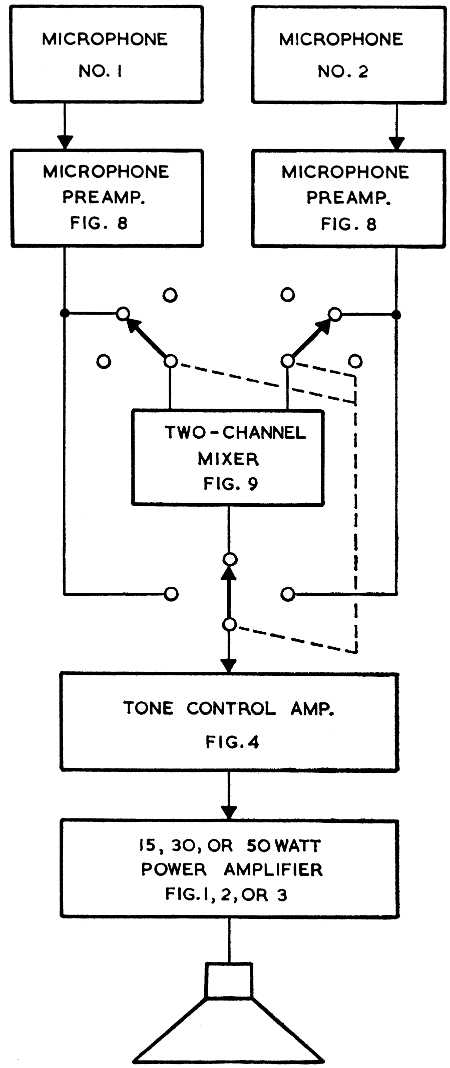
The power amplifiers and power-supply units described dissipate large amounts of heat and, therefore, should be constructed and installed in such a manner as to assure adequate ventilation for the valves and other components.

A beam power valve or rectifier should be separated by at least 1½ valve diameters from any other valve or component on the same side of the chassis.

Power amplifiers and power-supply units which are to be installed horizontally (that is, with valves vertical) in cabinets or on shelves should be provided with mounting feet, perforated bottom covers, and a number of small holes around each valve socket to permit relatively-cool air to enter from below and provide ventilation for the under side of the chassis and valves.

If a power amplifier, tone-control amplifier, and one or more preamplifiers are to be constructed on the same chassis, the mechanical layout should be planned so that the circuits operating at the lowest signal levels are farthest from the output stage and power supply. Amplifier units which normally operate at comparable signal levels but are not used simultaneously—such as preamplifiers for tape pickup heads and magnetic phonograph pickups—usually may be installed side by side on the same chassis without danger of interaction. Units which operate simultaneously, however—such as the channels of a stereophonic system—should not be installed side by side on the same chassis without careful consideration to placement of components and wiring, and the possible use of shielding, to prevent interaction.

When an amplifier, preamplifier, mixer or other unit requiring heater power is located more than five or six feet from its power-supply unit, the heater-current conductors in the power-supply cable must be large enough to assure that each valve receives its rated heater voltage. In cases where very large heater currents or very long power-supply cables are involved, it may be desirable to install a heater-supply transformer on or near the amplifier unit. If such a transformer is installed on or near a preamplifier for a magnetic-tape pickup head, a magnetic phonograph pickup, or a dynamic microphone, the transformer should be completely shielded and carefully positioned to prevent its field from inducing hum in the pickup device.



SYSTEM FOR MIXED OR INDIVIDUAL OPERATION OF TWO MICROPHONES.