High-Quality Dual Channel Amplifier

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A qualitative description of a preamplifier, high impedance R-C dividing network, and power amplifier that are intrinsically simple—yet capable of great performance.

A HIGH-QUALITY AMPLIFIER must be capable of passing rigid laboratory measurements, meet all listening requirements, and be simple and straightforward in design in the interest of minimizing performance degradation and eventual maintenance difficulties.

The circuits of the preamplifier, high-impedance dividing network, and power amplifier described in this paper are not fundamentally new; they represent a synthesis of well-known component circuits of recognized excellence.

In general, the playback system was evolved a "block" at a time after extensive experimentation and listening tests. Each unit had to "test" well, i.e., possess appropriate frequency response, adequate voltage or power output, low distortion and hum level, and then "sound" right when used as an integral part of the sound system. Any unit not meeting these criteria was rejected.

The preamplifier shown schematically in *Fig.* 1, consists of a type 6J7 input tube, followed by two type 6SN7 tubes. "Local" feedback is effective in all stages except the first; however, it is to be observed that the feedback loop never encompasses more than two stages. Unconditional stability, low output impedance and the minimization of distortion is thereby assured. The type 6J7 input tube was selected because it is reliable and quiet in operation. It does not generate periodic "frying" noises and the hum level output is acceptably low. In addition the tube fits a standard octal socket having lugs of sufficient mechanical strength to support one end of a resistor or capacitor. The first stage serves exclusively as a voltage amplifier. No equalization is accomplished. It has been the writer's experience that most preamplifiers featuring a frequency-selective feedback circuit for equalization which connects to the cathode end of the bias resistor of the input tube generate an intolerable hum in any reproducing system capable of good bass response. This statement is sometimes true even when complicated d.c. heater supplies are employed. It appears mandatory that one employ a large bypass capacitor across the bias resistor. Preamplifiers utilizing the method of "contact bias" are rejected because of the excessive intermodulation distortion developed in such circuits. (This bias method permits the direct grounding of the input tube cathode.) The distortion in the 6J7 stage is low even without feedback because the signal voltages rarely exceed 100 mv rms. If desired, the low-distortion input amplifier stage described later may be used, provided the entire bias resistor is heavily bypassed and the volume control is replaced by a resistor matching the pickup impedance.

Frequency correction of 6 db per octave below approximately 500 cps is accomplished by the passive R-C circuit shown between the 6J7 and first triode of the following 6SN7. The second triode furnishes some amplification and permits the application of negative feedback around the two stages associated with this tube. Following the volume control, a 36 position R-C equalizer appears. The maximum bass rise or cut is 12 to 15 db. At high frequencies the available rise is 3 to 5 db, and the cut is approximately 12 db. No interaction exists between the bass and treble sections of the equalizer.

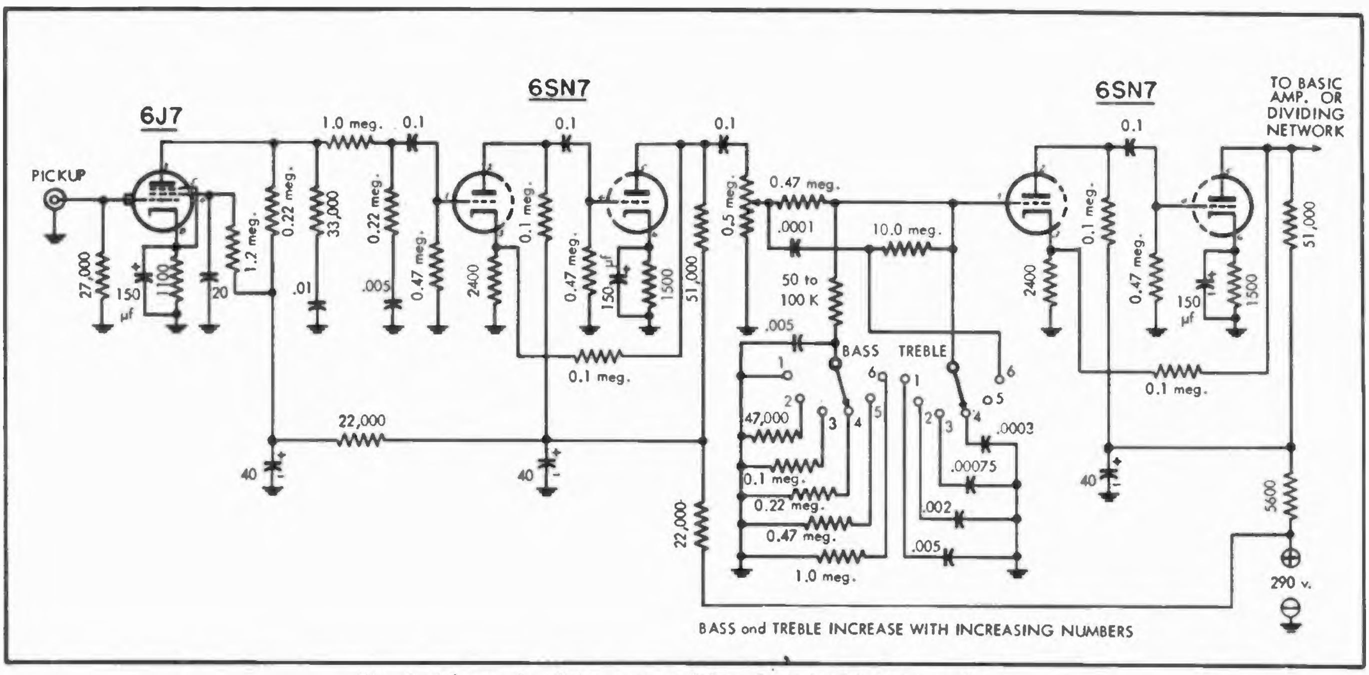


Fig. 1. Schematic of the preamplifier described by the author.

The resistor marked 50,000–100,000 should be selected on the basis of bass equalization required. Bass progressively increases as its value is reduced. The equalizer is followed by a two-stage amplifier, using a second 6SN7. Voltage-controlled feedback is applied around these two stages to minimize distortion and yield low output impedance. A cathode bypass capacitor is used in the output stage to eliminate degeneration at this point which would tend to raise the output impedance. If desired a cathode-follower output stage may be added to this preamplifier provided the power amplifier to be used in not high gain; otherwise hum problems are sure to be encountered. If feedback is not required around the first half of the 6SN7, the second half may be wired as a cathode follower. With slight circuit redesign, type 12AY7 low-noise dual triodes could be used in lieu of the 6SN7 tubes. If an FM tuner input is required, a two-position shorting-type switch should be installed adjacent to the volume control on the left.

The hum level of this preamplifier is extremely low. From experience the author can report that nothing is gained in this respect by the employment of d.c. on the tube heaters. It has been found that less than one-third of the equalizer positions available are needed in practice to compensate for the various recording characteristics in use.

This preamplifier does not feature built-in AES, NAB, RIAA (new orthophonic) response characteristics. The philosophy of precise preamplifier equalization which fails to take into account the frequency response of the pickup, power amplifier, and speaker to be employed is a mystery to the writer. System, rather than component engineering is required. As a practical example, suppose that the AES playback characteristic is specified for a given recording and that this response curve is built into the preamplifier. Excellent results will undoubtedly be obtained provided the pickup, power amplifier, and speaker are flat. Now let it be assumed that the speaker (high-frequency driver in a dual loudspeaker) is down 12.5 db at 12,000 cps, which is not at all unusual. The program material in this frequency region is now attenuated by some 12.5 db more than required by the AES playback curve. Percussion instruments will appear to be in the background, a condition not acceptable to a person who enjoys "high-highs." To approximate the AES play-back curve for a given sound system may actually require a preamplifier having essentially flat response above 500 cps; the high-frequency pre-emphasis used in recording being more or less offset by the high-frequency rolloff of the loudspeaker and pickup being employed. In addition to the factors mentioned above affecting preamplifier equalization, the influence of listening room acoustics must be given due weight.

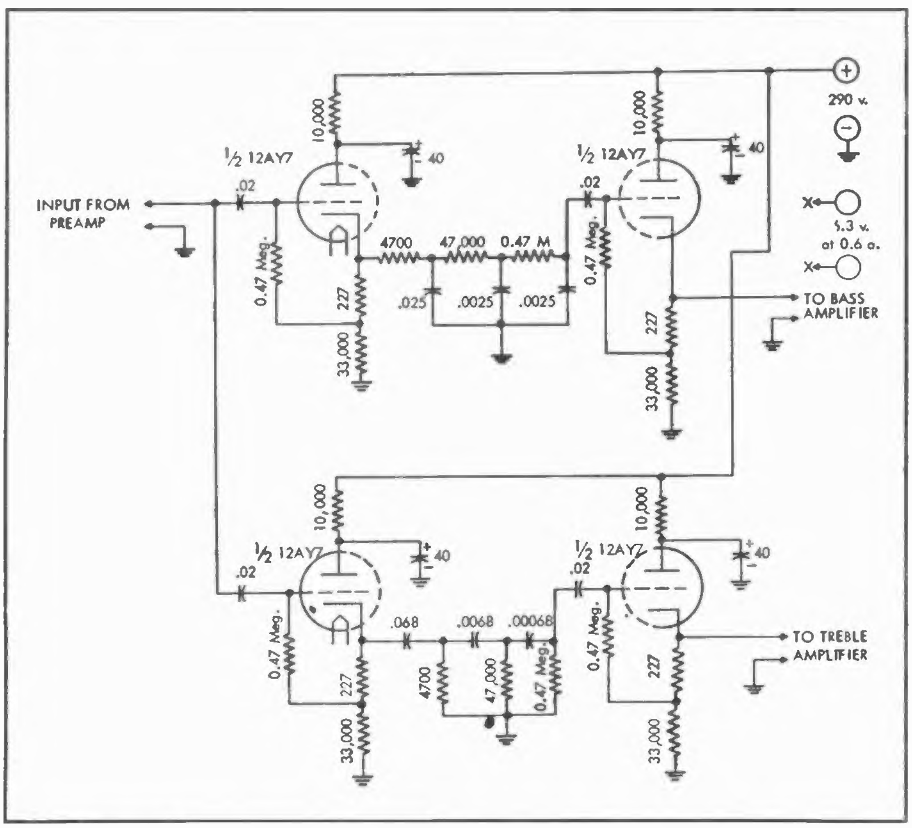


Fig. 2 Schematic of the high-impedance R-C dividing network between the amplifier and the inputs to the two power amplifiers.

A dual-channel amplifier has several advantages over a single amplifier for driving a dual loudspeaker. The use of a distortion-producing dividing network at high signal levels is avoided, as is the power-consuming attenuator normally required in the high-frequency channel to obtain bass and treble balance. The divided transmission system permits exact impedance matching between amplifiers and speakers and additionally permits one to obtain optimum generator impedance in driving the bass and treble speakers. This is generally impossible when a dividing network is interposed between an amplifier and dual loudspeaker. This scheme is a good way of achieving linear transmission of low frequencies (such as emanate from drums, gun shots, explosions, and thunder) together with linear transmission of high frequencies (such as emanate from triangles, castanets, cymbals, and tambourines), without severe modulation of high frequencies by the low frequencies.

The circuit diagram of an R-C dividing network employing cathode follower input and output stages is shown in *Fig* 2. Two type 12AY7 tubes are used; one in each channel. The values of capacitors and resistors shown result in an 800-cps crossover. If, for example, a crossover frequency of 500 cps is desired, the values of the filter capacitors should be multiplied by the ratio 800/500. The resistors do not change value. Similarly, multiplying the capacitor values by 800/1500 yields a crossover frequency of 1500 cps. Each R-C section of both filters should be adjusted to be down 1 db at 800 cps (for 800-cps crossover) by padding the appropriate capacitor and resistor so that the total attenuation for all three sections in cascade is 3 db. The low-frequency filter provides an attenuation approaching 18 db per octave above the crossover frequency, and the high-frequency filter provides an attenuation approaching 18 db per octave below the crossover frequency. By actual measurement on the R-C dividing network constructed by the author, the low-frequency filter is down 11 db at 1600 cps and the treble filter is down 11 db at 400 cps. Thus the attenuation afforded by the three-section R-C filters is 11 db in the first octave, the crossover frequency being taken as reference. The input impedance of the dividing network is extremely high. The output impedance of each channel is low, permitting the use of rather long cables to the bass and treble power amplifiers without deleterious effect on the high frequencies. Ten volts rms will not over-drive the dividing network. If the network is used in conjunction with power amplifiers like the one to be described in the following section the operating level need not exceed one-half volt. Thus essentially distortionless operation is assured.

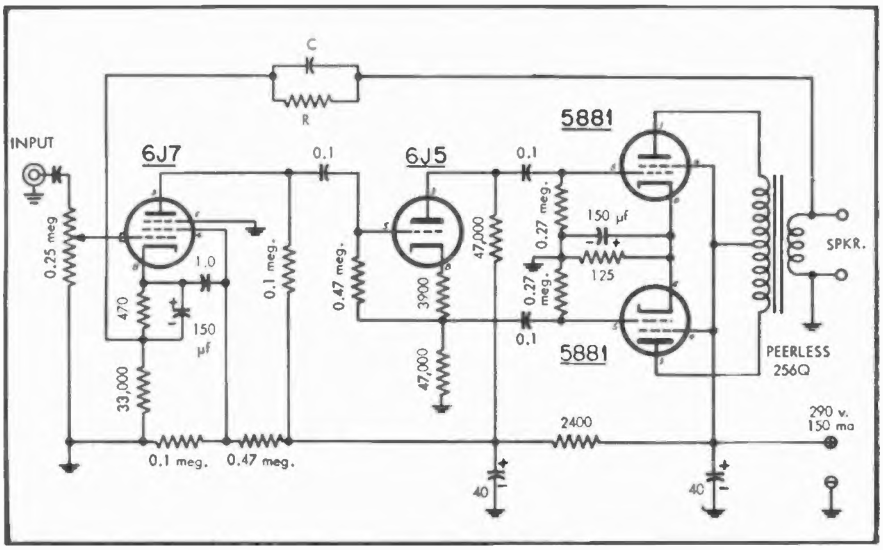


Fig. 3. Schematic of the power amplifier. Values of R and C in the feedback circuit are discussed in the text.

A schematic of the basic or power amplifier is shown in *Fig.* 3. The tubes employed are 1-6J7, 1-6J5 and 2-5881. Using tubes selected at random the amplifier is capable of delivering 10 watts at under 1 per cent intermodulation distortion; 12 watts at under 3 per cent. An 18-watt power output is available over the frequency range 20 cps to 140 kcs (by appropriate adjustment of the input voltage) without visible wave form distortion (estimated at under 3 per cent harmonic distortion). The amplifier is absolutely flat at 12 watts output from below 20 cps to 55 kcs for constant-voltage input, dropping to – 2 db at 125 kcs; – 5 db at 175 kcs and – 6.5 db at 200 kcs. One half volt rms will drive the unit to full power output. It will deliver 12 watts for 0.38 volts rms drive. These performance data are based on the use of 10 db feedback.

The component values, i.e., resistors and capacitors associated with the 6J7 voltage amplifier, were selected to minimize intermodulation distortion. It was found desirable to use a voltage divider to obtain screen voltage and to bypass the screen to the cathode of the tube. The bias resistor is almost entirely bypassed; only a small portion of the total resistance being left unbypassed for the application of negative feedback.

The phase splitter, employing a 6J5, is an excellent method of coupling a single-ended plate circuit to a push-pull grid circuit. (A phase splitter, as well as a cathode follower, is defined for later usage as "one-half" stage.) This circuit is self-balancing, and distortion is low. Any unbalance effects at high frequencies are generally negligible.

The output stage features the use of a Peerless type 256Q 20–20 plus transformer. Note that the bias resistor for the push-pull type 5881 tubes has a value of 125 ohms. The 5881 tube is similar to Western Electric type 350B and are interchangeable. Both have "power filaments" in that 1.8 amperes at 6.3 volts is required for cathode heating.

Feedback is applied around the "2.5" stages; the required voltage being taken from the secondary winding of the output transformer. The values of *R* and *C* in the feedback circuit must be selected by test. The value of *R* controls the amount of feedback (usually expressed in db), and *C* controls the high-frequency ringing, i.e., for the purpose of damping out any small oscillations that may appear on the leading edge of a square wave. The equipment needed to determine the proper value of *R* and optimum value of *C* is: a vacuum tube voltmeter and a sine and square wave generator. It is customary to load the amplifier by a resistor equal to the nominal load impedance of the amplifier when choosing the correct values of *R* and *C*, rather than use the loudspeaker as load. Optimum generator impedance can be obtained by varying the value of *R* in the feedback path and conducting simultaneous listening tests. As *R* is increased the value of feedback is decreased.

This power amplifier is basically simple and utilizes the minimum number of stages required to do the job effectively. Although feedback is applied around "2.5" stages the amplifier is stable with feedback values up to at least 30 db. Many of the popular circuits of today feature the application of large values of feedback around "3.5" to 4 stages. This is an invitation to serious trouble. Marginal stability obtains and at some signal levels violent subsonic and supersonic oscillations may be generated. Even though these frequencies may not be heard, i.e., they fall outside the audio spectrum, the power delivering capability of the amplifier is largely consumed. Thus little "clean" power is available in the frequency range of interest. This principle is too frequently overlooked in practice. The power amplifier will deliver a clean signal over its entire frequency range even without feedback. This is not true of one well known circuit which utilizes 20 db of feedback. A sine wave input at 60 kc is likely to appear at the load terminals as a series of triangles!

The writer is of the opinion that an otherwise essentially distortionless amplifier does not require the application of large values of feedback. The use of 20, 40 or 90 db feedback is nonsense. Values of 10 to 15 db voltage-control feedback are adequate for two important reasons:

(a) *Instability tendencies are reduced.*
(b) *The experimentally observed bass loss in the frequency region of speaker resonance is minimized.*

It is interesting to note that the designers of theater sound equipment restrict the use of feedback to the 10 or 15 db level.

There may be protests to the effect that the equipment described in this article is not an "all triode" playback system. It would seem meaningless to insist on the exclusive use of triodes in amplifiers until records are available bearing the label "We guarantee all electronic equipments used in making this recording were fitted throughout with triode vacuum tubes." Note also that AM, FM, and TV stations will never measure up to the standards of the perfectionist who insists on the utilization of triode vacuum tubes in every tube application.

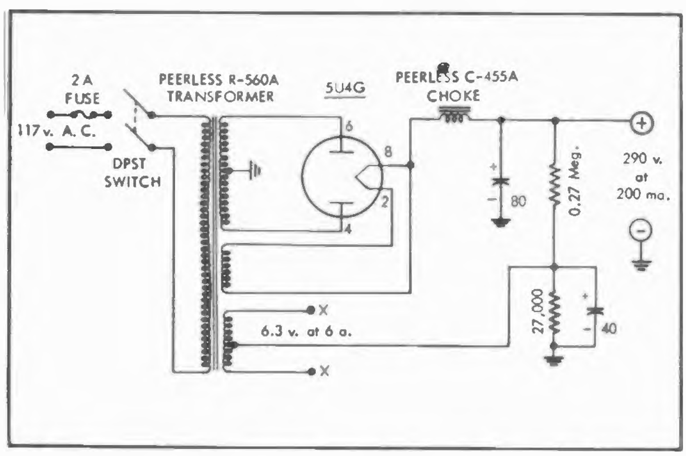


Fig. 4. Power supply schematic. Note that it is of conventional design.

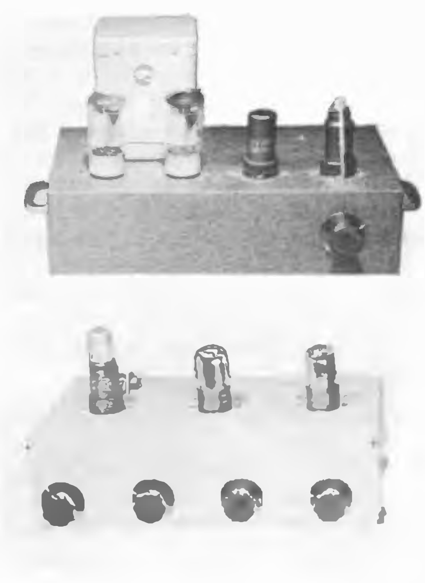
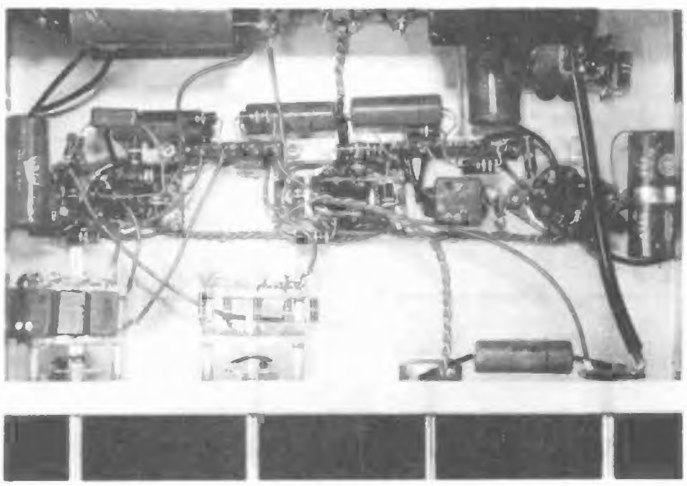


Fig. 5. Above, the preamplifier; below, the power amplifier. "Building block" construction makes for flexibility.

Fig. 6. Above, the power supply is a simple and neat construction; below, the dividing network chassis.

The power supply illustrated schematically in *Fig.* 4 is entirely conventional. It delivers 290 volts d.c. at 200 ma and 6.3 volts a.c. at 6 a. To minimize hum in the playback system, the heater winding is operated at a positive potential of about 29 volts, the center tap of the winding being heavily bypassed to ground. Although often omitted from commercial equipment, the bypass capacitor is a circuit element vital to the successful operation of this hum reduction scheme. Because of the relatively low d.c. voltages required for operation of the preamplifier, R-C dividing network and power amplifier, one may expect that 450-volt electrolytic filter capacitors, if used throughout the equipment, will have exceptionally long life.

The writer believes in building equipment with the best parts available. All coupling capacitors should be rated at 600 volts, and if 0.1 µf and less in capacitance should have a leakage resistance of at least 1500 megohms. The bass and treble controls in the preamplifier should be of the shorting type and feature silver contacts and steatite insulation. Capacitors used in the equalization circuits should be 5-per cent tolerance silver micas (except possibly in the largest sizes). Resistors in these circuits should be within 5 per cent of specified values, or better. Very precise values of resistance and capacitance are required in the filters of the dividing network. In the push-pull portion of the power amplifier the capacitors and resistors used should be selected for balance. The most reliable volume controls that can be obtained should be used, in log-taper form. In general, resistors rated at 1 watt dissipation are adequate, except in the following instances: The 33,000-ohm resistors in the dividing network are 2 watt types as is the 2400-ohm resistor in the power amplifier, and the 125-ohm bias



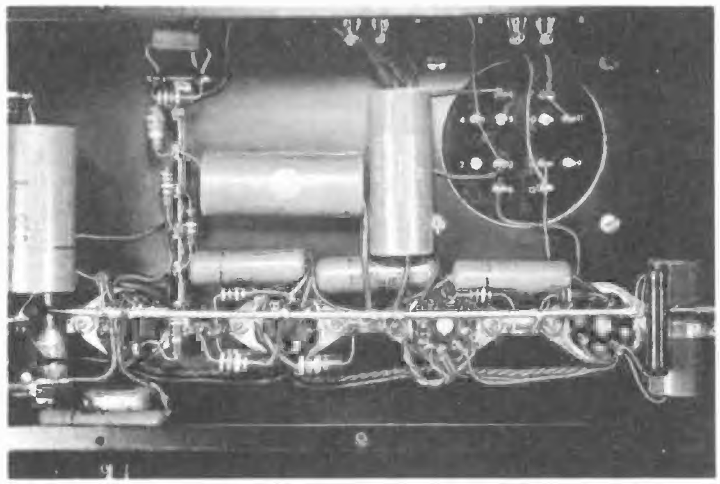


Fig. 7. Above, left, bottom view of the preamplifier with the base plate removed to show layout of parts and wiring. Fig. 8. Above, right, bottom view of power amplifier with base plate removed.

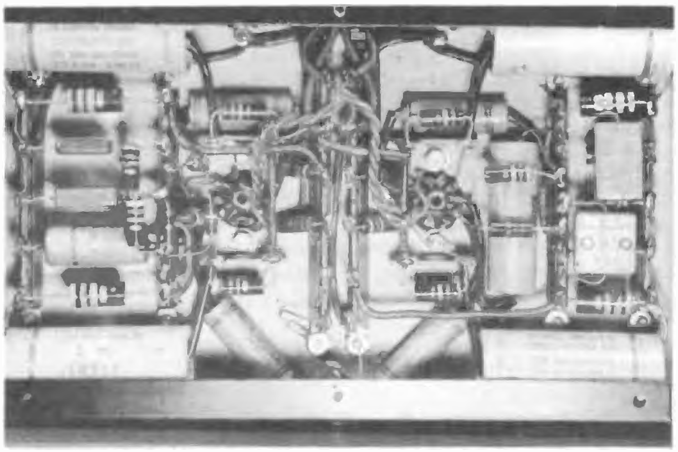


Fig. 9. Underside of dividing network chassis.

resistor in the power amplifier is a 10 watt type. It is a good idea to use wire-wound plate-load resistors in the low-signal-level stages. Although a Peerless transformer and choke are not essential circuit elements in the power supply, the writer built and tested the amplifier with a Peerless 256Q output transformer, and has no data on how another transformer type may operate in this circuit! Small broadcast-type connectors may be used conveniently for inter-chassis connections where audio voltages are involved. Four-conductor cables terminating in male plugs are useful for power connections and the chassis connectors being standard four-hole sockets.

The writer's present dual-channel playback system consists of a turntable, pickup and arm, a preamplifier (*Fig*. 1), an R-C dividing network (*Fig*. 2), two identical power amplifiers (*Fig*. 3), two power supplies (*Fig*. 4), and the dual loudspeaker described in an earlier paper.[1] The equipment corresponding to each schematic presented here was constructed on separate chassis as shown photographically in *Fig*. 5 and 6. This building-block technique was employed so that new innovations may be checked with minimum constructional labor. The preamplifier was built on an aluminum chassis having dimensions of 7 × 12 × 3 inches. The arangement of parts may be seen in *Fig*. 7. If Vector socket-turrets are used the circuit can be built in a 5 × 10 × 3 inch base. The employment of aluminum material that is not painted permits one to make the numerous low-resistance ground connections required by the circuit configuration. It is very important to keep ground leads short in high gain circuits. The dividing network and power supply fit nicely on a chassis measuring 5½ × 9½ × 1½ inches. The orientation of parts in the dividing network is shown in *Fig*. 8. The power amplifier can be built on a 7 × 12 × 3 inch black-crackle finish steel chassis with room to spare. A bottom view of this unit appears in *Fig*. 9. Since high signal levels obtain in this circuit a ground bus may be used (grounded to the chassis at each end) without development of hum difficulties. The writer finds the use of a ground bus a constructional advantage.

At present four parallel-connected bass drivers are in use in the bass section of the speaker described in reference 1. The driving-point impedance of the array is 2 ohms. Accordingly, the secondary of the output transformer in the bass amplifier is connected for this load, and *R* and *C* selected for 10 db feedback and minimization of ringing, respectively. The value required for *R* is 330 ohms, and for *C*. 0.005 μf. The high-frequency driver in use is a Western Electric type 594A having an impedance of 24 ohms. A resistor of 48 ohms is connected across the voice coil so that the impedance of the parallel combination is 16 ohms. The output transformer of the treble power amplifier is connected for this load. In this case *R* is 1500 ohms for 10 db feedback, and the optimum value of *C* = 1360 μf[2].

A schematic for the 24 volt d.c. field supply required for the operation of the WE 594A driver is not included in this article because this driver is not generally available. Several other makes of high-frequency reproducers are available with permanent magnet fields, however.

Acknowledgment

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[1] Charles W. Harrison, Jr., "Coupled Loudspeakers," AUDIO ENGINEERING, Vol. 37, No. 5, pp. 21, May, 1953.

[2] For a load of 4 ohms, *R* is 1000 ohms and *C* is 1500 μμf.