Compact 6AS7G Amplifier for Residence Audio Systems

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A new amplifier of exceptional performance especially designed for modernization where cabinet space is limited.

Many an experimenter or audio hobbyist has the desire—and often a definite need—for a high-fidelity amplifier, but is at a loss for sufficient space to install it in an existing cabinet or piece of furniture. So far, many of the writer's amplifier designs have been adequate for good quality reproduction, but none was arranged specifically for use by anyone desirous of modernizing a reproducing system because they were all laid out with a view to accommodating the components in a normal amplifier arrangement.

To solve any problem, it is first necessary to recognize its existence—the rest follows naturally. For a modernization problem, the requirements may be stated as follows:

Electrical: Around 5 to 6 watts of high-quality audio power.
- Switching to select standard and microgroove phonograph pickups, and two additional positions for AM and FM radio inputs.
- Sufficient gain and low-frequency equalization for low-level magnetic pickups.
- Separate high- and low-frequency tone controls.

To these may be added as desirable features a volume control compensated for loudness levels, and means for equalizing the levels of the various inputs so the compensated volume control works at its optimum position and to avoid undesirable level changes when switching between inputs.

Physical: Amplifier and power supply small enough to fit into reasonable spaces.
- Control facilities which may be mounted on a small panel space separate from the amplifier.

Considering these requirements separately, the first is fairly obvious. The reason for modernizing is to obtain a better quality of reproduction. This demands good components, and sufficient power to handle peaks without danger of overload. Since it is more economical and usually provides better overall quality to use a high-quality loudspeaker with a good reproducing system, a fairly high efficiency is generally encountered. Most high-quality speakers will provide plenty of volume for home use with much less than one watt of *average* power although more is necessary, of course, to handle the peak levels. Therefore, it is felt that five watts should suffice for practically any home system. It goes without saying that frequency response should cover the range from 30 to 15,000 cps, and that distortion must be held to an absolute minimum. The hum level should be so low that no sound is audible from the speaker in the absence of signal.

Multiple Inputs

Practically every reproducing system is used for more than one input. Since the advent of long-playing, microgroove records, it seems logical to include an input for a second pickup, with a single selector switch connecting the chosen input source to the amplifier.

Low-level magnetic pickups are firmly established, and any good amplifier must be designed to accommodate them without the need for an external preamplifier. As is well known, these pickups require equalization of the low-frequency spectrum, in addition to considerable gain to make their output comparable to that of a radio tuner. The microgroove pickups are slightly lower in output in most instances, due largely to a lower level on the record itself.

Although not generally known, a conventional crystal pickup can be fed into an equalized preamplifier, and will often sound better than if used with a high-impedance input. As far as the frequency response is concerned, this is easily explained. A crystal pickup may be regarded as a generator of zero impedance in series with a capacitance. An average crystal pickup, for example, has a

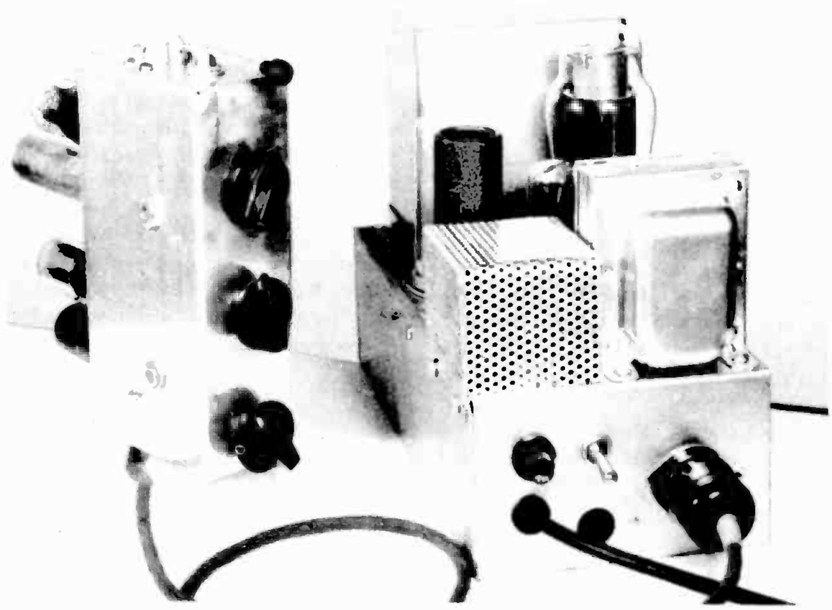


Fig. 1. Compact, two section amplifier with control section arranged for mounting in small panel area.

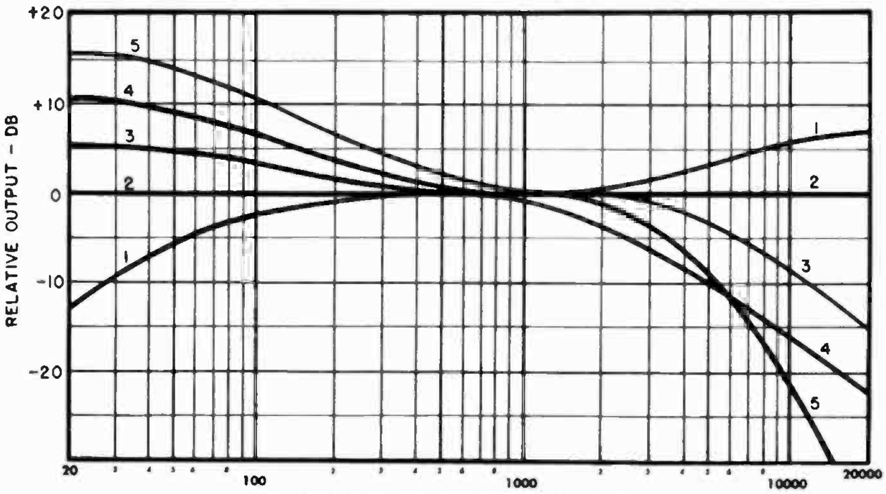


Fig. 2. Tapped high-and low-frequency tone control switches provide fixed response curves.

capacitance of around 1500 μμf. When such a pickup is fed into a resistive load, it has a natural droop of 6 db/octave below the frequency at which its reactance equals the value of the resistance into which it feeds. Thus, it has a "turnover" frequency of 500 cps when fed into a 0.2-meg load. Now, while a crystal pickup is a constant-amplitude device and delivers a constant voltage into a high resistance load up to the turnover frequency (of the record) from a disc cut with the normal 6 db/octave droop below the turnover, the low-resistance load causes a loss in bass response equivalent to that of a magnetic pickup. But the preamplifier corrects for this loss, so the output is again "flat." The voltage output of the crystal is higher than that of the magnetic pickup, so the loss due to the low-resistance load may be accepted readily. Since high-frequency equalization is still necessary for the crystal pickup, it is still necessary to add a resistor shunted by a capacitor in series with the high side of the pickup to make it workable with a high-gain preamplifier, if wide-range reproduction is to be obtained. Therefore, this type of preamplifier is reasonably suitable for crystal pickups.

Most users want some tone controls so as to be able to obtain desired response curves. While the compensated volume control reduces the need to a large extent, satisfactory reproduction of phonograph records demands some roll-off control, and also a sharper cut-off for particularly noisy records. Varying degrees of bass boost are also desirable. Therefore, both low- and high-frequency tone controls are employed, providing five curves for each as shown in *Fig. 2*. These are step controls rather than continuously variable potentiometers because more suitable curves are obtainable. The low-frequency control provides a 5-db droop at 50 cps, a flat position, and boosts of 4.5, 9, and 13 db at 50 cps. The high-frequency control provides a boost of 6 db at 10,000 cps; a flat position; a roll-off down 3 db at 4400 cps and 8 at 10,000; an NAB roll-off down 3 db at 1600 cps and 16 at 10,000; and a cut-off down 5 db at 3500 cps and 21 at 10,000. Listening tests have adjudged these steps to be desirable.

The particular type of fully compensated volume control used is that described in the article on page 39. The level adjusting is accomplished by means of three 0.5-meg potentiometers, with the microgroove pickup having no built-in adjustment, since the overall amplifier gain is designed to fit this input. If further adjustment is required, it may be accomplished externally.

The amplifier, shown complete in *Fig. 1*, is built in two sections—one is the output stage and the power supply, while the other is the control unit, with all the other stages. The power section is built on a standard 5 x 10 x 3 chassis, while the control section is housed in a 3½ x 7 x 2 chassis, made from 7 x 11 x 2 standard aluminum chassis. The two sections are connected by a three-foot cable which carries all power and signal circuits except for the a-c switch line, which is separate. The a-c switch is not a part of the control section, but is to be mounted at a convenient location on the panel.

Circuit Description

In general, amplifier design progresses backward, first involving the selection of the output stage, then adding the earlier stages to provide sufficient gain to drive the output tubes. Because the 6AS7G has so many advantages as a power output tube, it was chosen again for this application, in spite of the fact that it is relatively hard to drive.

It may also be said that the power

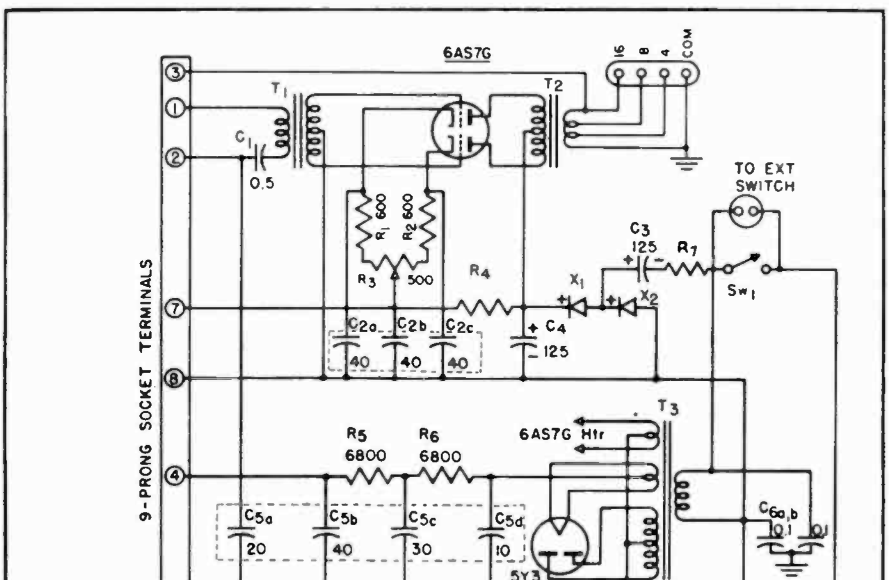


Fig. 3. Schematic of power amplifier section of the two-unit amplifier.

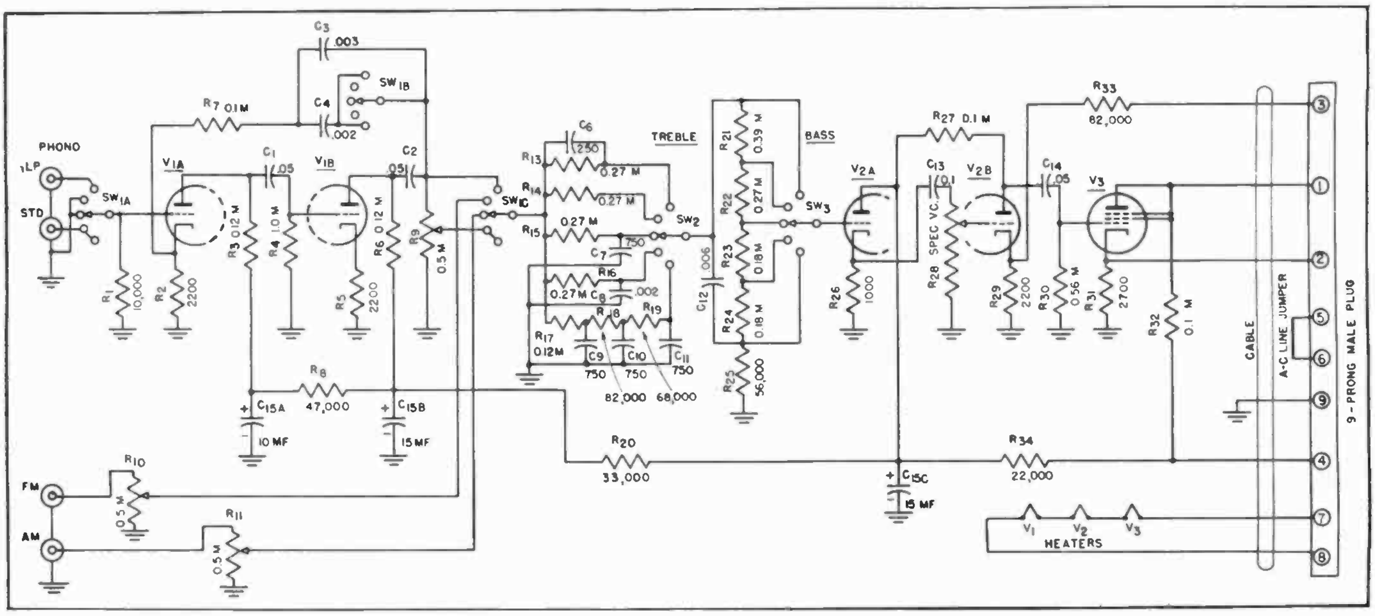


Fig. 5. Schematic of the control section.

supply requirements for this tube are fairly severe since it draws a rather heavy plate current. Normally, this necessitates a large power transformer and one or more large filter chokes. However, one of the requirements of the tube may be considered an advantage—because it needs an input transformer, the output stage can be completely isolated from chassis ground, thereby permitting the use of a voltage-doubling selenium rectifier circuit, as shown in the power section schematic, *Fig. 3*. This arrangement furnishes up to 150 ma at approximately 300 volts from a 117-volt a-c line. The 6AS7G draws about 120 ma, and an additional 30 ma is fed through a bleeder for heater current of the three input tubes. Thus the low-level heaters are energized by rectified alternating current. Considering the use of a push-pull output stage, the capacitor provides sufficient filtering for humless reproduction.

The input stages require a d-c supply which may be grounded to the chassis, and in addition, the 6AS7G heater must be energized. Thus a small power transformer is used with a conventional rectifier and an RC filter circuit. The 6.3-volt filament winding on the transformer is used only for the 6AS7G, since the other tubes have a d-c heater supply.

The output transformer is massive and occupies a large portion of the chassis area. The space underneath the output transformer is occupied by the two 125-μf capacitors on a bracket; the channel-type, push-pull input transformer is also under the chassis, as are the coupling and line bypass capacitors. The selenium rectifiers are mounted on Bakelite strips above the chassis, and are protected by a perforated screen cover. The capacitors in the voltage doubler power supply—the two 125-μf units and the triple 40-μf unit used for cathode bypass of the 6AS7G—are insulated by cardboard tubes. All connections except the output are made on one end of the chassis: a 9-prong socket for the control section feed; the a-c line cord, fuse, and switch; and a small two-prong socket for a remote power switch which is in parallel with the chassis switch. This permits a pair to be run up to a panel-mounted power switch, thus eliminating any a-c circuits from the interconnecting cable.

Control Amplifier

The control amplifier is of unique design, since three controls are mounted on the front apron of the chassis, and one on the end, and with the tubes on the rear apron projecting away from the panel. The controls are arranged so the unit may be mounted either vertically or horizontally, thus being adaptable to almost any cabinet space available. The selector switch is on the end of the chassis, with an operating lever which extends through the panel. Also mounted on the end are the two pickup jacks and the level-adjusting potentiometer for the standard pickup. The decoupling capacitor and the two radio input jacks are mounted on the rear apron along with the tubes, while the radio level-adjusting potentiometers are on the "top" of the chassis. The power cable comes out of the end opposite the selector switch.

To simplify wiring into the circuit, both tone controls are assembled completely on their switches as shown in *Fig. 4*. All resistors connecting to

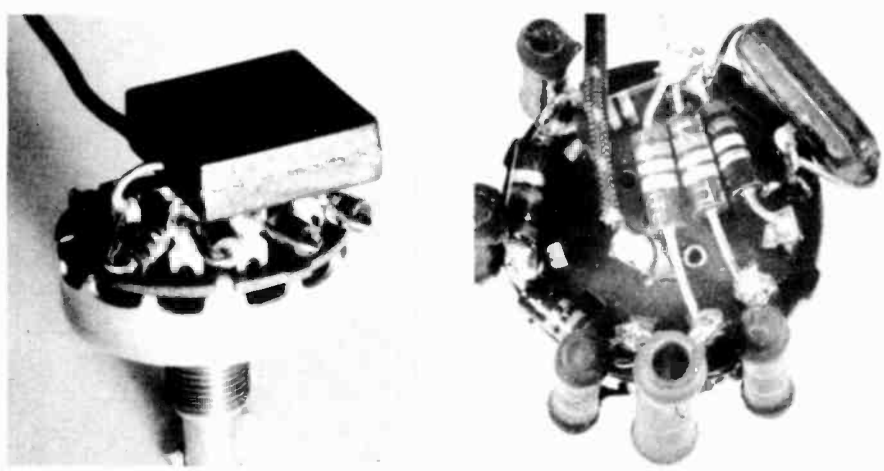


Fig. 4. Assembly of tone controls on standard switches to provide units easily wired into the control section. Left—bass control; right—treble control.

ground are wired directly to the tube sockets, and connections are made point-to-point where convenient. A resistor strip is mounted on the volume control, using the long screws of the switch assembly to hold it in place. This strip carries most of the plate and decoupling resistors.

The assembly of the control section in such a small chassis is somewhat tedious, but there is plenty of room, and the object of the whole amplifier was to make it convenient for mounting.

Inverse feedback is used around the last three stages, primarily to reduce the output impedance to a minimum. The output transformer has 4, 8, and 16-ohm taps, with the latter supplying the feedback voltage. Good frequency response, power, and phase-shift characteristics are readily obtainable with a transformer designed for feeding a speaker *or* a 500/600-ohm line, but it is difficult to obtain optimum performance from a transformer designed for *both* types of output load. Consequently, the output transformer has only one output winding for three speaker loads.

Control Section

The three tubes in the control section actually constitute five stages. V_1 is a dual triode in a conventional peramplifier circuit, with feedback equalization to supply turnover frequencies of 350 and 500 cps. One section of the input selector switches the pickup, or grounds the first grid. The second section varies the turnover frequency, and adjusts it to 350 cps for microgroove records. The third section connects the amplifier to the phonograph level-adjusting potentiometer at the output of the preamplifier in positions 1 and 2, to the AM and FM potentiometers in positions 3 and 4, and to the preamplifier through a roll-off circuit in position 5 for microgroove records. Thus the long-playing records are normally reproduced on the position 2, the "flat" settings of the tone controls. Victor and Decca ffrr records reproduce best on position 3 of the high-frequency control, Columbias on position 4, and exceptionally noisy records on position 5. The treble control is numbered counterclockwise, the bass control clockwise.

The two tone controls are designed to work together and into a grid with no resistance loading, as is the volume control. Since feedback is introduced at the stage ahead of the driver, the volume control is placed between the two sections of V_2, the first section acting as a cathode follower. V_3 is triode connected, and is shunt fed with the coupling capacitor in the cathode leg. This capacitor and the cathode bypass for V_3 are located in the power section.

The 6AS7G circuit is similar to those previously employed, with the 600-ohm 5-watt resistors in separate circuits, the 500-ohm potentiometer serving to balance plate currents, and the three heaters in series being connected between the arm of the balancing potentiometer and the negative side of the supply circuit. The 600-ohm value is used in the cathode circuits because of the drop across the heaters. The 15,000-ohm resistor bleeds the additional 30 ma for the control section heaters.

Part II

In the first part of this series, a radical departure from usual amplifier design practices was described. New designs usually result from a desire to fulfill some new set of conditions that may be laid down by a customer, if the builder is engaged in commercial work; or by a set of imagined conditions, as in this case. Preliminary tests indicated the amplifier to be good, and the final performance tests were awaited anxiously, as would be expected in practically any similar case.

The results of the performance tests are gratifying. Power output at one per cent harmonic distortion is 6.5 watts at 400 cps, 6.2 watts at 20 cps, and 6.35 watts at 20,000 cps. Eight db of feedback is employed, extending from the secondary of the output transformer to the cathode of V_{2b}. The output impedance on the 16-ohm tap is 1.85 ohms, which gives excellent damping. The frequency response curves were shown in Part I, with the tapped tone switches in various positions. Hum and noise measures —42 dbm, which is not exceptionally low, but which is within the range of good quality amplifiers.

With the volume control at maximum—which is the operating point for the greatest room volume normally desired—a two-volt input signal is required at the two radio input jacks for a two-watt output. This does not leave much leeway, but will suffice for most tuners. The phonograph preamplifier supplies the additional gain to bring the output of magnetic pickups to the equal of the radio inputs.

The original design provided for a roll-off in the LP phonograph position so that these records would reproduce normally with the tone con-

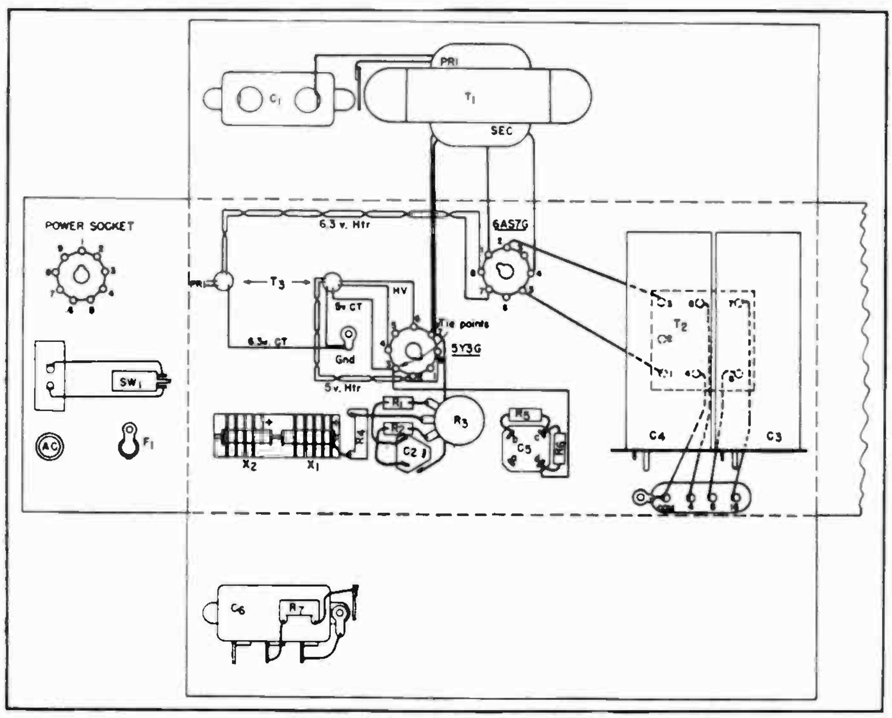


Fig. 6. Partial wiring diagram of power section to show component mounting.

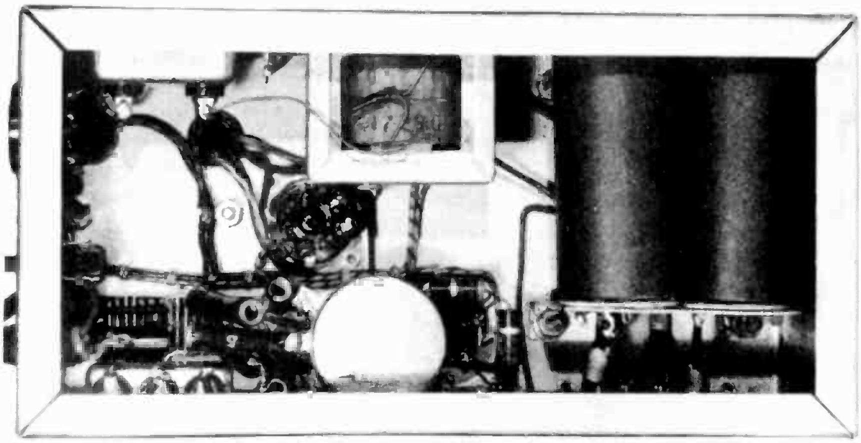


Fig. 7. Underside of power section chassis.

trols in the positions for flat reponse. However, this did not provide sufficient gain, and the components used for this purpose were later omitted. The elimination of this feature in no way hampers the operation of the amplifier or its flexibility of frequency-response correction, due to the presence of the high-frequency control, SW_2. At position 4 of this switch, the circuits are so arranged that the correct roll-off is provided for the reproduction of LP records. Actually this makes the amplifier more flexible because any high-frequency correction can thus be used, making it possible to play any type of record.

The performance of any amplifier depends to a large degree upon the quality of the components used. At the time this amplifier was designed, it was desired to use high-quality transformers throughout, and to make the power section as compact as possible the input transformer had to be mounted underneath the chassis. This ruled against a cased type, and few manufacturers list high-quality transformers in open-frame mounting. The unit employed was designed to work between a single 12SJ7, triode connected, with no d c. in the primary, and to obtain adequate driving voltage for the grids of the 6AS7G it was required that the step-up ratio should be fairly high. To get this performance and retain a wide frequency range, the transformer is wound in two sections, both placed on the center leg of a conventional E-I core. Measured frequency response of the transformer itself indicates a droop of 1 db at 30 cps and at 30,000 cps. The output transformer, also special, shows a droop of 1 db at 17 cps and at 120,000 cps when operated without feedback, and drooping 1 db at 15 cps and 62,000 cps when operated with feedback. Similar output transformers are available in the standard Freed line under number F-1951 with output impedances of 1.2 to 30 ohms, and under number F-1950 for impedances from 50 to 500 ohms.

The following table indicates transformers of high quality which are generally obtainable from jobber stocks and which should perform satisfactorily, since their characteristics are similar to those used in the original amplifier.

TABLE I

Mfgr	T_1	T_2	T_3
Audio Development Co.	214H[1] 215C[1]	314C 315F	515C (large)
Chicago Transformer Div.		BO-6	PCC-70
Peerless Transformer Div.	G-252-Q	S-240-Q	R-196-A
Stancor	A-4750	A-3800	P-4078
Thordarson	T20A22	T22S70	T22R02
UTC	LS-21[1] CG-132[1]	LS-57[2] LS-55[3] CG-16	R-54

[1] Insufficient space under chassis to mount these models.
[2] Voice-coil secondary only.
[3] Voice-coil and line secondary

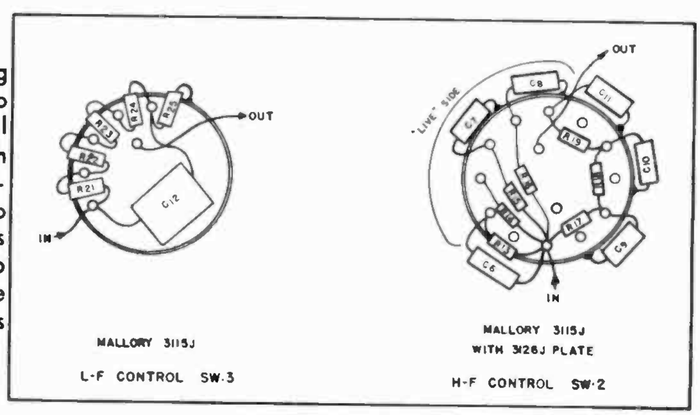
Construction Hints

There are a number of suggestions which may be of interest in the construction of these two units. Referring first to the power section, it will be noted that the two filter capacitors, C_3 and C_4, are mounted on a bracket under the ouput transformer. Therefore, they are necessarily installed after the wiring to the output transformer is completed. The balancing potentiometer, R_3, is also mounted on a bracket so that its shaft may be adjusted through a hole on the chassis between the two capacitors mounted on top. The selenium rectifiers are mounted on a 6-32 threaded rod which passes through two strips of Bakelite attached to bent-up angles on the chassis. Two saw-cuts are made ¼ in. apart and extending for two inches along the chassis. At the center of these two cuts, another cut is made between them. This frees two "flaps" which may be bent up to mount the Bakelite strips. The cover is bent up from perforated metal to prevent accidental contact with hands or tools.

The value for the resistor R_4 is shown as 15,000 ohms. This gives approximately correct current through the filament string, but the current should be measured, and the value of R_4 adjusted to give 36 volts across the heaters. Resistor R_7 is used to reduce the peak current through the selenium rectifiers, and 5 ohms is a suitable value. This resistor is connected between SW_1 and C_3.

The push-pull input transformer is mounted directly below the 6AS7G socket, using leads as short as possible. This will normally require that the leads be connected before the transformer is bolted in place, and since the leads are likely to be of relatively light wire, care should be exercised in this operation. The two bathtub capacitors are mounted on opposite sides of the chassis, with tie-points installed adjacent to them. One is needed

Fig. 8. Wiring diagram of two tone-control switches. Switch plate on H-F control is changed to furnish tie points on five-step frame. Only one contact arm is used.



to make the connection to the plate end of the primary, and the other serves to hold R_7.

With some transformers it is probable that there will be a tendency to oscillate at some super-audible frequency. This may require some experimentation, but it is suggested that a small capacitor across each half of the primary of the output transformer, or possibly across the secondary of the input transformer, will suffice to eliminate this trouble. Probable values will be in the vicinity of .002 μf. *Figure 6* is a partial wiring diagram of parts employed in the power section, while *Fig. 7* is a photograph of the underside of the completed amplifier chassis.

The preamplifier section shown in the photograph of Part 1 is somewhat smaller than the average constructor may wish to employ, but it was built in this manner to keep the space required to a minimum. The chassis was fabricated from a 2 x 7 x 11 aluminum chassis base, cutting it apart at the center. The sides of the chassis are then cut 1¾ in. from the open end, and folded in to provide a ⅜-in. angle. The top is folded down, resulting in a chassis approximately 3½ x 7 x 2. The tube sockets and the electrolytic capacitor are mounted on this section, with the controls on the opposite side of the chassis. The input selector switch is mounted on one end, with a lever extending through the panel for its operation. If the chassis length were extended to eight or nine inches, the selector switch could then be mounted on the front in line with the other controls, and it is quite probable that it would be easier to install in a cabinet because of the difficulty in cutting a neat slot

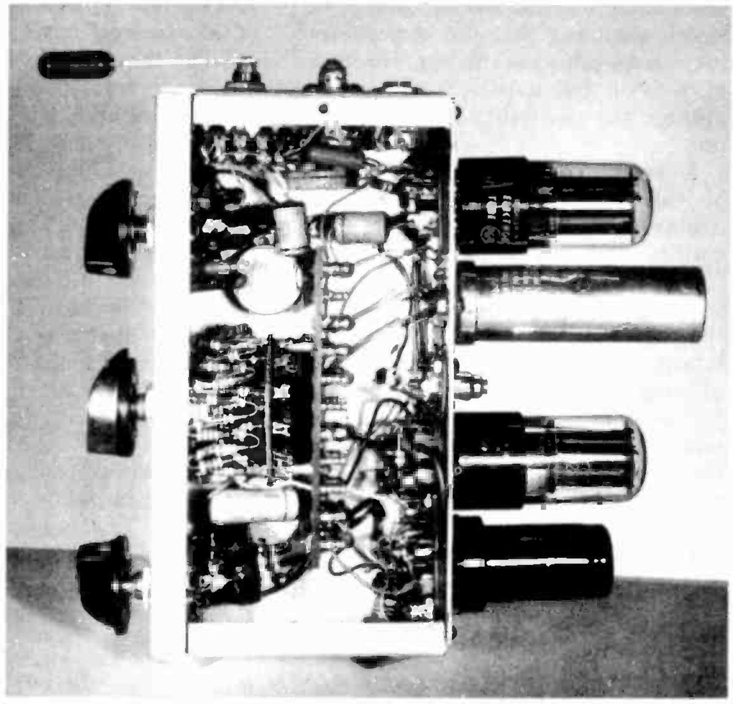


Fig. 10. Interior of input section, showing the mounting of resistor strip on rear of compensated volume control.

to pass the lever-type arm used to actuate the selector switch.

In the parts list several references were made to the text for further explanation. The volume control, R_{28}, is the loudness control described in detail on page 39, and consists of a Centralab 1443 switch on which are mounted the resistors and capacitors necessary to obtain the desired compensation.

The high-frequency tone control switch, SW_2, needs a little further description. The series of switches selected for the tone controls consists of small units which are desirable in such a compact amplifier. However, the exact assembly of contacts is not obtainable, so the switch used was made by using the frame and mechanism from a 3115J switch with the contact plate from a 3126J switch. This gives a number of tie points for the resistors used for the cut-off circuit, as well as for the input connection. The capacitors in this circuit are all mounted directly on the switch, being soldered to the frame for ground connection. This is not usually considered the best practice, but it must be remembered that this section of the amplifier does not have any a-c circuits in it, and there is little chance of ground loops causing hum trouble. Suffice that the unit as constructed exhibits no troubles from this source. The exact arrangement of the tone controls is shown in *Fig. 8*. Similar methods were used for both, in that all parts are wired directly to the switch, but the low-frequency control is a standard 3115J switch without modification.

The over-all schematic of the input section is self-explanatory and represents the final form of the circuit after all the performance data were determined. The wiring diagram, *Fig. 9*, indicates the arrangement of parts and the wiring between them, while the photograph of *Fig. 10* shows the method of mounting the resistor strip on the back of the volume control switch.

Unless the builder is reasonably well experienced in construction of small amplifier equipment, it might be desirable to increase the overall size of the input section. It is definitely possible to construct the unit in the size shown, but it must be admitted that it is extremely compact, and as the size is reduced the complexity of construction is increased. Of course, once the amplifier is completed

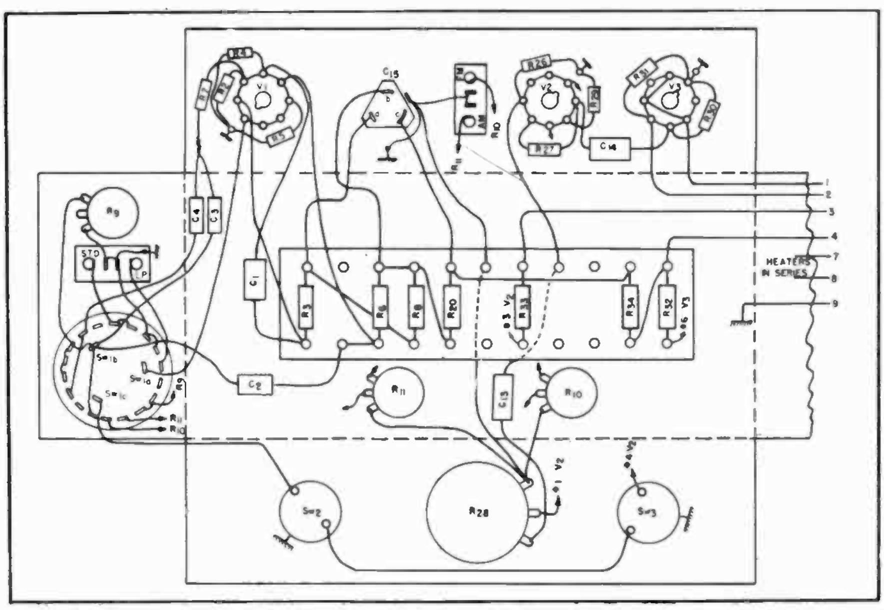


Fig. 9. Input section wiring diagram.

there should be no need to get at it again, assuming that the constructor takes reasonable care in the selection of resistor and capacitor ratings to prevent the possibility of failure in use.

A more conventional construction of this entire amplifier would undoubtedly reduce the hum level still further, and if a larger power transformer were used—one which could supply the 0.9 amps of filament current required by three 6-volt tubes in the input section—the electrostatic field existing between heater and cathode of the present first 12SL7 would be reduced. If made in two units, however, it would be preferable to use a separate cable from the power section to the preamplifier to carry the heater current, although the signal from the preamplifier to the power section is of a relatively high level and it is possible that no trouble would be encountered from this source.

If additional gain is required, the cathode follower section of V_2 can be changed to a conventional amplifier, thus giving approximately 32 db more gain than with the present arrangement. For the uses for which this amplifier was designed, however, this should not be necessary. Another possibility is that a 6SN7 could be substituted for the 6SL7 used as V_2, (if a filament transformer were being used, together with 6-volt tubes) again using the amplifier connection rather than the cathode follower, and the increased gain would be of the order of 10 db. This suggestion would only apply if the filaments were arranged to be supplied from a transformer winding, since the 12SN7 will not operate in a series string with the 12SL7 and the 12SJ7, inasmuch as the 12SN7 draws a filament current of 0.3 amps. These are design modifications, and some ingenuity on the part of the constructor will be necessary to arrive at the exact desired result. It is felt, however, that the amplifier as described performs satisfactorily, and that no changes are necessary *for the purpose for which it was designed.* The amplifier was designed for one application—that of modernizing an existing installation, or for providing a control arrangement which could be adapted to cramped quarters with the greatest of ease. This requirement is fulfilled adequately by the arrangement shown.

PARTS LIST

C_1, C_2, C_{14},	0.05 µf, 400 v, paper
C_3	.003 µf, mica
C_4, C_8	.002 µf, mica
C_6	250 µµf, Centralab Hi-Kaps
C_7, C_9, C_{10}, C_{11}	750 µµf, Centralab Hi-Kaps
C_{12}	.006 µµf, mica
C_{13}	0.1 µf, 400 v, paper
$C_{15}a$, b, c	15-15-10/450 electrolytic
R_1,	10,000 (all values ½-watt unless otherwise specified)
R_2, R_5, R_{29}	2200
R_3, R_6	0.12 meg, 1-watt
R_4	1.0 meg
R_7	0.1 meg
R_8	47,000, 1-watt
R_9, R_{10}, R_{11}	0.5-meg potentiometer
R_{13}, R_{14}, R_{15}, R_{16}, R_{22}	0.27 meg
R_{17}	0.12 meg
R_{18}	82,000
R_{19}	68,000
R_{20}	33,000
R_{21}	0.39 meg
R_{23}, R_{24}	0.18 meg
R_{25}	56,000
R_{26}	1000
R_{27}, R_{32}	0.1 meg, 1-watt
R_{28}	special volume control (see text)
R_{30}	0.56 meg
R_{31}	2700
R_{33}	82,000, 1-watt
R_{34}	22,000, 1-watt
SW_1	Mallory 3136J
SW_2	Mallory 3115J, modified (see text)
SW_3	Mallory 3115J
V_1, V_2	12SL7
V_3	12SJ7

The parts not specifically described for the power section are as follows:

C_1	0.5 µf, 600 v, oil filled, bathtub
C_2	40-40-40/150, electrolytic, with insulating tube
C_3, C_4	125 µf, 350 v, electrolytic, with insulating tube
C_5	40-30-20-10/450, electrolytic
C_6	0.1-0.1, 600 v, oil filled, bathtub type
R_1, R_2	600, 5-watt
R_3	500-ohm wire-wound potentiometer
R_4	15,000, 10-watt adjust to provide 36 volts across filament string.
R_5, R_6	6800, 2-watt
R_7	5, 5-watt
SW_1	SPST toggle switch
T_1	push-pull input, special channel mounting, no d.c. in primary; Freed 17290
T_2	4000 ohms plate to plate, 4-8-16-ohm secondary; Freed 15929
T_3	325-0-325 v at 50 ma; 5v at 2a; 6.3v at 2.5 a. Freed F-413
X_1, X_2	200 ma selenium rectifier