# A Simplified Control Unit

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**Believing it is not enough to propose simplicity in an audio system and then leave it at that, this author follows his own advice and describes a preamplifier unit designed in accordance with the principles presented some months ago**

Although many circuit diagrams of preamplifier control units designed to be built by the user have been published, none has shown agreement with the philosophy of system simplicity proposed by the author ("System Simplicity in Audio," Audio, January, 1957). The object of this paper is to present further arguments on the advantages of simplification as applied to a reproducing system. Chief advantages are reduction of distortion and improvement of reliability. Reduction of the number of parts and of cascaded controls which duplicate each other not only decreases the distortion but, since reliability is inversely proportional to the number of parts, improves the reliability.

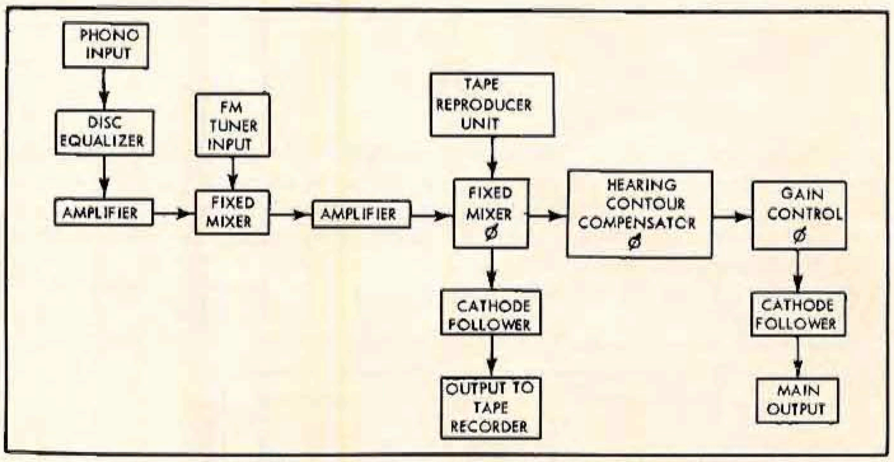


Fig. 1. Block diagram of simplified control unit

The philosophy of simplification includes the assumption that the user will not experiment with all types of input equipment but will settle on the best that he can afford. He will strongly resist the hi-fi dogma that equipment purchased at 12 noon is obsolete at 12:01 P.M. Quantitative and qualitative laboratory tests have shown that most of the current, better quality phonograph re-

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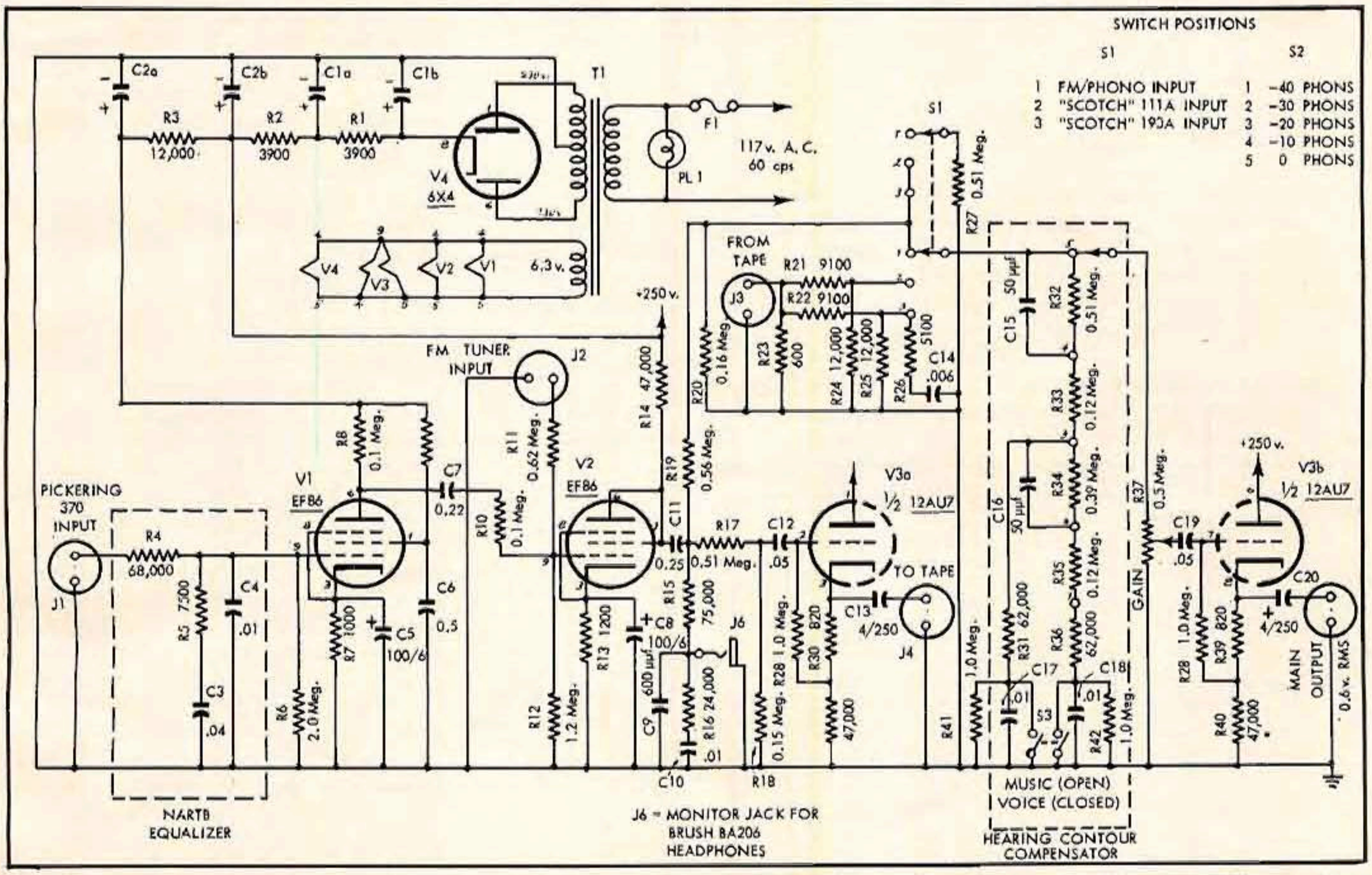



Fig. 2. Over-all schematic of the author's design for a control unit which is effective in performance and simple and convenient to operate

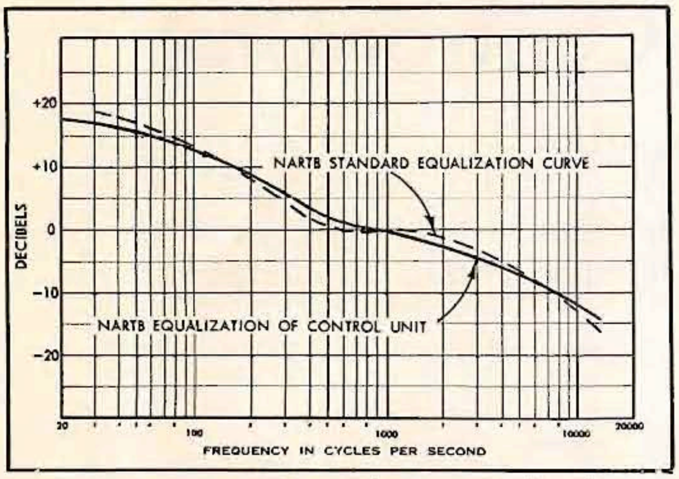


Fig. 3. Comparison between equalization provided and the standard NARTB (RIAA) curve

producers are about equal in excellence. The same is true for FM tuners using Armstrong circuits and also for professional-quality tape recorder-reproducers.

The components to be controlled by the author are a Pickering 370 cartridge, a Harman-Kardon FM-100 tuner, and an Ampex 601 tape recorder. The control unit is to have a minimum number of controls and adjustments and a fixed passive network wherever equalization is needed. In addition, the input signal should be able to be monitored continuously as a tape record is being made.

The phonograph cartridge has an output of 25 millivolts for a stylus velocity of 9 centimeters per second; the tape reproducer has an output of 1.228 volts (+4 dbm in 600 ohms); and the average peak output of the tuner, with its gain control fixed at its maximum position, is 1 volt at 30 percent signal modulation. A low-impedance output of 0.6 volts is required to drive the 30-watt power amplifier to half power (this allows 3 decibels for overdrive).

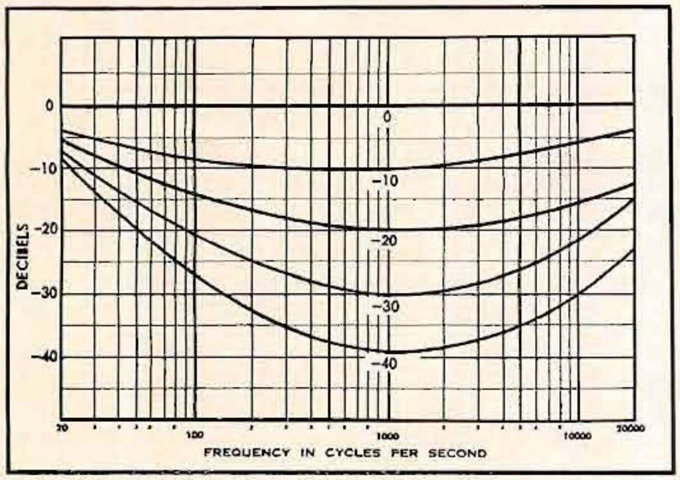


Fig. 4. Response curves of hearing contour compensator at various settings.

With the use of these design parameters a simple circuit was designed. A block diagram and an over-all schematic are presented in *Figs.* 1 and 2 respectively.

Conventional circuits are used exclusively, so detailed explanations are not necessary, but descriptions of certain portions are given in following paragraphs. To minimize the number of tubes, amplification is based realistically on actual needs. The amplification factor for design purposes is the difference between the average maximum voltage of each source and that needed to operate the power amplifier.

Essentially, the control unit is a two-stage amplifier with two cathode-follower outputs. Signal sources are mixed by means of resistive networks which assure the proper levels. Because each source has its own power supply, each input signal is removed by cutting off the power. Thus, a selector switch is not needed.

*Disc Equalization.* Although five equalization curves were formerly advocated, the RIAA curve has proved to be adequate for all long playing records, which are used exclusively. An RC network is used to obtain the equalization curve (*Fig.* 3). Values are first computed. The circuit is then built and corrected by component substitution in conjunction with frequency measurements to give desired equalization.

#### Hearing Contour Compensation

A "Hearing Contour Compensator" is being used with great success in place of separate bass and treble controls. Briefly, this Compensator improves the realism of reproduction by compensating for the difference in level between the intensity of the sound of the live orchestra at the recording session and that reproduced at a necessarily lower level in the living room. It compensates for the variations in human hearing sensitivity to sounds of different loudness. The principle of the Compensator is based on the study of the differences between Fletcher-Munson curves rather than on the contour of any one curve. The Compensator is designed to perform in fixed calibrated steps of 0, −10, −20, −30, and −40 phons, where the figures indicate the difference in phons between the original and reproduced program levels. The appropriate attenuation is designed into the Compensator. For speech reproduction a switch is provided to retain the attenuation but to remove the compensation. Music equalization is completely wrong for speech reproduction because speech, to provide naturalness, should be reproduced at about the same level as the original source, and hearing contour compensation is not needed. *Figure* 4 presents the response curves of the Hearing Contour Compensator. When compared with the characteristics of many commercial controls, these curves may seem to provide less emphasis to the middle low frequencies. This, however, is not the case. The Hearing Contour Compensator does not depart from the characteristic indicated as needed by the Fletcher-Munson curves.

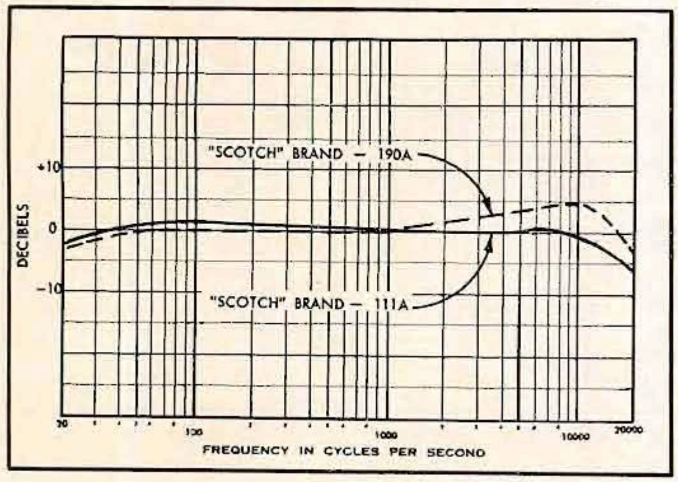


Fig. 5. Record-Listen frequency response of tape on Ampex 600 tape recorder

Correction for deficiencies in the loudspeaker or any other component does not enter into the design. The bass response of the selected loudspeaker is adequate. More realistic sound is achieved by elimination of any booming juke box effect.

*Tape reproduction.* In his program of system simplicity the author uses only two types of tape: Scotch 111A and 190A, since the tape recorder equalization is set for these tapes. *Figure* 5 shows the frequency response of the Ampex 601 using these tapes. Although the response using 111A tape is essentially flat, the 190A tape causes a 5 db rise above 1000 cps. A loss network, added to the control unit so that 190A tape will be reproduced with a flat response, is located at the "tape-FM/Phono" switch. This switch is necessary to prevent a feedback loop during tape playback and to permit both wanted and unwanted program material to be heard so that undesired signals (such as commercials) can be eliminated. Also, the original source for a tape record can be monitored by either headphones or loudspeaker.

*Gain Control.* This control is actually unnecessary. Acoustic shocks, however, are avoided by fading in and out the signal. The operating procedure is to set the Hearing Contour Compensator to the desired listening level. Then the program is brought in by turning the gain control *FULLY* clockwise. Thus, maximum use of the gain control is realized by full rotation instead of that portion produced by the 10 per cent rotation common in most volume controls.

*Power Supply.* The power supply is extremely conventional. No trick circuits are necessary. An elaborate power supply to produce direct current for the filaments or the necessity for biasing the filaments "above ground" is unnecessary through the use of low-noise, nonmicrophonic tubes. The electrolytic capacitors are mounted on the phenolic wafers supplied, and the holes punched in the chassis are large enough so the can will not be grounded. A ground loop is thus eliminated, reducing the possibility of hum pickup.

*Monitor Circuit.* During recording the input signal can be monitored continuously by means of the loudspeaker. However, there are times when headphones are preferred. An equalizing circuit designed exclusively for the Brush BA-206 headphones is included. This circuit provides a fixed Hearing Contour Compensator and makes the sound from the headphones as much like the sound from the loudspeaker as possible.

*Construction.* The location of the various small assemblies is slightly unconventional for home equipment but standard for rack-mounted equipment. The tubes, electrolytic capacitors, and so on,

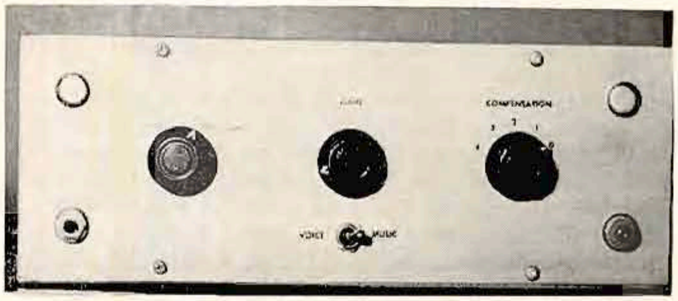


Fig. 6. Front view of control unit.

are mounted on the rear of the chassis, and the controls are on the front panel. This design permits mounting the control unit with either a horizontal or vertical front panel.

*Figures* 6 and 7 show the front and rear views of the assembled unit. The unit with the front panel opened is shown in *Fig.* 8.

The layout for drilling and punching the chassis is shown in *Fig.* 9. The dimensions should be followed closely in order to prevent the small assemblies

techniques are employed. All parts are mounted on the Vector socket turrets, the electrolytic capacitors, or on switches. Thus, any small assembly can be replaced easily and without disturbing any other assembly.

The best method for assembly is as follows. All parts are mounted and soldered onto the Vector socket turrets. All resistors and capacitors should be checked to ascertain that the resistors are not open and that the capacitors have a high resistance. After the turrets are

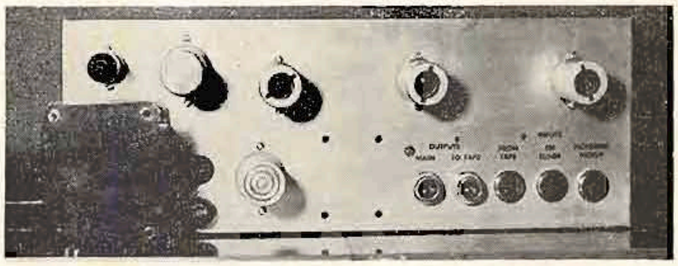


Fig. 7. Rear view of control unit. Tubes with shields from right to left are $V_1$, $V_2$, and $V_3$. Tube in upper left corner is 6X4.

from shifting and interfering with each other.

Some remarks about the parts are necessary. Adherence to the suggested list is urged because all the parts are chosen from the standpoint of size, tolerances, and proved reliability.

Parts with larger tolerances may be necessary for tailoring equalizer circuits exactly; for other uses they are permissible, but many measurements and considerable substitution of parts could be necessary to achieve desired results. The parts list also reflects the experience acquired during the actual construction.

The design of the wiring is shown in *Fig.* 10 and should be followed closely. The individual parts are located for minimum hum. Standard telephonic

inside the chassis, substitution of parts is not particularly easy. Wires do not have to be wrapped around the terminals before soldering. Even the U. S. Navy has accepted finally the fact that solder has sufficient strength to support parts. After the turret assemblies are complete, they are mounted on top (yes, on top) of the chassis. Now the Vector socket turrets are completely wired. This top of chassis technique, which provides plenty of working room, offers the greatest accessibility and ease of wiring. Although these turrets are handy little gadgets, once they are loaded with parts and mounted within a chassis soldering at the tube terminals is very difficult.

Twisted pairs of color coded wires are used profusely. The color code removes

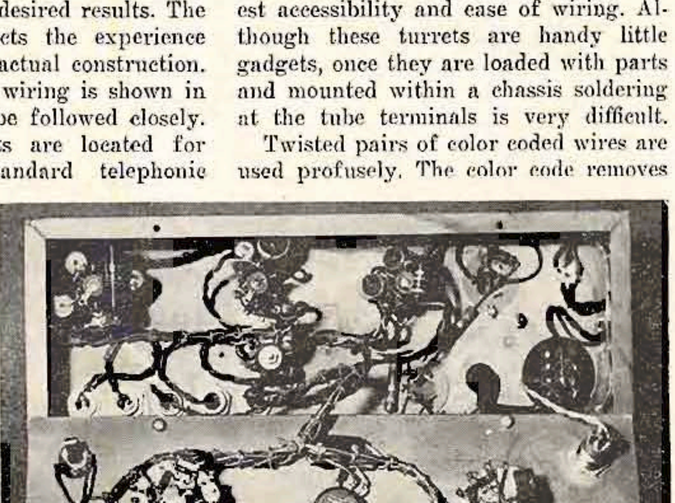


Fig. 8. Control unit with front panel open. On panel from left to right are headphone jack, tape/FM/phono switch, gain control, music-voice switch, hearing contour compensator, and pilot light. Vector turrets from left to right are $V_1$, $V_2$, and $V_3$.

the necessity for locating the end of a particular wire with an ohmmeter. A pair of wires should not be twisted by grabbing one end and twisting the other. The proper method is childishly simple. Two pieces of wire are cut to the desired length. One end of each is clamped together in a vise. A wire is grasped in each hand close to the vise. Then each wire is twisted clockwise with the fingers. At the same time the wrists are moved about each other counterclockwise. This action is repeated until the pair are twisted together. The twisted pair will be neat, tight and symmetrical. Describing the action is far more awkward than doing it.

The twisted pairs that go to switches should be soldered at the Vector socket only. The filament, plate and ground leads are laced at this time. The wired sockets are removed from the top of the chassis and relocated inside after all soldered joints have been inspected. After the remainder of the parts are mounted on top of the chassis, the power supply circuits are wired completely and laced into a cable.

Switches are assembled next. For reliability all active contacts are wired in parallel. Most of the resistors and capacitors require their leads to be very short. Extreme caution should be used in soldering so that the parts will not be overheated. An angle bracket (*Fig.* 9) is used to mount $C_{17}$ and $C_{18}$ on $S_2$. Switch $S_2$ and its bracket are mounted to the front panel and these capacitors are bolted to the inside of the bracket. Resistors $R_{21}$ and $R_{36}$ then complete the compensator circuit. The controls, monitor jack, and pilot light are mounted on the front panel. Once the twisted pairs of wires have been cut to length, the wiring can be completed. Lace as indicated. Those pairs of wires connecting the controls to the remainder of the circuit should be long enough so that the front panel can be opened at least 90 deg. without straining the wires.

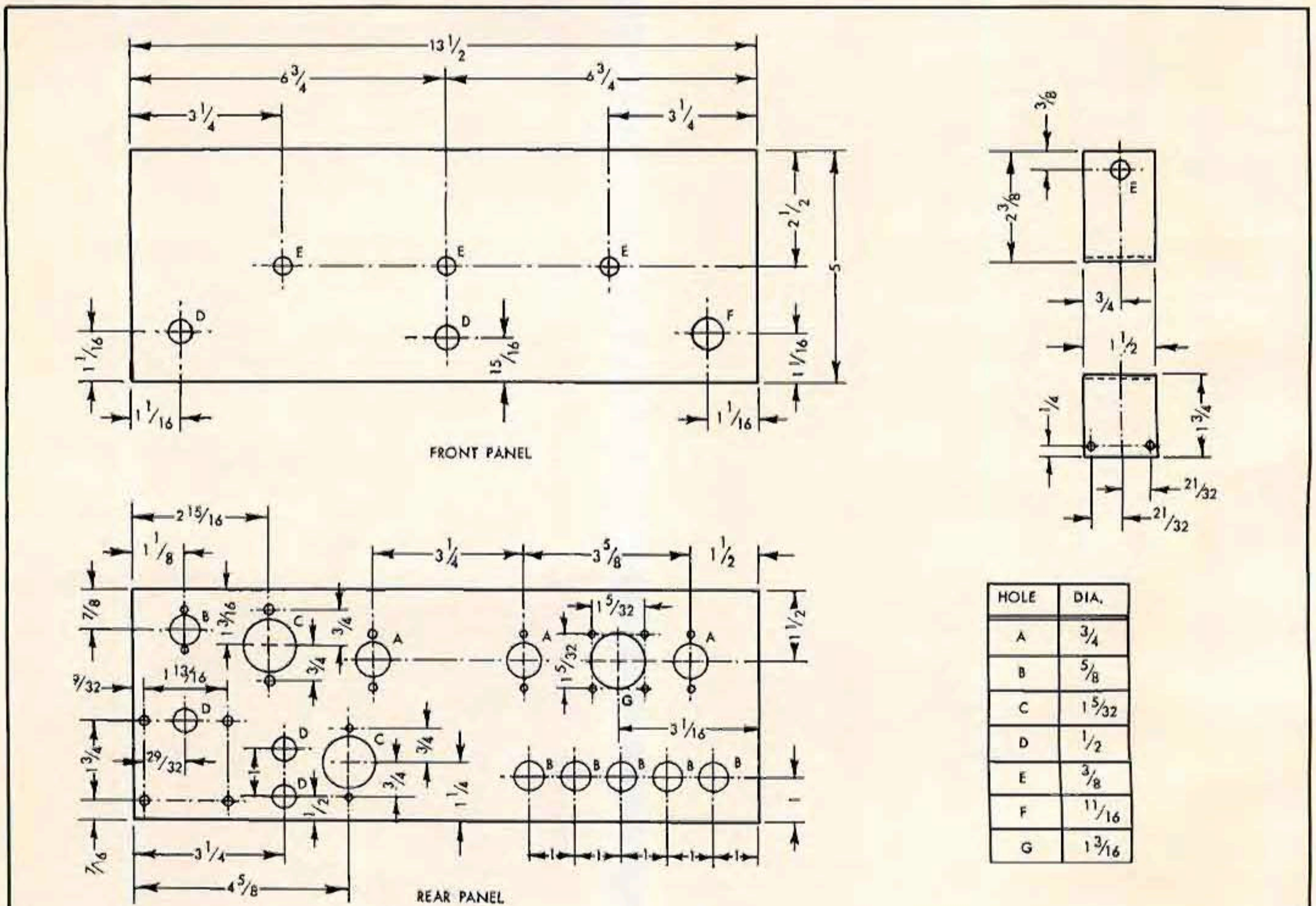
Each soldered joint should be reinspected. The filament and plate leads are checked for "shorts" to ground. If the unit passes a mechanical and electrical inspection, the front panel can be installed, the tubes and shields inserted, and the control unit is complete.

Construction of this amplifier was not without its problems. The proximity of the Hearing Contour Compensator to the power supply resulted in hum caused by electrostatic coupling. The electrostatic coupling can be removed by shielding which, in turn, can be accomplished by two methods. First and the more difficult of the two, the compensator switch can be completely enclosed in a metal box. In this case the switch recommended is Centralab PA-2002. Second and easiest, a shield can be mounted on the back of the switch, in which case Centralab switch PA-2010 should be used. This switch has two sections each having two poles and 2 to 6 positions. The rear section should be removed, and an intersection shield (Centralab catalog P-320) should be substituted. Although it is not shown in the photographs, the author employs the first method.

Observant readers will notice some discrepancies between the parts list and the parts visible in the photographs. The power transformer shown was employed because it was available. Unfortunately, male chassis connectors in the Amphenol type 80 series are no longer available. Anyone who wishes to duplicate this unit will have to employ short cables with male connectors ($J_4$ and $J_5$) for the outputs.

#### Results

The first model of the control unit did not have input transformer $T_2$. However, the noise level and gain of the first stage was unsatisfactory. The perform-




| HOLE | DIA. |
|---|---|
| A | 3/4 |
| B | 5/8 |
| C | 1 5/32 |
| D | 1/2 |
| E | 3/8 |
| F | 11/16 |
| G | 1 3/16 |

Fig. 9. Chassis layout. Screw-hole diameters for mounting of parts are left to discretion of builder. At right is shown bracket for $S_2$.

ance was improved by the addition of input transformer $T_2$ (Chicago Transformer WF-28) in conjunction with shield $SH_1$ (United Transformer shield A-33). The transformer is mounted between $V_1$ and $V_2$ with the name plate towards $V_1$. Then the shield is bolted to the transformer. During these tests considerable variation of hum pickup and microphonics was discovered in the EF-86. Therefore, three or four EF-86's should be purchased, and the one least subject to hum pickup and microphonics should be used for $V_1$.

The results of the construction of this control unit have more than compensated for the expense and time. The disc equalization is known to be within ±2 db of the standard curve. A more exact curve can be obtained by changing values of $R_4$, $R_5$, $C_3$, and $C_4$. However, the time involved to get an exact curve is not justifiable. Background noise is extremely low. With either FM tuner or disc input the noise is −61.8 db below the 0.6-volt output. With tape input the noise is even lower: −91.7 db below the 0.6-volt output. Compensation is provided for the differences between 111A and 190A tape. The Hearing Contour Compensation is the heart of the unit and audio system. Greater realism is achieved since the design is on a more scientific basis than that which depends upon the manipulation of bass and treble controls. The monitor circuit has another advantage besides being an aid in eliminating commercials. If one wishes to listen late at night without disturbing anyone, the power amplifier can be turned off and headphones used exclu-

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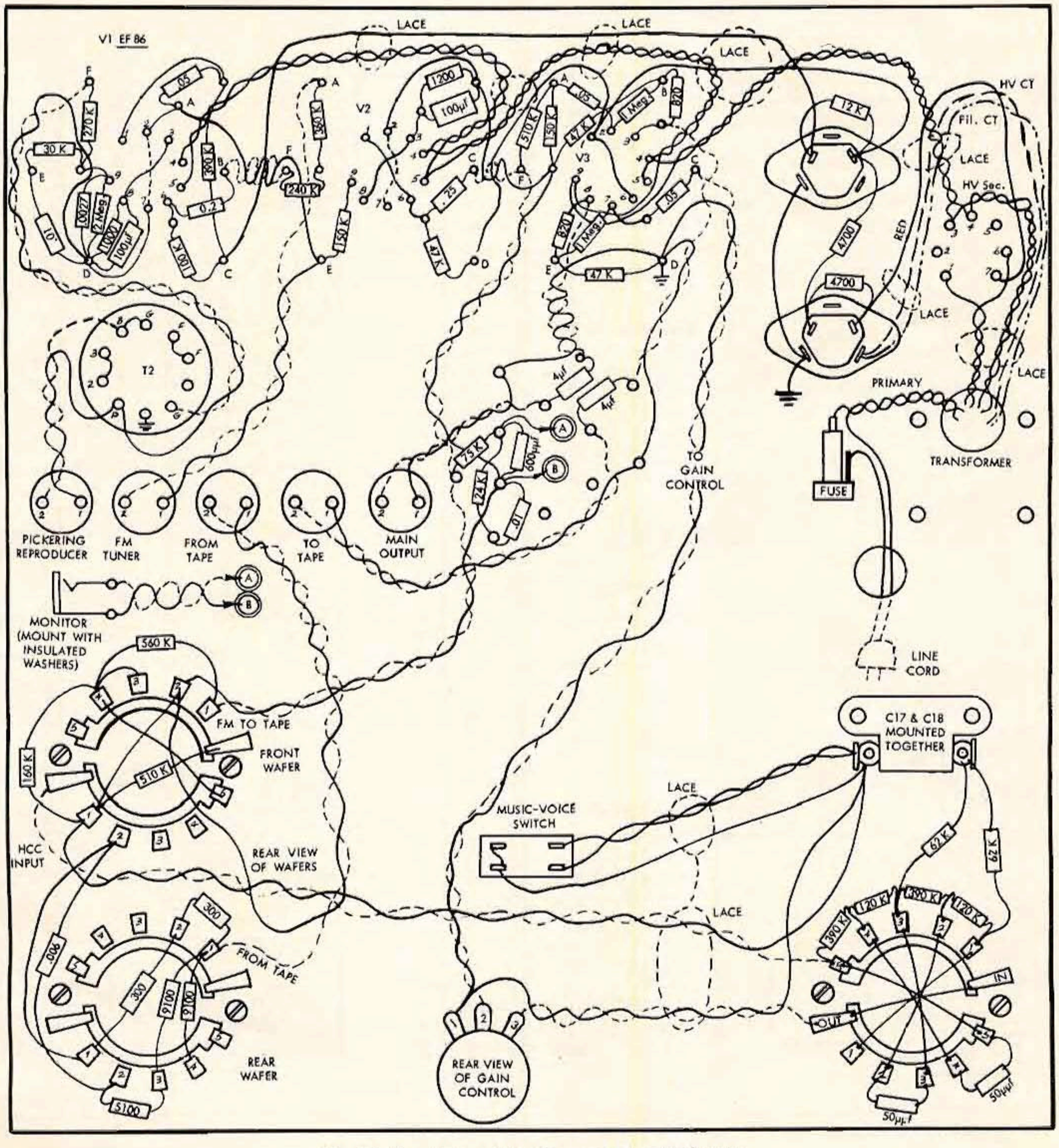


Fig. 10. Complete wiring diagram of control unit.

## CONTROL UNIT

*(from page 21)*

sively. A great improvement in reliability was realized by a 50 per cent saving in parts when compared to the control unit formerly used.

PARTS LIST

(All resistors ½ watt 5%, unless otherwise indicated)

| | |
|---|---|
| $C_1$, $C_2$ | 20-20/450, electrolytic |
| $C_3$ | .01 µf, mica |
| $C_4$ | .0025 µf, mica |
| $C_5$, $C_8$ | 100 µf, 6v., electrolytic |
| $C_6$ | 0.5 µf, 600 v., paper |
| $C_7$ | 0.2 µf, 600 v., paper |
| $C_9$ | 600 µµf, mica |
| $C_{10}$, $C_{11}$ | .05 µf, 600 v., paper |
| $C_{12}$, $C_{13}$ | 4 µf, 250 v., electrolytic |
| $C_{14}$ | .006 µf, mica |
| $C_{15}$, $C_{16}$ | 50 µµf, mica |
| $C_{17}$, $C_{18}$ | .01 µf, 600 v., mica (Sangamo type H) |
| $F_1$ | Fuse extractor post (Littelfuse 324003) |
| $F$ | ⅜ amp. fuse (Littelfuse 3AG) |
| $J_1$, $J_2$, $J_3$ | Amphenol 80-PC2F connector |
| $J_4$, $J_5$ | Amphenol 80-P-MC2M connector |
| $J_6$ | Phone jack (Mallory SC-1A) |
| $PL_1$ | Pilot light socket (Dialco 95408) |
| $R_1$, $R_2$ | 4700 ohms, 2-watt, 10% |
| $R_3$ | 12,000 ohms, 2-watt, 10% |
| $R_4$ | 0.27 meghoms |
| $R_5$ | 30,000 ohms |
| $R_6$ | 2 megohms, 10% |
| $R_7$ | 1000 ohms, 10% |
| $R_8$ | 0.1 megohms, 10% |
| $R_9$ | 0.39 megohms, 10% |
| $R_{10}$ | 0.24 megohms |
| $R_{11}$ | 0.36 megohms |
| $R_{12}$ | 0.15 megohms |
| $R_{13}$ | 1200 ohms, 10% |
| $R_{14}$ | 47,000 ohms, 10% |
| $R_{15}$ | 75,000 ohms |
| $R_{16}$ | 24,000 ohms |
| $R_{17}$, $R_{18}$ | 0.51 meghoms |
| $R_{19}$ | 0.56 meghoms |
| $R_{20}$ | 0.16 megohms |
| $R_{21}$, $R_{22}$ | 9100 ohms |
| $R_{23}$ | 600 ohms (use two 300-ohm resistors in parallel) |
| $R_{24}$, $R_{25}$ | 12,000 ohms |
| $R_{26}$ | 5100 ohms |
| $R_{28}$, $R_{33}$ | 1.0 megohm, 10% |
| $R_{29}$, $R_{34}$ | 47,000 ohms, 1-watt, 10% |
| $R_{30}$, $R_{35}$ | 820 ohms, 10% |
| $R_{31}$, $R_{36}$ | 62,000 ohms |
| $R_{32}$, $R_{37}$ | 0.39 megohms |
| $R_{27}$ | 0.5 megohm potentiometer |
| $S_1$ | 2-gang, 2-pole rotary switch (Centralab PA-2005) |
| $S_2$ | 1-gang, 2-pole rotary switch (see text) |
| $SH_1$ | UTC transformer shield, A-33 |
| $T_1$ | Power transformer: 500 v. CT at 20 ma; 6.3 v. at 2 a. (Triad R-3A) |
| $T_2$ | Input transformer—Chicago WF-28 |
| $V_1$, $V_2$ | EF86 tubes |
| $V_3$ | 12AU7A or ECC82 tube |
| $V_4$ | 6X4 tube |

Miscellaneous

| | |
|---|---|
| 3 | Vector Socket turret 8-N-9T |
| 1 | Vector turret 8-12 |
| 6 | Vector socket saddle nuts 4-40U |
| 6 | Vector socket screws, S4 |
| 1 | DPDT toggle switch |
| 1 | NE-51 neon bulb |
| 1 | 7-pin miniature socket |
| 3 | noval tube shields, 1⅜ in. |
| 1 | miniature tube shield, 2¼ in. |
| 1 | chassis, steel, 5 × 13½ × 2½ in. |
| 1 | bottom plate, steel, 5 × 13½ in. |

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