Elements of

RESIDENCE RADIO SYSTEMS

C. G. McPROUD* PART IV

Continuing the description of a high-quality home reproducing system comprising several unique features

IN ANY SYSTEM for radio and phonograph reproduction, there are a number of individual circuit entities which may or may not be physically separate units. The system being described in this series happens to be built in unit form—each section being essentially a separate unit—which has certain advantages for an experimenter's installation. It also has some disadvantages.

The principal advantage of unit construction lies in its flexibility. Suppose, for example, that a complete system were constructed on a single chassis. The wiring is simpler, no plugs or cables are necessary, and it is more economical, both of chassis space and of cost. But if the builder or owner should happen to want a major change in some specific section—and what experimenter is satisfied to leave well enough alone?—he must rebuild completely, or must try to adapt the new design to an already-cut chassis. However, with the unit system, a single section can be replaced easily, without the necessity of disturbing those portions which are working to the owner's complete satisfaction.

In the system being described, there are five separate units: the FM tuner; the AM tuner assembly; the control amplifier consisting of the phonograph preamplifier and equalizer, the noise suppressor, and the volume control; the main amplifier, and the power supply. The first three have already been discussed; this article covers the last two, also built as separate units.

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The Main Amplifier

The final amplifier in this system provides the voltage gain and output power to raise the signal level from the control amplifier sufficiently to drive the loudspeaker. Since the entire system is used only for home entertainment, and the loudspeaker itself is quite efficient, the power requirements are relatively low. The general design of the amplifier follows closely that of the 6AS7G amplifier previously described by the writer.[1] The output is approximately 6 watts at one per cent harmonic distortion, and the average power used with the present speaker is less than one watt.

[1] "High Quality Amplifier with the 6AS7G", AUDIO ENGINEERING, March, 1948

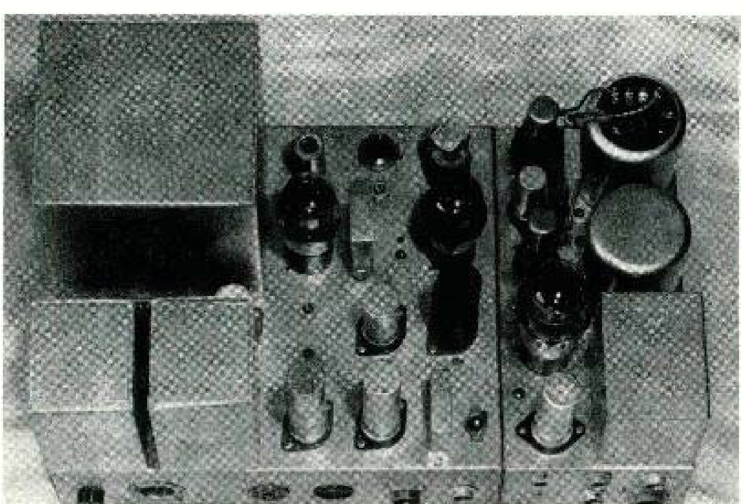


Fig. 1. Top view of the main amplifier and power supply units bolted together as a single chassis.

It will be remembered that the control amplifier terminates in a tube-to-line transformer, and that a 600-ohm line is used to feed the signal to the main amplifier. Thus an input transformer is required for the latter. Briefly, the main amplifier consists of a step attenuator, the input transformer, two stages of amplification using 6J7's as triodes, and employing 17.5 db of feedback, the push-pull interstage transformer feeding the 6AS7G, and the output transformer. The complete schematic is shown in *Fig.* 2.

The input transformer, T_1, is designed to work across a terminated line, which means that the apparent source impedance is one-half the nominal line impedance. Referring to *Fig.* 3, (*A*) shows a transformer working from a 600-ohm line, without a resistive termination. This arrangement does not terminate the line correctly for many circuits, and often results in a frequency response of the preceding equipment which differs from that measured into a resistance load. Some transformers, especially those at the input of a microphone preamplifier, are designed to operate from an open circuit, and similarly most microphones are intended to work into an unloaded transformer winding. Other transformers are designed to work with a resistance termination on the secondary, as at (*B*), but this often causes a reduction in high-frequency response. The transformer used in this amplifier was designed to work across a resistive termination, so the apparent source impedance is one-half the line impedance, as shown at (*C*).

This permits the use of a simple arrangement for a step potentiometer, since the transformer offers no load to the line, and it is not necessary to use a T-pad. The main requirement is that the transformer "looks back" at 300 ohms. In order to adjust the gain of the main amplifier to a value which

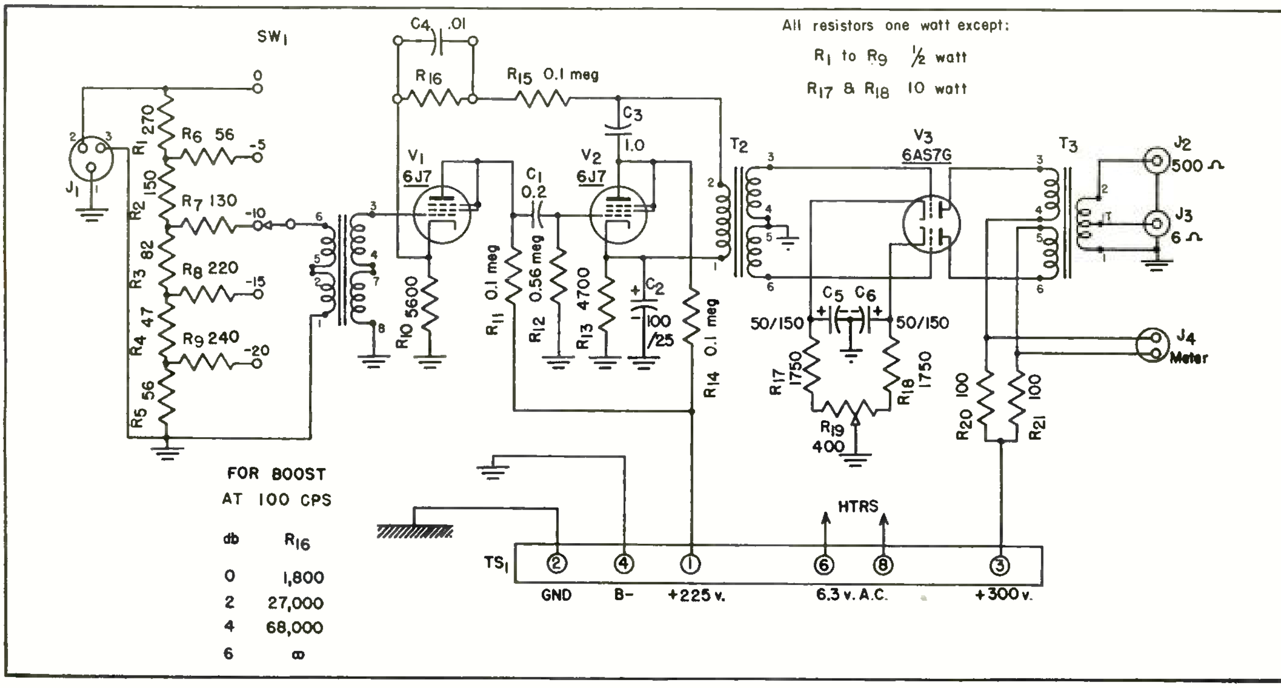


Fig. 2. Schematic of the main amplifier, closely following the original 6AS7G amplifier described in the March issue.

permits the compensated volume control (in the control amplifier) to operate over its optimum range, it is desirable to have discrete steps of attenuation, and 5 db is a suitable value for these steps. Thus the input attenuator consists of an L-pad designed to offer a constant 600-ohm load to the line, and to offer a 300-ohm source to the transformer when the 600-ohm line is connected. The entire attenuator is assembled on a Centralab #1404 switch, with one of the rotor contacts removed, and with the lugs bent back so as to provide a number of tie points for the resistors as shown in *Fig.* 4. The shunt resistors, R_1 to R_5, are selected from RMA values to provide a total resistance of approximately 600 ohms (actually 605) with 5-db steps. The resistance at point *X*, for example, is equal to (150 + 82 + 47 + 56) in parallel with (605 + 270), or 242 ohms; 300 less 242 equals 58 ohms for R_6, and the 56-ohm RMA value is sufficiently close. The same type of calculation is used to determine the values for R_7, R_8, and R_9.

Input Transformer

The input transformer has an impedance ratio of 300:90,000 which represents a voltage step-up ratio of 17.3. The secondary feeds the grid of V_1, a triode-connected 6J7, which is resistance coupled to a second 6J7, also triode connected. The choice of 6J7's was dictated by two conditions: it permitted mounting the selected input transformer in its normal position, with the terminal board on top and with a short lead to the grid cap, thus keeping the grid connection well removed from the heater leads; and according to the amplifier tables in the RCA Tube Handbook, the triode-connected 6J7 is capable of a higher output voltage than the 6J5, which would appear as a logical choice. The 6J7 also appears to be better than the 6N7 previously employed, both with respect to distortion and for a lower hum level.

Inverse feedback is employed on the first two stages, since the requirements from the second 6J7 are rather severe, and since the output tube has low gain and a low plate impedance and thus does not actually need feedback. Applying feedback around two transformers is also likely to introduce troubles which are difficult to eliminate, unless the transformer is designed specifically for such use. Parallel feed is used to

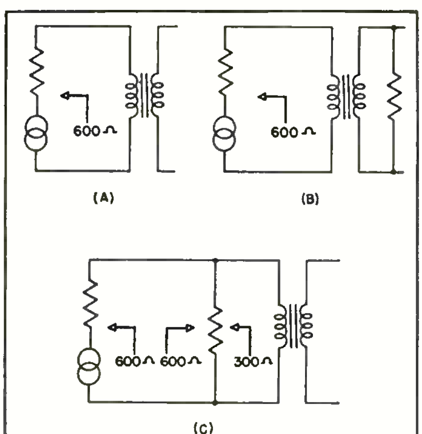


Fig. 3. Differing methods of operating transformers: (A) across an unterminated generator of 600 ohms impedance; (B) with a termination across the secondary; and (C) across a terminated line. Note that the transformer "sees" an impedance equal to one-half the nominal line impedance.

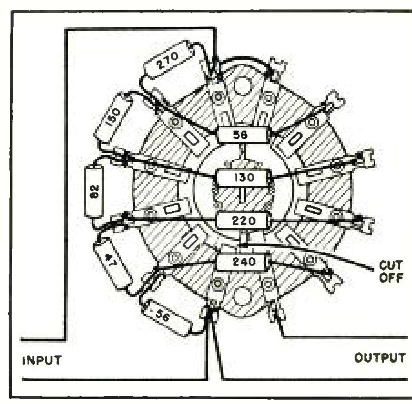


Fig. 4. Method of constructing input attenuator on a single switch deck. The contact fingers on one half are bent back or cut off, and the lugs serve only to mount the resistors.

keep d.c. out of the transformer primary, with the capacitor C_3 isolating the plate voltage from the transformer. Normally it is considered more desirable to place the capacitor between the low end of the primary and the cathode, as shown at (*A*) of *Fig.* 5, since this arrangement constitutes a bridge which balances out hum components in the plate supply. Referring to (*B*), R_p represents the plate resistance of the tube, R_L the shunt-feed resistor, C_c the coupling capacitor, and C_f a decoupling capacitor. The hum component of the

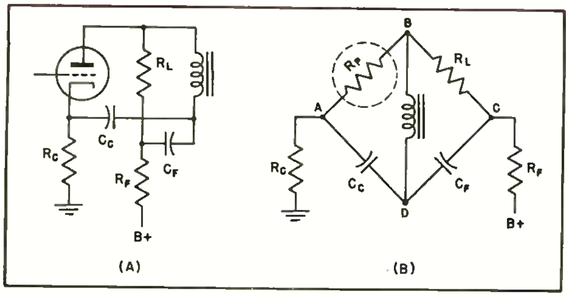


Fig. 5. Bottom-connected isolating capacitor (A), and rearrangement of elements in bridge form (B) to show hum balancing effect.

plate supply appears between *A* and *C*, and if C_c and C_f are chosen so their reactances are proportional to R_p and R_L respectively, the bridge will be balanced, and no hum voltage from the plate supply will appear between points *B* and *D*, to which the primary of the transformer is connected.

However, the plate voltage for this stage is practically humless, since it comes from a regulated supply, so this connection was not considered necessary. Therefore, the coupling capacitor C_3 is top-connected, and also serves to isolate the plate voltage from the feedback circuit. Feedback is applied to the cathode of the first stage through the network consisting of the resistor R_{15} in series with the capacitor C_4 across which is shunted R_{16}. This connection provides a quick means for varying the low-frequency response readily. The entire amplifier is flat with 1,800 ohms across C_4. For boosts of 2, 4, or 6 db at 100 cps. the value of R_{16} is 27,000, 68,000, and ∞, respectively. This is not intended as a variable tone control, but is a fixed adjustment which is set for a given speaker system. In general, this method of varying low-frequency response is not desirable, since it reduces the feedback at the low frequencies where it is most useful. However, the amplifier is in use with the 1,800-ohm resistor across C_4, so this problem is not encountered in practice. Even with 6 db of boost, the effect is not particularly important with program material, since there is a falling off in peak power requirements below the most probable peak at 350 cps[2]. It would, however, show up on constant-frequency measurement methods.

Output Stage

The output stage is conventional for the 6AS7G, using separate cathode resistors for each of the triode sections, and by-passing them heavily. The potentiometer R_{19} serves as a balance for the plate currents. The output transformer has a split primary, and a 100-ohm resistor is connected in series with each. A 150-0-150 microammeter is connected to the two junction points. When the plate currents in the two halves of the primary are balanced, the drops across the two 100-ohm resistors are equal, and the meter indicates a balance with no current through it. For initial adjustments of R_{19}, it is suggested that a resistor be used in series with the meter, to avoid possible overloading. The connections for the meter appear on a receptacle, as do the 6 and 500-ohm outputs of the amplifier.

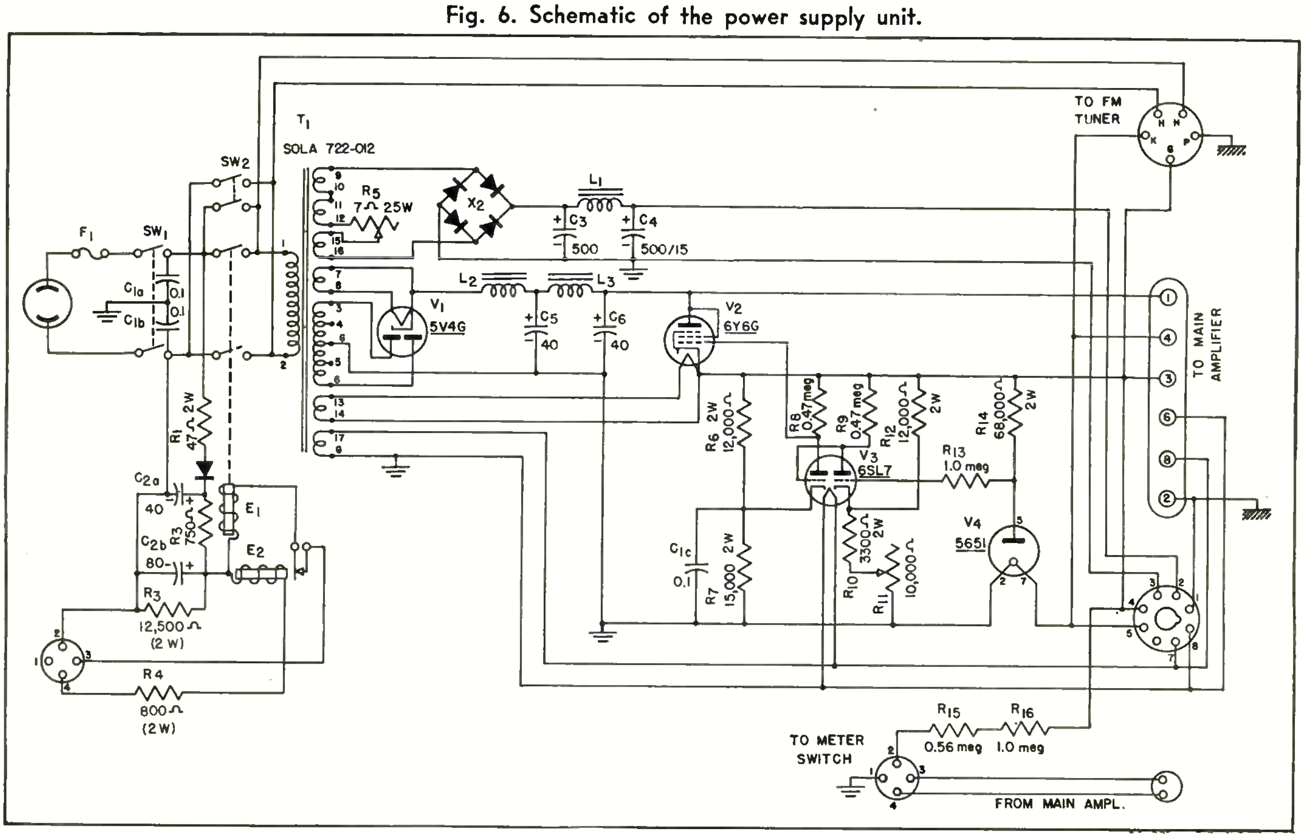
The overall gain of this amplifier is 50 db, with the input attenuator providing additional gain settings of 45, 40, 35, and 30 db. Power output at one per cent harmonic distortion is 6.2 watts, and the response is flat within ±1 db from 24 to 17,000 cps. The output stage works with a plate supply of 300 volts, and the bias is 87 volts. The first two stages are fed from a regulated supply at 225 volts, and the filaments are heated from a 6.3-volt winding on the power transformer.

The Power Supply

Aside from the relay system and the d-c filament circuits, the power supply is conventional. Surplus parts were used when their characteristics were suitable for the purpose, and no similar units are available from jobber stocks.

[2] "Powers Produced by Musical Instruments", John C. Steinberg, 9-23, Electrical Engineers Handbook, Pender & McIlwain, (Wiley)

Fig. 6. Schematic of the power supply unit.



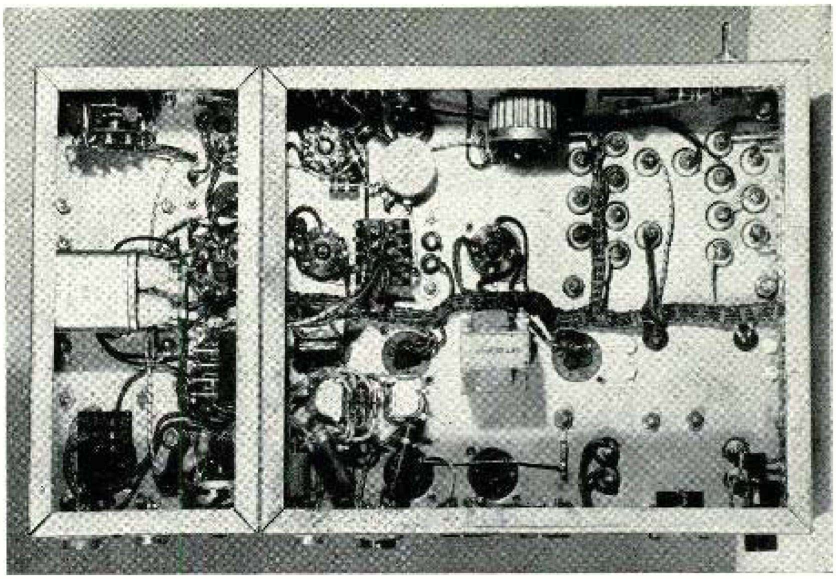


Fig. 8. Bottom view of two units bolted together, showing cabled wiring and use of resistor mounting strips.

However, equivalent voltage and current ratings may be obtained by using an additional filament transformer with a heavy-duty power transformer. Referring to the schematic of *Fig. 6*, it is seen that the a-c line first passes through a fuse and the main power switch Sw_1 thence to the contacts of the ON relay, E_1, which are paralleled by another switch, Sw_2, which permits the use of the unit without relay operation if desired.

The relay system, described in Part I of this series, consists of a 100-ma selenium rectifier and an RC filter system. Whenever any of the station selector relays is actuated by depressing its corresponding push button, the current flows through the relay circuits, first passing through E_1, and the normally closed contacts of E_2. The selector relays have holding contacts, and as long as any one is actuated, E_1 remains closed, applying power to the transformer primary. Depressing the OFF button energizes E_2, which operates and breaks the holding circuit; E_1 releases, and disconnects power from the transformer primary.

The power transformer has a total of six filament windings, of 6.3 and 5 volts. Two of the 5-volt windings and one of the 6.3-volt windings are connected in series, and feed a 1-amp bridge-connected selenium rectifier, with R_5 being used to adjust the d-c output voltage. The filter consists of L_1, C_3, and C_4, and the output is adjustable from 10 to 14 volts at 1-amp drain.

The high-voltage supply uses a 5V4G rectifier with a two-section choke input filter, furnishing 300 volts to the 6AS7G. The regulating circuit consists of a 6Y6G as the series tube, with a 6SL7 as the control amplifier and a 5651 for the voltage reference. The circuit is that recommended by RCA, and the output voltage is adjustable from 180 to 240 volts. It is normally set at 225 volts, and the regulation holds the ouput constant within two volts over a current range from 10 to 75 ma.

The metering circuit for balancing the 6AS7G output stage is fed to the power supply, and with another circuit consisting of ground and a series resistor from the regulated B+ bus is fed to a four-terminal receptacle for the meter. Either of these two circuits is selected by a 3PDT switch, not shown on the schematic, with the third position connecting to a jack on the front panel. This jack is used when aligning the FM tuner by inserting a patch cord between it and the jack on the tuner chassis. The discriminator balance is read directly on the meter, and the job of alignment is made as simple and accurate as possible.

Power for the control amplifier appears on an octal socket, and that for the main amplifier appears on a terminal block, mounted under the chassis. The FM tuner requires plate supply and 115-volts a.c. for the primary of the filament transformer, and this fed through a 5-p socket. The AM tuner obtains its power through the FM tuner, as indicated on the block schematic, *Fig. 7*.

TABLE I

Transformer	Thordarson	Audio Dev. Co.	UTC
Input	T2A68	214A or 215A	LS-10
PP Input	T2A40	214H or 215C	LS-21
Output (VC only)*	T3S21		LS-57
Output (Line and VC)	T3S22	314C or 315C	LS-55

*If amplifier is to be used only to feed a voice coil, a transformer without a line winding is recommended

Construction

The main amplifier is built on a 5"x10" chassis, and the power supply is on a 12"x10" chassis. As shown in the photos, *Fig.* 1 and *Fig.* 8, these two chassis are bolted together, with short leads connecting their terminal blocks. These two sizes were chosen so that they could be used together as a single unit, 10"x17", and thus fitting on a standard relay rack; or so they can be used separately if desired. The use of terminal blocks for each section permits interconnection with short leads when the chassis are used together, or with a cable as long as necessary when

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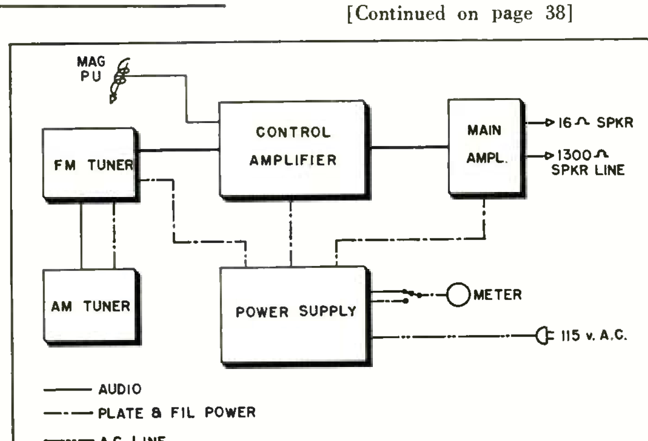

Fig. 7. Block schematic of the entire system described in this series.

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they are used apart from each other. This construction provides an effective stiffener for the large chassis dimensions, as well as some shielding between the two sections.

The transformers in the main amplifier are all Western Electric types—a 247J for the input, a 264C for the push-pull input, and a 166B for the output. The latter is designed for push-pull 300A tubes, and has an impedance ratio of 4130 to 500 and 6 ohms. It is normally used with a 16-ohm load circuit, and reflects a somewhat higher load upon the output tubes than its nominal value. However, since the load desired for the 6AS7G is of the order of 4,000 ohms, the 6-ohm winding feeds a 16-ohm speaker and the 500-ohm winding feeds a remote speaker load of 1,300 ohms, thus reflecting approximately 4,000 ohms to the tubes. The interstage transformer has an impedance ratio of 18,000:100,000, and is designed for shunt feed. Suitable jobber types of transformers are listed in *Table I.*

The power transformer has seven secondary windings: 400-0-400 at 250 ma; three of 5 volts, 3 amps; and three of 6.3 volts at 5, 3, and 1 amps respectively. The two chokes are 10 henry, 200 ma units, and the d-c filament supply choke has an inductance of 22 mh at 1 amp. The total d-c filament drain for the control amplifier is 0.9 amps. The a-c drain for the main amplifier is 3.1 amps, and this is supplied by the 5-amp winding, which also feeds the 6SL7 in the power supply and the 6SJ7 in the control amplifier, making a total of 3.7 amps. The 3-amp winding is used for the heater of the 6Y6G in the regulator circuit. Although all the transformers and chokes in the power supply are surplus items, they may be replaced by standard items, using a multiple-filament transformer in addition to a combined plate and filament transformer.

Operating Characteristics

The quality of reproduction from this entire equipment is considered somewhat above average. Hum level is approximately −41 dbm—note that this is not 41 db below the maximum output as most commercial amplifiers are rated, but actually 79 db below the 6-watt maximum at one per cent distortion, about 20 db quieter than the average. This includes the control amplifier in the measurement, and was made with the input attenuator on the main amplifier set at 40 db and the volume control at maximum.

The most outstanding single feature of the equipment is the completely compensated volume control, which provides the correct aural balance to suit the output level. Most of the quality of reproduction is credited to the use of high grade components in a simple straightforward design without any shortcuts or tricks. The results appear to prove the advantages of this form of construction, and while considerably more expensive initially, the continued performance of equipment built in the professional manner will ensure lasting satisfaction.

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not correspond any more to the thickness of the magnetic coating[6].

From the graphical analysis, it can also be concluded that overbiasing is not as harmful as underbiasing. One must, however, see to it that the biasing forces which produce the proper recording conditions for the nearby layers do not fall into "tail region" of the field distribution pattern where its decay becomes more gradual, since this will result in loss of output level for high frequency signals.

Much additional work has still to be done in order to learn more about all factors which control the recording process. Because of the complexity of the problem, certain assumptions have been made which may not prove to be completely justified. For example, in the above discussion no allowance was made for the fact that the permeability of the recording medium drops when saturated. A change of permeability will lead to a modification of the field distribution (*Fig.* 1).

The conclusions advanced here are not intended to provide a complete picture of the field strength phenomenon in the recording process, but thinking and experimental work along are intended to encourage additional similar lines.

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ringer box (9¾" x 7¼"). The weight is approximately 7 pounds.

Mounted therein are two multiple-purpose vacuum tubes (Type 12AU7s), two standard relays, a dry disc type rectifier, and the associated transformers, condensers, resistors, etc. Three "Line" terminals and three "Telephone" terminals are provided in the box, the third terminal in each case being for use with divided ringing. A power "on-off" toggle switch is mounted on the cover for easy access. Connections for the (a) "Start-Recording" Control Switch; (b) Commercial Power (115-V, 60 Cycles, AC) and (c) Recorder, are provided through a "Cannon" type multiple-conductor receptacle attached to the base. Simplicity of connecting and disconnecting the power and recorder are thus assured.

The equipment is arranged to provide a 1400-cycle-per-second oscillator, a single stage amplifier, an electronic timer and a simple selenium cell-type rectifier for plate potential power supply. The tube filaments are energized from the commercial power through a variable resistor which compensates for differences in line potentials, thus lengthening tube life.

The 1400-cycle oscillator, being an electronic device, is stable and extremely reliable, and its output is amplified to raise it to normal voice levels as required by the FCC. The electronic timer controls the 15-second tone interval and the 1/5 second tone duration as also required by the FCC order. This timing is accomplished through the operation of one of the associated relays.

During the time that the tone is connected to the line, it is also fed into the recorder but at a considerably reduced level so as to prevent recording "blast" effect. While normally designed for operation with recorders having a-v-c, there is included a feature in the coupling transformer network between the recorder and the line which permits one of two levels to be used, thus adapting the unit to both a-v-c and non-a-v-c recorders. Interlocking circuits are also included so that when the recording con-