Elements of

Residence Radio Systems

C. G. McPROUD

Part I. A push-button operated, fixed-tune FM receiver serving as a high-fidelity source of signal for home radio systems.

WHILE the audio engineer is interested primarily in amplifiers, speakers, microphones, and other equipment more closely related to the audio spectrum, it cannot be denied that one reason for high-quality amplifiers and speakers is for the reproduction of radio programs. Thus, the audio engineer must also consider the equipment used to provide the source signal, be it AM or FM.

By far the largest percentage of reproducing equipment is used for home entertainment, and there is some evidence to indicate that many listeners are sufficiently interested in good quality to go to the expense of installing an elaborate system as a semi-permanent part of the house. Such installations come under the heading of Residence Radio Systems, and while they include the same elements as is contained in a modern AM-FM-phono combination, the physical construction is usually quite different.

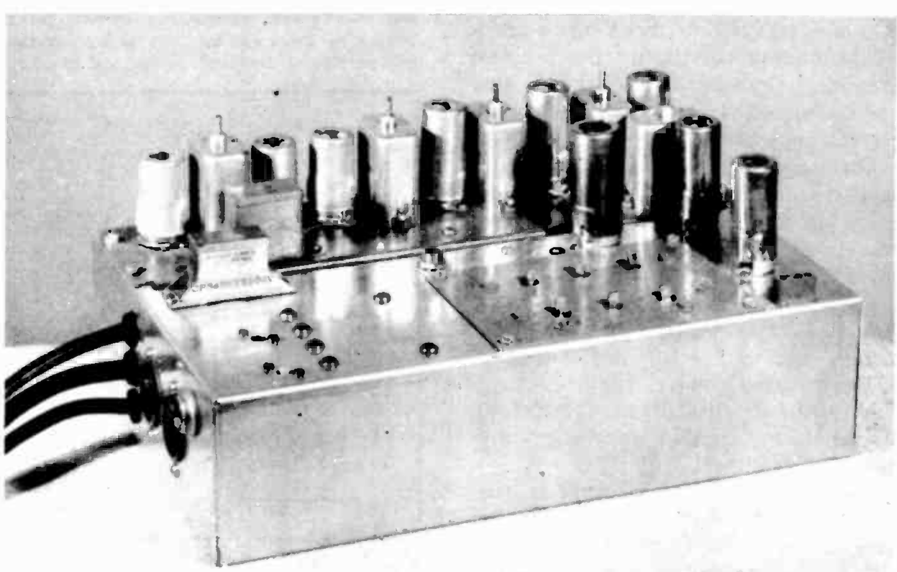
The reasons for this are fairly obvious. It is understood that a good speaker and amplifier are a necessity, and if of excellent quality, they might well be utilized for many years, although changes in the phonograph or in the radio tuners might be made more often. Therefore, in most such installations, the equipment is composed of a number of individual units, each serving a specific purpose, and all tied together by a control system to provide sufficient flexibility.

Typical System

A typical system, therefore, will contain a speaker, a "main" amplifier, a preamplifier—possibly with a scratch suppressor—a record player or changer, one or more radio tuners, depending upon the availability of programs, and a power supply. These sections are basic, and although various sections may be combined physically, all are represented in most instances. In the more elaborate installations, push-button controls may be employed, arranged for remote operation or not, as the owner desires. Some years ago the writer obtained a clock which is capable of completely controlling a radio, turning it on or off, and selecting any of six stations at any desired fifteen-minute interval for a 24-hour period. With such a device, some form of electrical push-button tuning is necessary.

Because programs on either AM or FM may be desired, the switching can become complicated if usual means are employed, so the system to be described has been assembled with the ultimate aim of obtaining good reproduction in the home from FM, AM, or phonograph, with adequate flexibility and with as few controls as possible. The complete system consists of a two-way speaker, a 6AS7G amplifier, a power supply, the preamplifier and scratch suppressor unit, and two tuners, each arranged for push-button station selection. Altogether, this equipment provides a complete home entertainment system; it may be either more or less elaborate than another user might wish. It is offered as an indication of what *can* be done in the way of a home entertainment system.

In the New York area, a total of ten stations appeared to be sufficiently popular to warrant inclusion in the system. Six of these are FM stations; four AM. To simplify switching, it was desired that any push button would select its associated station, whether AM or FM, without any other control operation. The clock made one other feature useful, since it can serve as an alarm clock. However, when set to turn off the set after its owner retires for the night—providing a restful lullaby—it would come on in the morning at too low a level to serve as an



Front view of FM tuner chassis.

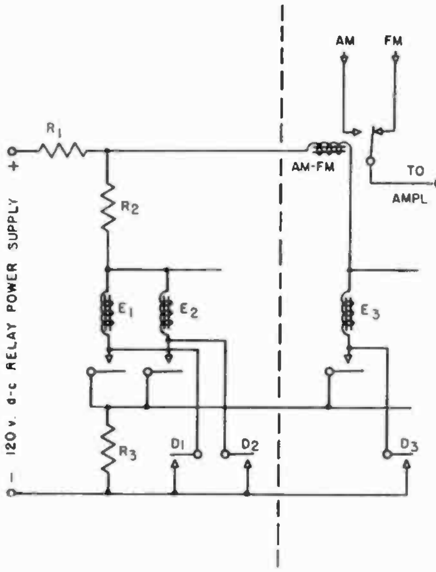


Fig. 2. Basic schematic of self-holding and automatic releasing relay circuits for station selectors.

alarm clock. Therefore, a muting arrangement was included which would reduce the level by about 20 db for the sleeping music, yet, as soon as the clock shut the set off for the night, the system would be restored to normal, and the morning level would be sufficient to serve as an alarm clock.

Thus the problem is stated, and the FM tuning unit is the first to be described. It includes the AM-FM switching relay and the muting circuit, as well as the tuner proper. Relays are used throughout for the various operations, and in spite of the high frequencies involved, the entire unit performs quite satisfactorily.

The Tuning Circuits

The front end of the FM tuner is fairly conventional—electrically. However, the antenna and r-f circuit are tuned with variable air trimmers and left set—the antenna circuit peaked at 101 mc and the r-f circuit at 97 mc. The r-f stage is a 6AG5, with its grid fed with avc voltage from the first limiter. The converter tube is another 6AG5 operated with the oscillator signal fed to an un-bypassed cathode resistor.

The oscillator circuit is a little unusual, and provides the advantages of automatic frequency control, almost a necessity with a fixed-tune unit. From the schematic *Fig.* 1, it will be seen that the oscillator is of the electron-coupled type, using one-half of a 12AT7 for the oscillator and the other as a reactance tube for the afc circuit. The tuning of the oscillator circuit is accomplished by the use of six variable trimmers, the desired one being selected by a relay. This all seems perfectly straightforward but, on account of the frequency range at which it operates, some care is necessary in its construction. Each relay is electrically self-holding, and once a push button is depressed, the associated relay holds in until another button is depressed, at which time the previous one releases.

This circuit is quite simple, yet requires only one lead to the push button, plus one lead common to all. Referring to the portion of *Fig.* 2 to the left of the dotted line, the operation may be explained as follows: Suppose push button D_1 is momentarily depressed; current flows through R_1, R_2, E_1, and D_1, energizing the relay which pulls in its armature and completes the circuit through its contact and R_3. The relays are all 24-volt, 300-ohm surplus units, and require about 60 ma to close and 30 ma to hold. Thus the relay is energized, and holds in with less current than is required to operate it. To change the station, another button D_2 is depressed, causing a greater voltage drop across R_1 and R_2, so E_2 operates (since R_3 is out of its circuit) but E_1 releases. Thus, the operation of any push button causes the associated relay to operate, and releases any other that may have been energized.

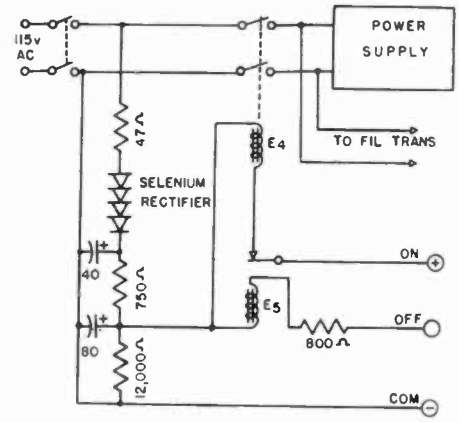


Fig. 3. Power supply for relay circuits, showing main power relay and arrangement for switching on and off.

When an AM station is to be selected, a button such as D_3 is depressed, and E_3 is operated, releasing E_1 or E_2. But the current for E_3 flows through the coil of the AM-FM relay, switching the a-f amplifier to the output of the AM tuner unit. Simultaneously, it switches the plate supply on another set of contacts. The operation is reliable, once the correct values are determined for the resistors. Although not built into the FM tuner unit, the power supply for the relay circuit is straightforward, and provides the means for turning on or off the entire system. Thus, when the set is off, it requires only the pressing of a station selector button to turn the set on and select the station. The relay power supply, shown in *Fig.* 3, is self-explanatory. The current for operating any of the station selector relays passes through the power relay E_4 to close the primary circuit of the power supply and the filament transformers. To turn off the system, relay E_5 is energized, breaking the holding circuit through its contacts.

Tuner "Front End"

Considerable flexibility is possible in the front end of the FM tuner. In the unit shown, the six tuning capacitors and the associated relays were mounted in a separate small box 3x3x4 inches, with a slot in the bottom to permit the adjustment and cleaning of the relay contacts. The rotors of all the capacitors were connected together, using #16 bus wire, and the stators were connected to the relay contacts. The capacitors were mounted on a piece of linen Bakelite, and the whole enclosed in a sheet metal box, with holes in the top to permit access to the adjusting screws. The capacitance of each trimmer is 25μμf, somewhat

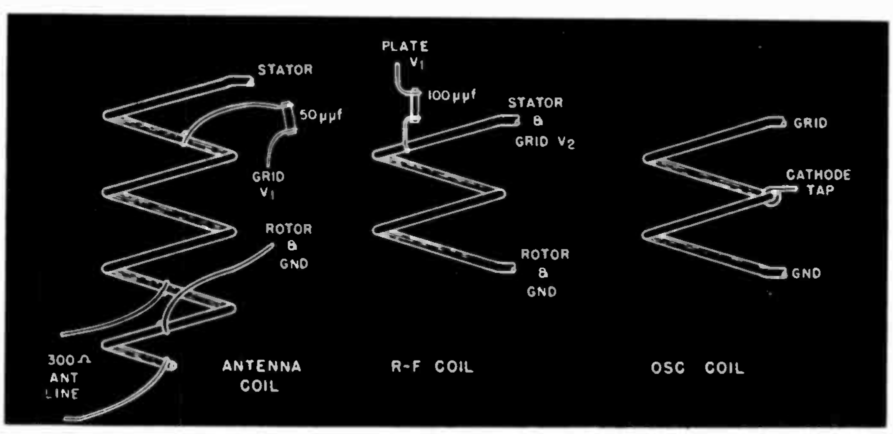


Fig. 4. Coils for front end of the FM tuner. All are wound on 5/8" mandrel of No. 14 copper bus wire.

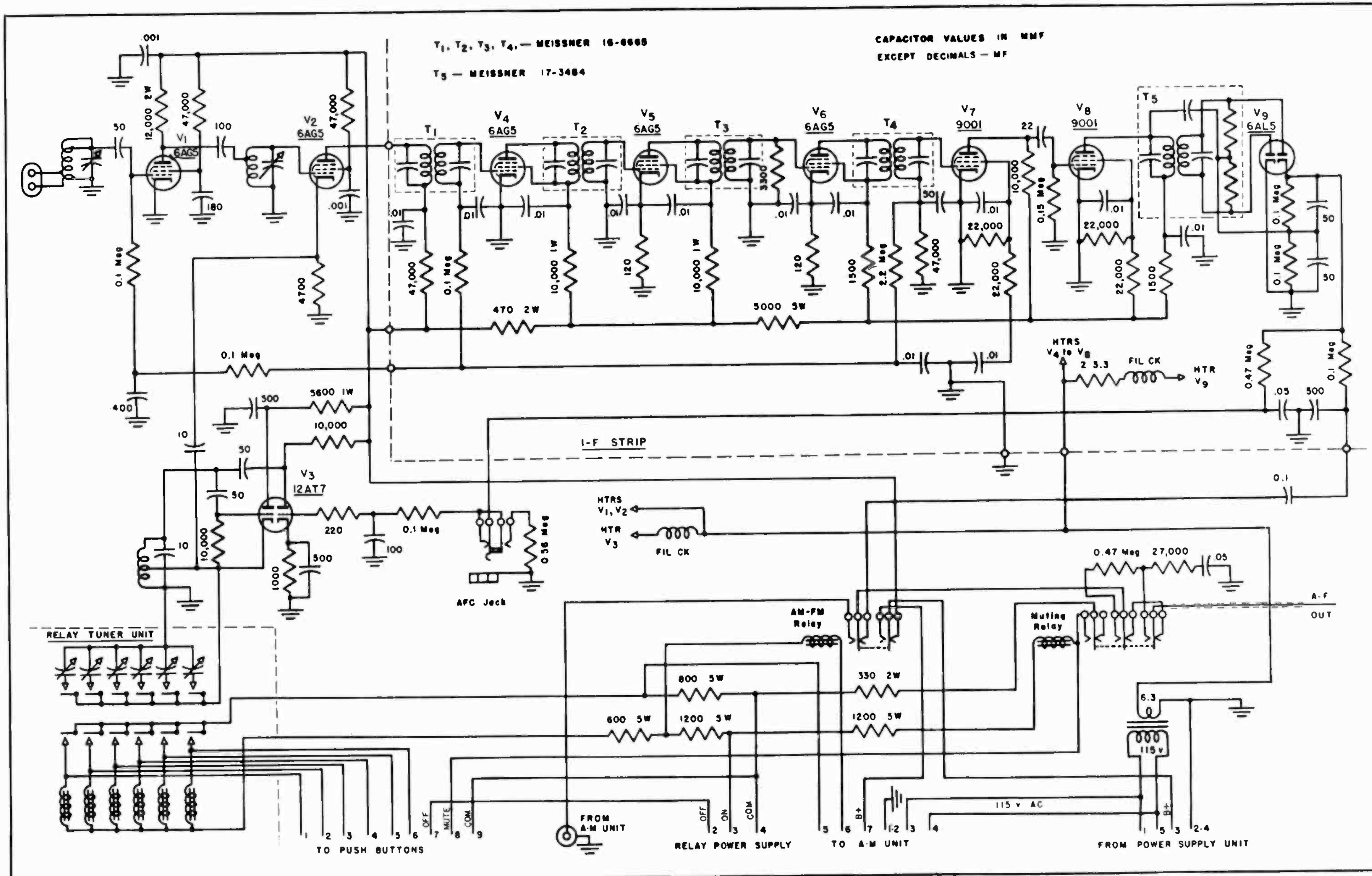


Fig. 1. Over-all schematic of FM tuner employing relay-selected fixed-tuned circuits for station selection.

greater than necessary to tune the band, so the tuning section was connected across one-half of the coil, the band being fixed by a capacitor across the entire coil. This provides a "band-spread" feature, and makes tuning easier. The three coils are shown in *Fig.* 4, all of them being wound of #14 bus wire on a ⅝" mandrel. The antenna coil has a total of three and a half turns, the ground connection being made at one-half turn from the end. The end and one turn from the end provide the connection for a 300-ohm line, which is effectively balanced to ground by this arrangement. The coil is mounted directly on a crystal socket which serves as an antenna terminal strip. The capacitor coupling to the grid of V_1 is tapped on at one-half turn down from the top.

The r-f coil consists of two full turns, soldered directly to the terminals of the air trimmer, and with the capacitor coupling to the plate of V_1 connected about three-eighths of a turn from the high end. The grid is connected to the stator of the tuning capacitor, with a tip jack provided to facilitate connection to the grid for alignment.

The oscillator coil may take a little more time, but it was found to oscillate perfectly with two turns, with the cathode tap at one turn from the bottom. The tuning capacitors—selected by the relays—are also connected at one turn from ground, as is the capacitor coupling to the converter cathode. The fixed band-setting capacitor connects across the entire coil.

In aligning the oscillator, it will be found necessary to set its frequency on the correct side of the signal, or else the afc circuit will always pull it away from the station. Setting procedure consists of inserting a plug into the afc jack, with leads to a vacuum-tube voltmeter, and adjusting the oscillator to get zero d-c voltage from the discriminator. Then, when the plug is removed, the afc will hold the setting quite accurately. If the oscillator is tuned to the wrong side of the carrier, the afc will always move off the station.

It is preferred to tune the oscillator to a frequency lower than the signal, since a reduction of even 20 mc is an appreciable amount to make the oscillator more stable. Once this is determined, the polarity of the afc voltage may be reversed, if necessary, by reversing the leads from the discriminator transformer to the plates of the 6AL5. Reducing the discriminator heater voltage by the use of the 2.7-ohm resistor aids in preventing "hunting" of the afc circuit.

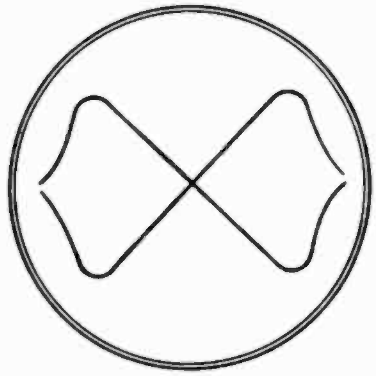


Fig. 5. 'Scope pattern obtained during alignment of i-f amplifier, using 400 kc sweep from frequency-modulated signal generator.

I-F Strip

The i-f amplifier and discriminator for this tuner is built on a separate chassis, three inches wide and ten inches long, which mounts in an opening on the main chassis. This construction was followed for two reasons: it is much simpler and more convenient to work on, and in case the relay-tuned front end did not work, it could have been removed and used with a more conventional front end. However, since the entire unit functions satisfactorily, there has been no need to change it. The circuit follows the Meissner 9-1091 AM-FM tuner almost exactly, with the addition of a filter circuit for the afc voltage. The transformers are apparently of the low-impedance type, and it will be noted that three i-f stages and two limiters are used. From the photo it will be noted that mica by-pass capacitors were used, surplus items at five cents each, thus cheaper than paper types. This construction is straightforward and fairly easy to align.

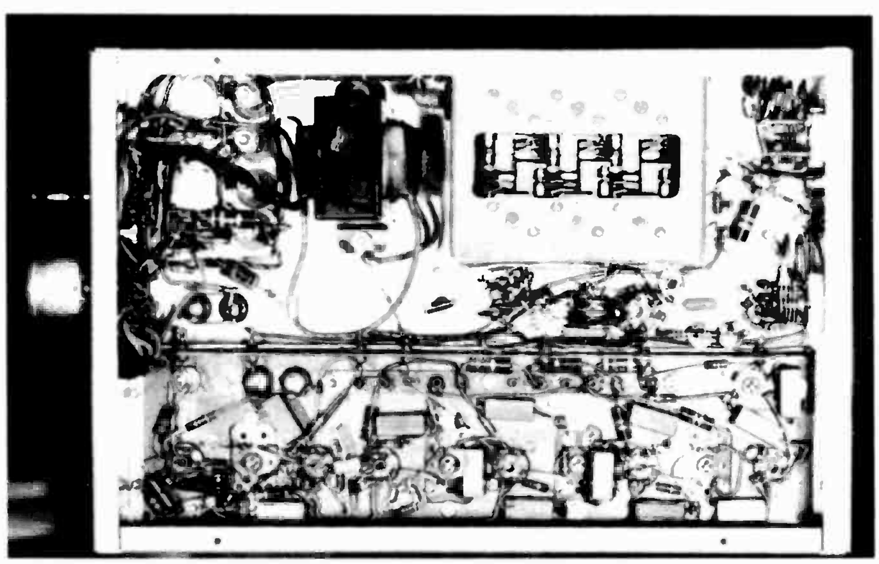
I-F Alignment

The alignment of the i-f section must necessarily follow the construction work. Feed a 10.7-mc signal to the grid of V_4 through a .01-μf capacitor, and connect a vtvm to the avc line at "A" on the schematic. Adjust both top and bottom cores of T_4, T_3, and T_2 for maximum voltage on the avc bus. Then shift the output of the signal generator to the grid of V_2, still using the .01-μf capacitor, and adjust the cores of T_1 for maximum. Due to the low impedance of the grid circuit of the converter tube to 10.7 mc, it may be necessary to increase the output of the generator somewhat. However, keep the output to as low a voltage as will cause sufficient deflection of the vtvm.

Then connect the vtvm to a plug and insert into the afc jack, and adjust the top core on T_5 for the maximum voltage, either positive or negative. Adjust the bottom core to obtain zero voltage again. This alignment should be checked several times, because the minimum distortion is obtained only when the adjustments are correct.

If a frequency-modulated signal generator and an oscilloscope are available, the usual procedure is followed for visual alignment except for the discriminator transformer. Connect the vertical input of the 'scope to the output of the tuner, and feed the signal to the grid of the converter as before, using a 400-kc sweep at a 60-cps rate. The sweep circuit in the 'scope should be set for a 120-cps linear sweep.

The pattern on the 'scope will resemble *Fig.* 5. Adjust the top core on the discriminator transformer for



Under the chassis of the FM tuner. Relay box is at upper right.

maximum amplitude of the peaks of the pattern. Then adjust the lower core for maximum straightness of the two crossed lines. The point of crossover should be in the center of the pattern. These adjustments should be repeated until the peaks are at the maximum, and the lines as straight as it is possible to get them.

Construction Hints

Connections to the i-f strip were made with Kovar bead seals, though any type of terminal strip would suffice. A small shield is mounted between the two limiter sockets, and between the r-f stage and the converter tube socket. All resistors are one-half watt types, unless otherwise marked on the schematic. The two chokes—one in the heater circuit of the oscillator and one in the heater circuit of the discriminator—may be made by winding a 1-meg resistor full of #32 enameled wire, soldering the ends of the wire to the resistor leads.

The muting relay is actuated by a separate push button, and when once set, the station selector relays cannot be changed without switching the set off first. In addition to lowering the level by about 20 db, the mute also changes the frequency characteristic, giving a 3-db/octave boost below 200 cps to compensate for the hearing curve at the lower level. Power connections to the unit are through attached cables, as is the output signal. Separate cables are used for the rectified line voltage for the relay circuits, and for the plate and heater supply voltages. The filament transformer for the tuner is mounted on its chassis, and 115-volts is fed from the power supply, and through to the AM tuner. A nine-terminal socket provides connections for the push buttons, an octal socket furnishes power to the AM unit, and a microphone-type socket receives the output from the AM tuner.

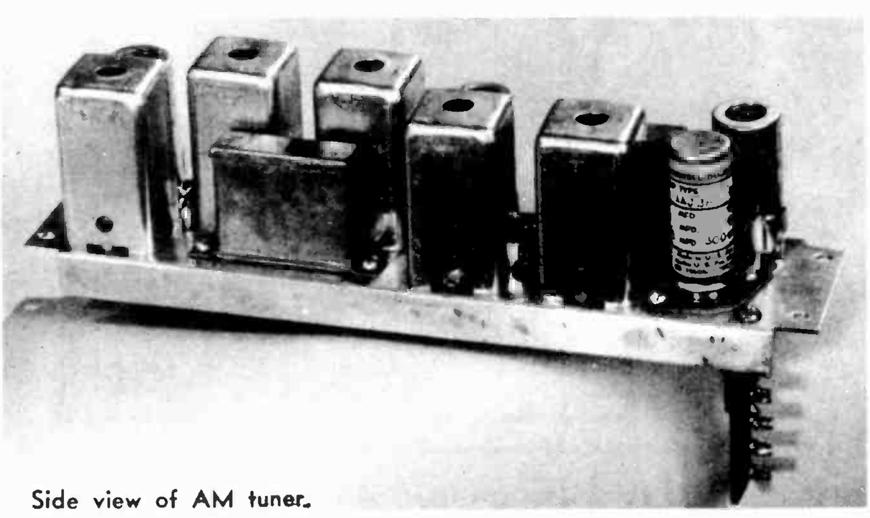
No trouble should be encountered in this construction. It is desirable to employ a steel plug in the miniature sockets when wiring to them to avoid misaligning the contacts, with the possibility of damage to the tube when it is later inserted. However, make sure the plug is removed before applying power. This information is offered as the result of experience, which necessitated replacing the 6AL5 heater choke.

Part II. Details of single-channel AM receiver chassis construction. With each station having its own receiver, optimum operation is obtained.

AN ideal AM tuner for a Residence Radio System may naturally take one of many forms, but the quality enthusiast is most certainly likely to insist on a t-r-f tuner to ensure complete listening satisfaction. Wide range t-r-f tuners are complex instruments, and while it is not difficult to *design* such a tuner, the execution of the design may be somewhat more involved. To be sure, several such tuners are available commercially, either as complete units or in kit form. However, for the system covered by this series, a different arrangement was desired.

The reasons for the development of the fixed-station tuner units to be described are several. Primarily, the particular installation planned by the writer required that four AM stations be accommodated, and that they be selected by push buttons which actuated relays. Additionally, fixed station tuners permit a large residence installation to be made with provision for feeding an audio signal from each desired station throughout a home, with a selector switch and an individual amplifier and speaker at each listening point. This allows a number of listeners to choose their own program fare without disturbing others' choices. A still further application for the fixed tuner is for recording studios which need high-quality receivers for off-the-air recordings. A separate tuner may be set up for each station frequently recorded, with the assurance that the audio signal is optimum for each.

A single-station tuner has at least two advantages over a conventional receiver. It may be tuned carefully and accurately, with the band-width set to the best value for the conditions involved, and it is always ready for instant service simply by switching its output to the recording or audio amplifier. The principal disadvantages are the cost and the space required, but the design shown reduces the cost considerably, and the units are small enough that a six-station assembly can be mounted behind a single 5¼-inch rack panel with ease. For recording studios which must record several programs simultaneously, the strip-tuner arrangement is actually less expensive, since the conventional arrangement would require a complete receiver for each recording channel, which actually duplicates the facilities. For example, ten strip tuners will provide service from ten stations to any number of recording machines at greatly reduced cost over an equal number of conventional receivers which would be necessary to record the ten stations simultaneously.



Side view of AM tuner.

The quality requirements, together with those of simplicity, dictate the use of a t-r-f circuit for the single-station tuner, and an arrangement using two r-f stages and an infinite-impedance detector serves adequately for the purpose. Because no more than one station is to be received at any time, no audio stage is included, and the switching from station to station is done by switching the plate supply from unit to unit, as will be described. This method eliminates complicated switching arrangements, and functions perfectly. For good quality, the interstage coupling is band-pass, using low-impedance capacitance coupling. The circuits of *Fig. 6* represent two methods of band-pass coupling, using capacitance for the common impedance. The tuned circuits are both adjusted to the frequency of the desired station, and the coupling capacitance C_m adjusted for optimum—or the maximum usable—band width. Actually, with this form of coupling, a change in the value of C_m causes the two resonant peaks to move apart, but not equally from the previous single peak. However, they may be set properly during alignment, and no trouble arises from this effect.

The response curve of either circuit of *Fig. 6* is shown in *Fig. 7*, with Δf being the separation between the peaks. The usable band width can be shown to equal $\sqrt{2}\ \Delta f$, and Δf is approximately equal to Kfo, where K is the coefficient of coupling. For the circuit of (A) in *Fig. 6*, K is roughly equal to C_m/C_o when the two inductances have equal values of Q. Since a 20-kc band width at 1,000 kc gives a Δf of $20/\sqrt{2}$, or 14.14 kc, K becomes 14.14/1,000 or .014, and C_m is a relatively small value of capacitance when practical values of L and C_o are used.

For the circuit of (B) in *Fig. 6*, K is approximately equal to C_o/C_m, so C_m becomes considerably larger, and thus easier to adjust easily. This type of coupling is known as low-impedance capacitance coupling, and is employed in the tuner strips.

In order to reduce the effect of the valley between the two peaks, a single tuned circuit is employed for the antenna coupling, as shown in *Fig. 8*. The coils used have adjustable cores, and the tuning capacitances are fixed. Since a number of tuners are to remain connected to the antenna at all times, the coupling to the antenna is such as to load the circuit only at the frequency of operation, rather than throughout the entire band. Thus a series resonant circuit is used for tuning the input, and the peaks of the over-coupled circuits are flattened out appreciably. The tuning circuits are seen to consist of a peaked series resonant circuit ahead of the first tube, a band-pass circuit between the two r-f stages, and another band-pass circuit between the second r-f stage and the detector.

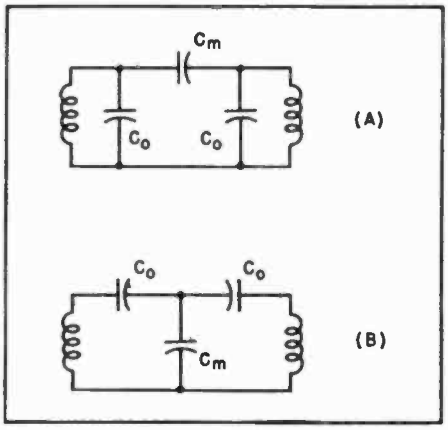


Fig. 6. Two methods of obtaining band-pass coupling by the use of two tuned circuits and an impedance common to both. (A). High-impedance capacitance coupling; (B). Low-impedance capacitance coupling

Station Switching

The method used to select the desired channel is quite simple, involving only the switching of the plate supply. This is made possible by using an infinite-impedance detector for each channel, and making a part of the cathode-ground resistance of each detector common to all channels, as shown in *Fig. 9*. Then, when the plate voltage is switched, the detector in the active channel passes current, with the common portion of the cathode-ground resistor serving to develop the signal voltage. This voltage is then fed to the audio amplifier. Since the value chosen for the common section is 18,000 ohms, while the remaining section is 82,000 ohms, the shunting effect of the remaining channels is negligible. Holding relays of the type described in Part I are used to switch the plate supply in the four-channel unit being used in the complete system.

The audio output level is fixed with respect to the detector, and since no avc is used, the gain is adjusted by varying the bias on the r-f stages. Each r-f stage has an isolating minimum bias resistor, with the common section being selected for suitable signal to the detector.

Construction

Convenient mounting of a number of strip tuners demands that they be reasonably small, with a 2½x10 in.

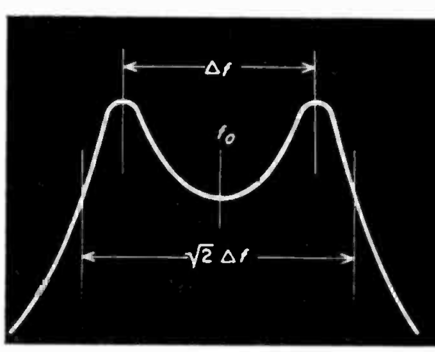
TABLE I
Turns of wire to be removed for various ranges

Freq. Range	C_o $\mu\mu f$	Turns Removed
550—800	50	0
800—1,000	50	40
960—1,175	50	70
1,075—1,300	50	90
1,300—1,550	25	80
1,500—1,700	25	100

chassis being about the minimum for the necessary parts. Five coil shields are required, together with space for three tubes and a filter capacitor for the detector plate supply. The necessary bypass capacitors are in two inverted cans, each containing three 0.1-mf sections.

The complete schematic is shown in *Fig. 10*. For the r-f coils, CTC[1] permeability-tuned coils type LSM are used. These coils are made in several inductance values, the 1-mc coils being used for this application. Since the inductance variation is not large, turns must be removed from the coils to make them suitable for the ranges in the broadcast band. The number of turns to be removed are shown in *Table I* for use with a 50-$\mu\mu$f capacitor for *Co* from 550 to 1,300 kc, and 25-$\mu\mu$f capacitors for *Co* for frequencies above 1,300 kc. The relative small

[1]*Cambridge Thermionic Corp.*, 445 *Concord Ave., Cambridge* 39, *Mass.*



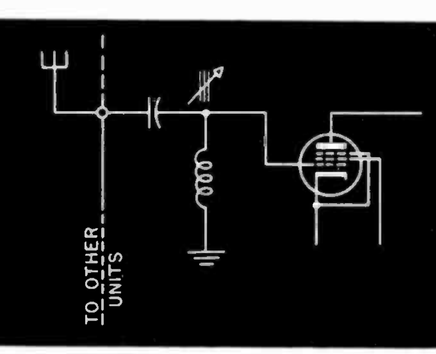


Fig. 7. (left). Curve resulting from over-coupled circuits of Fig. 6. The usable band width is represented by the limits √2 Δf. The valley between the peaks can be filled by using a single-tuned circuit in conjunction with the double-tuned circuits. Fig. 8. (right). Method of coupling the antenna to each of the tuner strips. This enables tuning the antenna circuit for each station and provides adequate signal input to the first stage.

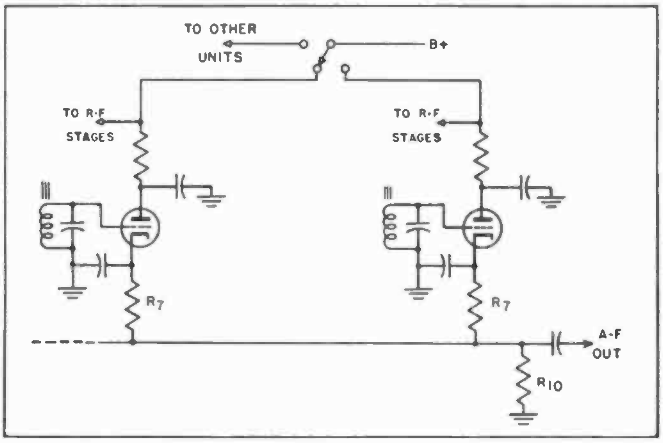


Fig. 9. Switching between channels is accomplished by simple switching of plate supply. Since R_{10} is common to all channels, the a-f output is developed across it for the one channel which is provided with plate supply.

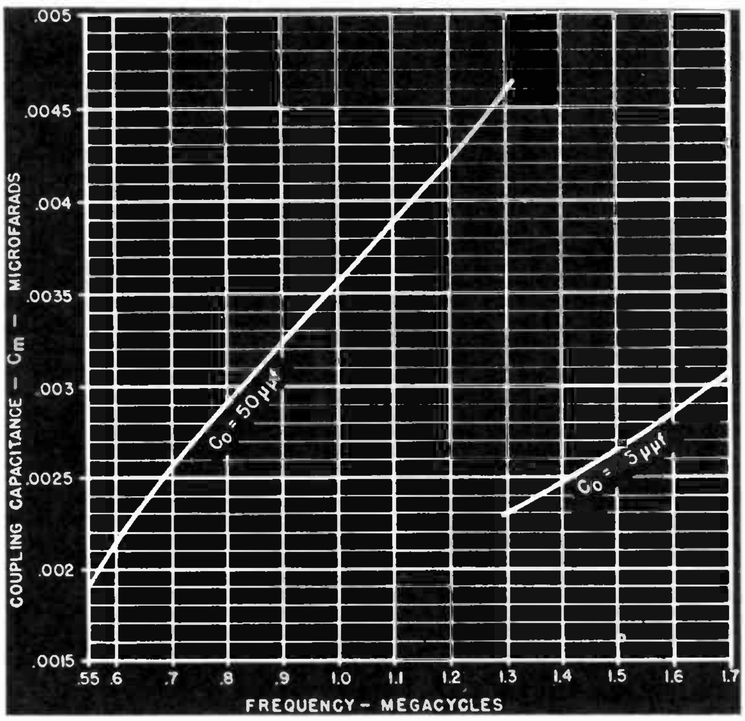


Fig. 11. Curve showing values of C_m for 20-kc band width with the coils recommended, and the values given for C_o.

tuning capacitances provide a high LC ratio, and the gain is fairly constant for all the bands. The approximate values for C_m for a 20-kc band width are shown on the curves of *Fig. 11*, and for convenience in adjusting, it is suggested that C_m be composed of a fixed mica capacitor of suitable value paralleled with a 320-to-1,000 μμf mica padder. This will permit a reasonable adjustment of band width.

The coil shields are 1-⅛ in. square by 2-⅛ in. high, and are sufficiently large to allow for good performance from the coils. The construction is straightforward, and after laying out the chassis, should offer no difficulties. There is no reason why several such tuners should not be built on a single conventional chassis since only one operates at a given time, and there is no chance of interaction between them.

Adjustment

Satisfactory alignment almost demands the use of a frequency modulated oscillator and an oscilloscope if proper adjustment of band width and correct flat-topping of the response curve is to be obtained. The second coupled pair of coils should be aligned first, feeding the signal to the grid of the second r-f stage. After the desired response is obtained, shift the oscillator to the antenna terminal and align the coils between the two r-f stages. For convenience, a potentiometer should be connected in place of the gain-setting resistor, R_9. The antenna coil should be adjusted when all the individual tuners are connected together and to the common antenna terminal, though for flat-topping it will be necessary to make preliminary adjustments on the single chassis. If an f-m oscillator and 'scope are not

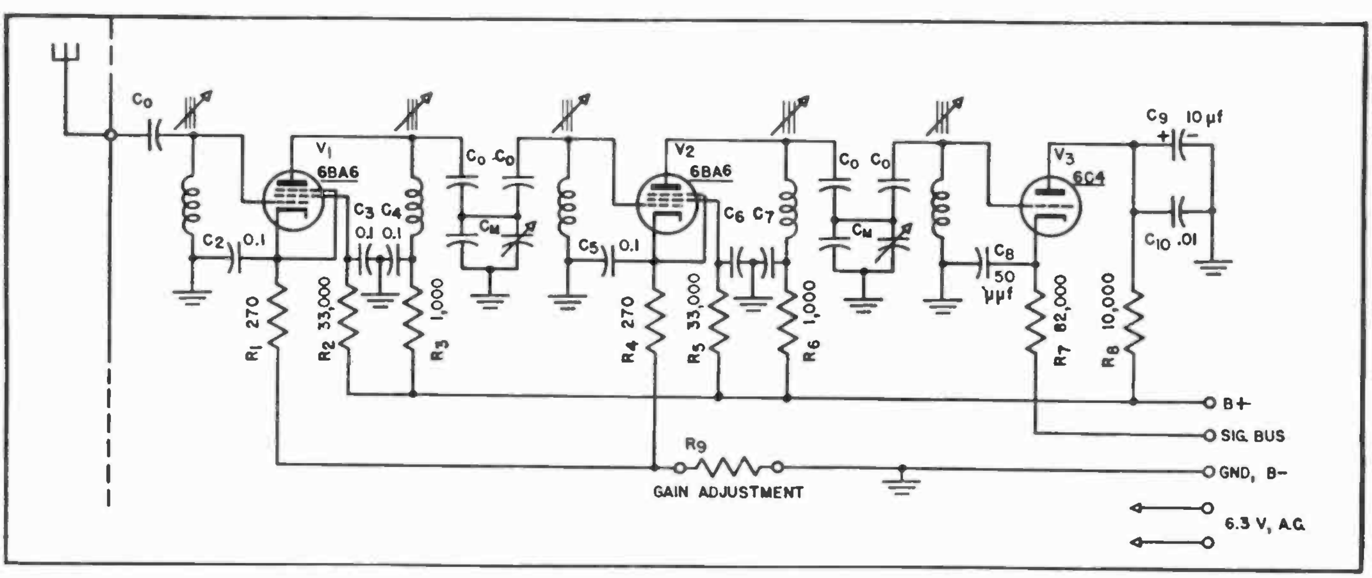
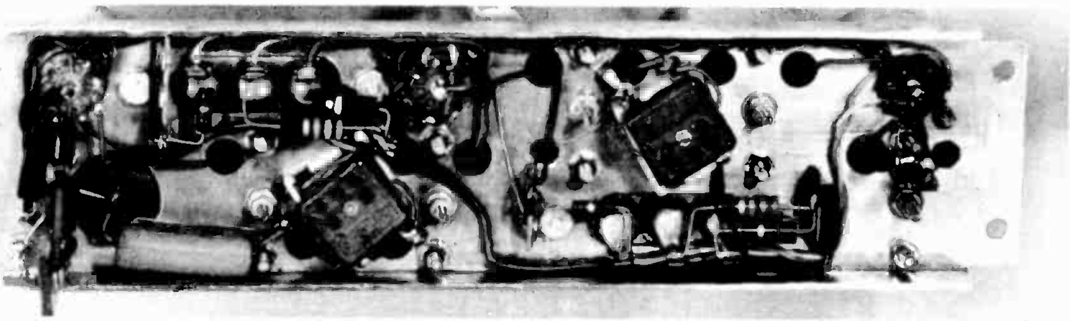


Fig. 10. Over-all schematic for the AM tuner strip. Values for C_o and C_M are given in the text, Table I, and Fig. 11.

Bottom view of AM tuner.



available, the tuner can be aligned approximately by ear, although it is doubtful if the response curve will have the ideal flat-topped shape. However, if no other means is available, fair results can be obtained by this method of alignment and the quality should be at least as good as that of a conventional receiver.

After the channels are all aligned and installed, they may be adjusted to equal audio output levels by selecting a suitable value for R_9 in each. Probable values for use in metropolitan areas will range from 1,200 to 2,700 ohms. Too low a value may cause oscillation, but the proper point at which the detector should work is the important parameter, and it is doubtful if it will be necessary to reduce R_9 below 1,000 ohms. Each r-f stage is essentially a tuned-grid, tuned-plate arrangement, and such a circuit is prone to oscillate if external feedback is sufficient or if the gain of the stage increases too greatly. The d-c voltage at the cathode of V_3 should be from 15 to 20 volts for a 200-volt plate supply.

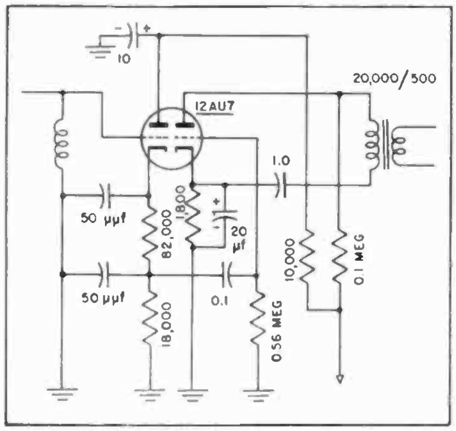


Fig. 12. Alternative output arrangement suitable for use in recording studios where several channels may be used simultaneously. Transformer matches output tube to 500-ohm line.

and this value is dependent upon the r-f signal applied to the grid.

With a number of these channels it is possible to select stations by means of a single-gang rotary switch, all filaments being heated whenever the system is turned on. For use in recording studios, however, an additional stage should be added, together with a tube-to-line transformer, as indicated in *Fig. 12*. One section of the 12AU7 twin triode is used for the detector, while the other is the audio output stage. Some such arrangement is required if it is necessary to record more than one station simultaneously.

For a large residence installation, the low-impedance outputs of several fixed tuners may be fed at approximately zero level throughout a home, with a selector switch and an amplifier at each room where a speaker is desired, or any of a number of switching arrangements may be employed. There is practically no limit to the applications to which the fixed tuner strip may be put, and their use will depend upon the ingenuity of the constructor. The cost for each tuner should be somewhere around $10.00, without the transformer, and for those who wish convenience and quality, they are considerably superior to more conventional receivers.

Part III. A description of the control unit, with design data on the phonograph equalizer and noise suppressor circuits.

IN THE FIRST TWO ARTICLES of this series, both **AM** and **FM** tuners were discussed as suitable input sources for a specific type of Residence Radio system. These units were designed with two primary considerations—quality of reproduction and convenience in use. Tuners alone do not make a radio receiver, and this article covers the next stage in the

The phonograph preamplifier and the noise suppressor are grouped into one unit known as the control amplifier, so called because it is the only point in the system where any control over volume or frequency response is exercised. It includes a number of circuit sections, but is constructed as a single unit. Throughout this entire system, professional practices are followed to a large extent, and the output of the control amplifier appears as a 600-ohm line feeding the power amplifier, which has a transformer input. This practice has the advantage of separating the various sections into units which may be changed individually if a desire for modification should arise or if new developments make it advisable, thus avoiding scrapping a complete system as would be necessary if it were built in one unit. It is not economical from the standpoint of tubes or chassis or plugs and cables, but it does provide a high degree of flexibility.

The control amplifier consists of a phonograph equalizer with two turnover points, a preamplifier, switching facilities for selecting various inputs, a Scott-type noise suppressor, and a compensated volume control. Since the suppressor can serve as a low-pass filter, and since the volume control furnishes almost complete compensation for the Fletcher-Munson hearing curve, no tone controls are employed. If they are ever considered necessary, they may be installed in the 600-ohm line to the power amplifier without disturbing either chassis, and constant-impedance equalizers can be used in accordance with professional practice. So far, no such controls are deemed necessary.

The physical arrangement is shown clearly in *Fig. 13*. The chassis is a standard 7x15x3 radio chassis, but all the tubes and some other components are mounted on one of the 3x15 sides,

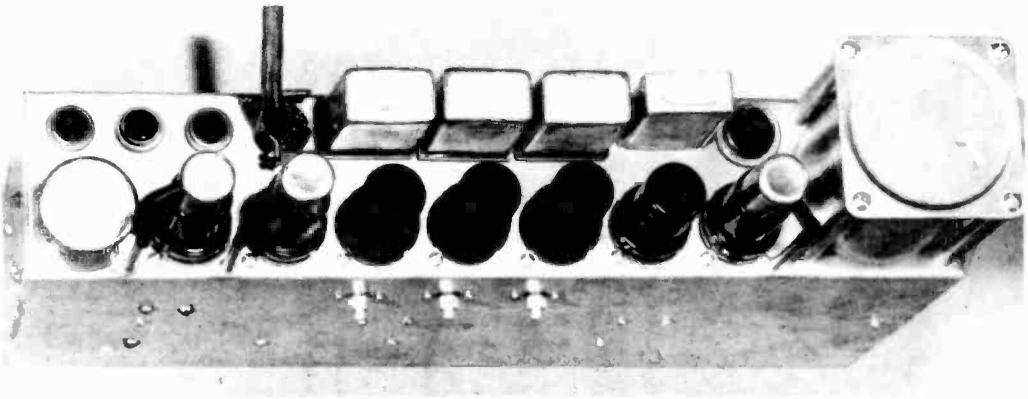


Fig. 13. External view of the control amplifier, showing the unique arrangement of the components. Operating controls are on the opposite side of the chassis.

with the controls on the opposite one. This makes parts accessible and provides a desirable chassis arrangement. The plate and filament power are obtained from the main power supply which furnishes 225 volts, regulated, for the plates, 12 volts d.c. for six of the heaters, and 6.3 volts a.c. for the seventh. *Figure 14* shows the inside of the unit before completion, with some of the resistors and capacitors mounted on the strips. Note the use of solid copper tubing for shielding leads that must be run any great distance. These tubes are shaped and soldered in place, and the wire pulled through afterward. Tubing provides better shielding and is self-supporting.

Electrically, the control and amplifier consists of a phono-preamplifier and equalizer, an input stage, two high-frequency gate tubes, one low-frequency gate tube, and the output stage, with the necessary side amplifier and rectifiers to actuate the suppressor gates.

Phonograph Equalizer

A more accurate low-frequency equalization curve, with lower losses, can be obtained from a magnetic pickup equalizer by the use of low-impedance elements. The unit used here consists of the elements to the left of T_1 in *Fig. 15*, the over-all schematic. To adjust such an equalizer requires the use of an audio oscillator, but once the principles are understood, an ideal equalization curve can be obtained.

The basic equalizer circuit is shown in *Fig. 16*. The series inductance L_1 is tuned by the capacitor C_1 to the turnover frequency and with R_2, serves to adjust the response in that region. The shunt elements, R_4 and C_3, control the low-frequency rise. The value of R_2 is somewhat critical, as shown at (A) in *Fig. 17*. The easiest method of adjusting C_1 and R_2 is to reduce the latter to about 2,000 ohms, and then to vary C_1 to obtain a dip at the turnover frequency. Then increase R_2 gradually until the curve is flat above the turnover. This will result in a smooth but fairly sharp turnover. The over-all schematic shows two capacitors, C_1 and C_2, together with two resistors, R_2 and R_3. These provide two turnover frequencies, one at 800 cps and one at 400 cps, a compromise between the common 300-and and 500-cps points.

The resistor R_4 adjusts the slope of the curve below the turnover, as shown at (B) of *Fig. 17*. In order to make measurements on this type of circuit, the oscillator should be connected with a series inductance equivalent to that of the pickup to be used. A simpler procedure is to connect the actual pickup between the oscillator and the input terminals, as at (C). The input transformer provides a voltage step-up to the grid of the first tube. Any good quality, well shielded input transformer should suffice, with the primary intended to work from a 250 to 600-ohm source. Resistor R_1 across the input terminals is used to flatten the response over the higher end of the spectrum, and a switch on the phonograph motor board shunts an additional 1800-ohm resistor across the pickup to provide a roll-off almost equivalent to that required for NAB transcriptions, and also necessary with the now quite popular LP records.

This type of equalizer is more efficient than RC types, and has a total loss of only 20 db, not counting the gain in the transformer. Actual measurements on this unit show a voltage of .023 on the grid of V_1 for an input of .016 volts at 1,000 cps. The transform-

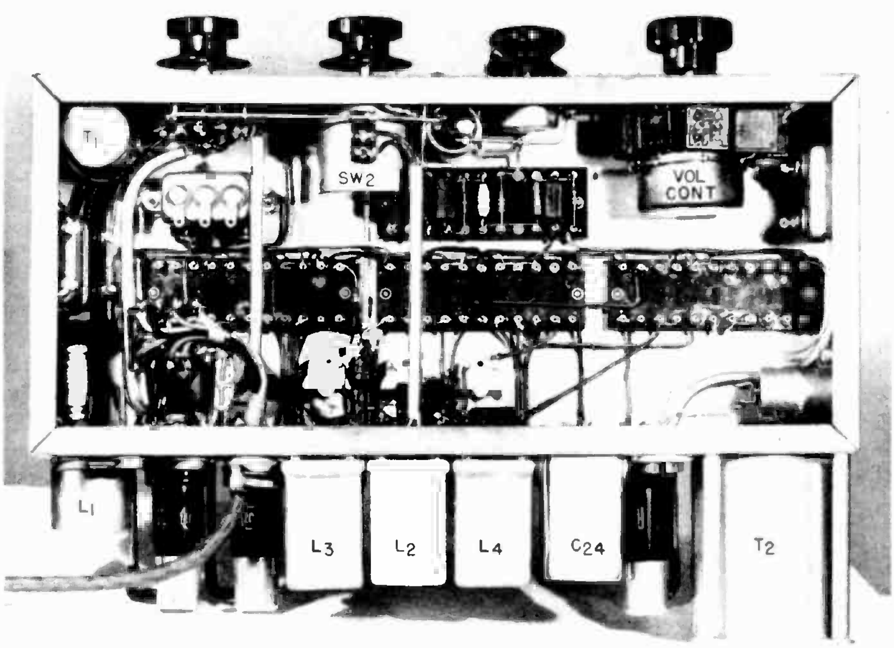


Fig. 14. Internal view of the chassis prior to completion. The input transformer is at the upper left corner, and resistors and capacitors will be mounted on the Bakelite strips. Note use of copper tubing for shielding long leads.

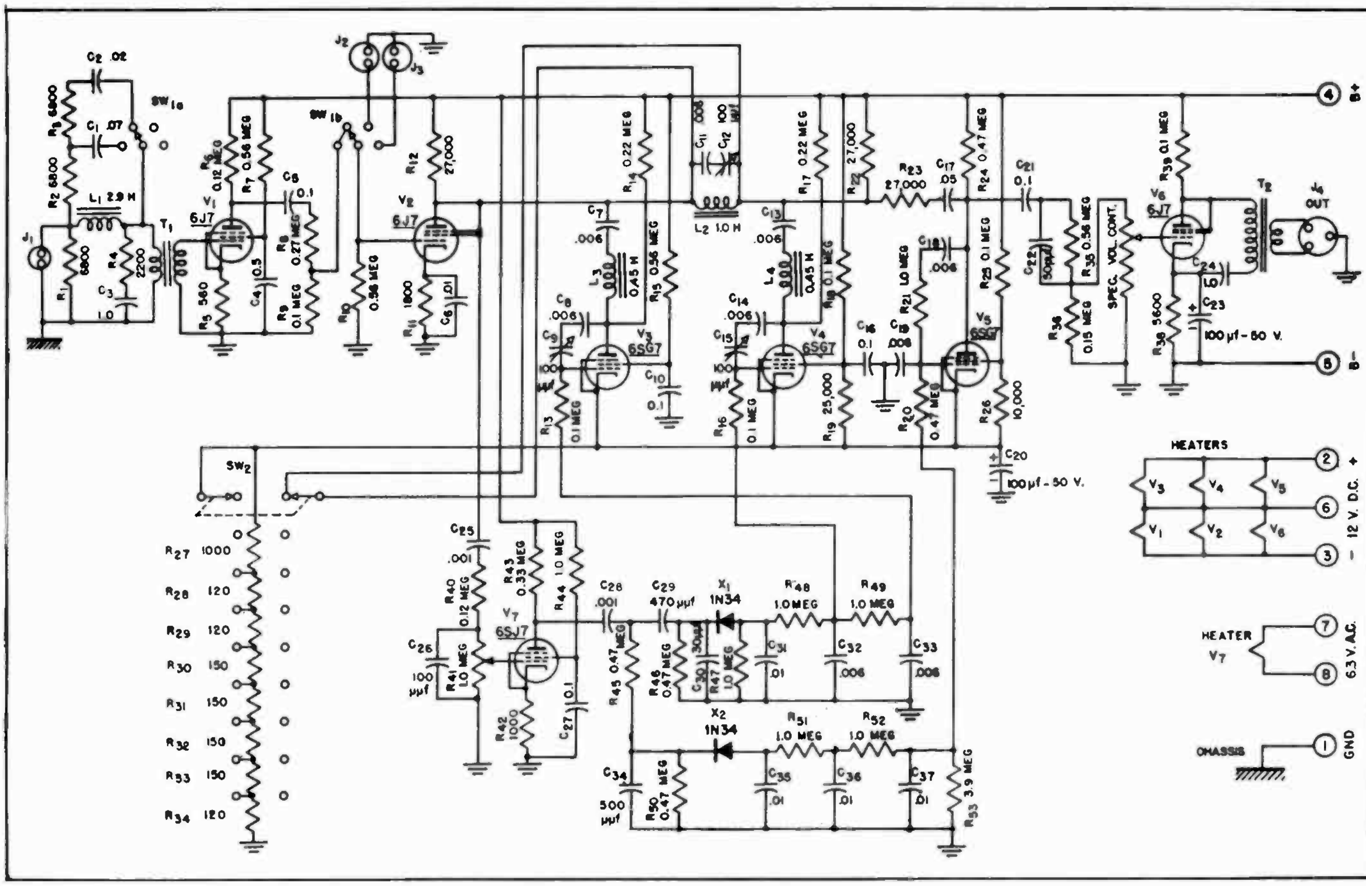


Fig. 15. Complete schematic of the control amplifier and noise suppressor.

er has an impedance ratio of 1:120, or a voltage step-up of approximately 11, yet the equalization realizes the total of 20 db. Typical RC equalizers lose up to 40 db for complete correction, and in addition, the curve is considerably more rounded at the turnover point. The response curve of this equalizer is shown in *Fig. 18*. The preamplifier tube, V_1, provides a voltage gain of approximately 31 as used in this circuit.

The Noise Suppressor

The input to the second stage, V_2, is preceded by a selector switch. Two positions are used for records, the ganged section, SW_{1a}, adjusting the turnover frequency. One other position is used for radio input, and the fourth is a spare. R_8 and R_9 serve as a voltage divider to balance the output of the preamplifier to the radio input.

The noise suppressor section is similar to that previously described by the writer[1]. However, some modifications have been made, and the reasons therefor will be discussed. C_6 across R_{11} is used to equalize the frequency response, providing a gradual increase in the high frequencies to compensate for all the circuits "hanging" on the high-impedance line from the plate of V_2 to the volume control. C_{11} isolates the plate voltage from the stator of the trimmer C_{12} so the latter will not be "hot" to chassis. C_8 and C_{14} perform similar functions.

The coils used in this particular suppressor will probably not be generally available. They have a Q of around 60 at 1000 cps—too high a value—and L_2 is 1.0 H; L_3 and L_4 are both 0.45 H units. The exact values of these coils are not important, provided the tuning capacitors are chosen to tune the circuits to the required frequencies. Any coils having an inductance ratio of approximately 2:1, and with the larger being from 0.8 to 2.0 H should be satisfactory. The Q should range from 10 to 20. The final adjusting operations accommodate these variations easily.

Filter circuits which employ high-Q coils are capable of extremely sharp cut-off, and as a result, it is not uncommon for the response to rise 2 to 3 db above normal just before the steep droop. This peak usually results in a poor-sounding output, and its presence is readily recognized by a trained ear. By way of digression, the

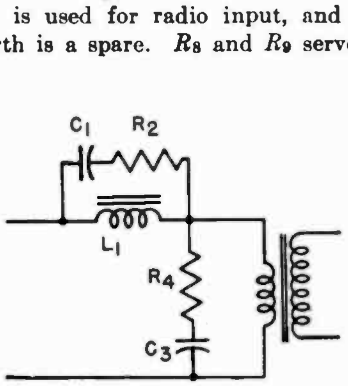


Fig.16. Simplified circuit of the phonograph equalizer.

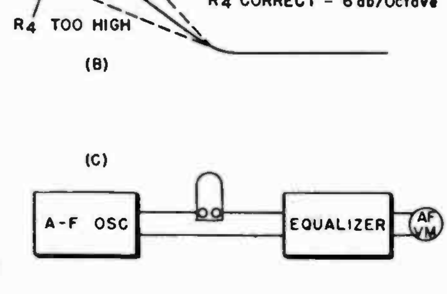


Fig. 17. Phonograph equalization curves at A and B show the effect of resistor values. C shows method of connecting oscillator to obtain correct results.

[1] "General Purpose 6AS7G Amplifier," See page 10.

filter circuits used in this type of noise suppressor are actually of the band-elimination type, and only the lower portion is normally measured. If the measurements were carried up to 40 or 50 kc, the signal voltage would rise again, assuming the other circuits would pass the higher frequencies. Such a filter is normally designed to work between specific impedances. As the suppressor operates, the various tuned circuits must be altered in order to remain correct for a given source impedance. However, in the suppressor, the capacitance of the shunt circuits—that of the reactance tubes—is the only element that is varied. Also, the coil L_2 in the series leg and its tuning capacitors are not changed.

According to filter design theory, practically any combination of coils and capacitors can be made to serve in a band-elimination circuit, but the impedance changes. However, the impedance of the source and load in the suppressor does not change appreciably, and the filter is not perfectly matched to its terminations. With high-Q coils, the peak becomes objectionable. This effect can be eliminated by loading the circuit by a resistor, which is the function of R_{22}. Its value should be adjusted to eliminate the peak just prior to the cutoff.

Another characteristic which is also objectionable is occasionally observed. That is the return of the response curve after the resonant point of the filter. For example, a filter of this type will have a response similar to that of the solid curve of *Fig. 19*, where f_r is the frequency of the dip due to the shunt circuits, L_3-V_3 and L_4-V_4, and f_∞ is the frequency of the dip due to L_2-C_{11}, C_{12}. This curve also shows, at *A*, the rise before the dropoff. The return, at

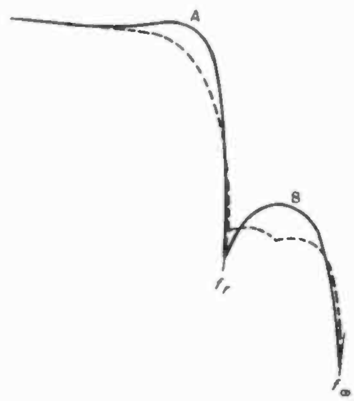


Fig. 19. Curves resulting from noise suppressor. Solid line represents initial measurement before correction, showing peak at A and return at B. Dotted line shows curve after applying corrective measures described.

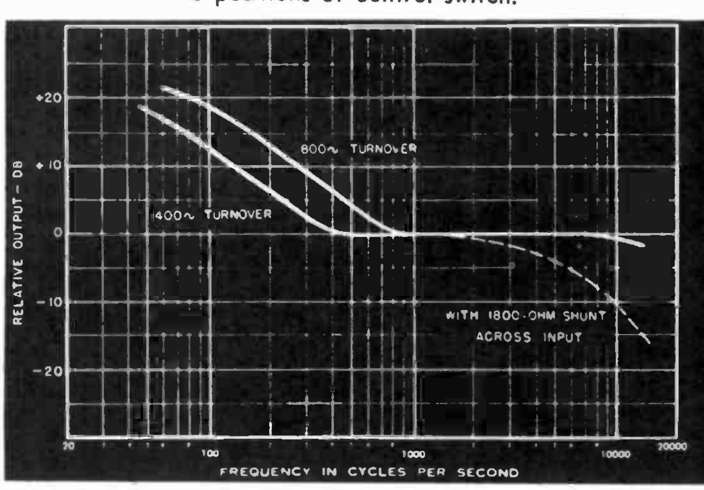
B, often rises as much as 10 db above the dip at f_r, and this too does not sound well. Therefore, in this suppressor, L_4-V_4 is tuned to one frequency and L_3-V_3 is tuned to a frequency midway between f_r and f_∞, giving a curve like that of the dotted line in *Fig. 19*, Now, while the dip at f_r is not as great as before by about 6 db, the response does not rise appreciably above f_r, and results are more pleasing to the ear. The problem now is to keep the dip at higher frequency midway between f_r and f_∞ during the shift of f_r by the action of the gate control circuits.

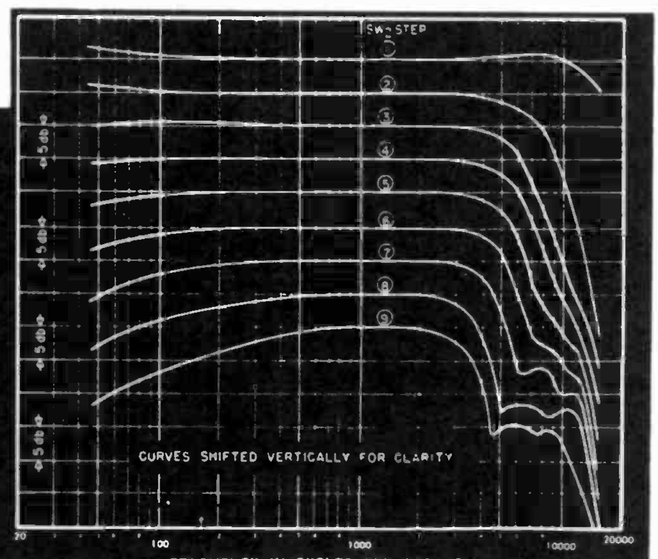
This can be accomplished readily by proper choice of the operating characteristics of the two reactance tubes. V_4 is tuned to 4,500 cps at maximum suppression, and its screen voltage is supplied from a voltage divider, R_{18}-R_{19}. This tube is connected to the side amplifier-rectifier circuit to operate more quickly than does V_3, so the lowest-frequency dip moves upward quickly in the presence of high frequencies in the signal. V_3, however, has its screen supplied by a series dropping resistor, thus changing the μ-bias characteristics of the tube. With this connection, the effective capacitance of V_3 varies less slowly with a given change in bias than does that of V_4, and the second dip in the curve remains approximately midway between f_r and f_∞, as f_r is increased by a shift of grid bias.

The side amplifier and the rectifiers are conventional, electrically, but 1N34 germanium crystal diodes are used instead of tubes. Turning to the side-amplifier input, C_{25} couples to the signal circuit at the plate of V_2. This capacitor is small to reduce low-frequency response. C_{26} across R_{41} serves to reduce high-frequency response. Thus, the gates are controlled principally by the mid-range signal, rather than by either highs or lows. The circuits between V_7 and the two rectifiers are essentially a dividing network, and each rectifier is followed by an RC filter.

The switch controlling the suppression has nine positions. At 1, the suppressor is inoperative because of a high grid bias, and another pair of contacts shorts out L_2, giving a curve which is essentially flat. At 2, the reactance tubes are still cut off, but the short across L_2 is removed, providing a roll-off down 1 db at 5,000 cps and down 13 db at 10 kc. This circuit is resonated at approximately 16 kc. In the remaining seven positions, the bias on the reactance tubes is reduced gradually, selecting a number of about equally spaced frequencies for f_r.

Fig. 18. (below). Final response curves of phonograph equalizer with two positions of the selector switch. Fig. 20(right). Over-all response curves of noise suppressor for nine positions of control switch.





The Compensated Volume Control

Following the suppressor section is the volume control. This unit is completely compensated for the Fletcher-Munson curve, and was originally described in these pages[2]. Since it is the only volume control in this system, it has more steps than the original model, but the operation is similar. This unit was assembled on an IRC commutator-type attenuator, with the capacitors mounted externally with Kovar bead seals leading through the shield case. The complete schematic of the volume control is shown in *Fig. 21*.

Until a listener becomes familiar with this type of volume control, he is certain to be somewhat amazed by its characteristics. It is necessary to adjust the over-all gain of the system so that the control is operated about five steps below maximum for normal room volume. This gives a slight boost to the low frequencies, but it is nearly correct for *normal* room volume when compared to the original sound source. As the control is turned, however, the apparent balance between low and high frequencies remains so nearly constant that it is sometimes difficult to determine whether or not the level has been changed. It is this control that relieves the necessity for tone controls, and the writer is convinced that this circuit is one of the outstanding contributions to the audio art in some time. The combination R_{35}, R_{36}, and C_{22} serve to adjust the total gain to a suitable amount to take advantage of this type of control, and the response curves of *Fig. 22* represent the output at various settings. C_{22} again adjusts frequency response occasioned by the residual capacitance of the volume control structure.

The two level-adjusting voltage dividers used in this amplifier could have been eliminated and the levels adjusted by selection of plate-load resistors, or by various other means. However, for the experimenter it is thought better to have some variable elements in the circuit. Once adjusted, these networks cause no trouble, yet they provide a measure of flexibility to allow for future modifications.

In this amplifier, 6J7's were used because of the grid connection separation. The only tube with a-c filament supply is V_7, which is not actually in the signal circuit. The other heaters are wired in a series-parallel arrangement, with the center tap brought out to a terminal. Normally operating from a 12.6-volt d-c supply, terminals 2, 3, and 7 of the terminal strip may

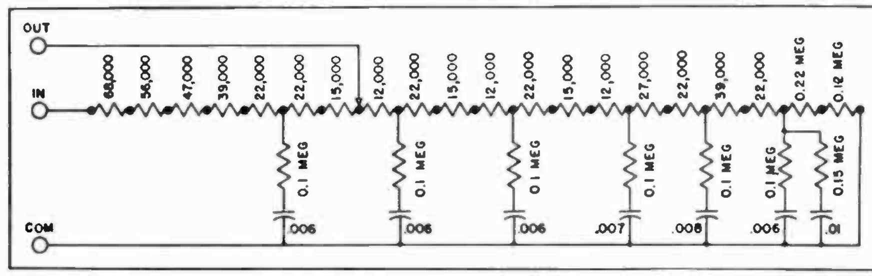


Fig. 21. Schematic of the volume control compensated for loudness contours.

be connected together, and 0 and 8 strapped together, and all tubes fed from a 6.3-volt a-c or d-c supply. The regulated 225-volt plate supply for this unit comes from the main amplifier-power unit. Since 6SG7's have a semi-remote cutoff, they are more desirable for the reactance tubes than either the 6SJ7 or 6SK7 types.

No difficulties should be encountered in adjusting this unit, provided the constructor has available an audio oscillator and an output meter, preferably a sensitive a-f voltmeter. All tuning circuits in the suppressor are made adjustable, and the resistor values for SW_2 can be determined easily. Since it is not expected that experimenters will follow the circuit exactly, this description has attempted to trace the steps taken in the design and adjustment of the noise suppressor circuits and of the phonograph equalizer. However, it is believed that if this entire circuit is duplicated, equivalent results should be obtained.

Components

Resistor and capacitor value are all shown on the schematic, *Fig. 15*, but the characteristics of the transformers and inductances used are not so obvious. In the unit shown L_1 is 2.9 H; L_2 is 1.0 H; L_3 and L_4 are 0.45 H. For these coils, UTC VIC adjustable inductances are suitable and readily obtainable. The types chosen should be used as near the minimum inductance setting as possible, to insure the highest Q of the coils, which will then be around 15. Therefore, L_1 should be a *VI-C*15; L_2 should be a *VI-C*13; and L_3 and L_4 should be *VI-C*11 units.

The input transformer used is a Langevin 401B, but suitable substitutions would be UTC A10, ADC 215A, Thordarson 20A05, Chicago BI-1, or Stancor A-4351. The output transformer used is a Western Electric 132C, but UTC LS-27 or HA-113, ADC 315A, Thordarson T-22S92, Chicago BO-1, or Stancor A-3315 should give equally satisfactory results.

Modifications

It should be understood that the use of the low-impedance equalizer is not necessary to the satisfactory operation of this circuit, but that any of the many pre-amplifiers described in various other articles on preceding pages could be substituted completely for all of the elements ahead of SW_{10} in *Fig. 15*.

Another optional change would involve resistance-capacitance coupling from the plate of V_6 to the grid circuit of a power amplifier, such as the "Musicians" described on pages 33-36. Experimenters rarely duplicate any suggested circuit exactly, but often make minor changes to fit their own particular conditions. However, this should not affect performance appreciably, provided these changes are made with care.

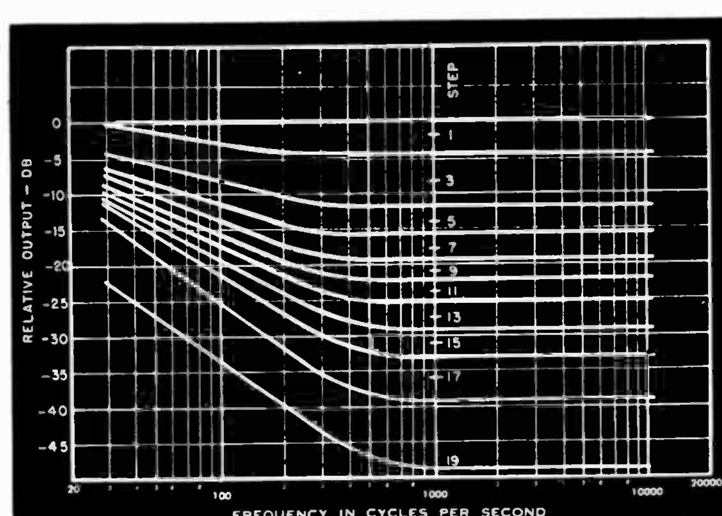


Fig. 22. Curves obtained with various settings of compensated volume control.

[2]"Loudness Control for Reproducing Systems," David C. Bomberger, page 37.

Part IV. A description of the main amplifier and the power supply units, concluding the series.

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.

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.

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. 24*.

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. 25*, (*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*).

[1] "High Quality Amplifier with the 6AS7G", beginning on page 5.

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 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. 26*. 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.

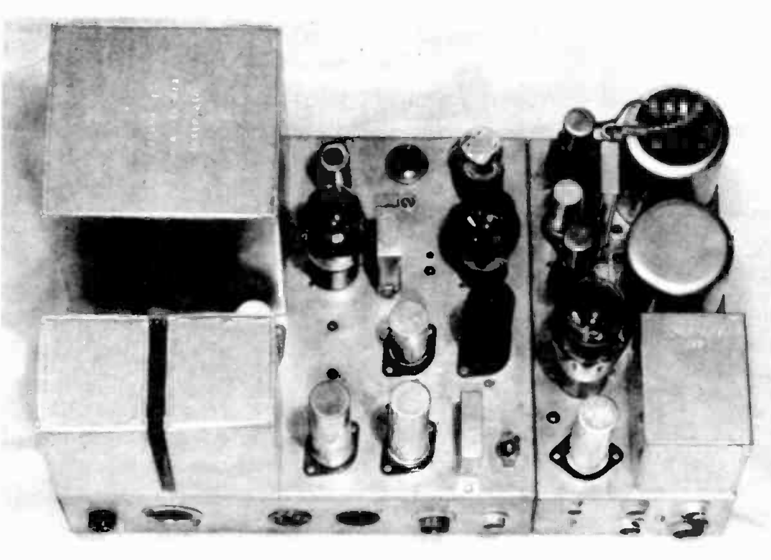


Fig. 23. Top view of the main amplifier and power supply units bolted together as a single chassis.

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 resist-

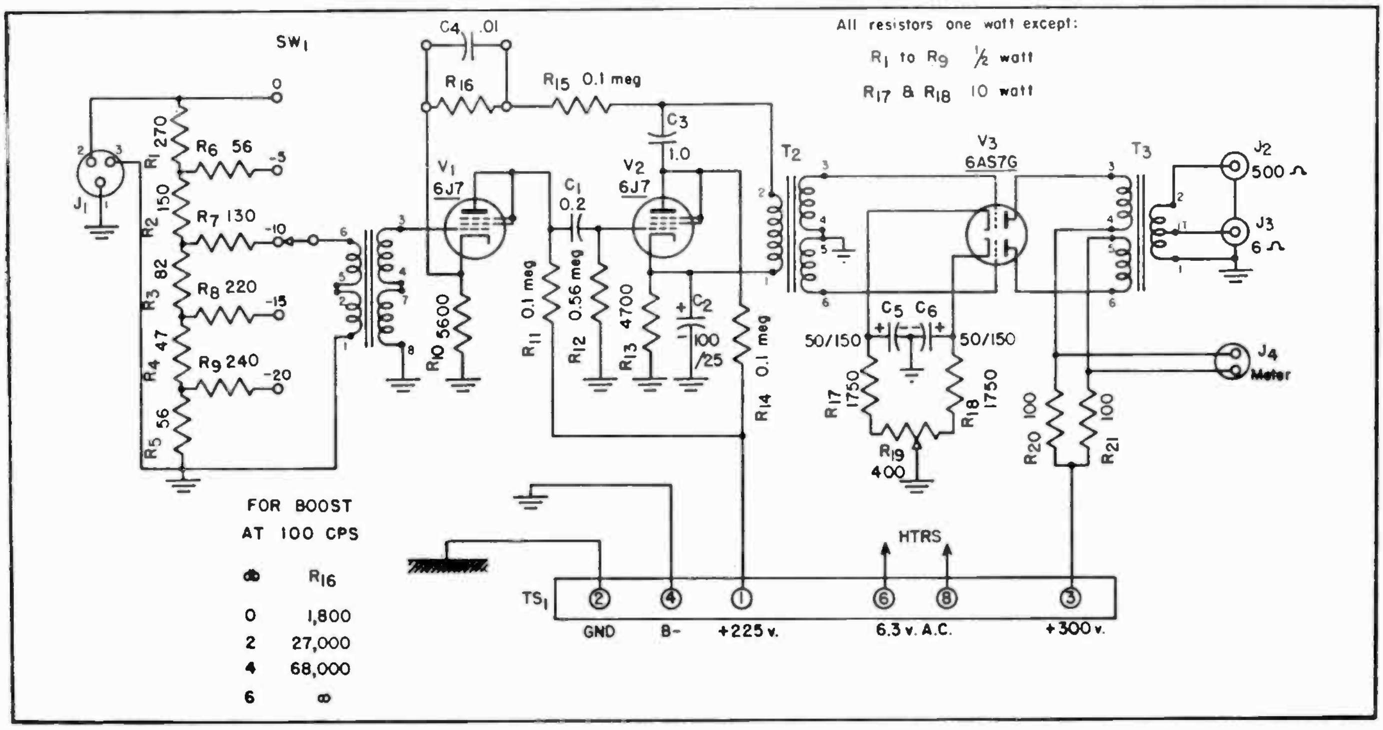


Fig. 24. Schematic of the main amplifier, closely following the original 6AS7G amplifier described back on page 5.

ance 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.

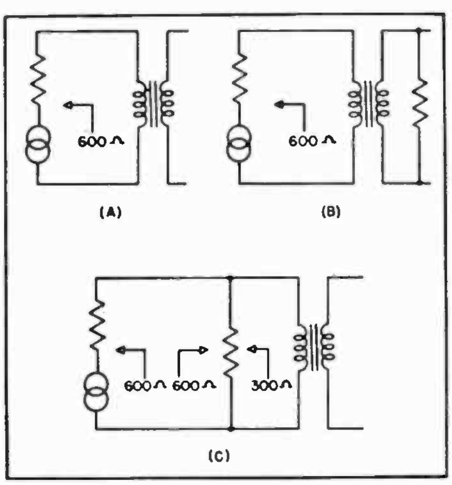


Fig. 25. Differing methods of operating transformers: (A) across an unterminated generator of 600 ohms impedance; (B) with a termination across the secondary; and (C) across a terminated line. Note that the transformer "sees" an impedance equal to one-half the nominal line impedance.

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 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. 27*, 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 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-

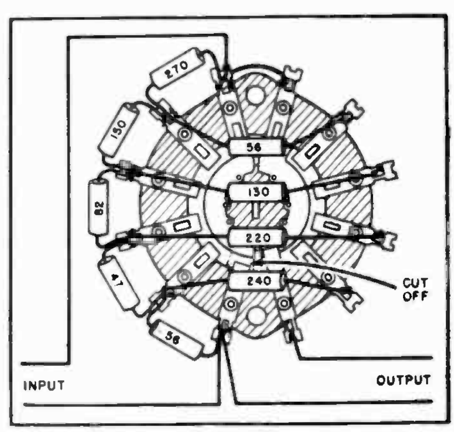


Fig. 26. Method of constructing input attenuator on a single switch deck. The contact fingers on one half are bent back or cut off, and the lugs serve only to mount the resistors.

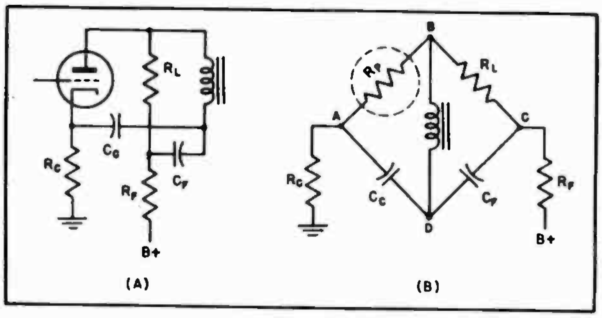


Fig.27. Bottom-connected isolating capacitor (A), and rearrangement of elements in bridge form (B) to show hum balancing effect.

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.

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

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. 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. 28*, 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. 29*.

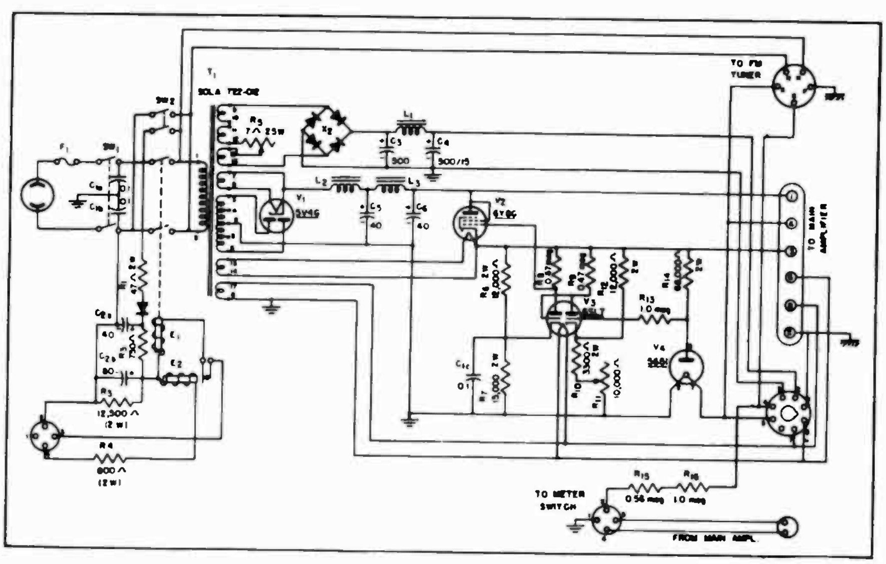


Fig. 28. Schematic of the power supply unit.

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.23* and *Fig.30*, 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 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.

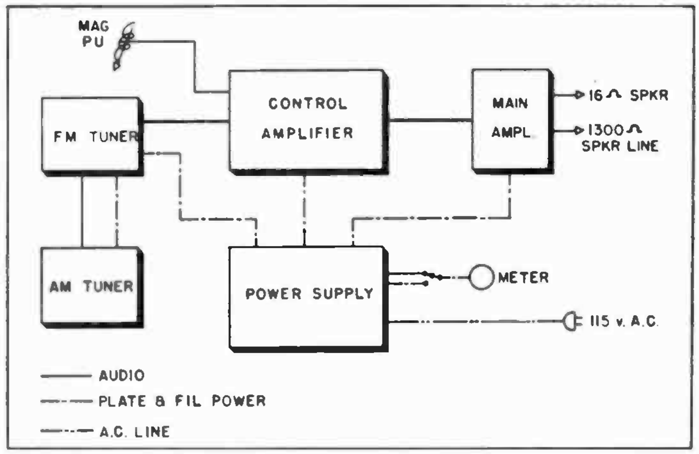


Fig. 29 Block schematic of the entire system described in this series.

TABLE I

POSSIBLE TRANSFORMER SUBSTITUTIONS

	Input	Interstage	Output (V.C.)	Output (Line)
Acro			TO-240	
ADC	215A	215C		315C (& v.c.)
Freed			F-1951	F-1950
Peerless	K-251-Q	C-212-Q	S-240-Q	
Triad	HS-1	HS-25	HS-84	HS-85
UTC	LS-10	LS-21	LS-57	LS-55 (& v.c.)

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.

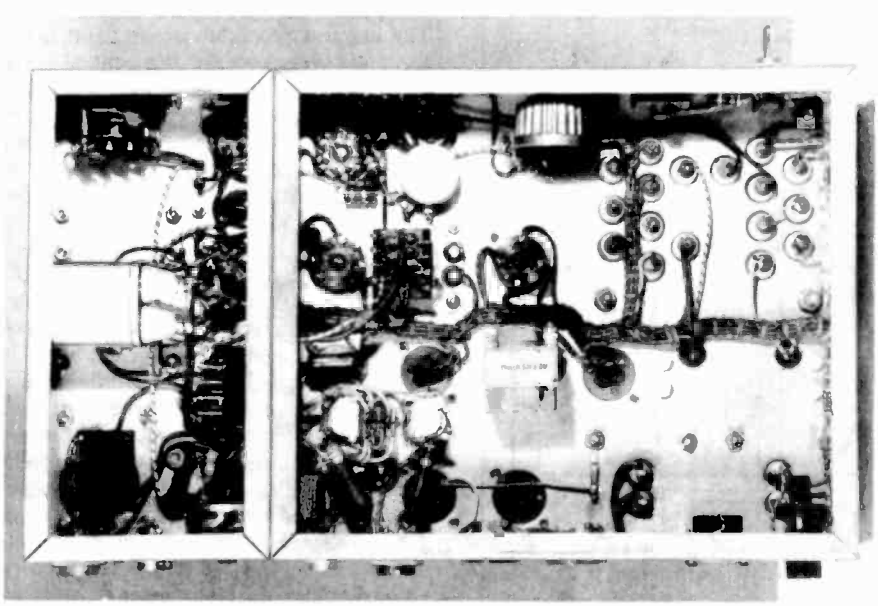


Fig. 30. Bottom view of two units bolted together, showing cabled wiring and use of resistor mounting strips.