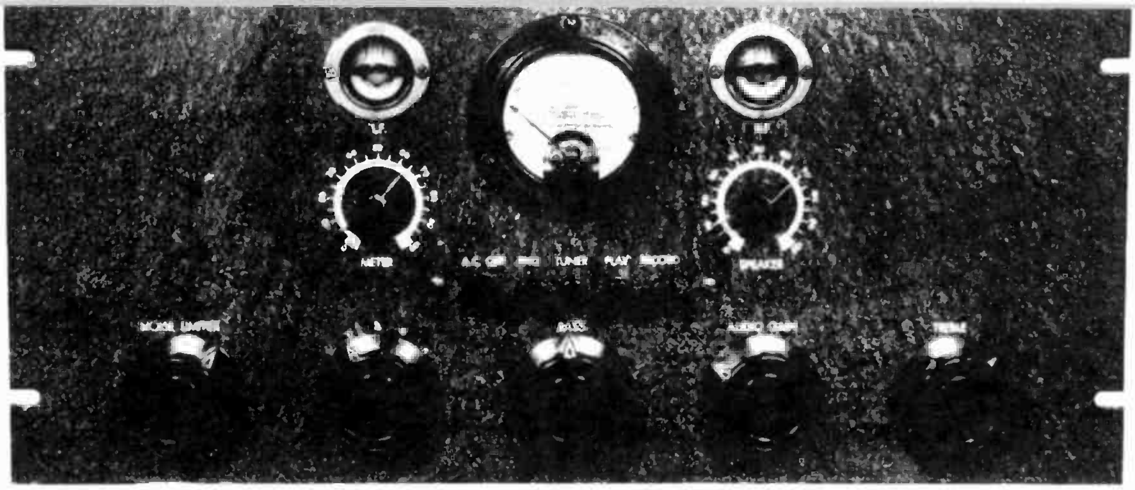


Panel view of amplifier described in this article.

General Purpose 6AS7G Amplifier

C. G. McPROUD

Modifications of the 6AS7G high-fidelity amplifier to provide bass and treble tone controls, a dynamic noise-suppressor, high-gain input stage, and recorder feeds—sectionalized for flexibility.

ALTHOUGH the three-stage high-quality amplifier of the preceding article leaves little to be desired in the way of performance, it has elicited many requests for information as to the best method of adding some form of tone control in the circuit. The gain of the amplifier is sufficient to accommodate certain types of tone controls, but others require still more amplification in order to perform correctly. The feedback placed around the first two stages eliminates the interstage coupling circuit as a location for tone controls, and in general, the amplifier is not suitable for this modification.

Added to this difficulty, some interest has been shown in the possibility of adapting the basic circuit to accommodate a dynamic noise-suppressor amplifier, and as a further incentive, one request was received for circuit data to permit the connection to a crystal cutter for use as a recording amplifier. In order to make the unit still more complete, it was decided to incorporate a low-level stage for use with a magnetic pickup of the Pickering or GE Variable Reluctance type.

The amplifier described in this article was accordingly designed and built as an answer to all these requirements. It is relatively complicated in construction—but only because it has a large number of components. The layout is straightforward, and the adjustments necessary to put the noise-suppressor section into operation are not difficult, *provided* an audio-frequency oscillator is available. One feature of this design is that it is sectionalized so that the basic amplifier may be constructed either with or without the noise suppressor, or it may be constructed without the preamplifier stage if it is to be used with an external preamplifier or with a crystal pickup. By so sectionalizing the design, it can be adapted readily for any specific requirement the user may wish.

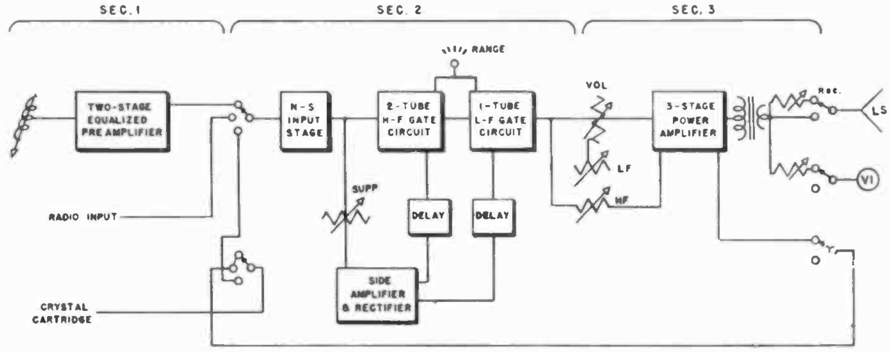


Fig. 1. Block diagram of sectionalized amplifier suitable for wide variety of uses.

Circuit Arrangement

The basic arrangement of the amplifier, reduced to its simplest form, is shown in the block diagram, *Fig. 1*. The power supply is omitted for the sake of simplicity. The first section includes the two-stage preamplifier, equalized by feedback to compensate for the low-end recording characteristic of commercial records. A three-position switch permits the selection of the desired input source—either phonograph, radio, or a recorder.

The second section is the dynamic noise-suppressor amplifier, which follows the H. H. Scott circuit (with some modifications lifted from the Goodell version of the original Scott amplifier). This section incorporates an input stage, providing a source impedance of the proper value, and enough gain to actuate the side amplifier which furnishes the control voltages. The input stage is followed by a two-tube high-frequency gate circuit and a single low-frequency gate circuit, together with the necessary control amplifier and rectifiers. The output of this section may then be fed directly into the output amplifier. This consists of three stages, essentially identical with the original 6AS7G amplifier. It employs a tapped volume control to provide an increase in low-frequencies which may be reduced at will by the low-frequency tone control, and a treble control which increases or decreases the high-frequency response as desired.

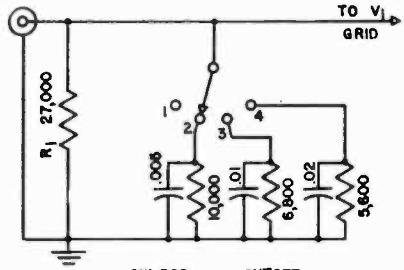
The output circuit contains switching arrangements which connect the speaker directly to the secondary of the output transformer for normal use, or through a variable resistor for monitoring, and which also connect a volume indicator and the recorder to the output stage during recording. Although the switching appears to be complicated in that it requires a number of operations to change from record to playback, such is not the case because of the use of a push-button switch which performs all of the switching operations quite simply.

The type of recorder used will control the switching circuits to a great extent. For the disc recorder unit used in this particular job, it is necessary to connect the crystal cartridge to either the input or the output of the amplifier. Most recorders employ a separate unit for playback, which simplifies this switching. It is desirable to connect the cutter of the disc recorder unit to the plates of the output tube through capacitors, giving a constant-amplitude characteristic over the entire range. With other crystal cutters, some series resistance should be employed to provide a characteristic which is similar to standard phonograph records. Low-impedance magnetic cutters will naturally be connected to a source of the correct impedance. Various arrangements for these connections are shown in *Fig. 7*.

The power supply section is conventional, with the exception of the d-c filament supply which is simply a connection between ground and the center tap of the high-voltage secondary through the heaters of the first two tubes, V_1 and V_2. Both of these tubes have 12-volt heaters, and they are connected in series. After the amplifier is completed, a value of bleeder resistor is selected which will make the total current drain equal 140 ma. It will be noted that this is slightly below the normal value, but the low-level stages operate perfectly with the lower current, and are somewhat less susceptible to the slight a-c component remaining in this supply. The amplifier is quite low in hum, but because of the large number of stages it is desirable to take all possible precautions.

Tone Control Methods

The methods of adding high- and low-frequency tone controls to the circuit are relatively simple. For general use in home reproduction systems, it is usually considered desirable to employ a tapped volume control so that when the output level is lowered, the frequency is altered somewhat in accordance with the Fletcher-Munson curve. A control with a single tap will not give complete compensation, but it is some improvement over an untapped control. The circuit used for this compensation consists of a



SW. POS.	CUTOFF
1	NONE
2	8,000 ~
3	5,600 ~
4	4,000 ~

Fig. 2. Input circuit for use with low-level magnetic pickups when noise-suppressor section is not employed.

resistor and capacitor connected in series between the tap on the control and the low end of the control, usually ground. If a potentiometer is connected across the capacitor, the amount of compensation is reduced as the shunting resistance is decreased. This serves quite adequately for the low-frequency control. For smoothest operation, the shunting potentiometer should have an audio taper, and should be connected so that clockwise rotation of the control increases the resistance across the capacitor, thus increasing the bass response. With a 1.0-meg volume control, the recommended resistor and capacitor values are 27,000 ohms and 0.01 μf. A 0.25-meg shunting potentiometer provides a smooth control of bass response.

In most amplifier designs, it is not considered desirable to utilize the feedback circuit for tone control purposes, since it reduces the amount of feedback available, and hence negates the beneficial effect of the feedback. This is particularly important in the case of a pentode amplifier, with feedback over the output and driver stages. However, with this amplifier the feedback is employed over only the driver and input stages, and its primary advantage is obtained over the low- and middle-frequency ranges because that is where the highest signal voltages are encountered. Therefore, with at least 20 db of feedback in use normally, it is felt that it will not affect the performance adversely if 10 db of this feedback is used up in the high-frequency tone control circuit. The signal voltage at high frequencies is comparatively low, and the driver stage will not be required to furnish as much signal voltage as at the middle and low frequencies.

Therefore, if a capacitor is shunted across the cathode resistor to which the feedback circuit returns, it will reduce the feedback at high frequencies, and thus increase the output. A potentiometer in series will permit variation of the amount of treble boost. If another capacitor in series with a potentiometer is connected across the entire volume control, the high frequencies may be reduced at will. Since highs will not be boosted and cut simultaneously, the two potentiometers can be combined so that clockwise rotation will increase highs and counterclockwise rotation will decrease highs. To make this circuit perform smoothly, the taper on the control must be the reverse of the standard audio taper. With these two potentiometers, a resistor, and the three capacitors, quite satisfactory tone controls for both bass and treble are provided.

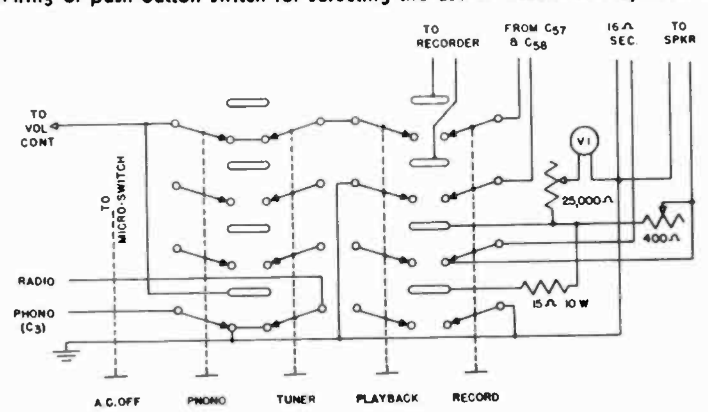
While some high-frequency cutoff is an advantage when reproducing phonograph records, no separate control is provided for this purpose since the dynamic noise suppressor section performs this function. It may be used simply as a controllable low-pass filter, with no dynamic action, or the suppressor control may be advanced so that the signals themselves control the opening of the gates. However, if the suppressor section is not included, it is suggested that a four-position switch be added, with the necessary resistors and capacitors, giving various cutoff frequencies. This is shown in *Fig. 2*, and was described in another article.[1] This control is not necessary if the noise suppressor section is included.

Construction Features

Since individual constructors will rarely choose the same components, a complete

[1] High-Frequency Equalization for Magnetic Pickups, by C. G. McProud, starting on bottom of page 48.

Fig. 3. Wiring of push-button switch for selecting the use to which the amplifier is to be put.



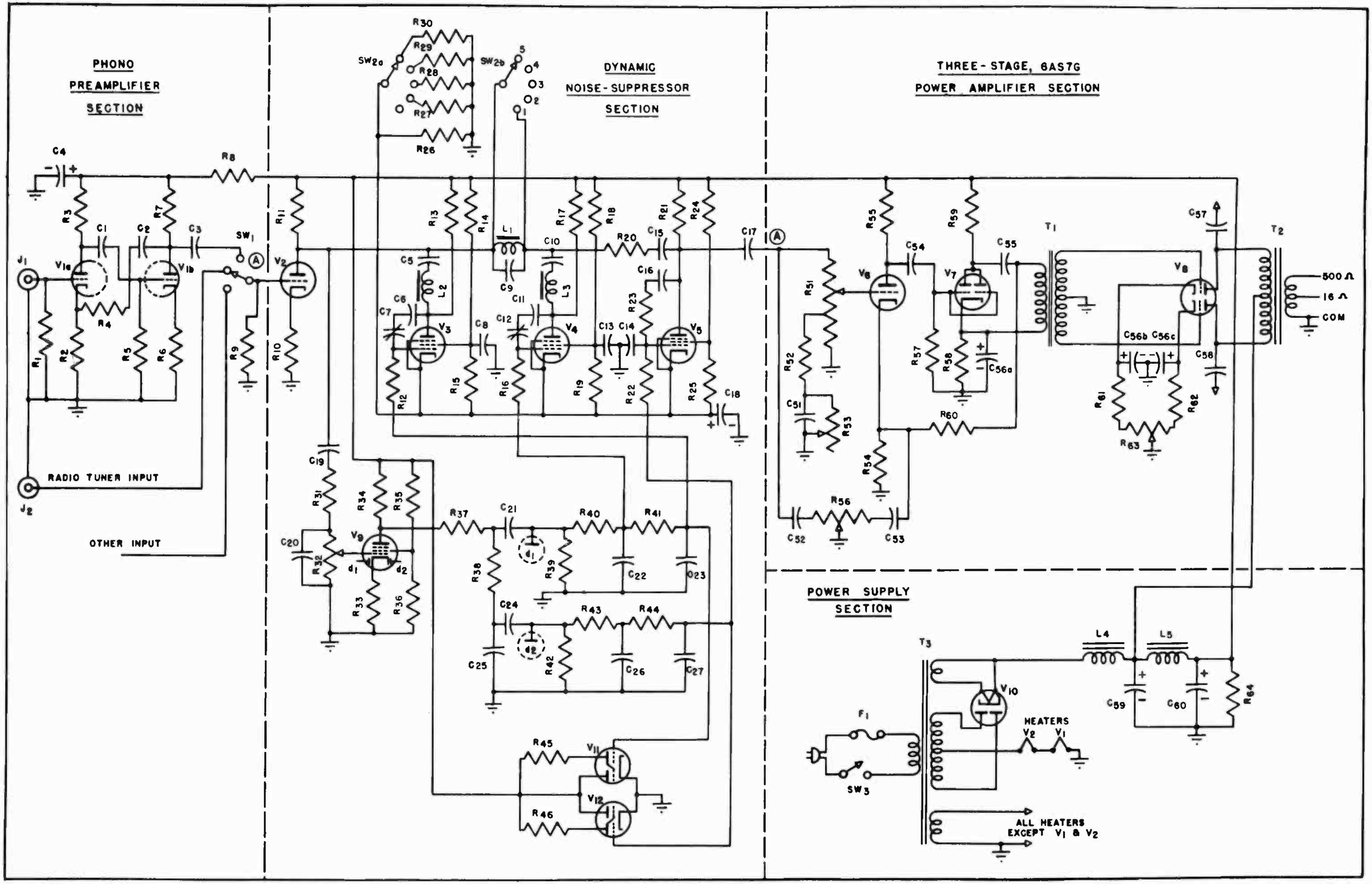


Fig. 5. Complete schematic for the sectionalized amplifier. By combining desired sections, practically any requirements may be met.

V_1—12SL7GT, V_2—12J5GT, V_3, V_4, V_5—6AB7, V_6—7A4 (6J5), V_7—6N7, V_8—6AS7G, V_9—7E7 (6B8), V_{10}—5V4G, V_{11}, V_{12}—6E5.

PARTS LIST

C_1, C_{22}, C_{23}, C_{26}, C_{27}, C_{51}, C_{53}—.01 μf, 600 v., paper.
C_2, C_{24}—.003 μf, mica.
C_3—.04 μf, 600 v., paper.
C_4, C_{59}, C_{60}—40 μf, 450 v., electrolytic.
C_5, C_6, C_{10}, C_{11}, C_{14}, C_{16}—.006 μf, mica.
C_7, C_{12}—7-45 $\mu\mu f$ adjustable, in parallel with 33 $\mu\mu f$ fixed mica.
C_8, C_{13}—.03 μf, 600 v., paper.
C_9—80 $\mu\mu f$ (select to resonate L_1 to 15,000 cps. approx).
C_{15}—.035 μf, 600 v., paper
C_{17}, C_{54}—0.1 μf, 600 v., paper.
C_{18}—100 μf, 50 v., electrolytic.
C_{19}—.002 μf, mica.
C_{20}, C_{21}—100 $\mu\mu f$, mica.
C_{52}—.001 μf, mica. C_{25} 500 $\mu\mu f$, mica.
C_{55}—2.0 μf, 600 v., oil filled.
C_{56}—40-40-20/150-150-25 electrolytic.
C_{57}, C_{58}—0.5 μf, 600 v., oil filled (omit if not for recording).

F_1—3 amp fuse in Littelfuse holder.

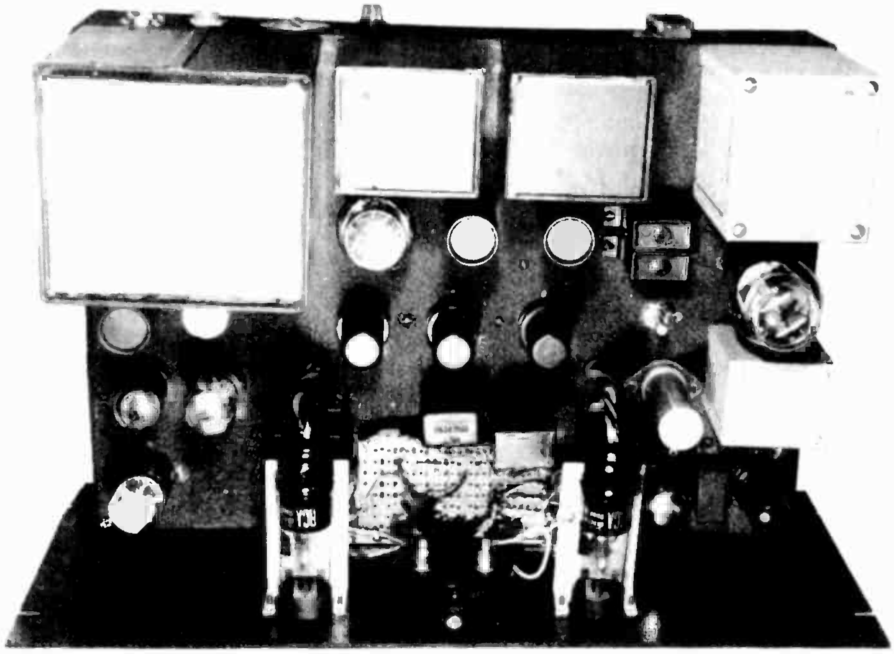
J_1—Phono pickup input.
J_2—Radio tuner input.

L_1—1.5 h
L_2, L_3—0.375 h
L_4, L_5—10 h, 200-ma power supply choke.

R_1, R_{52}—27,000 ohms, ½ w.
R_2, R_8—2,200 ohms, ½ w.
R_3, R_4, R_7—0.12 meg, 1 w.
R_5, R_9, R_{23}, R_{40}, R_{41}, R_{42}, R_{43}, R_{44}—1.0 meg, ½ w.
R_6—56,000 ohms, 1 w.
R_{10}, R_{54}—2,700 ohms, 1 w.
R_{11}—27,000 ohms, 1 w.
R_{12}, R_{16}—0.1 meg, ½ w.
R_{13}, R_{17}, R_{60}—0.22 meg, 1 w.
R_{14}, R_{18}, R_{24}, R_{34}, R_{55}, R_{59}—0.1 meg, 1 w.
R_{15}, R_{19}—22,000 ohms, 1 w.
R_{20}—18,000 ohms, 1 w.
R_{21}—0.47 meg, 1 w.
R_{22}—0.33 meg, ½ w.
R_{25}—10,000 ohms, 1 w.
R_{26}, R_{58}—2,200 ohms, 1 w.
R_{27}—470 ohms, ½ w.
R_{28}—330 ohms, ½ w.
R_{29}—220 ohms, ½ w.
R_{30}—68 ohms, ½ w.
R_{31}—0.27 meg, ½ w
R_{32}—1.0 meg, IRC D13-137, suppressor control.
R_{33}—560 ohms, ½ w.
R_{35}—0.33 meg, 1 w.
R_{36}—33,000 ohms, 1 w.
R_{37}, R_{38}—0.22 meg, ½ w.
R_{39}—3.9 meg, ½ w.
R_{45}, R_{46}—1.0 meg, ½ w. (in Amphenol MEA-6 socket)
R_{51}—1.0 meg, tapped for tone compensation, IRC D13-137X
R_{52}—27,000 ohms, ½ w
R_{53}—0.25 meg, bass tone control, IRC D13-130.
R_{56}—1.0 meg, treble tone control, IRC D14-137.
R_{57}—0.56 meg, 1 w.
R_{61}, R_{62}—1,750 ohms, 10 watts, Ohmite Brown Devil.
R_{63}—500 ohms, 4 watts, wire-wound control.
R_{64}—30,000 ohms, 20 watts, Ohmite Brown Devil.

SW_1—1 cct, 4 position, rotary switch, Centralab 1402 (or use push-button switch; see text).
SW_2—2 cct, 5 position, rotary switch, Centralab 1404.
SW_3—SPST toggle switch (or use push-button with Micro-Switch).

T_1—ADC 215C interstage transformer, turns ratio 1:3.
T_2—ADC 315F output transformer, 3,000/-500, 16, 8, 4, etc.
T_3—400-0-400, 200 ma 5 v. 3 a; 6.3 v. 6 a.



Top view of amplifier chassis.

layout of the chassis is not shown. The unit as built occupied a 12 x 17 x 3 chassis quite completely, and an 8 ¾-in. rack panel was used for the front. The power transformer and filter chokes were surplus items, but the table at the end of this article lists a number of possible transformer and choke selections which should be obtainable from regular stocks. While the first 6AS7G amplifier was constructed with broadcast quality ADC transformers, this one uses the industrial line which is somewhat less costly. Excellent results were obtained, however, and unless the highest possible quality of all components is desired, it is suggested that these are quite satisfactory. All other transformers shown in the table were selected from specifications, but it is expected that the results obtained would be about in proportion to the cost of the components.

In the interests of simplicity of operation, a push-button switch was chosen for the selector switch. Again resorting to surplus stocks, a switch was located which consists essentially of four separate 4pdt switches, with a fifth push button bar which actuated no switches, only releasing all other buttons. This switch was mounted just above the chassis with the bottons extending through the panel. A normally-closed micro-switch was mounted under the chassis, with a spring actuator extending upward through a slot and so positioned that the push-button bar causes the switch to operate when the button is depressed. Thus one position of the switch is marked "A.C. OFF," and the amplifier is turned off whenever this button is depressed. When any other button is pressed, the "off" button is released, and the power is turned on. The other four push buttons are wired for radio tuner, phono, playback, and recording. The wiring of the switch is shown in *Fig. 3*. One advantage of the push-button switch is that it permits connection to either radio or phonograph pickup as a source for recording simply by depressing two buttons simultaneously.

In order to maintain a proper recording level, it is desirable to incorporate a volume indicator in the amplifier. When used with a crystal cutter recording unit, the output transformer should be terminated with a resistive load and the cutter connected to the plates of the output tube through 0.5-μf capacitors. However, the recording level required—of the order of 30 volts—furnishes too high a level to the monitor speaker, so the switching is arranged to connect a 16-ohm terminating resistor across the secondary of the output transformer, and insert a 400-ohm rheostat in series with the voice coil. Thus it is possible to adjust the speaker volume to a de-

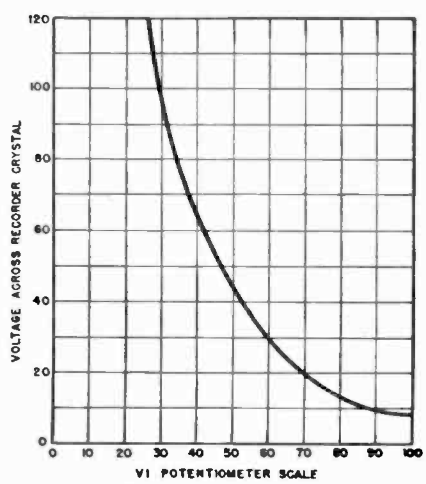


Fig. 4. Calibration of VI potentiometer for voltage across recorder head at zero indication

sirable level while maintaining the correct recording level to the cutter.

The volume indicator is a standard db meter, calibrated at 1.73 volts for zero indication. A 25,000-ohm potentiometer in series with the VI provides a control over the output level, with the calibration of the scale for this resistor being plotted on a curve, *Fig. 4*, so the desired output level may be obtained. The potentiometer used for this circuit is a grid-bias control, and while the curve is apparently reversed, it seems correct in use because the meter deflection is increased as the knob is turned clockwise.

From the photo of the amplifier, it will be noted that the panel is labeled quite profusely, giving a professional appearance. This is made possible by the new Tekni-Cals, which provide a wide range of identifying names. They are easy to apply, inexpensive, and of excellent appearance.

Adjustment of Suppressor

The circuit of the dynamic noise-suppressor amplifier is shown in the complete schematic, *Fig. 5*, and since the operation of this circuit has been described many times in the literature, no further mention of the principles underlying this section will be made here. It will be noted that it is practically identical to the Goodell amplifier, even to the physical layout of the schematic. In any discussion of this circuit, the coils have been described as rather critical, and of high Q. These will undoubtedly be difficult to obtain—one source of supply of 2.4 and 0.8 henry chokes used in one model of the suppressor being ADC, which supplies them under part numbers 414D and 414E respectively. One of the former and two of the latter would be required. Another source of suitable coils would be the UTC adjustable types, VI-CIO and CI-C12—again requiring two of the former and one of the latter. All of these types are very satisfactory for this unit. Another suitable coil, available in surplus at the time of construction, was found to have a measured inductance of approximately 1.5 H, and is center tapped, providing 0.375 H across either half. The half between terminals 1 and 2 has the higher Q, and should be employed for the inductances L_2 and L_3 while the entire coil is used for L_1. These are the coils used in the amplifier shown, and they work satisfactorily.

Once the complete amplifier is constructed, the alignment of the noise-suppressor section is not particularly difficult, but an a-f oscillator is essential. The value of the capacitor C_9 is specified, and is determined so as to resonate L_1 and C_7 at 15,000 cps. Some noise-suppressor amplifiers employ a variable or adjustable capacitor for this circuit, but the adjustment is not critical, and a calculated value is adequate if the value

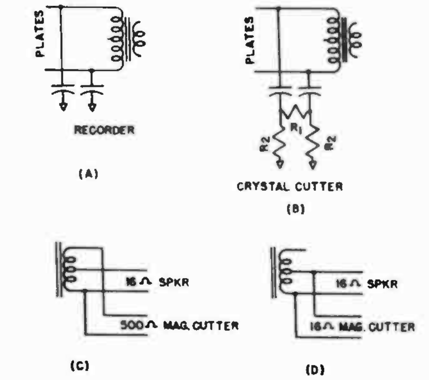


Fig. 7. Change in output wiring for feeding different types of recorders.

may be obtained with fair accuracy. With the switch SW_2 on position *2*, capacitors C_7 and C_{12} are adjusted for minimum signal at 9,000 cps, R_{32}—the suppressor control—being at the minimum position so there is no opening of the gates by the signal itself. Then, turning SW_2 to position *5*, check the frequency of mimimum output, which should be around 4,000 cps. Minor adjustments in the values of R_{18} and R_{19} may be employed to cause the circuits to "track" at 9,000 and 4,000 cps. Any change in the resistor values will necessitate returning of C_7 and C_{12}, so the work is of the nature of a "cut and try" process, but no trouble was experienced in adjusting the first model, so it is assumed that the work may be duplicated by a careful constructor with the assurance that the final unit will work as it should.

The time constants for the rectifier circuits are quite satisfactory as shown. Longer release times may be obtained by an increase in the values of R_{41} or C_{23} for the high-frequency gates, or of R_{44} or C_{27} for the low-frequency gate. The value of R_{31} may have to be adjusted for the individual amplifier. This should be such that with about three-quarters rotation of R_{32} the gates open and close with the applied signal. The average signal at the arm of Sw_1 will normally be around 1.5 volts, whether from a tuner or from a phonograph pickup. This will give adequate signal level to cause the side amplifier to operate with the resistor value given in the parts list. It may be stated safely that if the circuit values are followed accurately, the amplifier should perform in the normal manner for a noise suppressor.

Construction Hints

As with any high-gain amplifier, it is necessary to exercise normal care in shielding grid and plate circuits, especially where there are any long runs. This does affect the frequency response if carried to extremes, and minor compensation may be effected by the addition of a small capacitor across R_{44}. It is at this point that the high-frequency losses may be corrected if found necessary. However, with the parts layout shown in the photo, such compensation will probably not be necessary.

Because of the large number of wires in a circuit of this type, it is desirable to cable the wiring. This necessitates either of two procedures—a complete full-size wiring diagram may be made first and the individual wires laid in place using a forming board with finishing nails driven in at points where the cable makes a bend or where wires branch off. After all the wires are in place, the cable may be laced up. The other method appears to be simpler in that it does not require the full-size wiring diagram, but once the wiring is in place it is often difficult to form it into cables smoothly. In the long run it is easier to cable the wires outside of the chassis. After the lacing is completed, the form is put into place and the wires cut off at suitable lengths for connection to the sockets and other components. The form is then removed, the insulation stripped back, and the wires tinned. Then the form is replaced and connections made and soldered, a very rapid process after the initial cable forming is completed.

Measurements made on the complete amplifier indicate an output of 5 watts at 7 per cent intermodulation distortion, with frequency response curves as shown in *Fig. 6*. The upper curves show the effect of the high- and low-frequency tone controls with the volume control at one-third rotation and the suppressor range switch, SW_2, on position *1*. The lower curves show the response for positions, *2*, *3*, *4*, and *5* of the range switch and the suppressor control, R_{32}, off. Note that the amount of suppression increases as the range is narrowed, which is a desirable condition since the worst records necessitate a narrower transmission band as well as greater suppression outside the band.

POSSIBLE TRANSFORMER AND CHOKE SUBSTITUTIONS

Mfgr	T_1	T_2	T_3	L_4, L_5
ADC	215C*	315F*	515D	415D
ADC	214H†	314C†		
Chicago	BI-8	BO-9	PCC-200	RC-12200
Freed		F-1951	F-424A	F-633
Peerless	G-212-Q	S-240-Q	R-560-A	C-390-A
Stancor	WF-28	HF-65	P-6165	C-1646
Thordarson	T-20A23	T-22S72	T-22R34	T-20C55
Triad	HS-25	HS-84	HS-215	HS-315
UTC	LS-21	LS-55	LS-70	LS-92

† original specification for 6AS7G amplifier * as employed

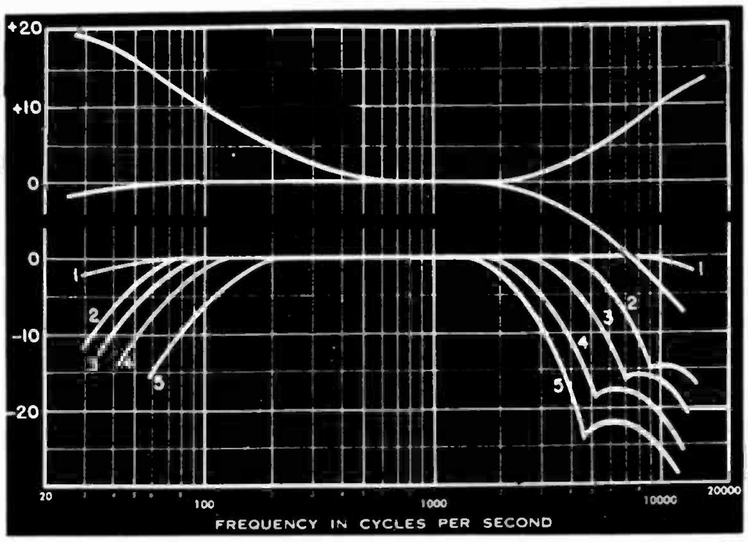


Fig. 6. Frequency response curves (upper) effect of tone controls; (lower) effect of noise suppressor in various positions of range switch.

Adaptation of Sections

Since this amplifier is laid out so as to be flexible in construction, it may be well to indicate the various arrangements possible. The simplest arrangement consists of the preamplifier and the output section, which simply omits the center portion of the circuit, connection being made between points "A." This provides sufficient amplification for use with a low-level magnetic pickup and furnishes the tone controls desired by most users. The high-frequency cutoff for the pickup should be added in the form of the circuit of *Fig. 2* across R_1.

When desired for use with an ordinary crystal cutter, the wiring of the output circuit and the feed for the recorder should be modified as shown at (B) of *Fig. 7*. (C) and (D) show connections for 500-ohm and 16-ohm magnetic cutters respectively. The wiring of the complete output circuit for feeding the recorder is shown in *Fig. 3*, complete with VI and speaker circuit wiring.

If the previous 6AS7G amplifier has already been built, the first two sections may be connected to the output section with results similar to those obtained with the complete single-unit amplifier.

Conclusion

Although the parts list specifies the transformers and chokes employed in the amplifier as built, some substitutions may be desirable, depending upon availability of parts. Therefore, the table shows a number of components which should perform similarly.

Assuming the use of good components throughout, this amplifier should give completely satisfactory performance for the record enthusiast or for the home recorder. The output power is not sufficient for use with professional disc cutters, but reasonably satisfactory results may be obtained with the better quality of either magnetic or crystal cutters, assuming that the correct coupling circuits are used between the transformer and the magnetic types gf cutters. For ordinary reproduction of records or of radio programs, this amplifier will be found to answer most of the requirements of critical listeners.

Tubeless Hi-Fi Tuner

High-fidelity addicts will remember the Western Electric 10A Radio Receiver as, for its time, one of the best from the standpoint of quality but it was not commercially available to the home user. The circuit of this tuner was simplified and appeared on the market as a wide range unit, employing a four-gang capacitor and a total of eight coils (two of them untuned) and three or four tubes. Having a wide pass band, it was useful only in close proximity to radio stations, and the sensitivity was not very great for this reason. However, the audio quality was excellent, and there are many of these wide-range tuners still in use.

Utilizing the same circuit principles, a new tuner has recently appeared which serves practically the same purpose. It is broad, and thus suffers from no side-band cutting; it has low sensitivity, which is desirable for tuners of this type; and it has remarkable audio quality. The circuit of the tuner is shown in *Fig.* 1, and it will be seen to consist of two antenna coils essentially back-to-back, with a two-gang tuning capacitor and a negative-mutual coupling coil (EL-56 on the schematic). The 1N34 Germanium diode serves as the detector, with the signal being developed across the resistor.

This tuner is designed for use in metropolitan areas where there are likely to be a number of radio stations within a radius of 20 to 25 miles, and when used with a good antenna from 75 to 100 feet in length will give an audio output ranging from .05 to 0.5 volts. Even with a shorter antenna, satisfactory results are obtained with an output of less than .001 volts, providing the signal is fed into a high-impedance microphone input channel of a high-quality amplifier.

The coils specified for this tuner are the products of J. W. Miller Co. of Los Angeles, and while a complete kit is available—consisting of the coils, tuning capacitor, slide-rule dial, and chassis—it is possible to assemble the tuner with any desired chassis and capacitor, provided it covers the tuning range. For satisfactory results, it is necessary that high-Q coils be employed, and this requirement is fulfilled by the 242-A coils specified.

Fig. 1.