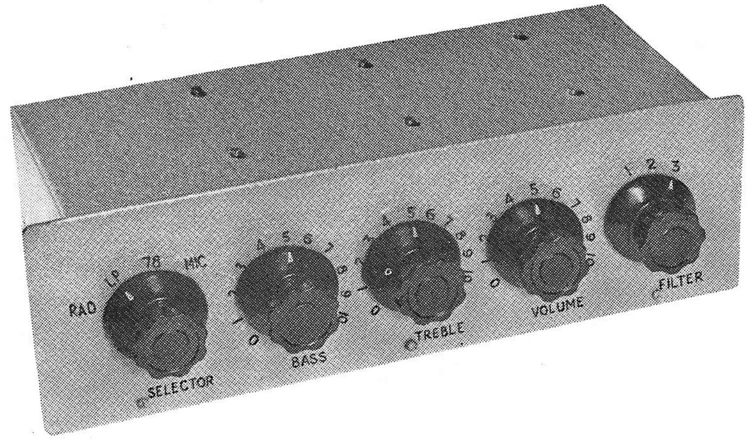
Mullard

PRE-AMPLIFIER CIRCUIT DESIGN

FOR THE 20 WATT HIGH QUALITY AMPLIFIER



The circuit described in this article was designed primarily for use with the 20-watt high-quality amplifier described in last month's issue of this journal[1]. The pre-amplifier requires a line voltage of 250V at 3.0 mA and may be used with high-quality amplifiers requiring not more than 200-250 mV input, at high impedance, for full rated output. The circuit employs three Mullard EF86 high-gain low-hum pentodes and offers a maximum pickup sensitivity of 3.5-4 mV for 200 mV output. Provision is made for continuously variable tone control, playback equalization and high- and low-pass filtering.

Performance.—An output of approximately 200 mV from the pre-amplifier will fully load the 20-watt amplifier to its rated output.

The total harmonic distortion at 400 c/s on any switch position for 200 mV output is not more than 0.1%. Since the gain control is at the output of the pre-amplifier the overload characteristic is the overall figure for the whole pre-amplifier, and at 20-db overload, i.e., for an output voltage of approximately 2V, the total harmonic distortion for any switch position is not more than 0.2%.

Intermodulation distortion was measured by the S.M.P.T.E.† method at 40 c/s and 10 kc/s through the combination of the pre-amplifier and the power amplifier[1], due to the difficulties encountered when making such critical measurements at low levels on the pre-amplifier alone. With the gain control fully advanced and 20 watts equivalent sine-wave power output the intermodulation distortion was not more than 1%. With 20 db overload in the pre-amplifier, and the gain control set for 20 db attenuation in order to produce 20 watts equivalent sine-wave power output, the intermodulation distortion was not more than 3%. The intermodulation of the power amplifier alone at this level was found to be 0.7%. When measurements are made on positions which involve playback equalization it is necessary to weight incoming signals, due to the differing sensitivities at 40 c/s and 10 kc/s, to obtain the correct ratio through the pre-amplifier.

Background noise was measured on all switch positions and input sockets under practical conditions, which are stated in the summary of performance, and is referred to the nominal input sensitivity, since this is the most general way of stating the signal-to-background ratio. Since the gain control is at the output of the pre-amplifier it follows that the stated signal-to-background ratio will be maintained at all settings of the gain control.

Layout.—Considerable thought has been given to layout, since many difficulties may be encountered when working at such high sensitivity and the proposed layout was found to be very suitable from all considerations. In general with pre-amplifier circuits it is essential to adhere closely to the suggested layout if the published performance is to be obtained in practice. The components and sections of the pre-amplifier have been arranged in logical sequence as far as is compatible with satisfactory performance.

In order to obtain the required line voltage of 250V in conjunction with the 20-watt power amplifier[1], it is necessary to arrange that a 56 kΩ resistor, decoupled by at least 8 μF, is introduced to drop the available voltage (410V) at the power amplifier.

Input Stage.—Four input sockets are provided, one for radio and equalized tape, two for pickups and one for microphone, the basic sensitivity for each position being arranged by anode-to-grid feedback. The input is selected by switch SA1. The basic sensitivity of the pickup input is employed to make it possible to use pickups of sensitivities 3-6 mV on socket PU1 and suitable attenuation is introduced to facilitate the use of magnetic

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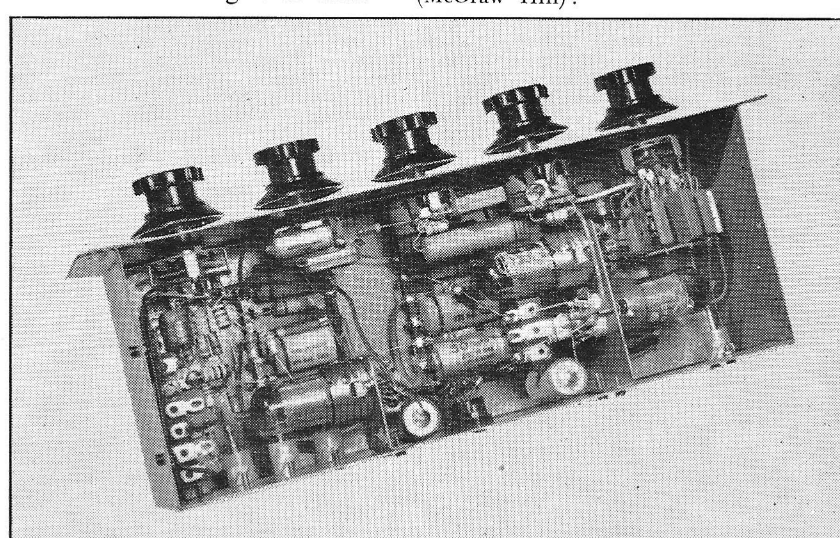
† Society of Motion Picture and Television Engineers. See also "Electronic Measurements" by Terman and Pettit (McGraw Hill).



pickups and good-quality crystal pickups on socket PU2. The crystal pickup must be loaded suitably for output proportional to stylus velocity. By using a large proportion of the full gain of the first stage a microphone input sensitivity of 1.5 mV is obtained. The sensitivity for radio/tape input is basically 30 mV but has been attenuated to 100 mV in the circuit.

V2 and Tone Control.—V2 in Fig. 1 is employed as a convenient method of obtaining sufficient amplification to overcome the loss of the passive tone control which is included in the circuit. At the same time the use of anode-to-grid feedback offers a comparatively low source impedance and therefore has little or no effect on the tone control stage. The resistor R_{20} in the grid of V2 minimises interaction between this stage and the input stage due to the inherent variation of impedance with anode-to-grid feedback.

The tone control stage was designed specifically to employ potentiometers which follow a logarithmic law, with 10% of maximum resistance at 50% rotation. It will be found convenient in practice to arrange that each potentiometer has a resistance, between slider and the earthy end, of 25 kΩ when the indication knob is at 50% rotation. Provided all the components of the stage are within the stated tolerances the "flat" position should be obtained very close to the 50% rotation position of the bass and treble controls. The curves in Fig. 2 show the tone control characteristics with the filter at Position 3, the "flat" position. The curves include the action of the high-pass filter.

Filters and V3.—When considering the choice of frequencies to be employed for low-pass filtering it was thought that a minimum number should be employed to preserve a certain measure of simplicity, whilst still maintaining a useful choice. Position 3 of switch SB is known as the "flat" position and limits the frequency response above 20 kc/s. Peak amplitude components beyond 20 kc/s are frequently contained in the output of wide-range pickups and may be greater than these below 20 kc/s. These inaudible components can introduce distortion or unnecessary limiting of available output power. Position 2 attenuates frequencies above 10 kc/s and is envisaged as being useful to curtail the effects of high-frequency distortion due to the input signal. Crystal pickups do not extend in frequency response much above 10 kc/s and at present the f.m. transmissions are not in general modulated above 10 kc/s; consequently this position may also be used to advantage under these conditions. Position 1 attenuates frequencies above 5 kc/s and is not intended for use with microgroove records but is intended to enhance reproduction of standard shellac records with inherently high-surface noise. By the use of R-C filtering and feedback[2] an attenuation is obtained at these frequencies of not less than 12 db/octave. A high-pass, or rumble, filter has been introduced into this stage to attenuate frequencies below 35 c/s, at a slope of not less than 12 db/octave, in order to obviate the possibility of sub-audio frequencies overloading the system, and to cut motor rumble.

Output.—The 100 kΩ logarithmic gain control is an integral part of the output stage, since it is part of the feedback arm, and since the output is taken from this point it is of comparatively low impedance. The output of the pre-amplifier, however, should not look into an impedance less than 1 MΩ. It was found, in fact, that a capacitance of 400 pF could be placed across the output, with the gain control fully advanced, with negligible loss of output at 15 kc/s. This means in practice, for instance, 20 ft. of coaxial cable of capacitance 20 pF/ft.

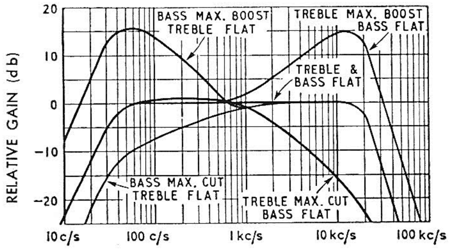


Fig. 2. Tone control frequency response characteristics.

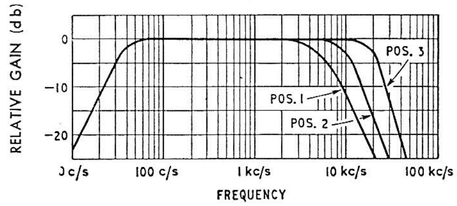


Fig. 3. Response with high-pass and low-pass filters.

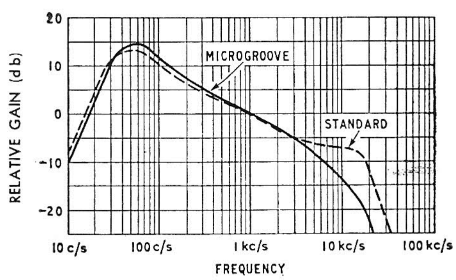
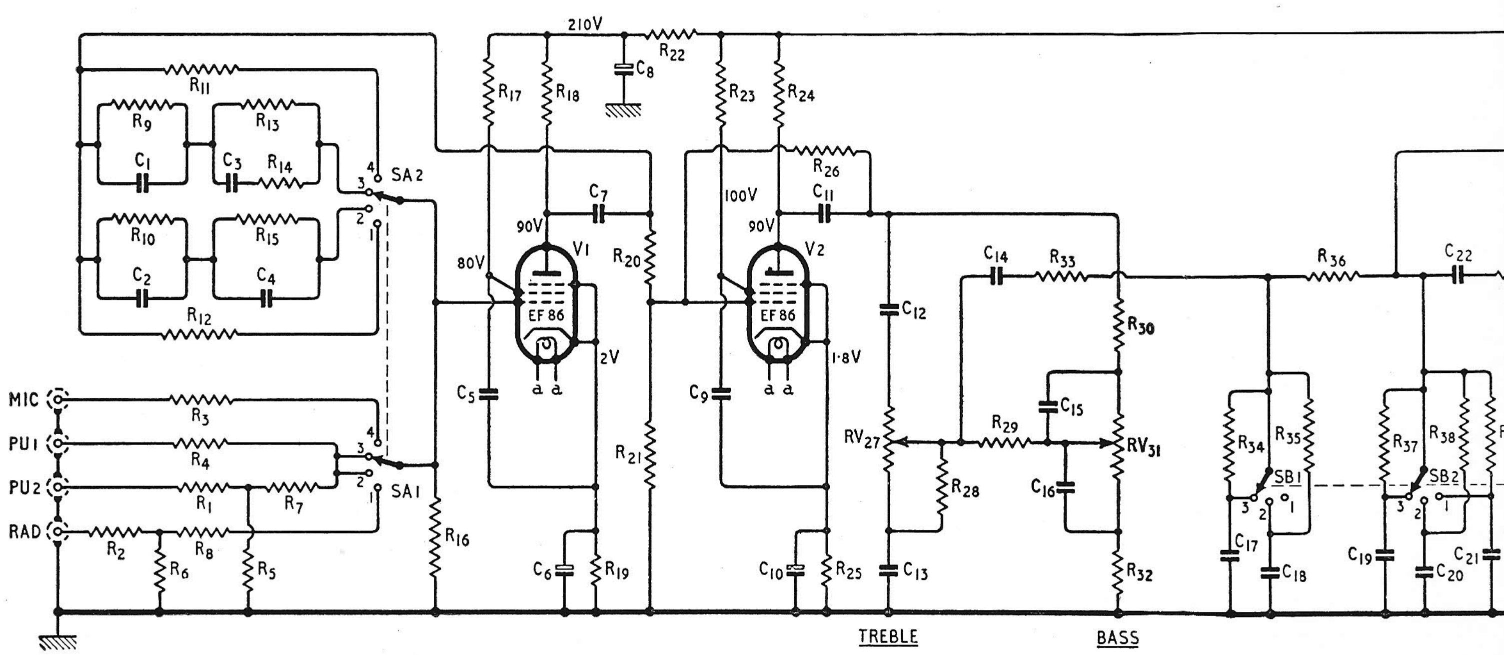


Fig. 4. Record playback characteristics adopted in the pre-amplifier.



Playback Equalization.—Consideration of the utility of providing a number of playback characteristics resulted in a decision to use only one characteristic for microgroove and one for standard records. This departure from conventional design was decided not only from the point of view of a considerable saving in components but also from the fact that the majority of record manufacturers are recording nominally to the R.I.A.A.[3] characteristic for microgroove recordings, and those remaining are sufficiently close to make it possible to compensate for the difference by judicious use of the wide-range tone controls available. The microgroove playback characteristic employed in this circuit is based upon the R.I.A.A. playback curve, but below 1 kc/s is slightly different to the extent of providing closer approach to a mean curve encompassing earlier recording characteristics. The standard playback characteristic is based upon the suggested E.M.I. playback characteristic,[4] but is modified above 1 kc/s to provide additional cut to offset slightly the inherently higher noise level of standard recordings.

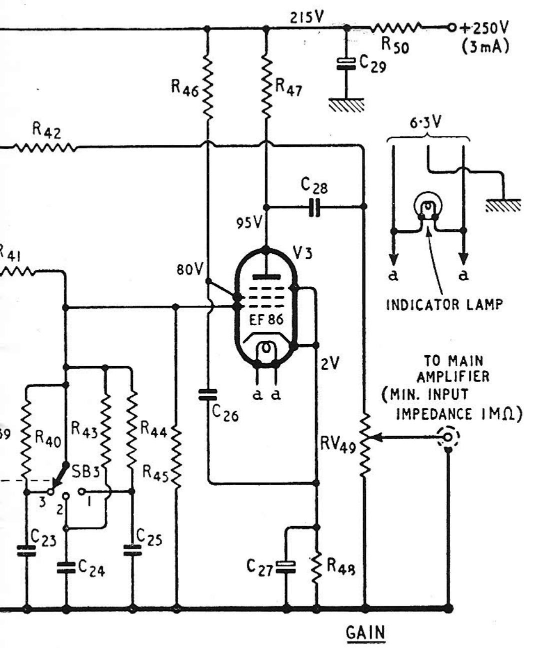
Acknowledgment. — The author wishes to express his thanks to Mr. W. A. Ferguson for his assistance in designing the pre-amplifier and for his constructive criticism in the preparation of this article.

1 "Design for 20-Watt High Quality Amplifier," by W. A. Ferguson, "Wireless World," June, 1955.

2 "Gramophone and Microphone Pre-amplifier," by P. J. Baxandall, "Wireless World," January, 1955.

3 Record Industry Association of America, Inc., "Radio Electronics," May, 1954, p. 63.

4 "The Pursuit of High Fidelity," booklet by E.M.I., Ltd.



SUMMARY OF PERFORMANCE

Sensitivity (220 mV output at 1 kc/s)

Radio/Tape	Input Impedance 100 kΩ	100 mV
PU1 LP	Input Impedance 100 kΩ	4.0 mV
PU1 78	Input Impedance 100 kΩ	5.0 mV
PU2 LP	Input Impedance 100 kΩ	50 mV
PU2 78	Input Impedance 100 kΩ	60 mV
Microphone	Input Impedance 1 MΩ	1.5 mV

Distortion

Total harmonics better than 0.1% on all positions at approximately 200 mV output.

Total harmonics better than 0.2% on all positions at approximately 2 V output.

Intermodulation: see text.

Filters

Low pass at 5 kc/s, 10 kc/s and 20 kc/s, cut off better than 12 dB/octave.

High pass at 35 c/s, cut off better than 12 dB/octave.

Background Noise

Radio/Tape input socket loaded with 100 kΩ:—64 dB.

PU1 input socket short-circuited (PU2 o/c) L.P.:— (— 53 dB).

PU1 input socket short-circuited (PU2 o/c) 78:— (— 54 dB).

PU2 input socket loaded with 50 kΩ (PU1 o/c) L.P.:— (—55 dB).

PU2 input socket loaded with 50 kΩ (PU1 o/c) 78: —(— 56 dB).

Microphone input socket short-circuited:— (— 45 dB).

CIRCUIT VOLTAGES

Testing Point	D.C. Voltage (V)	Meter Range
C_{29}	215	1000 V d.c.
C_8	210	1000 V d.c.
Anode V3	95	1000 V d.c.
Screen grid V3	80	1000 V d.c.
Cathode V3	2	10 V d.c.
Anode V2	90	1000 V d.c.
Screen grid V2	100	1000 V d.c.
Cathode V2	1.8	10 V d.c.
Anode V1	90	1000 V d.c.
Screen grid V1	80	1000 V d.c.
Cathode V1	2	10 V d.c.

The voltages were measured with a Model 8 "Avometer" (20,000Ω/Volt) with zero input signal.

Power Supply

High tension	250 V at 3 mA
Heaters	centre tapped 6.3 V at 0.6 A.

LIST OF COMPONENTS

Valves

Mullard EF86 (three).

Switches

SA 2-pole 4-way make-before-break wafer switch.

SB 3-pole 3-way make-before-break wafer switch.

Indicator Lamp

6.3 V, 0.04 A.

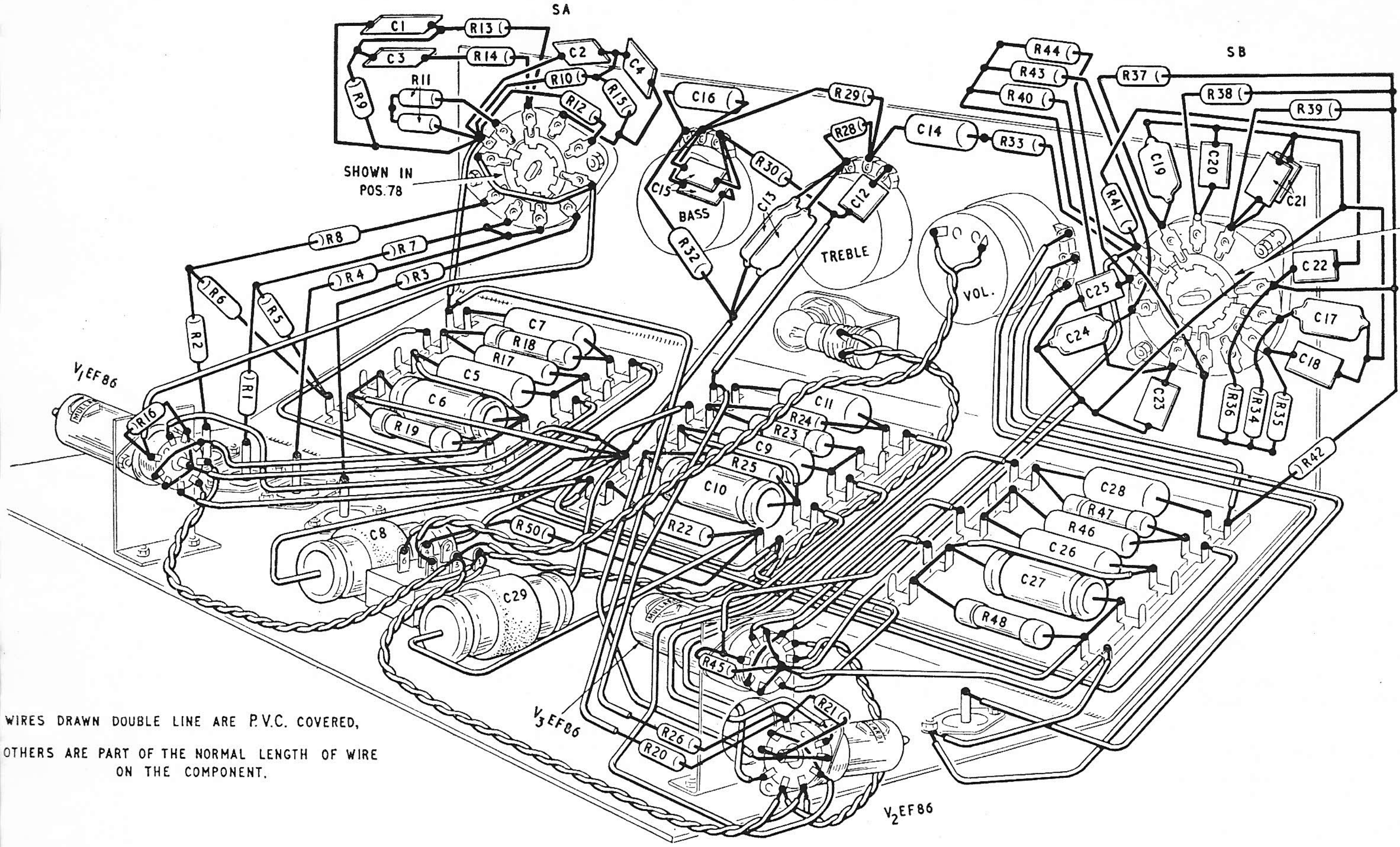
Resistors

R_1	82kΩ	10%	0.25W
R_2	68kΩ	10%	0.25W
R_3	680kΩ	10%	0.25W
R_4	82kΩ	10%	0.25W
R_5	8.2kΩ	10%	0.25W
R_6	27kΩ	10%	0.25W
R_7	82kΩ	10%	0.25W
R_8	100kΩ	10%	0.25W
R_9	5.6MΩ	5%	0.25W
R_{10}	6.8MΩ	5%	0.25W
R_{11}	20MΩ	5%	0.25W
R_{12}	120kΩ	5%	0.25W
R_{13}	680kΩ	5%	0.25W
R_{14}	390kΩ	5%	0.25W
R_{15}	680kΩ	5%	0.25W
R_{16}	2.2MΩ	10%	0.25W
R_{17}	1.5MΩ*	10%	1W
R_{18}	270kΩ*	10%	1W
R_{19}	3.9kΩ*	10%	1W
R_{20}	220kΩ	10%	0.25W
R_{21}	470kΩ	10%	0.25W
R_{22}	18kΩ	10%	0.25W
R_{23}	470kΩ*	10%	1W
R_{24}	100kΩ*	10%	1W
R_{25}	1.2kΩ*	10%	1W
R_{26}	8.2MΩ	10%	0.25W
RV_{27}	250kΩ	logarithmic (10% law)	
R_{28}	47kΩ	10%	0.25W
R_{29}	39kΩ	10%	0.25W
R_{30}	68kΩ	10%	0.25W
RV_{31}	250kΩ	logarithmic (10% law)	
R_{32}	6.8kΩ	10%	0.25W
R_{33}	82kΩ	5%	0.25W
R_{34}	10MΩ	20%	0.25W
R_{35}	10MΩ	20%	0.25W
R_{36}	68kΩ	5%	0.25W
R_{37}	10MΩ	20%	0.25W
R_{38}	10MΩ	20%	0.25W
R_{39}	10MΩ	20%	0.25W
R_{40}	10MΩ	20%	0.25W
R_{41}	47kΩ	5%	0.25W
R_{42}	820kΩ	5%	0.25W
R_{43}	10MΩ	20%	0.25W
R_{44}	10MΩ	20%	0.25W
R_{45}	470kΩ	5%	0.25W
R_{46}	1.5MΩ*	10%	1W
R_{47}	270kΩ*	10%	1W
R_{48}	3.9kΩ*	10%	1W
RV_{49}	100kΩ	logarithmic (10% law)	
R_{50}	12kΩ	10%	0.25W

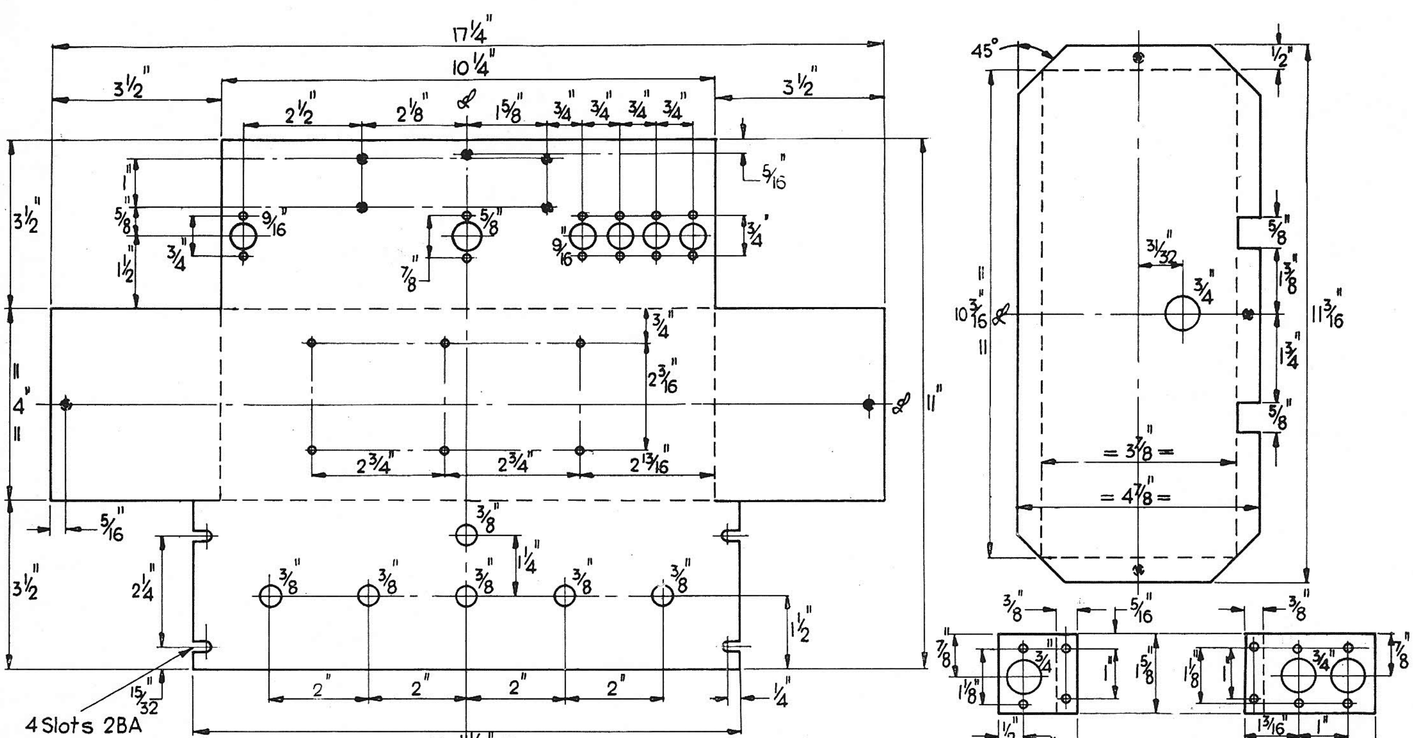
Capacitors

C_1	820pF	Silver mica	5%
C_2	470pF	Silver mica	5%
C_3	120pF	Silver mica	5%
C_4	120pF	Silver mica	5%
C_5	0.1μF	Paper	350 V d.c. wkg.
C_6	50μF	Electrolytic	12 V d.c. wkg.
C_7	0.1μF	Paper	350 V d.c. wkg.
C_8	8μF	Electrolytic	350 V d.c. wkg.
C_9	0.1μF	Paper	350 V d.c. wkg.
C_{10}	50μF	Electrolytic	12 V d.c. wkg.
C_{11}	0.1μF	Paper	350 V d.c. wkg.
C_{12}	560pF	Silver mica	5%
C_{13}	8200pF	Silver mica	5%
C_{14}	0.05μF	Paper	150 V d.c. wkg.
C_{15}	2200pF	Silver mica	5%
C_{16}	0.02μF	Paper	150 V d.c. wkg.
C_{17}	180pF	Silver mica	5%
C_{18}	270pF	Silver mica	5%
C_{19}	180pF	Silver mica	5%
C_{20}	470pF	Silver mica	5%
C_{21}	1800pF	Silver mica	5%
C_{22}	820pF	Silver mica	5%
C_{23}	220pF	Silver mica	5%
C_{24}	390pF	Silver mica	5%
C_{25}	560pF	Silver mica	5%
C_{26}	0.1μF	Paper	350 V d.c. wkg.
C_{27}	50μF	Electrolytic	12 V d.c. wkg.
C_{28}	0.01μF	Paper	350 V d.c. wkg.
C_{29}	8μF	Electrolytic	350 V d.c. wkg.

* High-stability carbon, 10% or better



Point-to-point wiring diagram for pre-amplifier to 20-watt amplifier.



Note: Bend up on dotted lines 90°
All holes not indicated 6BA

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