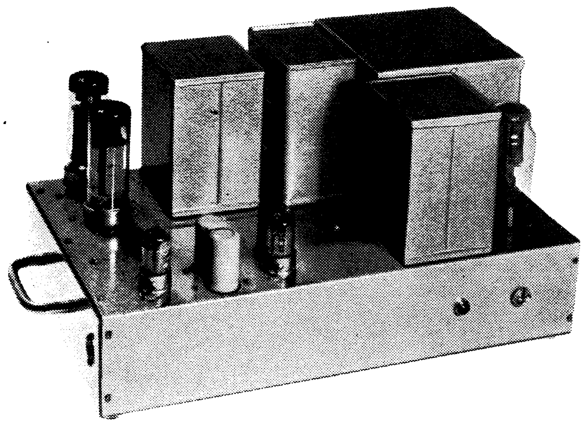
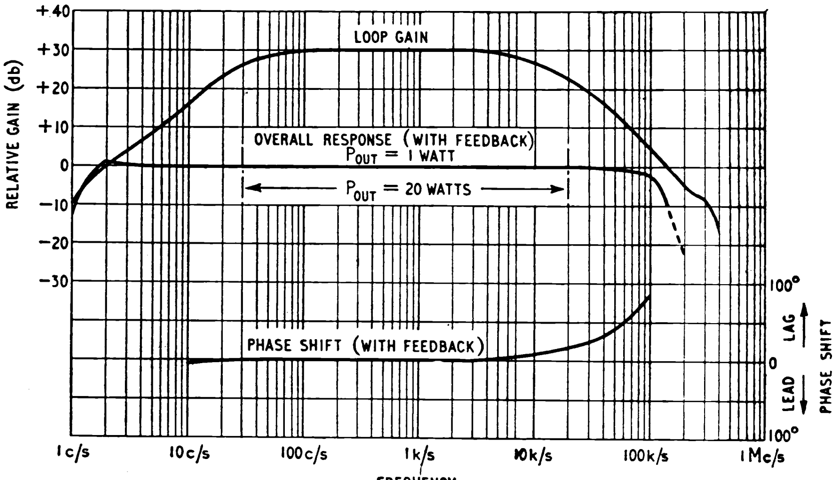
Mullard

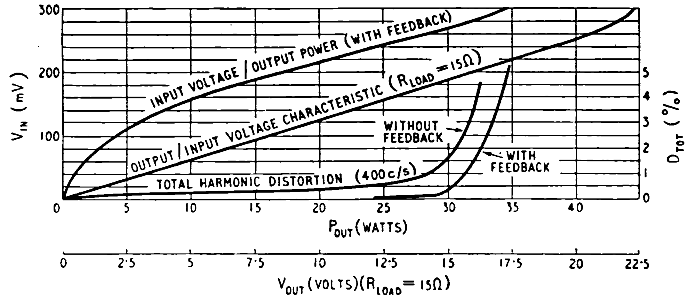
THE 5-VALVE 20-WATT HIGH QUALITY AMPLIFIER



General view of top of prototype 20-watt amplifier.



Loop gain and frequency response and phase shift characteristics with feed-back.



Harmonic distortion and input/output characteristics of prototype.

GENERAL

With amplifiers designed to handle power outputs greater than 12 to 15 watts and in which low-distortion operation towards peak power output is still required, the use of distributed load operation with valves of the 25-watt anode dissipation class is of particular interest. By using this method of valve loading the effective power output of a low-distortion triode push-pull stage (approximately 12 watts) can be raised to 30 to 35 watts whilst the benefits of low inherent distortion and relatively low output impedance are well maintained.

This article describes a design for a high-quality amplifier of 20 watts rated output in which distributed load conditions are used for the 6CA7/EL34 valves in the output stage. The amplifier is intended to allow of the highest standard of sound reproduction when used in association with suitable pre-amplifier circuits, high-grade pickups and loudspeaker systems. A summary of the overall performance of the amplifier is given in Table 1.

The circuit arrangement is basically similar, except for the output stage, to that used in the Mullard 5-valve 10-watt high-quality amplifier design in that the output stage is driven from a cathode-coupled twin-triode phase-splitting amplifier which is in turn preceded by a high-gain voltage amplifier stage. The first stage in the amplifier is d.c. coupled to the phase splitter in order to minimise low-frequency phase shifts. The main feedback loop includes the whole circuit, the feedback voltage being derived from the secondary of the output transformer and injected in the cathode circuit of the first stage.

OUTPUT STAGE

The main feature of interest in the output stage is the use of the Mullard 6CA7/EL34 high-slope output pentode with partial screen-grid loading, the screen grids being fed from taps on the primary of the output transformer. Measurements during the course of design showed that optimum conditions are obtained in this form of output stage when about 43% of the primary winding of the output transformer is common to anode and screen grid circuits.

The anode-to-anode loading of the output stage is 6.6kΩ and, with a feed voltage of 440 at the centre-tap of the output transformer primary the combined anode and screen-grid dissipation of the output valves is 28 watts per valve. With the particular screen-grid to anode load ratio used, it has been found that improved linearity is obtained at power levels above 15 watts when resistors of the order of 1,000Ω are inserted in the screen-grid feeds. The slight reduction in peak power-handling capacity which results is not significant in practice. Separate cathode-bias resistors are used to limit the out-of-balance d.c. current in the output transformer primary and the use of further d.c. balancing arrangements in the output stage has not been considered necessary.

TABLE 1

Summary of Performance of Prototype Amplifier

Power output:
20 watts minimum from 30 c/s-20 kc/s.

Power response:
within 0.5 db of 1 kc/s level at 20 watts over range 30 c/s-20 kc/s.

Frequency response (1 watt level):
within 1 db of 1 kc/s level 2 c/s-100 kc/s.

Harmonic distortion (400 c/s):
$<$0.05% at 20 watts.

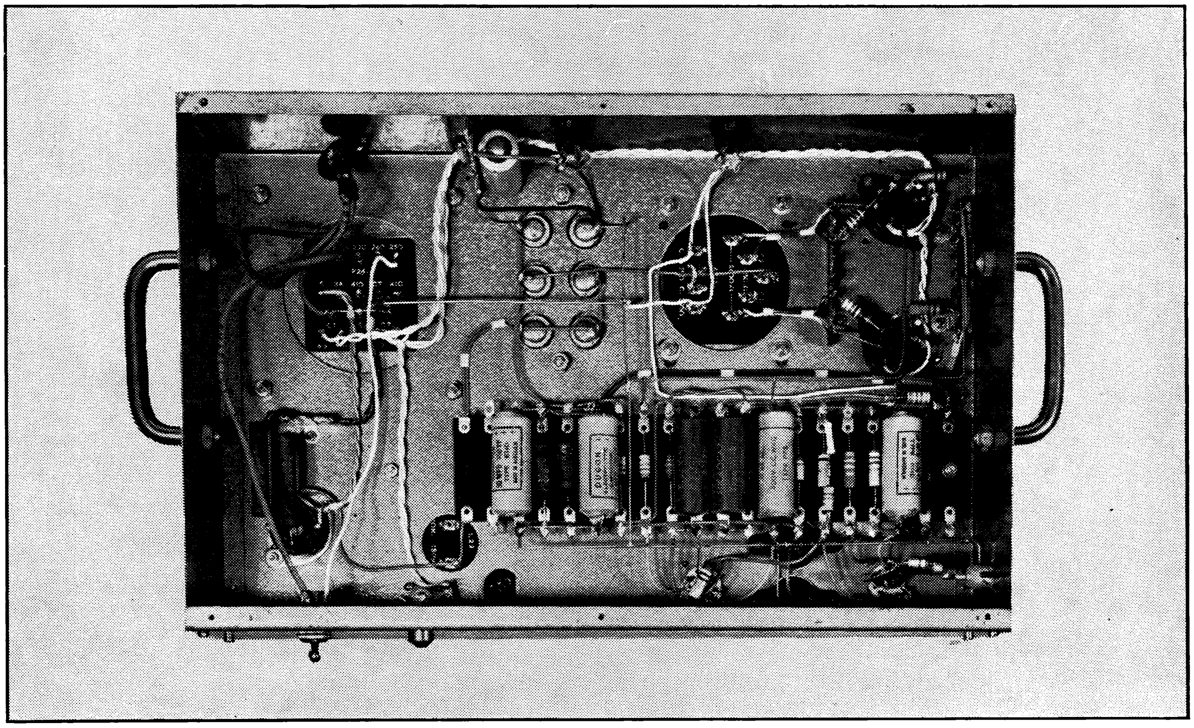
Intermodulation distortion (40 c/s, 10 kc/s; ratio 4:1):
0.7%, with peak corresponding to 20 W sine-wave power.
1.0%, with peak corresponding to 29 W sine-wave power.

Hum and noise:
−89 db relative to 20 W with 10-kΩ source resistance.

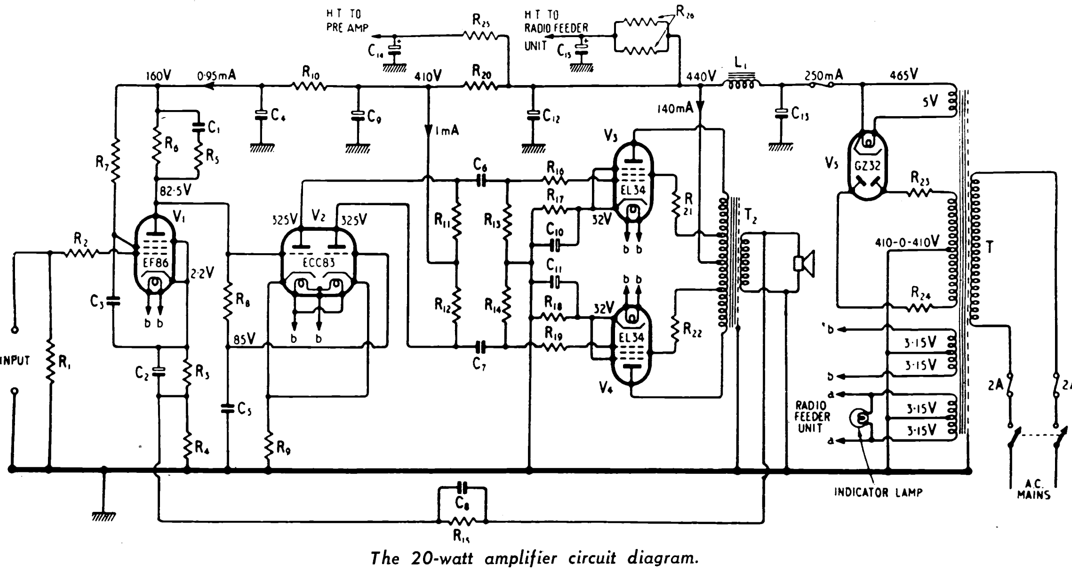
Sensitivity:
220 mV for 20 W output.

Phase shift:
10° maximum at 10 c/s.
20° maximum at 20 kc/s.

Output impedance:
approximately 0.3 Ω at 40 c/s, 1 kc/s and 20 kc/s at 20 watts output.



Underside of chassis showing one possible grouping of the smaller components.



The 20-watt amplifier circuit diagram.

LIST OF COMPONENTS

R_1 1 MΩ ¼ watt ±20%
R_2 4.7 kΩ ¼ watt ±20%
R_3 2.2 kΩ* ±10%
R_4 100Ω* ±5%
R_5 4.7 kΩ ¼ watt ±10%
R_6 100 kΩ* ±10%
R_7 390 kΩ* ±10%
R_8 1.0 MΩ ¼ watt ±20%
R_9 82 kΩ ½ watt ±10%
R_{10} 270 kΩ ½ watt ±10%
R_{11} 180 kΩ† ½ watt ±10%
R_{12} 180 kΩ† ½ watt ±10%
R_{13} 470 kΩ‡ ¼ watt ±10%
R_{14} 470 kΩ‡ ¼ watt ±10%
R_{15} 8.2 kΩ* (15-Ω load) ±5%
R_{16} 2.2 kΩ ¼ watt ±20%
R_{17} 470Ω 3 W min ±5%
R_{18} 470Ω 3 W min ±5%
R_{19} 2.2 kΩ ¼ watt ±20%
R_{20} 15 kΩ ½ watt ±20%
R_{21} 1 kΩ ½ watt ±10%
R_{22} 1 kΩ ½ watt ±10%
R_{23}, R_{24} { May be required for voltage control depending on mains transformer.
R_{25} 56 kΩ 1 watt ±10%
R_{26} = 6 kΩ made of two 12 kΩ 6 watt resistors in parallel ±20%
C_1 47 pF ±10%
C_2 50 μF 12 V wkg.
C_3 0.05 μF 350 V wkg.
C_4 8 μF 450 V wkg.
C_5 0.25 μF 350 V wkg.
C_6 0.5 μF 350 V wkg.
C_7 0.5 μF 350 V wkg.
C_8 220 pF (15-Ω load) ($C_8 R_{15} = 1.8\ \mu$ sec)
C_9 8 μF 450 V wkg.
C_{10} 50 μF 50 V wkg.
C_{11} 50 μF 50 V wkg.
C_{12} 8 μF 500 V wkg.
C_{13} 8 μF 500 V wkg.
C_{14} 8 μF 500 V wkg.
C_{15} 16 μF 450 V wkg.
L_1 10 H, 180 mA, 200 Ω
T_1 Power transformer Secondary 410-0-410V, 180 mA; 5 V, 3A; 6.3 V, 4 A centre-tapped; 6.3 V 2.5 A centre-tapped.

* High-stability carbon. † Matched within 5%. $R_{12} > R_{11}$. ‡ Preferably matched within 5%.

POWER SUPPLY

The power supply is conventional and uses a Mullard 5V4G/GZ32 indirectly heated full-wave rectifier in conjunction with a capacitor input filter. Oil-filled paper smoothing capacitors have been used in the prototype amplifier, though the alternative use of electrolytic capacitors is possible. The value of the limiting resistors R_{23} and R_{24} will depend on the winding resistances of the mains transformer used. Their purpose, when required, is normally one of voltage control only. Where a transformer having very low winding resistance is used, a secondary voltage rated at 400-0-400 may be found adequate.

The rating of the mains transformer is such that an additional 30mA may be drawn from the h.t. supply to feed pre-amplifier circuits and radio tuner. Additional decoupling will of course be required for these supplies.

The driver stage uses a Mullard 12AX7/ECC83 twin triode and fulfils the combined function of phase splitter and driver amplifier. The anode load resistors R11 and R12 should be matched within 5%, R12 having a higher value for optimum operation. High frequency balance will be largely determined by wiring layout since equality of shunt capacitances is required. Low frequency balance is controlled by the value of the time constant R8,C5 in the grid circuits and this value has been chosen to ensure adequate balance down to very low frequencies.

The first stage employs a Mullard EF86 high gain low hum pentode. High stability resistors are used at critical points and provide a low noise level when compared with ordinary components.

NEGATIVE FEEDBACK

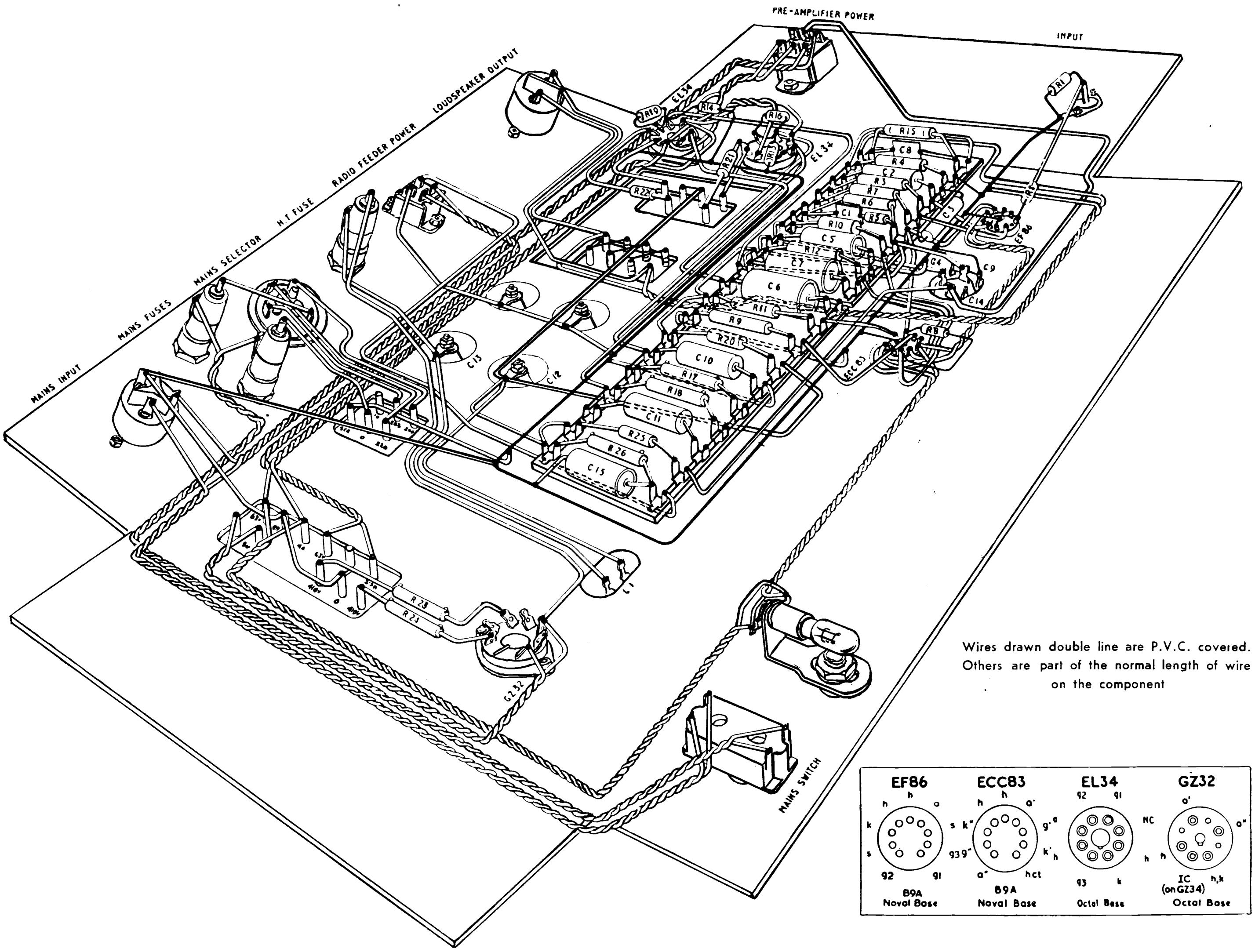
The sensitivity of the amplifier without feedback is 6.5mV for 20W output. With feedback approximately 220mV is required for the same output level, the desired overall loop gain being 30dB. An adequate margin of stability has been achieved in the prototype amplifier and an increase in feedback of approximately 10dB is possible before signs of high frequency instability occur.

OUTPUT IMPEDANCE

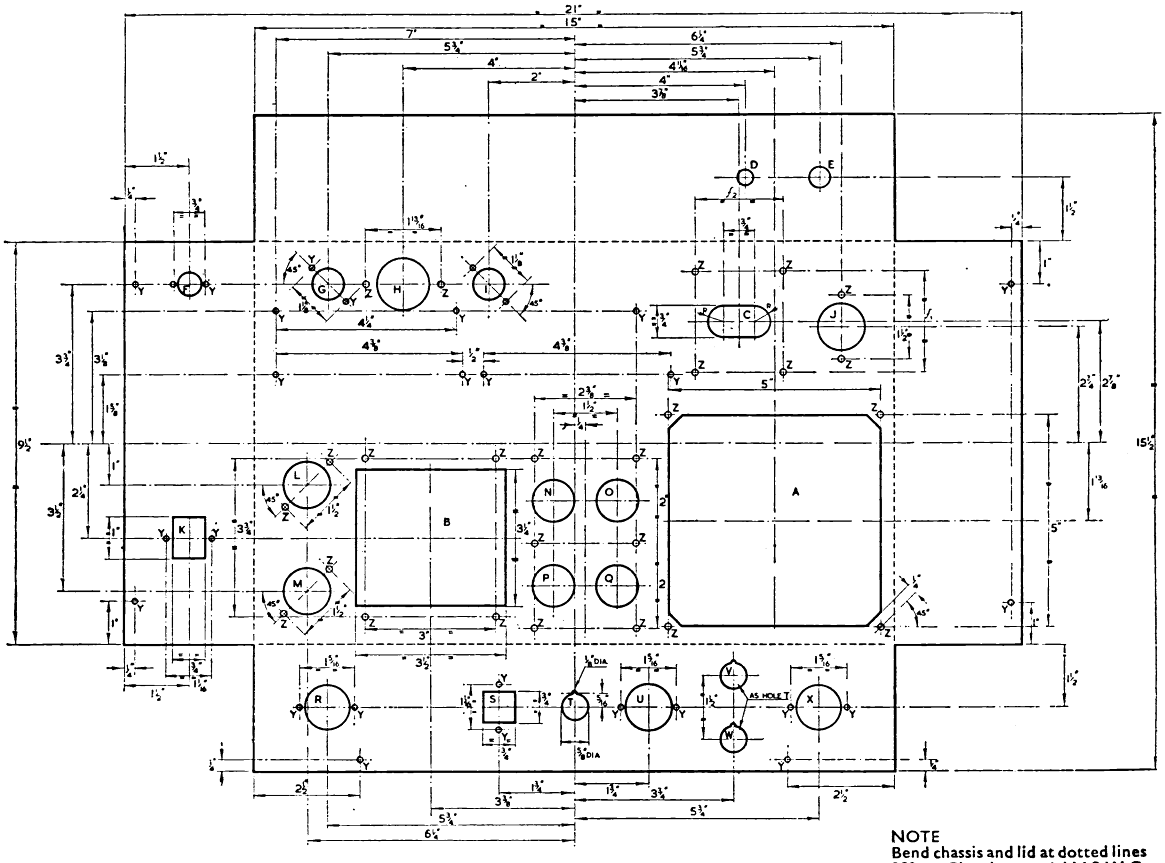
Due to the low inherent output impedance of the output stage, combined with a high degree of negative feedback, the output impedance is very low, measuring approximately 0.3 ohms on a 15 ohm termination for 20W output at 40 c/s, 1 Kc/s and 20 Kc/s. This corresponds to a damping factor of approximately 50.

MECHANICAL CONSTRUCTION

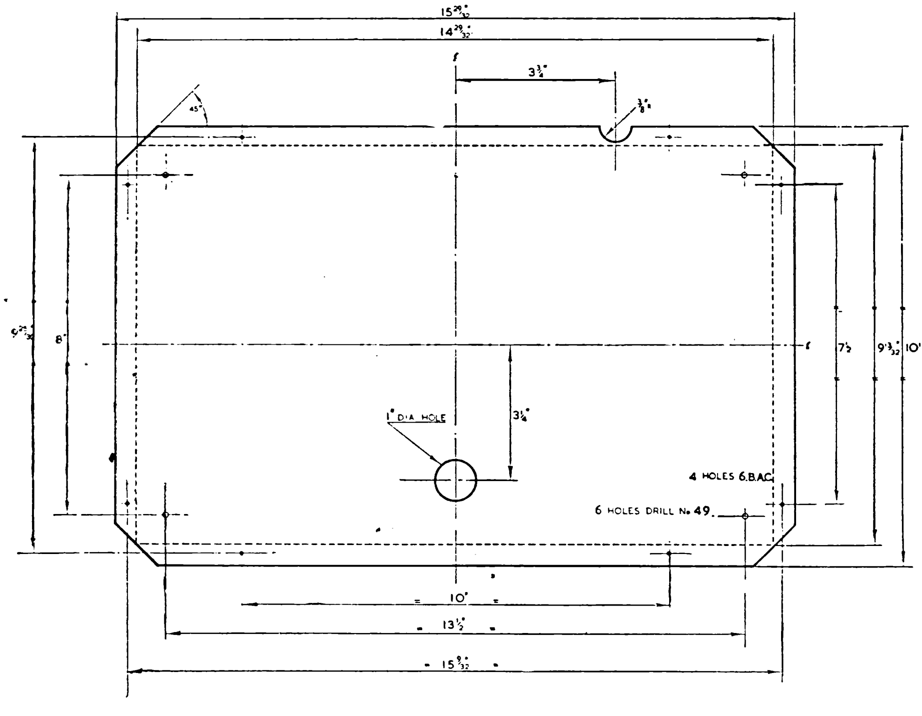
A diagram of the layout of the main components as used in the prototype amplifier is shown. A busbar earth return has been used with chassis connection at the input socket only in order to achieve a permissible hum level. With minor exceptions all resistors and capacitors are mounted on group terminals, shown dotted on the diagram.



Point-to-point wiring diagram for the 20-watt amplifier. The bus-bar is shown as a heavy line.



NOTE
Bend chassis and lid at dotted lines 90° up. Chassis material 16 S.W.G. brass or B.M.S. Braze corners of chassis.



Main chassis drawing for the 20-watt amplifier.

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