



Fig. 4. Loop gain, frequency response, and phase characteristics. Over-all frequency response at 36 watt operation is flat, 30 to 20,000 cycles-per-second.

TABLE 2.
SUMMARY OF PERFORMANCE CHARACTERISTICS OF THE
POWER AMPLIFIER

Power output:	36 watts; 30 to 20,000 cps
Frequency response: (at 36 watts)	within 1 db from 20 to 20,000 cps
Harmonic distortion: (at 400 cps)	.05% at 20 watts, .2% at 36 watts
IM distortion: (40 to 10,000 cps, 4:1 ratio)	.8% with peak corresponding to 36 watts sine-wave power
Hum and noise:	-89 db (relative to 36 watts)
Sensitivity:	.3 volt for 36 watt output
Damping factor:	50

well balanced push-pull drive of adequate amplitude and low distortion content. With the EL34 the maximum drive voltage required is approximately 2 x 25 volts r.m.s. Input voltage requirements are similar for triode, pentode, or distributed-load operation.

Bearing in mind the need to insure stability when feedback is applied over the whole amplifier, the circuit should contain the minimum number of stages in order to reduce phase shifts. If the function of phase splitting and amplification can be combined in the next-to-the-last stage, so much the better. This can be conveniently achieved by using a cathode-coupled form of phase splitter. A high degree of balance is possible with this circuit, combined with a low distortion level at maximum drive to the output stage. By using a high-impedance double triode, an effective gain of about 25 times can be obtained simultaneously. This, combined with a preceding high-

gain stage, enables a high over-all sensitivity to be obtained, even when a large amount of negative feedback is used. A high sensitivity in the main amplifier enables the output voltage requirements of preamplifier and tone control circuits to be reduced, thereby enabling low distortion to be more easily achieved in these circuits. It should be remembered that circuits preceding the main amplifier must be capable of handling, without appreciable distortion, voltages which are much greater than those necessary to load the amplifier fully.

With the use of such tubes as the EF86, which is particularly suited for use in a high-sensitivity input stage due to its low hum and noise levels, it is found that when feedback is applied, input sensitivities of 100 to 300 millivolts for 36-watt output can be achieved while keeping hum and noise levels extremely low.

In an amplifier employing single-

loop feedback from output/input, instability will occur if the loop gain exceeds unity at frequencies for which the total phase shift around the loop becomes either 0° or 360° and so renders the feedback signal in-phase with the input. The conditions for negative feedback imply a phase change of 180° so that instability is approached as the additional phase shift in the amplifier and feedback network approaches 180°.

It is, therefore, necessary to control the amplifier characteristics over a frequency range greatly in excess of the designed working band. As the degree of feedback increases, control becomes more difficult and is usually limited by the leakage inductance, self-capacitance, and primary inductance of the output transformer. It is quite difficult in practice to provide a constant and high level of feedback over the whole audible range in a 3- or 4-stage amplifier where the main feedback loop includes the whole circuit and the output transformer. An adequate margin of stability in such circumstances is very difficult to obtain. Thus it is more usual to find that the effective feedback decreases towards the upper and lower audible frequencies. The Mullard 520 circuit is especially designed and engineered to maintain a constant degree of feedback throughout the audible range.

The performance of any high-quality amplifier is, ultimately, dependent on the quality of the output transformer. The use of distributed-load conditions does not modify the essential requirement of a first-class component; on the contrary, the output transformer may be a more critical component since precise balance of primary windings must be maintained.

We can summarize by stating that with the introduction of distributed-load operation using the Mullard EL34 output pentode we can design efficient high-quality amplifiers with very high power handling capacities to reproduce the widest dynamic range of modern program sources.

Construction Details

The plate-to-plate loading of the output stage is 6600 ohms and with a feed voltage of approximately 440 at the center-tap of the output transformer primary the combined anode and screen-grid dissipation of the output tubes is 28 watts per tube. With the particular screen-grid-to-plate-turns ratio used, it has been found that improved linearity is obtained at power levels above 15 watts when resistors on the order of 1000 ohms 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; the use of further d.c. balancing arrangements in the output stage has not been considered necessary primarily because of the uniform characteristics of the

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Fig. 5. Harmonic distortion and input/output characteristics of the amplifier.

