TEN-WATT VALVE HIGH-QUALITY STEREOPHONIC AMPLIFIER

This section describes a seven-valve, high-quality amplifier which uses one EF86 and two ECL86 in each channel and produces a maximum audio output of 10W from each channel. The distortion is very low (typically 0·2% at full output), and good hum and noise performance is ensured by the use of the EF86 in the first stage.

The overall negative feedback at 1kc/s is approximately 20dB. Particular care has been taken to ensure that at least 17dB is effective over the full audio range of 30c/s to 20kc/s.

CIRCUIT DESCRIPTION

The circuit diagram of the amplifier is given in Fig. 4. Only one channel is shown: except for the loudspeaker phase-reversal switch, the other channel is identical. The circuit is conventional and only the salient features will be discussed in detail.

The phase characteristic of the amplifier is an important consideration in the application of negative feedback. As the frequency response and the gain of each stage are related, the phase characteristic depends on the choice of individual stage gains. With the correct choice of stage gains, complicated feedback networks are avoided, and a good margin of stability is achieved.

Input Stage

The input stage uses one EF86 and has a voltage gain of approximately 120 times. The stage is capacitively coupled to the phase splitter.

Phase Splitter

The phase splitter uses the triode sections of two ECL86 in a long-tailed pair. Fixed bias to the grids is provided by a potential divider across the h.t. supply. The voltage gain is approximately 24 times between the input of the stage and the control grid of each pentode section.

The long-tailed pair is chosen because of its low distortion (less than 1%, mainly third harmonic, at 7V output) and its excellent amplitude and phase-balance characteristics. However, the residual unbalance with the nominal values of resistance in Fig. 4 is about 2%, and this and the spread in values of the high-stability anode resistors (2% tolerance) will make a contribution to the distortion of the complete amplifier.

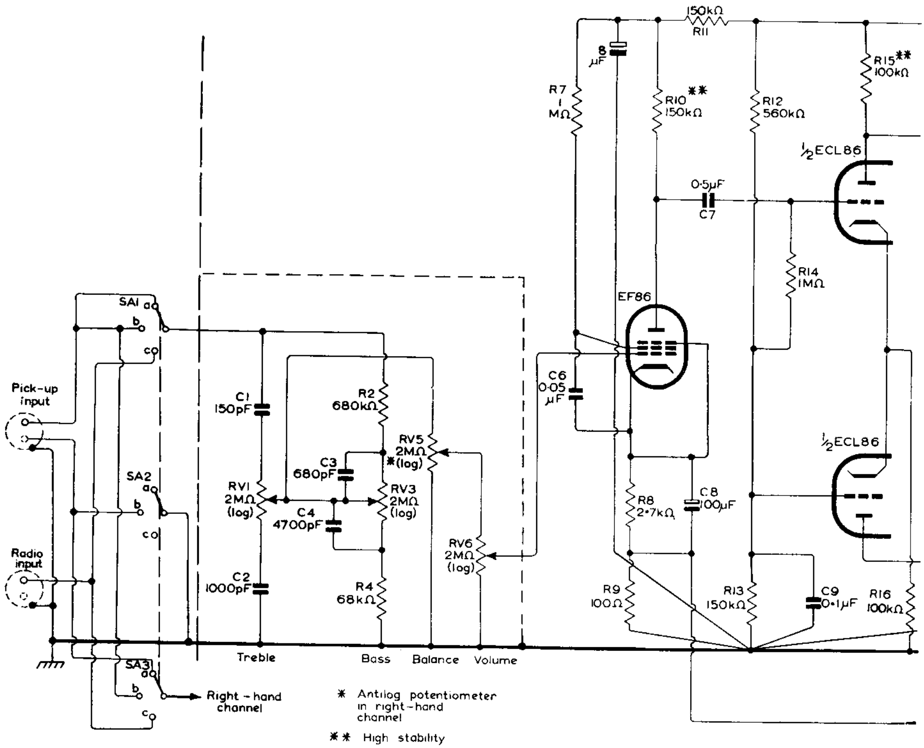


Fig. 4—TEN-WATT VALVE

Output Stage

The push-pull output stage of Fig. 4 uses the pentode sections of the two ECL86 operating under class AB conditions with distributed loading.

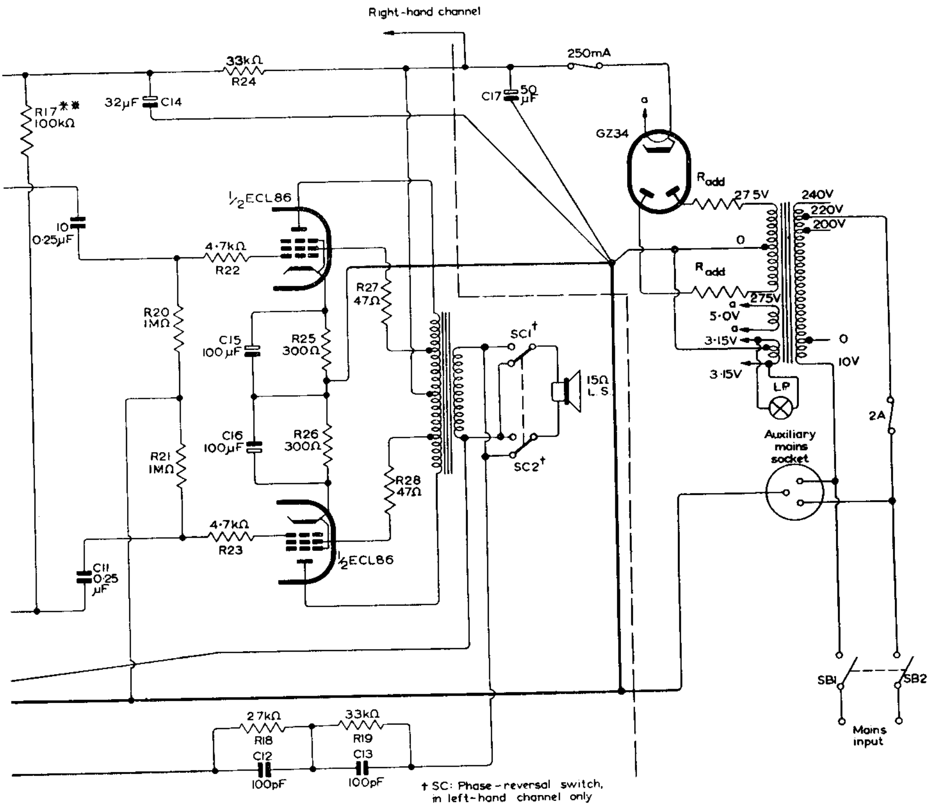
The output transformer should be of the construction normally used in high-quality amplifiers. In particular it should be free from any pronounced resonances. The turns ratio should be such that the anode-to-anode load is 9kΩ after allowing for the winding resistances.

Negative Feedback

Negative feedback of about 20dB is taken from the secondary winding of the output transformer to the cathode circuit of the input stage.

Low-frequency Stability

Coupling time-constants and screen-grid and cathode bypass time-constants which are considerably greater than the transformer time-constant ensure low-frequency stability. The loop phase shift when the l.f. loop gain is unity is 300 degrees.



HIGH-QUALITY STEREOPHONIC AMPLIFIER

The frequency response curve of the amplifier with feedback is flat to within $\pm$3dB between 4c/s and 60kc/s. A hump of 1dB occurs at 12c/s and will increase if the value of any of the coupling or bypass capacitors is decreased, or if the value of transformer primary inductance is increased. A large change in any of these values will produce instability.

High-frequency Stability

A phase-advance network in the feedback loop ensures high-frequency stability. This amplifier has a good margin of stability. The phase change when the h.f. loop gain is unity is about 35 degrees, and the loop gain at zero phase change is -17dB. The stability is much better with normal loudspeaker loads. A capacitance of 0·5μF can be placed across a 15Ω resistive load without causing instability. The capacitance required to cause instability with normal loudspeaker loads would be smaller because of speaker resonances.

The high-frequency stability of the amplifier will require reappraisal if an output transformer having a resonance frequency lower than about 110kc/s is used.

Controls

The circuit for the tone, volume and balance controls can be seen from Fig. 4. The network for the other channel is the same except that the balance-control potentiometer should obey a reverse-logarithmic law.

Simple passive tone-control networks are used, and the design is straightforward. The ranges of control relative to the response at 1kc/s are:

Bass: +12 to −12dB at 30c/s
Treble: +12·5 to −12dB at 15kc/s

Dual-ganged, 10% log-law potentiometers are commonly used in tone-control circuits. The tolerance on the angular position corresponding to 10% resistance is wide with these potentiometers, and this results in a similar tolerance on the location of the 'flat-response' position of the tone controls. Closer angular tolerance on the 10% resistance value can be obtained if 5% log-law potentiometers are used.

Either 5% or 2% log-law and reverse-log-law ganged potentiometers can also be used for the balance control. These cause a lower loss in the central position than the 10% log-law and reverse-log-law potentiometers.

Switched Tone Controls

Because of the coarseness of matching (20%) of ganged potentiometers, the tone-control characteristics of the two channels may not be identical, but identical responses can be obtained if switched controls rather than the continuously variable controls are used. Resistor values are given in Fig. 5 for switched tone controls; the resistances have been chosen to give equal increments (in dB) of boost and cut.

Power Supply

The valve complement of the amplifier is two EF86, four ECL86 and a rectifier valve. The h.t. supply requirement, and therefore the choice of rectifier, depends on whether the output stage is designed for full-dissipation operation (full power with sine-wave drive) or for low-dissipation operation (speech or music signals only).

The h.t. line voltage should be such that the quiescent anode-to-cathode voltage for the pentode sections of the ECL86 is 300V. Care should be taken to ensure that the maximum anode voltage rating of the valve (300V) is not exceeded.

A value of limiting resistance $R_{lim(min)}$ is required at each anode of the rectifier, and unless this value is provided by the winding resistances of the mains transformer, some value of resistance R_{add} must be included in each anode circuit of the rectifier. The value of R_{add} is given by the standard equation:

$$R_{lim(min)} = R_s + n^2 R_p + R_{add} ,$$

where R_s is the resistance of half the secondary winding of the mains transformer, R_p is the resistance of the primary winding and n is the ratio of half the number of turns on the secondary winding to the whole number of turns on the primary winding.

Full-dissipation Operation

The cathode resistance required for the pentode section of each ECL86 is 300Ω. The quiescent current drain of the amplifier is 140mA, and the current drain with full drive is 160mA. Reference to the rating chart of the EZ81 published in the Mullard Technical Handbook shows that a current drain of 160mA at 300V is excessive for operation with a capacitive input filter. The EZ81 is therefore unsuitable as the rectifier and the GZ34 is thus the recommended rectifier. The required value of $R_{lim(min)}$ is 50Ω per anode.

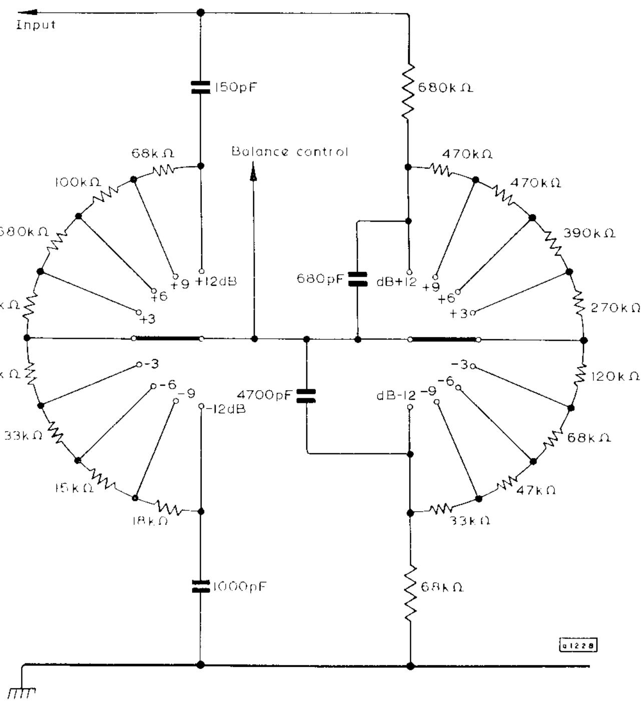


Fig. 5—SWITCHED TONE CONTROLS

The heater supply requirements for an amplifier using a GZ34 rectifier are:

6·3V, centre-tapped, 3·2A
5·0V, 2A

If an indicator lamp is included in the amplifier, the current requirement at 6·3V becomes 3·35A.

Low-dissipation Operation—Speech or Music Signals Only

The cathode resistance required for the pentode section of each ECL86 is 470Ω. The quiescent current drain of the amplifier is 105mA, and the current drain at full drive (music) is 120mA. Thus for speech or music operation only, the EZ81 can be used, provided that current is not required for ancillary equipment. The required value of $R_{lim(min)}$ for the EZ81 is 190Ω. Whether the GZ34 or the EZ81 is used, the line voltage must be adjusted so that the quiescent anode-to-cathode voltage of the pentode sections is 300V. The heater supply requirements for an amplifier using the EZ81 rectifier are:

6·3V, centre-tapped, 3·2A (plus optional 0·15A)
6·3V, 1A

Earthing

Care in the routing of earth returns and in the wiring layout is necessary to attain a low level of hum and also to minimise second harmonic distortion resulting from common-impedance coupling. For instance, at full sine-wave output, the peak current in each output pentode section is about 120mA, the peak from each valve occurring once in every cycle of the input signal. These pulses of current combine in the common h.t. and earth lines to form a steady current with a ripple content which has twice the frequency of the input signal and a peak-to-peak amplitude of 82mA. If any voltage produced by either the current in one output pentode section or the current in the common line is injected into the input circuits, it will produce an output at even multiples (mainly twice) of the input frequency. This, of course, is experienced as distortion. The voltage developed across a resistance of only 0·01Ω in the common earth return will, if fed back to the input, result in approximately 10% second-harmonic distortion (in the absence of negative feedback).

The earth returns of each stage are grouped together, the h.t. supply decoupling capacitors being included with the appropriate stage. The input stage is connected to the chassis at the input socket. The phase splitter and output stage returns are taken to the reservoir capacitor, which is also connected to the chassis at the input socket.

Magnetic fields caused by the flow of the output-stage current in wiring loops can also induce voltages in the input circuit and can thus cause second-harmonic distortion. The layout of the wiring and the location of the cathode bypass capacitors should be arranged so that magnetic coupling with the input circuit is avoided.

PERFORMANCE

The sensitivity of each channel in the basic amplifier for an output power of 10W is 2·3mV without feedback and 23mV with feedback. The sensitivity of the complete amplifier, including tone controls, is 250V.

At 50mW output with feedback, the response is flat to within ±3dB from 4c/s to 60kc/s; at 10W output, it is flat from 12c/s to 50kc/s.

The small amount of ringing on the pulse waveform is attributable to the very short rise time of the edges of the pulses. No ringing occurs on pulses with rise times longer than 5μs, and since those of transients present in music are considerably longer than this, the response of the amplifier is more than adequate for music reproduction.

Harmonic Distortion

The values of distortion of the amplifier are slightly higher than would be expected from the output stage alone because of the distortion and unbalance introduced by the phase splitter. Since the distortion in the phase splitter can either add to or subtract from the distortion in the output stage, the distortion was measured again with the ECL86 interchanged. The total harmonic distortion is likely to vary from amplifier to amplifier but should not exceed 0·4% at 10W. A typical value of total distortion is 0·2% at 10W.

Output Impedance

The output impedance of the amplifier measured at the 15Ω terminals for an output of 1W at 1kc/s is 1·4Ω. This low value is maintained over a frequency range of 30c/s to 15kc/s.

Hum and Noise

The combined hum and noise level in the amplifier with the input short-circuited at the control grid of the EF86 is typically 75dB below 10W for the audio bandwidth of 20c/s to 20kc/s. The hum and noise with a 470kΩ resistor connected across the input is −65dB.

With the input short-circuited, the level of hum alone is typically −76dB. Most of this derives from ripple on the h.t. line. The contribution of hum from a.c. heating in the EF86 is −86dB and is negligible. The change in the hum level when a 470kΩ resistor is connected across the input is also negligible.

The level of noise with the input short-circuited is −80dB. With a 470kΩ resistor connected across the input, the level rises to the predictable value of −66dB. This figure is determined entirely by the Johnson noise in the 470kΩ resistor; the contribution of the EF86 is negligible in comparison.