CHAPTER XVIII

THE MULLARD 5-VALVE 10-WATT AMPLIFIER

ALTHOUGH only four amplifying valves and one rectifying valve are used in this amplifier it is sufficiently sensitive to be driven by many popular gramophone pick-ups without recourse to expensive pre-amplifying stages. Circuits for tone control and for the compensation of recording characteristics have been developed. Harmonic distortion has been kept to a very low figure—less than 0·4 per cent at 10 W output. The frequency response is extremely wide and level, being almost flat from 10 to 20,000 c/s.

The Circuit

The circuit of the amplifier (Fig. 139) is of conventional form. A single-ended high-gain pentode (EF86) feeds a cathode-coupled phase-splitter using the high-mu double triode ECC83. The balanced output voltages derived from the ECC83 are used to drive the grids of two EL84 pentodes in push-pull. Negative voltage feedback is applied from the secondary of the output transformer to the cathode of the input valve.

Frequency Response

Relative to 1,000 c/s the response is not down by more than ½ db at the two extremes of 10 c/s and 20,000 c/s. Overall feedback of 26 db is taken from the secondary of the output transformer.

Power Response

From 40 to 10,000 c/s, maximum output is 1 db relative to 10 W.

From 20 to 16,000 c/s, maximum output is 0 db (10 W).

From 16 to 30,000 c/s, maximum output is —2 db relative to 10 W.

Distortion

Less than 0·4 per cent at 10 W. Total harmonic distortion has been measured at 40 c/s, 400 c/s and 2,000 c/s. For the rated output of 10 W the total distortion is:

Less then 0·4 per cent at 40 c/s.
" " 0·2 " " " 400 c/s.
" " 0·3 " " " 2,000 c/s.

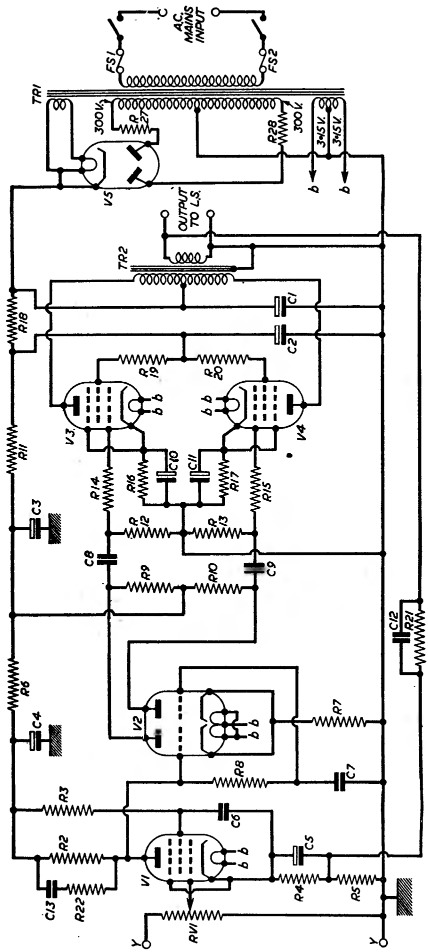


Fig. 139.—THEORETICAL CIRCUIT.

Hum and Noise

73 db below 10 W. With the ear close to the loudspeaker no hum can be detected and residual noise is only a slight rustle. Under normal listening conditions hum and noise are completely inaudible. Hum and noise are 73 db below 10 W, or 74 db below the maximum rated output of 12·5 W.

Output Resistance

0·9 Ω on 15 Ω output. The output resistance of 0·9 Ω on a 15-Ω output is sufficiently small in practice to ensure adequate electrical damping of the speaker coil.

Tone Control

10 db boost in treble and bass; 10 db attenuation in treble and 5 db attenuation in bass. The

LIST OF COMPONENTS

CAPACITORS

C1, C2—Double electrolytic, 50 + 50 μF 350 V wkg.
C3—Electrolytic, 10 μF 350 V wkg.
C4—Electrolytic, 10 μF 350 V wkg.
C5—Electrolytic, 100 μF 12 V wkg.
C6—Paper, 0·02 μF 350 V wkg.
C7—Paper, 0·1 μF 350 V wkg.
C8—Paper, 0·1 μF 350 V wkg.
C9—Paper, 0·1 μF 350 V wkg.
C10—Electrolytic, 100 μF 25 V wkg.
C11—Electrolytic, 100 μF 25 V wkg.
C12—Ceramic or Mica. See below.
C13—Ceramic, 100 pF (20%).
C14—Ceramic, 33 pF (10%).
C15—Ceramic or Mica, 680 pF (10%).
C16—Ceramic or Mica, 270 pF (10%).
C17—Ceramic or Mica, 3,300 pF (10%).

The values of the resistor R21 and its shunt capacitor C12 in the main feedback loop depend upon the impedance of the loudspeaker. A selection of values is given below :

RESISTORS

RV1—Variable, carbon, 1 MΩ (log law).
R2—Fixed, carbon (high stability), 180 KΩ (10%—1 W).
R3—Fixed, carbon, 1 MΩ (10%—¼ W).
R4—Fixed, carbon, 1·8 KΩ (10%—¼ W).
R5—Fixed, carbon, 100 Ω (5%—¼ W).
R6—Fixed, carbon, 100 KΩ (10%—¼ W).
R7—Fixed, carbon, 68 KΩ (10%—1 W).
R8—Fixed, carbon, 1 MΩ (10%—¼ W).
R9—Fixed, carbon, 100 KΩ (10%—½ W).
R10—Fixed, carbon, 100 KΩ (10%—½ W).
R11—Fixed, carbon, 33 KΩ (10%—¼ W).
R12—Fixed, carbon, 820 KΩ (10%—¼ W).
R13—Fixed, carbon, 820 KΩ (10%—¼ W).
R14—Fixed, carbon, 4·7 KΩ (20%—¼ W).
R15—Fixed, carbon, 4·7 KΩ (20%—¼ W).
R16, R17—Fixed, carbon :
  Normal loading, 270 Ω (5%—3 W).
  Low loading, 390 + 47 Ω (5%—3 W).
R18—Fixed, carbon, 1·2 KΩ (10%—1 W).
R19—Fixed, carbon, 47 Ω (20%—¼ W).
R20—Fixed, carbon, 47 Ω (20%—¼ W).
R21—Fixed, carbon (see below) (5%—¼ W).

R22—Fixed, carbon, 18 KΩ (10%—¼ W).
RV23—Variable, carbon, 2 MΩ (log law).
RV24—Variable, carbon, 2 MΩ (log law).
R25—Fixed, carbon, 1·5 MΩ (10%—¼ W).
R26—Fixed, carbon, 150 KΩ (10%—¼ W).
R27—Fixed, carbon (see below) (20%—1 W).
R28—Fixed, carbon (see below) (20%—1 W).

The resistors for R9 and R10 should be matched to within 5 per cent, and the larger used for R10.

The values of R27 and R28 depend on the winding resistances of the mains transformer and on the choice of rectifier. They must be chosen to make the total effective limiting resistance of each anode of the rectifier up to the required value.

The total limiting resistance, R_{lim}, in series with each anode of the rectifier must be at least 47 Ω for the GZ30 or at least 215 Ω for the EZ80. The amount of series resistance, Rt, contributed by the transformer is:

$$Rt = \tfrac{1}{2}Rs + n^2Rp$$

where Rs = resistance of secondary,
Rp = resistance of primary,
n = ratio of number of turns on half the secondary to number of turns on the primary.

Thus if Rt is less than R_{lim}, then R27 and R28 must both be chosen equal to the difference between them.

Speaker impedance (Ω)	C12 (pF)	R12 (KΩ)	*Tolerance* ±%
3·75	180	15	5
7	120	22	5
15	82	33	5

VALVES (Mullard)

V1—EF86.
V2—ECC83.
V3, V4—2 × EL84.
V5—GZ30 or EZ80. See note below.

The EZ80 must not supply a current of more than 90 mA.

MAINS TRANSFORMER (TR1)

Primary—10-0-200-220-240.
Secondaries—Normal loading: 300-0-300 100 mA; 3·15-0-3·15 2 A; 0-5 2 A. Low loading: 300-0-300 60 mA; 3·15-0-3·15 2 A; 0-6·3 1 A.

FUSES

FS1, FS2—1A.

tone-control unit provides boost and attenuation at both treble and bass frequencies.

Details of a well-known type of tone control using a wide-range, passive circuit are included on page 226 (Fig. 140). The treble control is RV23 and the bass control RV24.

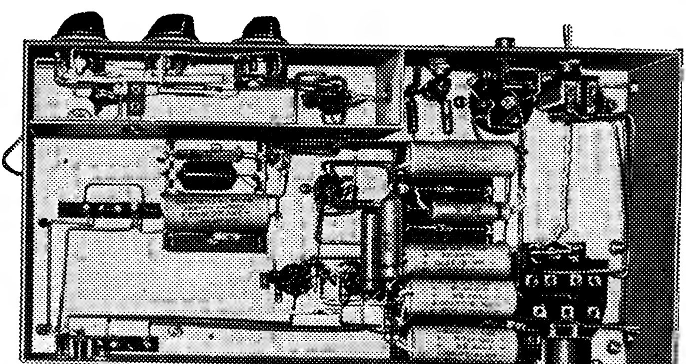
This circuit produces an attenuation of about 12 times. Because of the high sensitivity of the amplifier —50 mV at *Y-Y* with feedback—the tone-control unit is suitable for use with a crystal pick-up having a relatively large output, without the need arising for a separate valve pre-amplifier. The input voltage at *X-X* (Fig. 140) must be approximately 600 mV to load the amplifier fully.

Pick-ups and Equalizing Networks

The Collaro " O " and " P " " Studio " pick-up heads and the Acos Hi-g microgroove and standard pick-ups are particularly suitable for use with the amplifier. Details of some equalizing networks which have been found very satisfactory are given in Fig. 141. They are designed to match into the input impedance of the tone-control circuit, and were derived using the Decca K1804A (78 r.p.m.) and Decca LXT2695 ($33\frac{1}{3}$ r.p.m.) recordings.

Detailed Circuit Description

The first stage of amplification is provided by the EF86 in a circuit having a gain of approximately 150 times. The negative



UNDERSIDE OF AN AMPLIFIER BUILT TO THIS DESIGN.

feedback voltage from the secondary of the output transformer is introduced across the 100 Ω resistor, R5, in the cathode circuit. In a feedback amplifier with a wide frequency response stability can be achieved only if the required difference in phase is maintained between the input signal and the feedback voltage. The EF86 has accordingly been coupled directly to the following stage in order to reduce the phase shift at low frequencies. The *C-R* network (*C*13, *R*22) shunting the anode load produces an advance in phase which increases the stability of the amplifier at high frequencies.

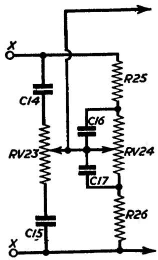


Fig. 140.—THE TONE-CONTROLLING INPUT CIRCUIT.

The pick-up or equalizing circuit is connected across X-X.

Phase-splitter

The output stage is fed by an ECC83 double triode operated as a cathode-coupled phase splitter. The two grids are coupled together by R8, the second being capacitively earthed by C7. The correct value of 1·5 V grid-to-cathode bias is produced when the anode voltage of the EF86 is 70 V. Anode resistors R9 and R10 (= 100 KΩ) should be matched within 5 per cent, R10 being given the larger value.

The use of the cathode-coupled circuit provides for low distortion and facilitates direct coupling to the first stage. The gain obtained with the cathode-coupled circuit is about half that obtained from each valve section operated as a normal voltage amplifier. Nevertheless, it is sufficient as the ECC83 has an amplification factor of 100.

Output Stage

The output stage is equipped with two EL84 output pentodes operated in a self-biased push-pull circuit. The anodes are fed from the reservoir capacitor C1, the screen grids and the rest of the amplifier being supplied via R18 and C2. Separate bias resistors R16, R17 are used. Stopper resistors (R14, R15, R19, R20) are included in the control- and screen-grid leads.

A resistor with a value of about 1 KΩ may be placed across the output terminals to prevent instability from occurring with a disconnected loudspeaker.

Operating Conditions

Alternative modes of operating two EL84's in a push-pull output stage are available, and may be referred to as the "normal loading" conditions, the anode-to-anode impedance being 8,000 Ω and the quiescent anode current 2 × 36 mA.

An alternative set of operating conditions will result in lower distortion when the amplifier is used for the reproduction of speech and music. Under these alternative conditions the anode-to-anode load is reduced to 6,000 Ω and the quiescent anode current to 2 × 24 mA. This may be termed "low loading" operating.

For low loading operation the appropriate value of both cathode resistors R16 and R17 is 437 Ω (= 390 Ω + 47 Ω), as compared with the value of 270 Ω

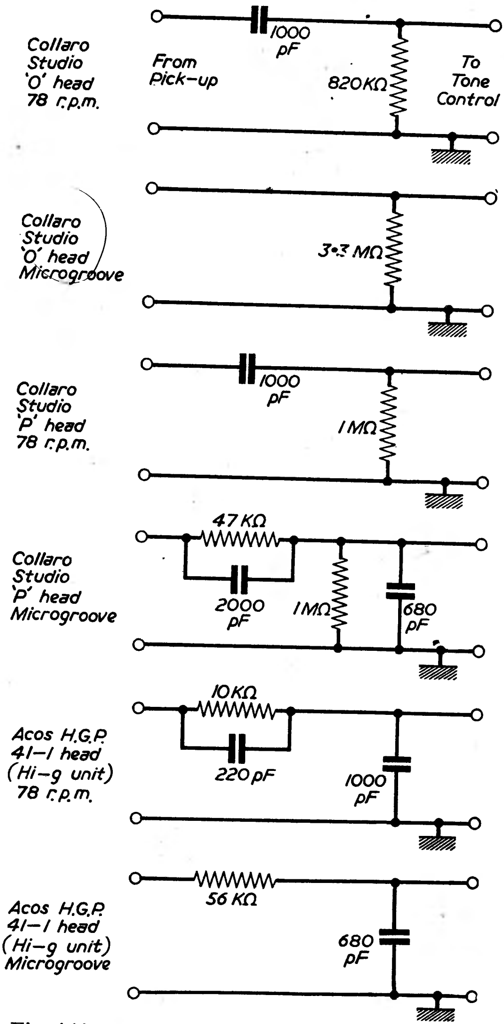


Fig. 141.—Equalizing Networks suitable for Use with the Tone-control Input Unit.

each for normal loading (that is, for the Class AB conditions given in the data).

The H.T. consumption is considerably smaller when the output stage is adjusted for low loading. In consequence, the standing dissipation in the output stage is reduced from 11 W at each anode to 7·5 W at each anode, the output valves then being run well below their maximum permissible anode dissipation of 12 W. There will also be less ripple on the H.T. line. As a measure of economy the mains transformer can be given a lower rating provided the amplifier is to remain permanently adjusted to low loading.

Effective distortion for the low loading adjustment cannot be measured easily because standard measurements of harmonic distortion and intermodulation distortion are not practicable when the maximum output is approached. A low-level sine wave, however, may be used to measure frequency response on condition that the output power does not exceed 1–1·5 W, otherwise excessive distortion will occur. Normal square-wave testing can be undertaken, but the input should not exceed a level similar to that used for the low-level sine wave.

CIRCUIT VOLTAGES

Testing point	Voltage		Meter range
	D.C.	A.C.	
C1	320	The ripple across C1 is 4 V normal loading, and 2·5 V low loading, measured with a valve voltmeter	1,000 V, D.C.
C2	310		1,000 V
Cathodes V3, V4 . . .	12		100 V
Anodes V3, V4 . . .	310		1,000 V
Screen grids V3, V4 . .	310		1,000 V
C3	255		1,000 V
Anodes V2	210		1,000 V
Cathodes V2	71·5		1,000 V
C4	182		1,000 V
Anode V1	70		1,000 V
Screen-grid V1 . . .	65		1,000 V
Cathode V1	1·5		25 V

These voltages were measured with Model 8 Avometer (20,000 Ω/V) with zero input signal.

Peak Handling Capacity

Larger peak currents are produced in the output stage under low loading conditions than with normal Class AB operation. These peak currents are of short duration with a speech and music input. They are supplied by the reservoir capacitor C1, which is of large value (50 μF). When the amplifier is at the point of overload on peak signal the momentary fall in line voltage should not be more than 2 V on the nominal line voltage of 320 V.

As the current in the output stage increases there follows an increase in the bias voltage across the cathode resistors at a rate determined by the time constant of the bias networks. Measurements have shown that in practice this increase in bias is not likely to exceed 1 V. The working conditions of the output stage are such that the output valves are then driven back into a region where lower distortion is obtained.

As a result, however, of any change in the bias of the output stage a variation in gain will occur; but the distortion which is introduced in this way is held to a low level by the large amount of negative feedback.

Output Transformer

The output transformer is the most important component in a feedback amplifier, and it is essential that it shall give adequate performance. It is therefore advisable to obtain the output transformer from a manufacturer who has undertaken to build this component specially for the amplifier. It is essential that a component meeting the minimum specification be used, otherwise there will be instability and deterioration in performance.

Of the output transformers currently available the Partridge PPO may be recommended.

Rectifier

The GZ30 full-wave rectifier can supply a current drain of 125 mA and is completely suitable for all applications of the amplifier. With the GZ30 sine wave testing can be pursued up to full output power. Under practical conditions, with speech and music inputs, the GZ30 will have sufficient current reserve to supply an F.M. unit in conjunction with the amplifier.

The GZ30 has a 5 V heater and is mounted on the octal base.

Most readers will not have the necessary equipment to undertake sine wave testing at high output powers. Rectifier type

EZ30 can then be recommended, the restriction being that the EZ80 must not supply a current in excess of 90 mA. Thus the EZ80 can be fitted when the amplifier is to be permanently adjusted to " low loading " condition, since sine wave inputs can then be used to produce an output power of up to 1–1·5 W. Under " normal loading " conditions the power output can be increased up to 6 W before overloading of the EZ80 will occur. Square wave testing can be used with the EZ80 for both the normal loading and low loading adjustments, provided the input is of a similar level to that used for the corresponding sine wave testing.

The EZ80 should not be expected to supply the additional current required for radio feeder units and the like.

The EZ80 has a 6·3 V heater and is mounted on the B9A (noval) base.

It can be seen that before making up the amplifier some consideration must be given to the way it is to be used and how this will affect the choice of rectifier.

If a much greater output is desired, then the output valves may be replaced by EL34's and the rectifier by a GZ32. The EL34's are of the 25 W class. A new rectifier has been introduced since these details were prepared, and this is the GZ34. This may be used without any change of base connections or mains transformer. The values of limiting resistors R27 and R28 which depend on the type of mains transformer (as mentioned on page 224) must be increased. For example, with the Partridge P3878 used in the prototype (with EL34's) R27 and R28 were each 82 Ω. These should be increased to 100 Ω when the GZ34 is fitted. With either rectifier they should be 6 W wirewound types.