Mullard

5 VALVE 10 WATT HIGH QUALITY AMPLIFIER CIRCUIT

CONTENTS

Details of Amplifier design and performance. Tone controls. Output transformer. Valve Data. Introductory notes on playback equipment, including equalisation networks

2'6

Mullard
5 valve 10 watt
High Quality
AMPLIFIER
CIRCUIT

Mullard

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MV 8104

FOREWORD

As more and more high quality recordings become available, and with the advent in the near future of F.M. broadcasting on a large scale, the choice of music open to high quality enthusiasts will become even wider.

This booklet introduces a design for an amplifier and inexpensive tone-control circuit which should appeal especially to the home constructor. The complete circuit can be built up around five Mullard valves. It is intended that crystal pick-ups should be used, several makes being available which give a high standard of reproduction.

A full description is given of the performance figures and circuitry, and there are also illustrations showing a suitable layout. Brief sections are included on the playback equipment used in conjunction with the amplifier. Finally, there is complete data on the five valves required, and on other valves which Mullard recommend for use in audio amplifiers.

It should be noted that Mullard Ltd., who originated the design, do not manufacture audio amplifiers.

ACKNOWLEDGEMENTS

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CONTENTS

INTRODUCTION

In the design of this amplifier, it has been the aim to produce a circuit which can be built up easily and at relatively small cost, and yet meet in every way the basic requirements of a high quality amplifier. On account of its high sensitivity, the voltage output of crystal pick-ups is generally sufficient to make a separate valve pre-amplifier superfluous. A tone control circuit is included to compensate for widely differing listening conditions.

The basic requirements, which are well known, are:—

Adequate Available Peak Power

To re-create realistic sound quality the level should ideally be similar to that which would be heard under "live" conditions, though personal preference may determine a lower level of listening. This means that the amplifier must be capable of handling peak powers considerably in excess of the average level, to allow reproduction of peak sounds without overloading and audible distortion.

Negligible Distortion up to the Maximum Output Level

Distortion is due to the presence in the output of frequency components which were not present in the input signal. These consist in the first place of harmonics of the original frequencies. In addition, new components are created as sum and difference tones by intermodulation between different frequencies. The general effect of these forms of distortion is to mar the clarity and timbre of the reproduction.

Uniform Frequency Response in the Audible Range

The average ear is capable of responding to frequencies in the range of 15–15,000 c/s. The upper limit may extend to 20kc/s, particularly in the case of young people; on the other hand with older people the upper limit may be well below 15kc/s. The upper partials of some musical instruments extend to around 10kc/s whilst the noise spectrum associated with them may extend towards the upper limit of audibility. To make possible realistic reproduction of music, it is essential that the amplifier should handle a range of frequencies at least as wide as that capable of being heard.

Good Transient Response

Many sounds, in particular those associated with musical instruments, rise very rapidly to a high intensity which is followed by a relatively long period of decay. Examples of these are the clashing of cymbals and the plucking of strings.

Such sounds are spoken of as "transients" and their steeply rising wave-fronts may be shown to comprise a wide range of component frequencies. Thus the ability of an amplifier to reproduce transient sounds faithfully is dependent in the first place on a wide frequency response in the reproducing system. In addition the phase shift must be small over the whole frequency range, since a variation in the relative phasing of component frequencies of a transient sound results in a change in its aural character.

Low Output Resistance

A low output resistance is desirable from the point of view of improving the performance of the loudspeaker and ensuring crisp and clean reproduction, particularly of transient sounds.

Air loading of the loudspeaker controls to a large extent the low frequency resonance of the cone and suspension. The electro-magnetic damping afforded by a low output resistance in the amplifier is, however, effective in ensuring adequate control of the cone movement over the whole frequency range.

The output resistance should preferably be much less than the impedance of the loudspeaker voice coil, the ratio of the two being termed the damping factor. In practice, damping factors of at least 8–10 are desirable.

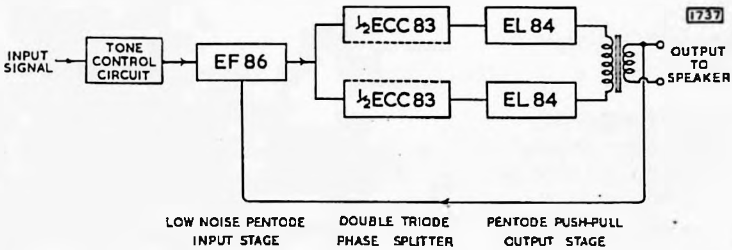
Low Hum and Noise

The presence of noise and hum in the loudspeaker output will detract from the enjoyment of otherwise good reproduction. Thus the amplifier should not contribute noise or hum at an audible level.

SPECIFICATION

Mullard 5 valve 10 watt Amplifier Circuit

The circuit is for an easily constructed, three-stage, 10W amplifier with negative feedback (26db) taken from the output to input stage. The high gain input stage (EF86) is directly coupled to the phase splitter (ECC83), which feeds the output stage employing two pentodes in push-pull (2×EL84).



The output stage can be operated under either "normal loading" or "low loading" conditions (page 15):—

Normal loading corresponds to the Class AB conditions given in the valve data; it must be employed when sine wave inputs are to be used for testing up to full output power.

Low loading produces less distortion with a speech or music input; under these conditions sine wave testing can only be undertaken at relatively small output power.

Valve Line-up

EF86 :	Low hum, low microphony pentode
ECC83:	High-μ double triode
2×**EL84:**	Pentodes with max. anode dissipation of 12W
GZ30:	Full-wave rectifier to supply up to 125mA
or EZ80:	Full-wave rectifier to supply up to 90mA.

Power Output

Rated output 10W
Max. output 12–13W

(For the "low loading" adjustment these figures relate to equivalent sine wave power).

Total Harmonic Distortion

Measured for 10W output with normal loading and sine wave input, the total harmonic distortion is:

less than 0.4% at 40c/s
less than 0.2% at 400c/s
less than 0.3% at 2000c/s

Hum and Noise

–73db relative to 10W

Frequency Response

±0.5db, 10c/s to 20,000c/s

Power Response

The power output, with normal loading and sine wave input, is:

+1db relative to 10W in the range 40c/s to 10,000c/s
0db relative to 10W in the range 20c/s to 16,000c/s
–2db relative to 10W in the range 16c/s to 30,000c/s

Output Resistance

The output resistance at 1,000c/s is 0.9Ω measured at the 15Ω output terminals. These figures correspond to a damping factor of about 17.

Sensitivity

An input of 50mV to the first valve gives 10W output. With the tone control circuit this output power is produced with an input of 600mV.

Treble Control

Continuously variable control of treble from +10db to –10db at 10,000c/s.

Bass Control

Continuously variable control of bass from +11db to –5db at 20c/s.

Output Transformer

An output transformer which gives at least the minimum performance must be used (page 25). There are at least three suitable makes available commercially:

Parmeko P2629; 8,000Ω primary with 6,000Ω tap; price 50s.

Partridge P3650 with 8,000Ω primary; or P3666 with 6,000Ω primary; both types priced at 50s.

Wynall G1287; 8,000Ω primary with 6,000Ω tap; price 47s. 6d.

Mains Transformer

The current rating for the high tension secondary (300–0–300 V) should be chosen sufficiently high to allow for present and future requirements.

The highest current drain will occur when the normal loading adjustment is used and the rectifier is also required to supply an F.M. unit. The rating must then be 120mA.

Since the use of an F.M. unit implies a speech or music input, the low loading adjustment is more suitable when an F.M. unit is incorporated. The current rating can then be 100mA. This rating is also required when a sine wave input is used to test the amplifier up to full output power with normal loading.

The lowest possible rating, when an F.M. unit is not employed, and when the amplifier is adjusted to low loading, is 60mA.

(**Note:** These requirements also influence the choice of rectifier. When the current drain requires a rating of 120mA or 100mA, the GZ30 must be used. When the rating is 60mA, the EZ80 may be used.)

A separate heater winding for the rectifier is essential for the GZ30, and is recommended for the EZ80. It should supply a heater voltage of 6.3V (rating 1A) for the EZ80, or of 5V (rating 2A) for the GZ30.

	Voltage Tappings
Primary:	10–0–200–220–240
Secondaries:	
Normal loading:—	300–0–300
	3.15–0–3.15
	0–5
Low loading:—	300–0–300
	3.15–0–3.15
	0–6.3 (for EZ80)
	or
	0–5 (for GZ30)

Estimated Cost

The list price of the components in the amplifier and tone control circuit, including valves and output transformer, is estimated to be in the region of £12. This does not include any allowance for pressing and drilling the chassis, or for special control knobs, etc.

Power Consumption

55 to 60 watts

Layout

A recommended layout is given on page 8. The chassis dimensions are 14×7×3 inches. The mains input and speaker output should be well separated, and the mains transformer and output transformer should be positioned so that the axes of the windings are at right angles.

Pick-ups

Crystal pick-ups must be used to drive the amplifier when the recommended tone control circuit is employed. Suitable equalising networks (page 34) for 78 r.p.m. and microgroove recordings have been derived for the Collaro Studio "O" head; and the Acos H.G.P. 41–1 head. Similar Acos crystal units are used in several other pick-ups.

Loudspeakers

The 3.75Ω and 15Ω output terminations are suitable for almost all makes of loudspeaker.

In order to obtain the best results, it is essential to use a suitably housed, high quality loudspeaker.

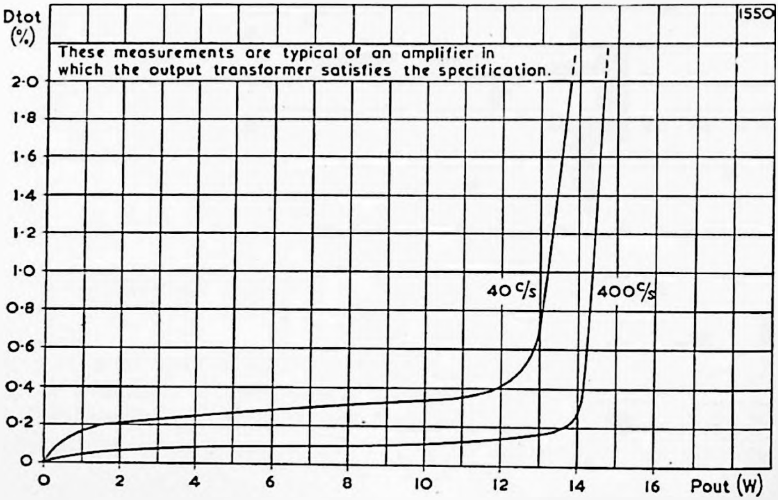


FIG. 1 TOTAL HARMONIC DISTORTION PLOTTED AGAINST OUTPUT POWER

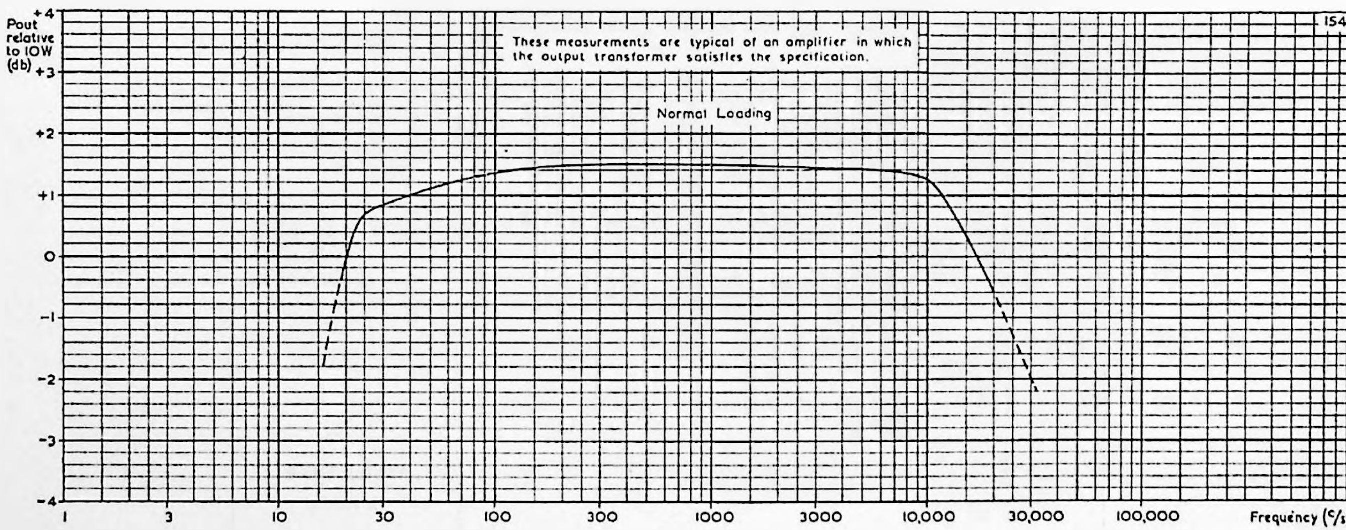
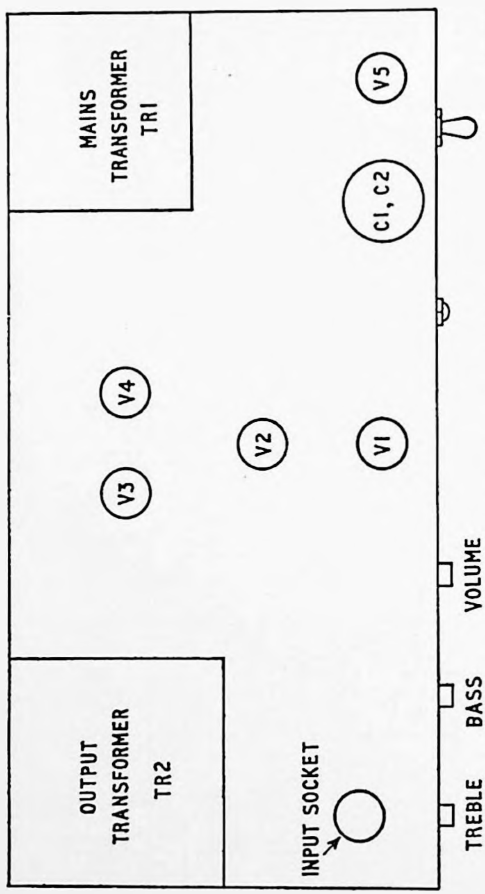


FIG. 2 MAXIMUM OUTPUT POWER RELATIVE TO 10 WATTS PLOTTED AGAINST FREQUENCY



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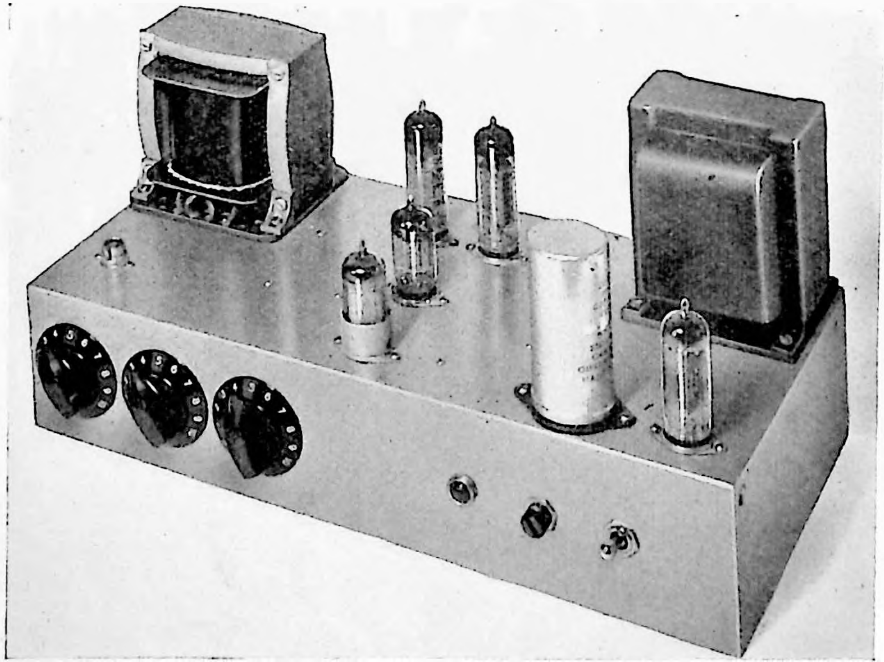
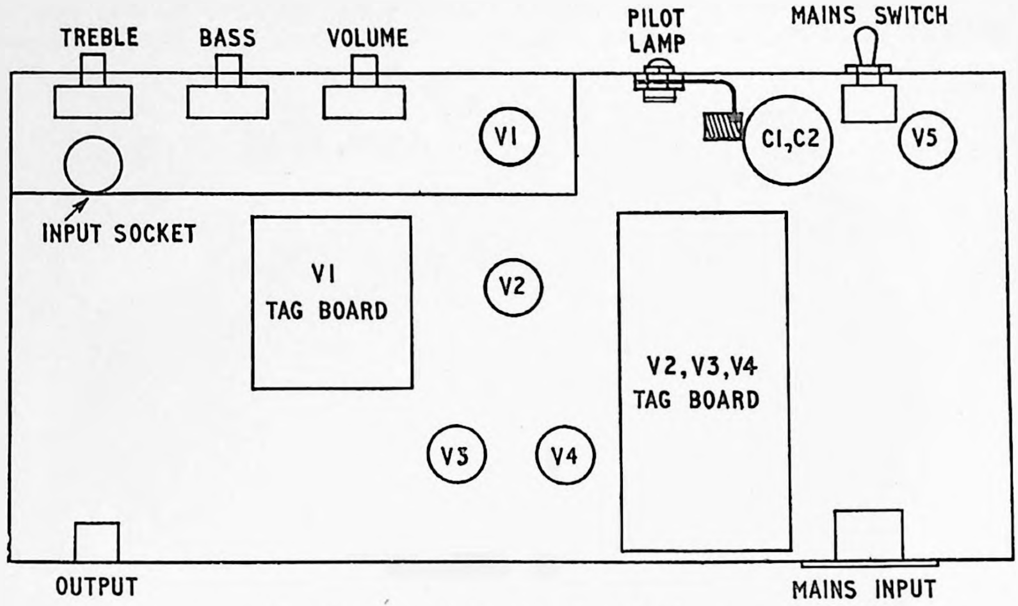
CHASSIS DIMENSIONS: 14 × 7 × 3 Inches.

TOP CHASSIS VIEW OF RECOMMENDED LAYOUT



VIEW OF AMPLIFIER BUILT TO RECOMMENDED LAYOUT WITH PERFORATED COVER REMOVED.
THIS PARTICULAR MODEL HAS BEEN CONSTRUCTED WITH AN EZ80 RECTIFIER (V5)



CHASSIS DIMENSIONS: 14 x 7 x 3 inches.

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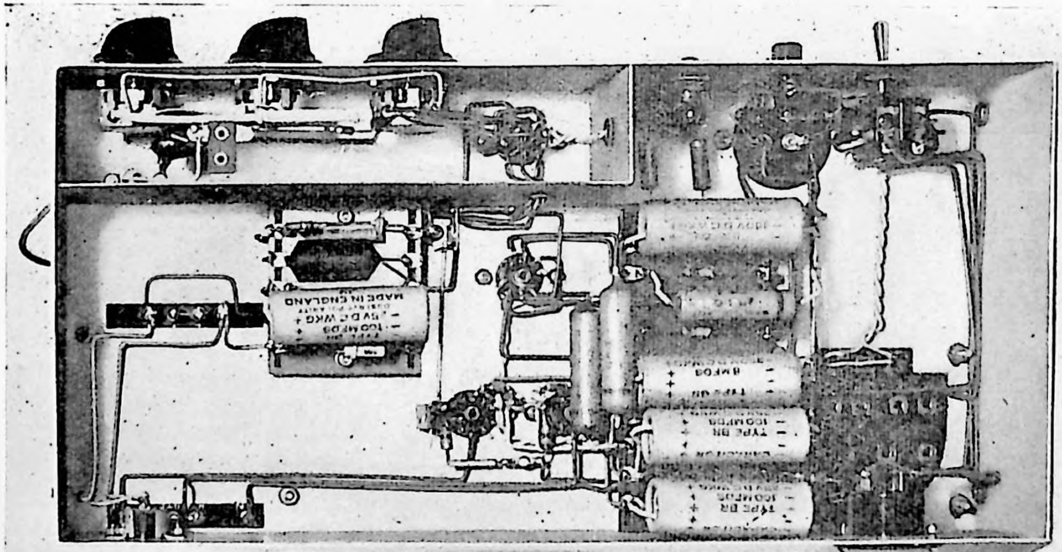
UNDER CHASSIS VIEW OF RECOMMENDED LAYOUT



UNDER CHASSIS VIEW OF AMPLIFIER BUILT TO RECOMMENDED LAYOUT

CIRCUIT DESCRIPTION

TONE CONTROL CIRCUIT

A separate valve pre-amplifier is not required when the input to this tone control circuit is provided by one of the recommended types of pick-up unit. A considerable reduction in cost is possible when this circuit is used.

The amplifier has a high basic sensitivity of 2.5mV, so that after allowance has been made for the level of feedback (26db), the input signal at the Y–Y terminals has to be 50mV to give maximum output power. This high sensitivity of the amplifier makes it possible to use a tone control circuit which produces an attenuation of 12 times. An input signal of 600 mV at the X–X terminals (see circuit diagram) will give the maximum output power (12–13W), so that the tone control circuit and amplifier can be driven directly by a crystal pick-up.

Details of the tone control, which is quite conventional, are included on the main circuit diagram. The treble control is RV23 and the bass control RV24. Reference to Fig. 3 shows the effect of varying in turn the bass control (Curves Nos. 1 and 2) and the treble control (Curves Nos. 3 and 4). A flat response (Curve No. 5) can be obtained by a suitable setting of treble and bass controls. The tone control circuit provides sufficient boost and attenuation, at both treble and bass frequencies, to compensate for widely differing listening conditions.

INPUT STAGE

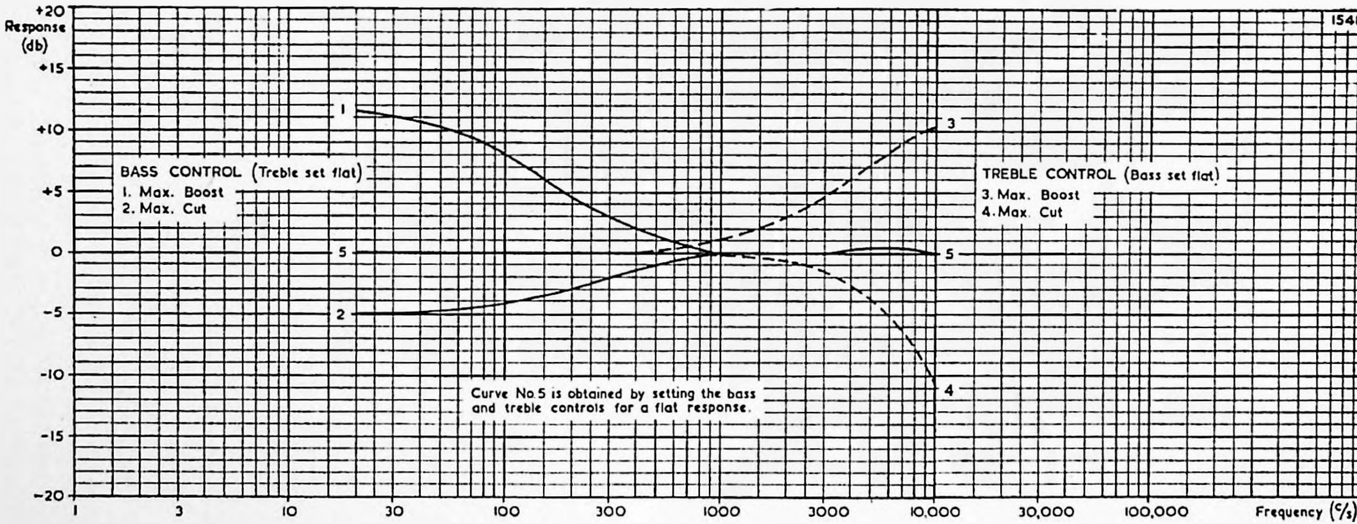
The first stage of amplification is provided by the EF86 in a circuit having a gain of approximately 150 times. The negative feedback voltage from the secondary of the output transformer is introduced across the 100Ω resistor, R5, in the cathode circuit.

The EF86 has been coupled directly to the phase splitter to reduce the phase shift at low frequencies. A C–R network (C13, R22) shunting the anode load produces an advance in phase, which increases the stability of the amplifier at high frequencies.

Because of the high gain in the input stage, any excessive noise, hum, or microphony introduced here will lower the quality of the output from the loudspeaker. The following notes describe the precautions needed to ensure that the good properties of the EF86 are realised in the actual circuit.

Noise

A high stability resistor should be used for the anode load R2, in order that the advantage of the low noise level provided by the EF86 shall not be lost on account of additional noise generated by the



1548
Response (db)
+20
+15
+10
+5
0
-5
-10
-15
-20
BASS CONTROL (Treble set flat)
1. Max. Boost
2. Max. Cut
TREBLE CONTROL (Bass set flat)
3. Max. Boost
4. Max. Cut
1
2
3
4
5
5
Curve No.5 is obtained by setting the bass and treble controls for a flat response.
1
3
10
30
100
300
1000
3000
10,000
30,000
100,000
Frequency (c/s)

FIG. 3

passage of current through a normal carbon resistor.

Hum

The cathode resistor R4 is by-passed at possible hum frequencies as a safeguard against hum being produced by current flowing between heater and cathode. This current may be caused by heater emission, or by capacitive coupling and leakage between the pins. These points should be watched:

1. A low loss holder must be used. In this application, a "Mikacin" or nylon-loaded phenolic holder, preferably a skirted type, is adequate.
2. The external leads to the heater should be run as a twisted pair to neutralise their external magnetic fields. (The heater of the EF86 is itself of spiralised form.) The heater wiring should be kept as close to the chassis as possible.
3. Earth returns should be made to a bus-bar. Connections can be made to the centre spigot of each valve holder in the first instance. The bus-bar should be connected to the chassis at one point, preferably the input terminal. This will minimise hum pick-up due to chassis currents.
4. With the recommended layout (page 8), no trouble should arise from hum pick-up due to the influence of the mains transformer field. If some other layout is tried, there is a possibility that hum may be picked up from the magnetic field of the mains transformer.

Microphony

The EF86 has a rigid electrode structure so that, when correctly sited, there should be no tendency for it to respond to mechanical vibrations and sound waves. Microphony will not arise if the amplifier unit is mounted away from the gramophone and the loudspeaker. When the EF86 is less favourably sited, a flexible mounting for the valveholder or a separate weighted sub-chassis may be advisable.

PHASE SPLITTER

The output stage is fed by an ECC83 double triode operated as a cathode coupled phase splitter. 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 approximately half that obtained from each valve section operated as a normal voltage amplifier. Nevertheless it is sufficient since the ECC83 has an amplification factor of 100.

It is necessary in a cathode coupled phase splitter for the anode load of the grounded section to be slightly higher than that of the first section if perfect balance is to be obtained. Thus R10 should ideally be slightly higher than R9, by a percentage which depends on the amplification factor of the valve. The high amplification factor makes this difference only a few percent; and further a reasonable balance is still maintained with equal values of anode load resistance. Optimum results will be obtained when R10 is larger than R9 by 3%. If R10 is 5% larger than R9 the unbalance of output voltages will be no more than 2%. If R10 and R9 are of exactly equal value the unbalance resulting will be less than 3%. Thus it can be seen that less than 2% unbalance can be expected when R10 and R9 are matched within 5%.

At low frequencies the presence of C7 and R8 in the grid circuit of the second triode section produces both phase and amplitude unbalance. The frequency at which this unbalance becomes significant depends on the time constant C7R8; this should be as long as possible to provide maximum decoupling within the pass band of the amplifier. Adequate balance can easily be maintained in practice, the component values used in the present circuit maintaining adequate balance down to low audible frequencies.

The anode voltage of V1 determines the operating conditions of the phase splitter, and, provided the values of the associated components are within the stated tolerances, the stage will operate correctly. If the anode voltage of V1 is too high the bias on the phase splitter will be too low and grid current distortion due to overdrive on peak signals will result; alternatively if this voltage is too low the phase splitter bias will be too high and the stage will operate away from the linear portion of the valve characteristics, thus resulting in increased distortion.

OUTPUT STAGE

The output stage operates with two EL84 output pentodes in cathode-biased push-pull. The anodes are fed from the reservoir capacitor C1, the screen grids and the rest of the amplifier being supplied via R18 and C2.

The slightly different currents drawn by any two valves of the same type are, for the EL84, adequately taken care of by using separate cathode resistors R16 and R17. *Matching of the output valves is therefore unnecessary.*

Stopper resistors R14 and R15 in the control-grid leads, and R19 and R20 in the screen-grid leads, have been included as a normal measure to prevent parasitic oscillations. These resistors should not be by-passed, and a close connection should be made to the tags on the holder.

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

Operating Conditions

There are two ways of operating the output stage, known as the "normal loading" conditions, and the "low loading" conditions. Normal loading is used when the amplifier is to be tested up to full output power with a sine wave input. Low loading gives reduced distortion when the amplifier is driven **only** by a speech or music input.

The amplifier is adjusted to either normal loading or low loading by choosing the appropriate value for the cathode resistors R16 and R17:

Normal loading, R16=R17=270Ω.

Low loading, R16=R17=437Ω (i.e. 390Ω+47Ω).

It will be realised straight away that when the amplifier is being used for its primary purpose, as a means of home entertainment, the low loading adjustment is to be preferred. Sine wave testing must not be undertaken up to the full output power with low loading, but a *low level sine wave may be used to measure frequency response provided the output power does not exceed 1–1.5W, above which point 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.* These restrictions are not felt to be any disadvantage, as most home constructors will not have the equipment needed to undertake sine wave and square wave testing. Should it be desired to make sine wave tests up to the full output power of 12–13W, the normal loading adjustment **must** be used (and, by the way, the rectifier must be type GZ30, see page 20).

Low Loading

The normal loading conditions correspond to the Class AB conditions given in the valve data (page 62); the only slight difference is that in the actual circuit separate cathode resistors are used (=270Ω) instead of a common cathode resistor (=130Ω). The anode to anode load for these conditions is 8,000Ω, and the anode current with zero input signal is 2×36mA.

The low loading adjustment is so called because with this adjustment the anode to anode load is reduced to 6,000Ω; at the same time, the quiescent anode current is reduced to 2×24mA.

With speech and music inputs, although the output stage is connected for cathode bias, its operation approximates very closely to fixed bias conditions. A comparison between the distortion in the output stage, when speech and music inputs are used with normal loading and low loading, can therefore be seen directly from Fig. 4. Curves No. 1 and 3 have been plotted for fixed bias. Curve No. 1 shows that distortion increases seriously above 10W when normal loading is used; curve No. 3 is for low loading, and shows the lower level of distortion achieved with this adjustment.

Curve No. 2 is for cathode bias and therefore refers to a sine wave input. It has been plotted for normal loading, as this is required for sine wave testing of the amplifier up to its maximum output (12–13W).

Fig. 4 shows the distortion figures for the output stage; those for the complete amplifier are given on page 6.

Advantages of low loading

The maximum rated output of the amplifier is only required in the output stage for a small part of the time, the *average* power being comparatively low. A high maximum power output has to be available to cater for the widely differing sound levels occurring during the reproduction of speech and music. The low loading adjustment provides reduced distortion at just these peak levels, although the improvement may be hard to detect, until the ear is accustomed to high quality reproduction, because it affects such short intervals of time.

The H.T. consumption is smaller when the output stage is adjusted for low loading. Consequently the standing dissipation in the output stage is reduced from 11W at each anode to 7.5W at each anode. The output valves are then being run well below their maximum anode dissipation of 12W, and their expectation of life will be correspondingly increased. Also, with low loading there

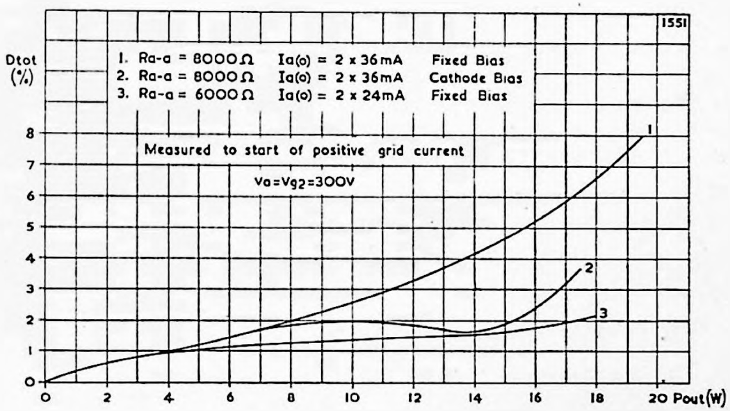


FIG. 4

will be less ripple on the H.T. line. The mains transformer can be given a lower rating, as a measure of economy, when the amplifier is to stay permanently set for low loading.

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 or music input. They are supplied by the reservoir capacitor C1 which has to be given a large value (50µF) in any case to provide satisfactory smoothing. When the amplifier is at the point of overload on a peak signal, the momentary fall in line voltage should not be more than 2V on the nominal line voltage of 320V.

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 1V. 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 of this change in the bias of the output stage, a variation in gain will occur. However, the distortion introduced by gain variation is held to a low level by the large amount of negative feedback. The total effect, therefore, is to improve the performance at peak power.

OUTPUT TRANSFORMER

The quality of the amplifier depends to a large extent on the output transformer. It must give adequate performance, and therefore a **minimum specification** has been drawn up (pages 25 and 26).

It is advisable to obtain the output transformer from a manufacturer who has undertaken to build this component specially for this circuit. An 8,000Ω primary is only suitable for normal loading, and a 6,000Ω primary is only suitable for low loading. In some types the 8,000Ω primary has a tapping for 6,000Ω (see page 4).

More highly priced output transformers may be used by those who want even better results.

The most important factors determining the performance of this component are:

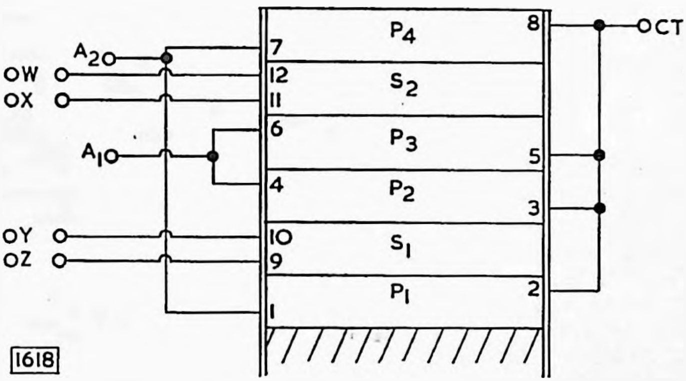
1. Primary winding inductance
2. Leakage inductance
3. Core material and core size
4. Intrinsic capacitance of the coils (especially of the primary)
5. Capacitances between the various coils
6. Power efficiency

In an actual design a compromise must be found between the primary inductance and the capacitance of the primary. The primary inductance has to be sufficiently high to minimise the fall in response which occurs at low frequencies. On the other hand, a very high inductance necessarily produces a high primary capacitance due to the larger number of primary turns, and this might give a large voltage loss at high frequencies.

The inductance of the primary and the capacitance in parallel with it form a tuned circuit. It is desirable for the resonant frequency of this tuned circuit to be as high as possible; in practice it usually lies between 50 and 100 kc/s in a good component. The parallel capacitance can only be kept to a small value by winding the coil carefully. A high value may cause trouble when feedback is used, because of the increased phase shift.

If the coupling between the primary and secondary is not sufficiently high, corresponding to increased leakage inductance, an excessive phase shift will be introduced at high frequencies which may lead to parasitic oscillation.

In the specified output transformer, a high coupling is obtained by dividing the primary into sections (Fig. 5), and winding the secondaries between the primary sections. The footnote shows that the secondaries are connected in series for 15Ω or in parallel for 3.75Ω. These output terminations are suitable for almost all makes of loudspeaker.



For 15Ω secondary: link X and Y; make connections to W and Z.
For 3.75Ω secondary: link W and Y, link X and Z; make connections to WY link and XZ link.

FIG. 5

NEGATIVE FEEDBACK

Negative voltage feedback is used to improve the performance of the complete amplifier. It decreases distortion; improves the frequency response; reduces phase shift; reduces the output resistance; and makes the amplifier less dependent on small changes in supply voltage, etc.

In the Mullard 5 valve 10 watt amplifier circuit, overall negative voltage feedback (26db) is taken from the secondary of the output transformer to the cathode of the input stage. Fig. 6 shows the gain in the complete feedback loop, frequency response, and phase shift. The frequency response is flat to within ±0.5db between 10c/s and 20,000c/s, and the phase shift is less than 30° at these two extremes.

The output resistance with feedback is 0.9Ω measured at the 15Ω output terminals. This gives a damping factor of about 17 (=15/0.9).

The feedback connection to the secondary winding of the output transformer must be found by trial and error. Reversing the connection introduces a 180° change of phase. When connecting up the feedback circuit, a low grade loudspeaker may be connected to the output terminals. With unsuitable phasing relative to the input signal, there will be violent oscillation which might damage a delicate speaker coil suspension. If a low grade loudspeaker is not available, a momentary connection of the feedback loop should be sufficient to determine the correct phasing.

Should it be desired to experiment with the level of feedback, this may be done by varying the value of R21. Increasing the value of R21 will reduce the level of feedback. Reducing the value of R21 would increase the feedback and might introduce instability, unless an output transformer of a higher grade is used. A suitable value for C12, the shunt capacitor for R21, must then be found empirically. There is not, however, much audible improvement when the feedback level is greater than the designed level of 26db.

CHOICE OF RECTIFIER

The full-wave rectifier recommended for this amplifier is type GZ30. Many home constructors, however, will prefer to use type EZ80, and this is quite permissible when the amplifier is used with a speech or music input only. Before choosing the rectifier, it will be necessary to decide whether it will be required to supply extra current in the future (see "F.M. Unit" below), and also to what extent, if any, the amplifier will be tested with a sine wave or square wave input.

The GZ30 is completely suitable for all applications of the amplifier. With the GZ30, sine wave testing can be pursued up to full output power when normal loading conditions are used.

This valve has a 5-volt heater and is mounted on the Octal base.

The EZ80 can be recommended provided sine wave testing will not be undertaken at high output powers. It can be fitted when the amplifier is to be permanently adjusted to "low loading" conditions (page 16), since sine wave inputs can then be used to produce an output power which does not exceed 1–1.5W. Under "normal loading" conditions, the output power can be increased up to 6W before overloading of the EZ80 will occur. Square wave testing can be used with the EZ80 for both the normal loading and low loading adjustment, provided the input is of a similar level to that used for the corresponding sine wave testing.

The EZ80 has a 6.3-volt heater and is mounted on the B9A (noval) base.

Maximum Currents

The current drawn from the rectifier must not be allowed to exceed its maximum rating.

The current from the **GZ30** must not exceed 125mA.

The current from the **EZ80** must not exceed 90mA.

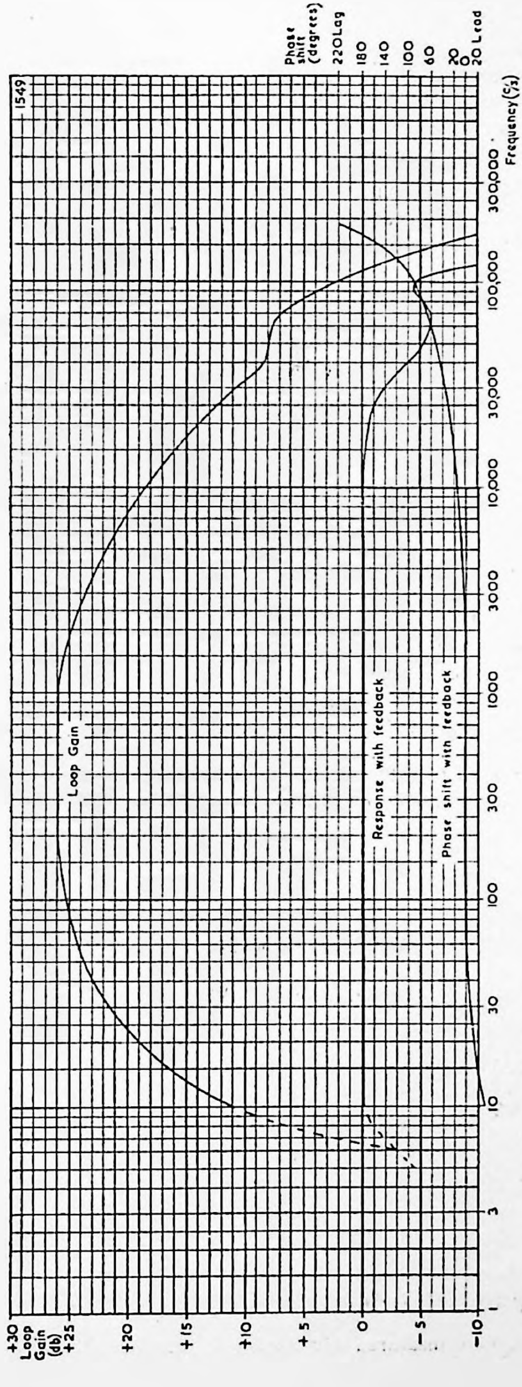

1549
Loop Gain
Response with feedback
Phase shift with feedback
+30
Loop Gain (db)
+25
+20
+15
+10
+5
0
-5
-10
1
3
10
30
100
300
1000
3000
10,000
30,000
100,000
300,000
Frequency (c/s)
Phase shift (degrees)
220 Lag
180
140
100
60
20
0
20 Lead

FIG. 6

Smoothing

As one means of reducing the cost of components, smoothing chokes have been dispensed with in this circuit. The resistance-capacity smoothing employed is perfectly satisfactory, the reservoir capacitor C1 having been given a large value (50µF) for the purpose.

The combined hum and noise level is 73db below 10W, or 74db below the maximum rated output of 12–13W. With the ear close to the loudspeaker no hum can be detected. (Noise close to the loudspeaker is a slight rustle, but in normal listening positions this, too, is inaudible).

F.M. UNIT

The proposed F.M. transmissions will provide reception which covers a comparatively wide range of sound frequencies, and is almost free from noise interference. This high quality reception is heard to advantage when the available output power is higher than can be obtained from normal broadcast receivers.

An F.M. unit can be combined very suitably with this amplifier circuit. It will be well capable of driving the amplifier, and need only be connected to the input terminals X–X. Under practical conditions—that is, with speech and music inputs—the GZ30 rectifier will have sufficient current reserve to supply the F.M. unit in conjunction with the amplifier (see page 20). The EZ80, however, should not be expected to supply units outside the amplifier.

Details of an F.M. unit suitable for home constructors will be released by Mullard Ltd. in the near future.

CIRCUIT VOLTAGES

Testing Point	D.C. Voltage (V)	Meter Range
*C1	320	1000 V d.c.
C2	310	1000 V
Cathodes V3, V4	12	100 V
Anodes V3, V4	310	1000 V
Screen grids V3, V4	310	1000 V
C3	255	1000 V
Anodes V2	210	1000 V
Cathodes V2	71.5	1000 V
C4	182	1000 V
Anode V1	70	1000 V
Screen grid V1	65	1000 V
Cathode V1	1.5	25 V

* A.C. voltage at C1 is 4V for normal loading, and 2.5V for low loading.

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

PARTS LIST

Resistors

Circuit Ref.	Description	Value (Ω)	Tolerance (±%)	Rating (W)
RV1	Variable, carbon	1 M (log law)		
R2	Fixed, carbon (high stability)	180 k	10	1
R3	Fixed, carbon	1 M	10	¼
R4	Fixed, carbon	1.8 k	10	¼
R5	Fixed, carbon	100	5	¼
R6	Fixed, carbon	100 k	10	¼
R7	Fixed, carbon	68 k	10	1
R8	Fixed, carbon	1 M	10	¼
R9	Fixed, carbon	100k, see below[1]	10	½
R10	Fixed, carbon	(R9, R10 bracketed)	10	½
R11	Fixed, carbon	33 k	10	¼
R12	Fixed, carbon	820 k	10	¼
R13	Fixed, carbon	820 k	10	¼
R14	Fixed, carbon	4.7 k	20	¼
R15	Fixed, carbon	4.7 k	20	¼
R16, R17	Fixed, carbon:			
	Normal loading	270	5	3
	Low loading	390+47	5	3
R18	Fixed, carbon	1.2 k	10	1
R19	Fixed, carbon	47	20	¼
R20	Fixed, carbon	47	20	¼
R21	Fixed, carbon	see below[2]	5	¼
R22	Fixed, carbon	18 k	10	¼
RV23	Variable, carbon	2 M (log law)		
RV24	Variable, carbon	2 M (log law)		
R25	Fixed, carbon	1.5 M	10	¼
R26	Fixed, carbon	150 k	10	¼
R27	Fixed, carbon	see below	20	1
R28	Fixed, carbon	see below	20	1

[1] The 100kΩ resistors for R9 and R10 should be matched to within 5%, and the larger used for R10.

[2] 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:—

Speaker Impedance (Ω)	C12 (pF)	R21 (kΩ)	Tolerance (±%)
3.75	180	15	5
7	120	22	5
15	82	33	5

R27 and R28

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 47Ω for the GZ30 or at least 215Ω for the EZ80. The amount of series resistance, R_t, contributed by the transformer is:

$$R_t = R_s + n^2 R_p$$

where R_s = resistance of half the secondary
R_p = resistance of primary
n = ratio of the number of turns on half the secondary to the number of turns on the primary

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

Capacitors

Circuit Ref.	Description	Value (μF)	Rating (Vd.c. working)
C1, C2	Double electrolytic	50+50	350
C3	Electrolytic	8	350
C4	Electrolytic	8	350
C5	Electrolytic	100	12
C6	Paper	0.02	350
C7	Paper	0.1	350
C8	Paper	0.1	350
C9	Paper	0.1	350
C10	Electrolytic	100	25
C11	Electrolytic	100	25
C12	Ceramic or Mica	see above[2]	
		(pF)	Tolerance (±%)
C13	Ceramic	100	20
C14	Ceramic	33	10
C15	Ceramic or Mica	680	10
C16	Ceramic or Mica	270	10
C17	Ceramic or Mica	3300	10

Transformers

TR1 Mains transformer. See page 5.

TR2 Output transformer. See page 25.

Valves

Circuit Ref.	Make	Type No.
V1	Mullard	EF86
V2	Mullard	ECC83
V3, V4	Mullard	2×EL84
V5	Mullard	GZ30 or EZ80*

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

Fuses

FS1, FS2 — 1 amp.

Pilot Lamp

A 6.3V pilot lamp may be used, if desired, to show when the mains supply is switched on. It should be connected to the b–b winding which supplies the heaters of the EF86, ECC83 and EL84's.

MINIMUM SPECIFICATION FOR OUTPUT TRANSFORMER

Matching: The primary of 8,000Ω or 6,000Ω can be matched to either the 15Ω or 3.75Ω secondary.

> **Note:** An 8,000Ω primary must be provided if normal loading is to be used. The 6,000Ω primary is only suitable for use with low loading. In winding table (A) refers to 8,000Ω primary, (B) to 6,000Ω primary.

Winding Data

Laminations: Square stack of 1⅛ inch centre limb, E and I laminations, "NO WASTE" series.
Pattern No. Sankey No. 158, proposed British Standards No. 29.

Core Material: 4% Si steel, 0.014″ laminations.

Core Size (External): 3.375×2.8×1.125 inches. Bobbin to suit.

Winding Table

Winding	No. of Turns	No. of Layers	Turns per layer	Wire SWG
P1	1650 (A) 1450 (B)	7	236 (A) 207 (B)	40
S1	76	2	38	22
P2	1650 (A) 1450 (B)	7	236 (A) 207 (B)	40
P3	1650 (A) 1450 (B)	7	236 (A) 207 (B)	40
S2	76	2	38	22
P4	1650 (A) 1450 (B)	7	236 (A) 207 (B)	40

Wire: Enamelled Copper.

Width of Windings: 1.35 inches.

Insulation: Between layers of primary sections: 0.001″ paper. Between layers of secondary sections: 0.003″ presspahn.

Between various sections: 1 layer of 0.003″–0.004″ presspahn, and 1 layer of 0.002″ paper.

Winding Sense:

All windings to be in the same sense.

The following windings are connected in parallel:

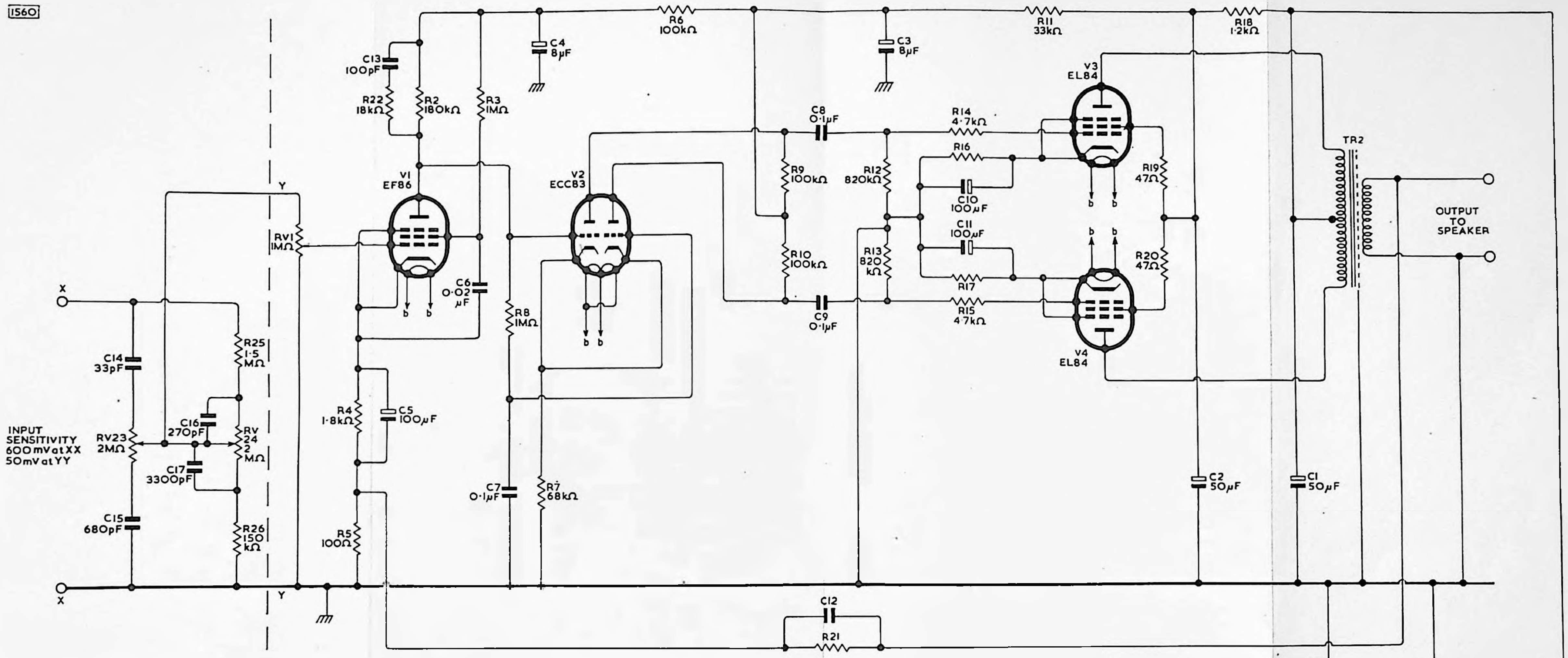
P1 and P4 to form one half of primary;
P2 and P3 to form other half of primary wound from Right to Left; all other windings to be wound from Left to Right.

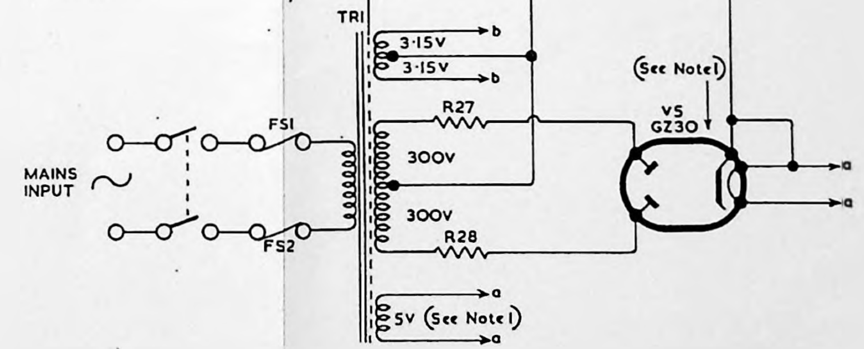
S1 and S2 are brought out separately for series (15Ω) or parallel (3.75Ω) connection (see page 19).

Electrical Characteristics:

Primary shunt inductance (8,000Ω)	40H at 10V, 50c/s.	
Primary leakage inductance	25mH	
Primary d.c. resistance	240Ω per half primary (8,000Ω)	
Secondary resistance	S1	approx. 0.5Ω
	S2	approx. 0.5Ω

CIRCUIT DIAGRAM





NOTES.

1. The EZ80 may be used instead of the GZ30 provided the current drawn does not exceed 90mA. Sine wave testing up to full output power cannot be undertaken when the EZ80 is used, and also this rectifier should not be expected to supply the additional current required for other units used in conjunction with the amplifier.

   For the EZ80, the heater winding a–a must supply 6.3V.

   If sine wave testing is to be employed for outputs up to maximum power, type GZ30 must be used and a 5V-heater winding will be required. The GZ30 can be made to supply additional power for F.M. units etc.

2. The total limiting resistance, Rlim, 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:

   $$R_t = R_s + n^2 R_p$$

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

   Thus if Rt is less than Rlim, then R27 and R28 should each be chosen with a value equal to the difference between Rlim and Rt.

3. For a sine wave input R16 and R17 must both be 270 Ω. If however the amplifier will only be used for speech or music inputs, the alternative value of 437 Ω (=390 Ω + 47 Ω) can be used, together with a primary load of 6000 Ω.

4. C12 and R21 must be chosen to match the loudspeaker according to the following table:

Speaker Impedance (Ω)	C12 (pF)	R21 (kΩ)
3.75	180	15
7	120	22
15	82	33

ASSOCIATED EQUIPMENT

SOURCES OF DISTORTION IN THE SOUND OUTPUT

Some distortion is always present in the sound reproduced from a gramophone record. It is inevitable that part of this distortion will be distortion actually recorded on the disc itself, but the loudspeaker and pick-up also make substantial contributions. An amplifier built carefully to the Mullard 5 valve 10 watt amplifier circuit is therefore far from being the weakest link in the chain of playback equipment. This means, from the practical point of view, that reproduction can be very much improved by paying attention to the sound input and to the loudspeaker. In practice the performance of the amplifier is unlikely to set the limit to the quality which can be obtained.

Even if *perfect* acoustical equipment could be obtained, however, it would not be possible to eliminate distortion entirely. There would still be some distortion—a comparatively small amount it is true—which is bound to arise when discs are used. The next few paragraphs indicate briefly how this inherent distortion occurs.

Tracing Distortion

One form of distortion is caused by the difference in shape between the groove and the rounded needle used for playing back.

The way it arises can best be seen by considering the width of the groove. Of course, when no sound is being recorded the cutting stylus produces a "straight" groove of constant width. In actual recording the stylus has to trace a curve and will usually be moving at an angle to the unmodulated position. This is illustrated in Fig. 7, which shows a sine wave groove very much magnified.

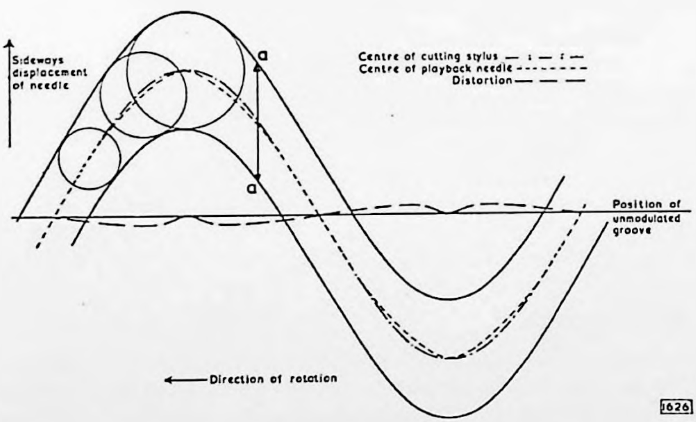


FIG. 7

The sideways width (a–a) of the groove always corresponds to the effective width of the cutting edge. The *minimum width* of the groove varies and except at the top of the peaks is less than the width of the stylus, as can be seen by comparing the various circles drawn touching the two sides.

In order to avoid distortion, the sideways movement of the needle should reproduce exactly the movement of the cutting stylus. Now the circles in Fig. 7 represent the point of the needle as it rests in the groove during playback, and the centres of the circles should therefore follow the line traced by the centre of the stylus. The figure shows that this condition is not fulfilled; the dashed line traced by the needle is not the same as the dotted line traced by the centre of a–a. The distortion depends on the difference between the two traces measured perpendicularly to the position of the unmodulated groove. There is no distortion at the peaks of the curves, or in the unmodulated position.

Tracing distortion increases when the groove waveform becomes more spiky. Thus it increases with both the frequency and amplitude of the recorded signal. It increases when the waveform is more compressed, as it will be near the centre of the record.

Tracing distortion consists of odd harmonics.

Pinch Effect

Fig. 7 also illustrates the so-called "pinch effect". Because the width of the groove is continually varying, the needle has to ride up and down (Fig. 8). At the end of a microgroove recording, the maximum vertical movement may be as much as 11% of the maximum sideways movement. The output from some pick-ups varies slightly with this vertical movement, and the pinch effect can be an additional source of distortion. As the needle has to move up and down again *twice* during each complete cycle, the distortion is of even harmonic order.

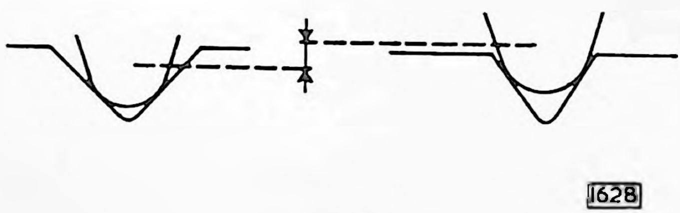


FIG. 8

Needle Scratch

As the needle traces the groove, the fine particles in the material of the disc cause the needle to make small, irregular movements. The signal set up by these movements is amplified and heard as needle scratch. This noise lies mainly between 2,000c/s and 10,000c/s.

Needle scratch will be particularly bad when the diameter of the needle is too small for the groove (Fig. 8); for good reproduction the needle should rest on the two sides. If it rests right in the trough it may ride up the walls, thus leading to excessive scratch and additional distortion. Too large a needle, on the other hand, rests only on the top of the walls and cannot follow the groove correctly. There will then be a tendency for the needle to "skate" across the record.

Tracking error

Another important difference between the making and playing back of records is that the reproducing stylus, or needle, on its course towards the centre of the record, does not follow the same path as the cutting stylus. Whereas the cutting stylus is set to move along a straight line, the needle must necessarily be mounted on a pivoted arm so as to swing across the record on an arc. The stylus is not always held at right angles to the groove and the output will vary slightly. Clearly this effect is greater for larger records, and can be reduced by using a longer pick-up arm.

THE HISTORY OF THE GRAMOPHONE PICK-UP

We do not have to be very old to remember the days of the acoustic gramophone consisting of a sound box and amplifier in the form of a magnificent horn. What were its main faults? Most people would say, lack of bass giving thin reproduction, lack of volume, and very hard wear on the record. The heavier passages could be completely ruined by playing the record only a few times. The wall of the record groove had to move the needle sideways against considerable stiffness, created by the direct coupling of the needle and its holder to the diaphragm.

This stiffness, and the weight of the needle and holder, were so great that it is surprising that the record stood up to its task at all. The downward force on the needle must always exceed the sideways force required to move it, otherwise the needle will simply leave the groove altogether by riding up the groove wall. A very heavy downward pressure therefore had to be applied to the needle, and the pressure at the tip was so great that wear took place after only a few revolutions. There was a lack of bass, mainly because the sound box and horn amplifier could not compensate for the limited amplitude used for recording bass notes below a certain frequency. The limit to the bass amplitude was (and still is) necessary to prevent the "groove" cut during one revolution from breaking through into its neighbours' territory. Also, the horn could not be made large enough to deal with low frequencies, so that the bass was still further reduced.

Considerable improvements were made possible by converting the record tracks into electrical voltages, which were fed into a valve amplifier. In the earlier electric pick-ups the movement of the needle was made to generate a small voltage across a coil of wire. The voltage could then be amplified electrically and finally re-converted into sound via a loudspeaker. Bass compensation could be applied in the amplifier. The stiffness of the needle coupling was reduced but this, and the weight of the needle and holder, were still too great and caused considerable record wear. The response to higher notes was generally poor, and the resonance to peak output usually occurred at a frequency which emphasised the needle scratch so much, that sometimes it almost amounted to a whistle. The next step was to reduce the weight of the moving parts by eliminating the large and clumsy needle chuck, and by using miniature needles or jewel tips. These measures made the response more even, and reduced the record wear; unfortunately, the output voltage was also reduced, so that expensive high gain amplifiers had to be employed. Other pick-ups, such as the moving coil type, were developed and many were, and still are, very successful, but their low output still leads to added expense, and, in addition, the price of these pick-ups is high.

A new type of pick-up, the piezo-electric or crystal type, was developed. Certain crystals, when bent or twisted, develop a voltage across their faces which is proportional to the applied force. The voltage produced even for small forces can be quite large and, therefore, if the sideways movement of the needle can be coupled to the crystal, a voltage can be obtained which is the electric counterpart of the sound recorded in the groove. The first crystal pick-ups had heavy needle chucks, and suffered from many of the drawbacks of the earlier magnetic types. They were not associated with high quality reproduction, and also had the disadvantage of being fragile. The output voltage, however, left little to be desired, sometimes being as much as several volts. At that time things did not look very hopeful for the would-be quality enthusiast, unless he had a lot of money to spend on expensive pick-ups and elaborate and expensive amplifiers.

However, after years of painstaking work on crystal pick-ups, many of the disadvantages were overcome. Ways were found of preventing the shocks produced by dropping the pick-up on to the record from being applied directly to the crystal. The fragility of crystal pick-ups was rapidly on its way out. The use of plastic materials and special resistive material to mount the crystal made it possible to check the resonances, and produced a really smooth response, which was well maintained in the treble. The introduction of long playing records made even greater demands on pick-ups (and incidentally reduced the average output to about one-third). Many could not believe that the earlier disadvantages had been overcome, but the facts were convincing. These pick-ups could hold their own against high quality types costing four or five times the price. The compliant movement enabled them to be used at a playing weight of 10 grammes. Record wear was small and the frequency response was good. It soon became obvious that the crystal pick-up had come to stay, now that the earlier troubles had been ironed out. Continued development has further improved the frequency response, and the force required to move the stylus has also been reduced, so that even the most heavily recorded long playing records can be traced without any signs of distress at a playing weight of only 8 grammes. This has been done while retaining an output of over 1V on standard records, and more than one-third of a volt on long playing records.

GRAMOPHONE UNIT

The home constructor will be well-advised to buy a well-known make of gramophone unit. The essential points to watch are that the mechanical driving system is accurately made, and sufficiently steady, these requirements necessarily being very severe if the equipment is to match up to the performance expected from acoustical and electrical gear.

An unsuitable gramophone unit can spoil the loudspeaker output in three objectionable ways, for which the amplifier should not be blamed:

Wow. This effect is produced by variations in the speed of the turntable. The variations are usually caused by the spindles and other rotating parts being 'loosely' mounted or off-centre, so that 'wow' is heard at regular intervals. Unevenness in the drive, changes of friction (catching and slipping), and record slip may give rise to 'wow' which is not necessarily periodic.

Flutter. Small irregularities are normally experienced when driving from a motor. Sudden changes in speed of as little as 0.5% will be clearly noticeable as 'fluttering' when playing back a long note. The speed can be kept sufficiently steady to avoid most of the flutter by providing a heavy turntable, or other moving part, which acts as a flywheel.

Rumble. The mechanical parts should run sufficiently quietly for no objectionable rumbling to be heard at full gain when there is no other input signal.

The above remarks suggest the mechanical features to be looked for in the design.

Care should be taken to see that the speed change mechanism is not subject to undue wear which leads to 'wow' or flutter after much use.

In a high quality installation where the loudspeaker is kept separate, the gramophone unit can be mounted solidly to the motor board, and the motor board itself floated on rubber to ensure that no mechanical vibration is transmitted to the cabinet.

RECORDING CHARACTERISTICS

Up to the present time the various gramophone record manufacturers have been using different recording characteristics. It is hoped that agreement on standard characteristics will be reached at a conference which is to be held within the next few months. In the meantime, specimen recording characteristics have been included in this section to illustrate the principles discussed in the text ; the correction to be applied during playback corresponds to the inverse of the recording characteristic, and is made by means of the appropriate equalisation network.

It is normal to apply bass cut, and sometimes treble boost also, during recording, and correct for it by equalisation networks during playback. The equalisation required depends partly on the recording characteristic (78 r.p.m. or microgroove), but also on the type of pick-up used.

78 r.p.m. recordings

These "standard" recordings have been made on the assumption that they will be played back by a moving-coil pick-up.

The current induced in the coil is determined by the rate at which the velocity of the playback stylus is changing; for a constant volume output, the average sideways velocity of the 'needle' must stay constant independent of frequency. Thus, if the bass notes are not attenuated before being recorded, the needle traces a very large amplitude in the time taken by each cycle, this amplitude becoming larger as the frequency is reduced. The groove traced during each revolution of the disc then needs to be separated from its neighbours by a lot of 'land'. A recording made in this way has a 'constant velocity' characteristic.

In practice, the bass notes below some frequency (for example, 400c/s) are attenuated to avoid excessive recorded amplitudes, to permit closer groove spacing, and to retain a reasonably long playing time. In this frequency range the amplitude of recording is made proportional to recording level; in this way the maximum amplitude is restricted and the response with a velocity type pick-up falls below the turnover frequency at a rate of 6db per octave.

Pre-emphasis of the treble (above about 3,000c/s) is sometimes used to provide a more favourable signal-to-noise ratio on playback, and so makes needle scratch less pronounced. The constant velocity characteristic therefore only applies (Fig. 9) between about 400c/s and 3,000c/s.

Microgroove recordings

The microgroove (or minigroove) recordings are not designed with a constant velocity characteristic in mind. Bass cut and treble boost are applied during recording as previously, but they are combined so that there is no flat portion on the curve (Fig. 10). Microgroove recordings are therefore made on what is very nearly a constant amplitude characteristic. This has to be taken into account when choosing the equalisation to be used with any particular pick-up,

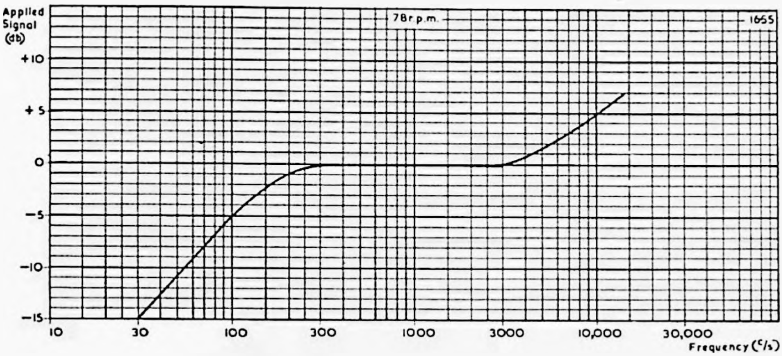


FIG. 9

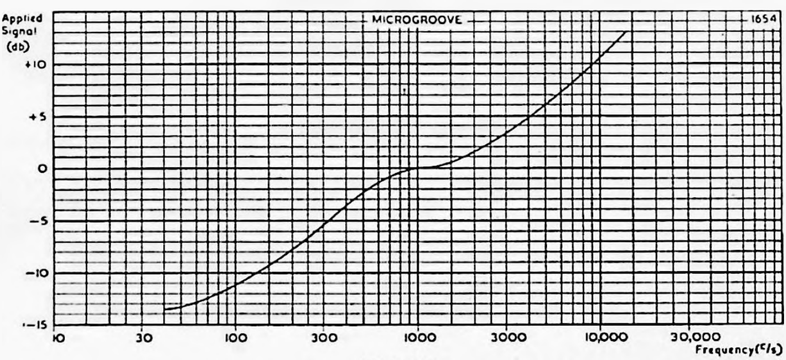


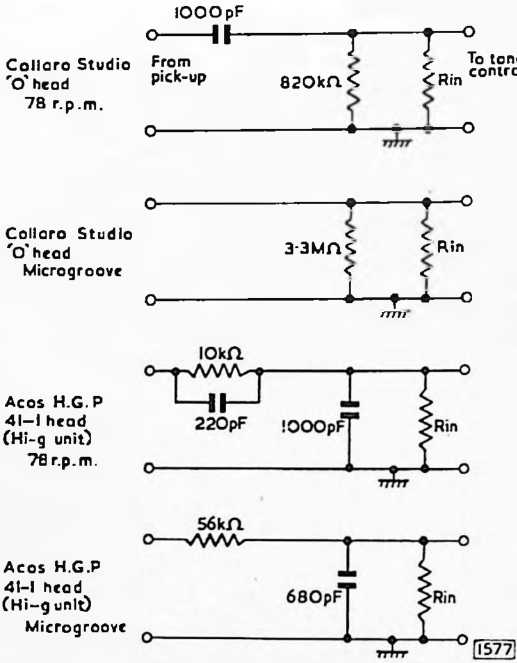
FIG. 10

since crystal pick-ups respond to changes in amplitude instead of to changes in velocity. Less correction is required for a crystal pick-up than for a moving coil type.

With microgroove records, needle scratch is small on account of the homogeneous vinylite material used to make the disc. The needle scratch for standard and microgroove recordings cannot be compared directly, however, as the latter are recorded with an input level which is lower by 10db.

Equalisation Networks

Suitable equalisation networks (Fig. 11) have been derived for the Collaro Studio "O" head and the Acos H.G.P. 41–1 head. These are both crystal units producing an output which makes it possible to incorporate the recommended tone control circuit to correct for the effect of the room, etc., on the reproduction. It is not necessary to go to the extra expense of a separate valve pre-amplifier when pick-ups of this type are used.



Rin represents the input resistance of the tone control circuit.
These circuits are based on Rin=1·5MΩ.

FIG. 11

LOUDSPEAKERS

The choice of a suitable loudspeaker is particularly difficult, but it is well worth remembering that the higher grade of loudspeaker will well justify its extra cost by giving correspondingly better reproduction. You only get what you pay for!

A simple direct radiator loudspeaker, that is, a single cone unit handling the entire range of frequencies, can give excellent results when mounted in a suitable enclosure. It is important to remember that this enclosure should always be that specified by the unit manufacturer, since it is not possible to design a suitable cabinet without knowing accurately the basic performance of the loudspeaker unit. One of the main disadvantages of all types of simple direct radiators is that the high frequency response is very directional. This fact, however, can to some extent be overcome by using the loudspeaker in conjunction with some form of reflector. The reflector can be built into the cabinet, or the corner of the room used for the same purpose. The effect is to distribute the high frequency components in a more random manner, so that with the adequate top lift provided by the amplifier good results will be obtained.

There is no doubt, however, that even the simplest of dual systems is much better than a single unit. Such a dual system may consist of two direct radiators—for example, a 12″ unit for the bass end of the spectrum and a 5″ unit for the middle and treble components—used in conjunction with a suitably designed crossover network. It must be remembered that while the effective frequency response may not be very much increased by the use of this type of dual system, various forms of distortion will be considerably reduced, added to which there will be a better distribution of high frequencies from the smaller source.

Dual systems employing twin direct radiators are available in two forms: either with two completely separate units, each mounted in its own enclosure; or alternatively, with the high frequency unit mounted on some form of modified frame, making it an integral part of the low frequency unit.

Further improvement may be obtained by using three loudspeaker units, together with a 3-way crossover network. This extends the frequency range and reduces the distortion still further, as well as providing a wider range of distribution patterns.

One advantage of horn loading is that the effective damping is increased, and consequently there is improved reproduction of transients. Some loudspeakers incorporate a combination of direct radiator bass units and horn loaded treble units. They enable a higher conversion efficiency to be obtained in the treble portion of the spectrum, thus ensuring a more even distribution for a given frequency response. In other words, the total energy output of the high frequency unit is maintained up to a higher point in the musical scale. Although it is possible to use a completely separate horn loaded tweeter, at least two manufacturers employ a double magnet system which permits the high frequency unit to be mounted concentrically with the low frequency unit. Thus phase distortion at the crossover frequency, which is produced in other systems by the distance between the two units, is avoided; also, the overall response can be made more smooth.

The most complicated form of dual loudspeaker system is that which is horn loaded over its entire range. This may be achieved by using separate horn assemblies, each associated with a loudspeaker unit covering part of the frequency spectrum; alternatively, loudspeakers of the concentric type can be employed. Such systems are always expensive, but they have certain advantages; the electro-acoustic conversion efficiency is high, the acoustic damping over the entire audio range is much improved over any simple direct radiator system, and the larger size of the bass horn gives better realism.

Loudspeaker systems should never be judged hurriedly simply by listening to one or two gramophone records. It is quite easy to construct a system which sounds "impressive" at a first hearing and reproduces certain tones "larger than life". To test a loudspeaker, live with it for a while, find out whether or not you suffer mental fatigue when listening to music; and apply the best test of all by listening to the reproduction of good quality broadcast speech. It is easier to judge the fidelity with which relatively simple sounds are reproduced rather than the effect produced by special orchestral recordings.

VALVE DATA

AND

GENERAL TECHNICAL INFORMATION

The following pages contain data on Mullard valves recommended for use in audio amplifying equipment including the Mullard 5 valve 10 watt amplifier circuit. Information on other valves and tubes can be obtained on request from :—

MULLARD LIMITED,
Technical Service Department,
Century House,
Shaftesbury Avenue,
London W.C.2

LIST OF SYMBOLS USED IN VALVE DATA

These symbols are based on British Standard No. 1409:1950, "Letter Symbols for Electronic Valves".

I. SYMBOLS FOR ELECTRODES

Anode	a	Fluorescent Screen or Target ...	t
Cathode	k	External Metallisation	M
Grid	g	Internal Metallisation	m
Heater	h	Deflector Electrodes	x or y
Filament	f	Internal Shield	s
Beam Plates	bp		

NOTE 1. In valves having more than one grid, the grids are distinguished by numbers—g_1, g_2, etc., g_1 being the grid nearest the cathode.

NOTE 2. In multiple valves, electrodes of the different sections may be distinguished by adding one of the following letters:

Diode	d	Hexode	h
Triode	t	Heptode	h
Tetrode	q	Octode	h
Pentode	p	Rectifier	r

Thus, the grid of the triode section of a triode-hexode is denoted by g_t.

NOTE 3. Two or more similar electrodes which cannot be distinguished by any of the above means may be denoted by adding one or more primes to indicate to which electrode system the electrode forms a part.
Thus, the anode of the first diode in a double diode valve is denoted a^1.

2. SYMBOLS FOR ELECTRIC MAGNITUDES

Voltages		Current	
Direct Voltage	V	Direct Current	I
Alternating Voltage (r.m.s.)	$V_{r.m.s}$	Alternating Current (r.m.s.)	$I_{r.m.s.}$
Alternating Voltage (mean)	V_{av}	Alternating Current (mean)	I_{av}
Alternating Voltage (peak)	v_{pk}	Alternating Current (peak)...	i_{pk}
Peak Inverse Voltage ...	P.I.V.	No Signal Current	I_o

Miscellaneous

Frequency	f	Anode Efficiency	η
Amplification Factor ...	μ	Sensitivity	S
Mutual Conductance ...	g_m	Brightness	B
Conversion Conductance ...	g_c	Temperature	T
Distortion	D	Time	t

	Inside Valve	Outside Valve
Resistance	r	R
Reactance	x	X
Impedance	z	Z
Admittance	y	Y
Mutual Inductance	m	M
Capacitance	c	C
Capacitance at Working Temperature	c_w	
Power	p	P

3. AUXILIARY SYMBOLS

Battery or other source of supply	b
Inverse (Voltage or Current)	inv
Ignition (Voltage)	ign
Extinction (Voltage)	ext
No Signal	o
Input	in
Output	out
Total	tot
Centre Tap	ct

4. COMPLEX SYMBOLS

Symbols in Sections 1 and 3 above may be used as subscripts to symbols in Section 2, to denote such magnitudes as Anode Current, Grid Volts, etc., e.g.:—

Anode Voltage ...	V_a	Anode Current (A.C. r.m.s.)	$I_{a(r.m.s.)}$
Control-Grid Voltage	V_{g_1}	No Signal Anode Current ...	$I_{a(o)}$
Anode Supply Voltage	$V_{a(b)}$	Control-Grid Current ...	I_{g_1}
Filament Voltage ...	V_f	Total Distortion	D_{tot}
Heater Voltage ...	V_h	3rd Harmonic Distortion ...	D_3
Anode Dissipation ...	p_a	Equivalent Noise Reistance	R_{eq}
Output Power ...	P_{out}	Limiting Resistor	R_{lim}
Drive Power	P_{drive}	Cathode Bias Resistor ...	R_k
Anode Current (D.C.)	I_a		

	Internal	External
Anode Resistance	r_a	R_a
Insulation Resistance (heater to cathode)	r_{h-k}	
Resistance between Control-Grid and Cathode ...	r_{g_1-k}	R_{g_1-k}

Capacitance (cold)—

Anode to all other electrodes	c_{a-all}
Anode to control-grid	c_{a-g_1}
Control-grid to cathode at working temperature ...	$c_{g_1-k(w)}$
Control-grid to all other electrodes except anode (Input Capacitance)	c_{in}
Anode to all other electrodes except control grid (Output Capacitance)	c_{out}
Inner Amplification Factor	$\mu_{g_1-g_2}$

VOLTAGE AMPLIFYING PENTODE

Mullard

EF86

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.

HEATER

Suitable for series or parallel operation, a.c. or d.c.

V_h	6.3	V
I_h	0.2	A

MOUNTING POSITION

Any

CAPACITANCES (Measured without external screen)

c_{out}	5.5	µµF
c_{in}	4.0	µµF
c_{a-g1}	0.025	µµF
c_{g1-h}	0.0025	µµF

CHARACTERISTICS

V_a	250	V
V_{g3}	0	V
V_{g2}	140	V
I_a	3	mA
I_{g2}	0.6	mA
V_{g1}	−2	V
g_m	1.8	mA/V
r_a	2.5	MΩ
μ_{g1-g2}	38	

OPERATING CONDITIONS AS R.C. COUPLED A.F. AMPLIFIER

Pentode connection

V_b (V)	R_a (kΩ)	I_k (mA)	R_{g2} (MΩ)	R_k (kΩ)	$\frac{V_{out}}{V_{in}}$	V_{out} ($V_{r.m.s.}$)	D_{tot} (%)	R_{g1}* (kΩ)
400	100	3.3	0.39	1.0	124	87	5.0	330
350	100	2.85	0.39	1.0	120	75	5.0	330
300	100	2.45	0.39	1.0	116	64	5.0	330
250	100	2.05	0.39	1.0	112	50	5.0	330
200	100	1.65	0.39	1.0	106	40	5.0	330
150	100	1.0	0.47	1.5	95	22	5.0	330
400	220	1.55	1.0	2.2	200	73	5.0	680
350	220	1.4	1.0	2.2	196	63	5.0	680
300	220	1.1	1.0	2.2	188	54	5.0	680
250	220	0.9	1.0	2.2	180	46	5.0	680
200	220	0.75	1.0	2.2	170	36	5.0	680
150	220	0.55	1.0	2.7	150	24.5	5.0	680

*Grid resistor of following valve.

Mullard

EF86

VOLTAGE AMPLIFYING PENTODE

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.

OPERATING NOTES

1. *Hum.*

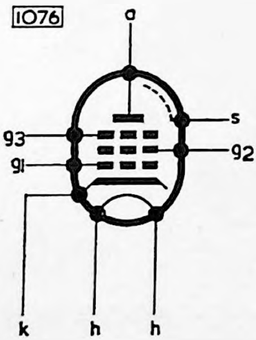
When used as a normal voltage amplifier with a line voltage of 250 V, an anode load of 100 k Ω and a grid resistor of 470 k Ω the maximum hum level of the valve alone is 5μV, the average value being about 3 μV when operated with one side of the heater earthed. This can be further reduced by centre-tapping the heater to earth. Under these conditions the maximum hum level is 1.5 μV. The low level of hum attained with this valve can be completely masked by that due to an unsuitable valve-holder in which excessive leakage and capacitive coupling between pins will introduce considerable hum.

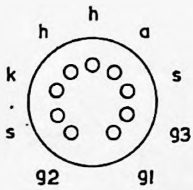
2. *Noise.*

The low-frequency noise generated by a valve is most conveniently specified as an equivalent voltage on the control grid for a specific bandwidth. For the EF86 under normal conditions, i.e. line voltage of 250 V and an anode load of 100 k Ω, the equivalent noise voltage is approximately 2μV for the frequency range 25-10,000 c/s.

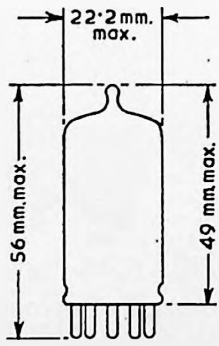
3. *Microphony.*

Care in the design of the valve to ensure that the electrode structure and its mounting are as rigid as possible has reduced the microphony of the EF86 to a very low level. There are no appreciable internal resonances at frequencies below 1,000 c/s. At higher frequencies the effect of vibration is usually negligible on account of the damping provided by the chassis and the valve-holder. In high-gain applications such as tape recording, care should be taken in siting the valve, particularly when a loudspeaker is present in the same cabinet or when a motor is mounted on the same chassis. In such cases a flexible mounting for the valve-holder or a separate weighted sub-chassis is advisable.





B9A
Noval Base

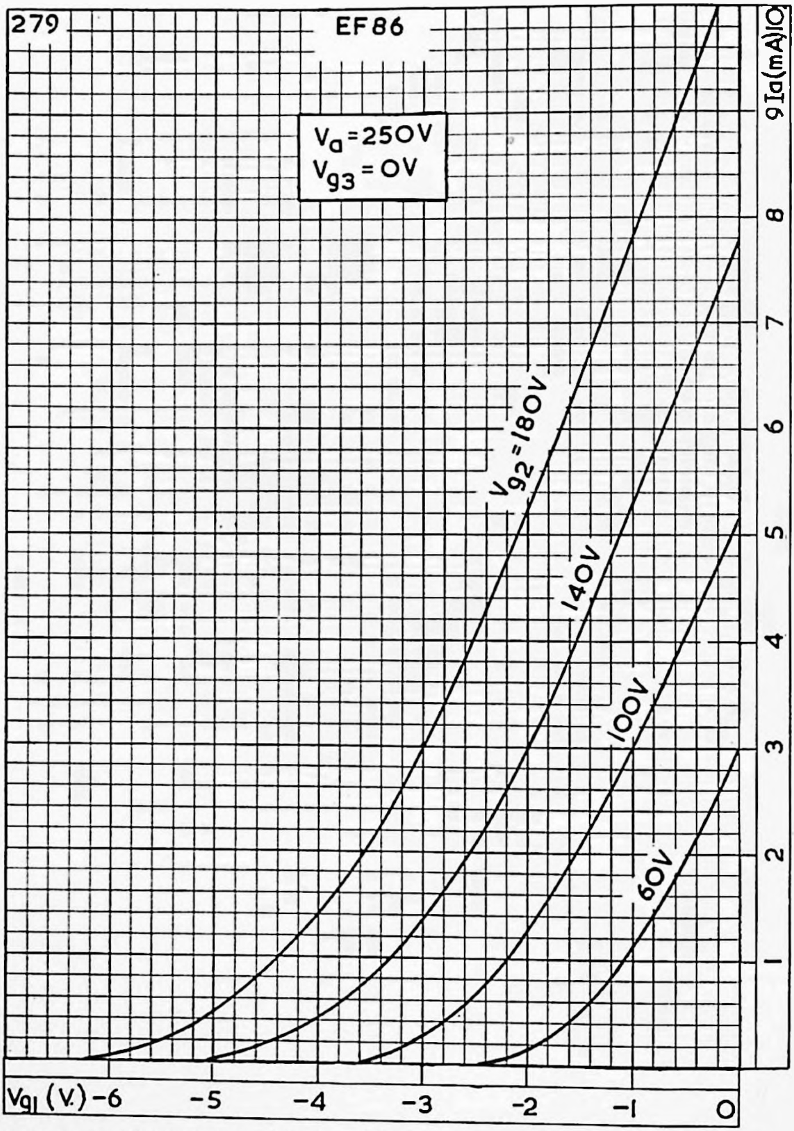


Mullard

EF86

VOLTAGE AMPLIFYING PENTODE

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.



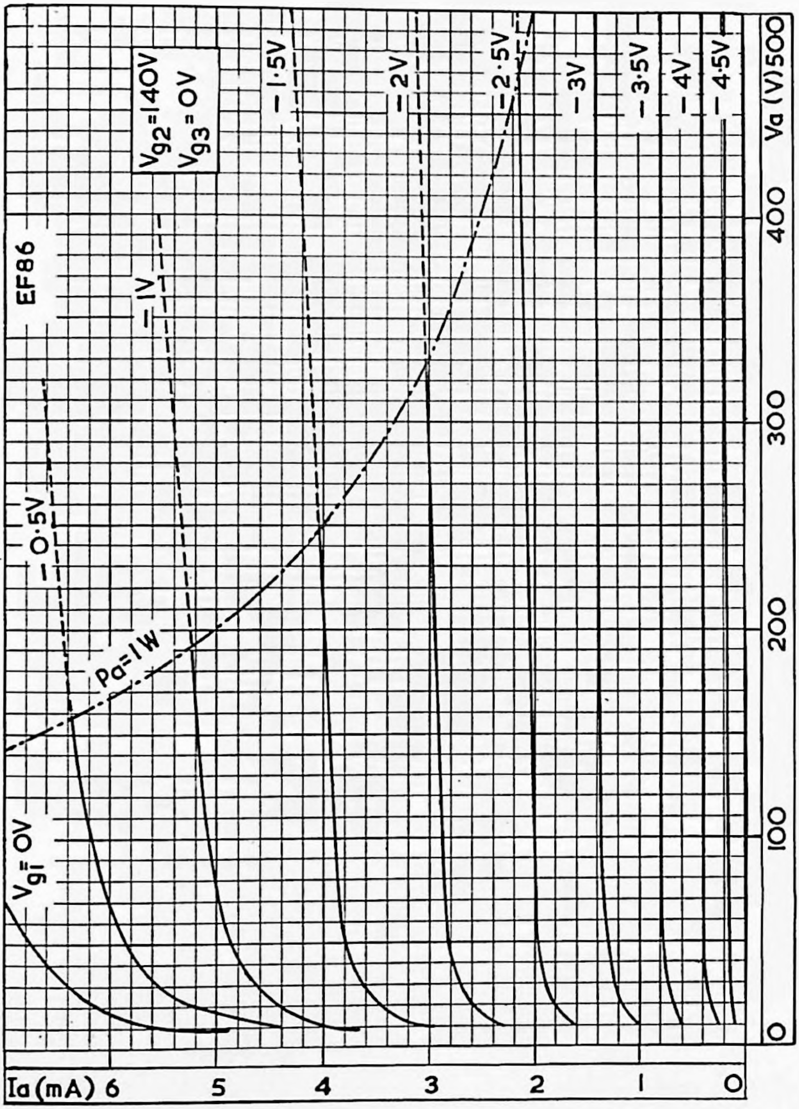
ANODE CURRENT PLOTTED AGAINST CONTROL-GRID VOLTAGE WITH SCREEN-GRID VOLTAGE AS PARAMETER

VOLTAGE AMPLIFYING PENTODE

Mullard

EF86

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.

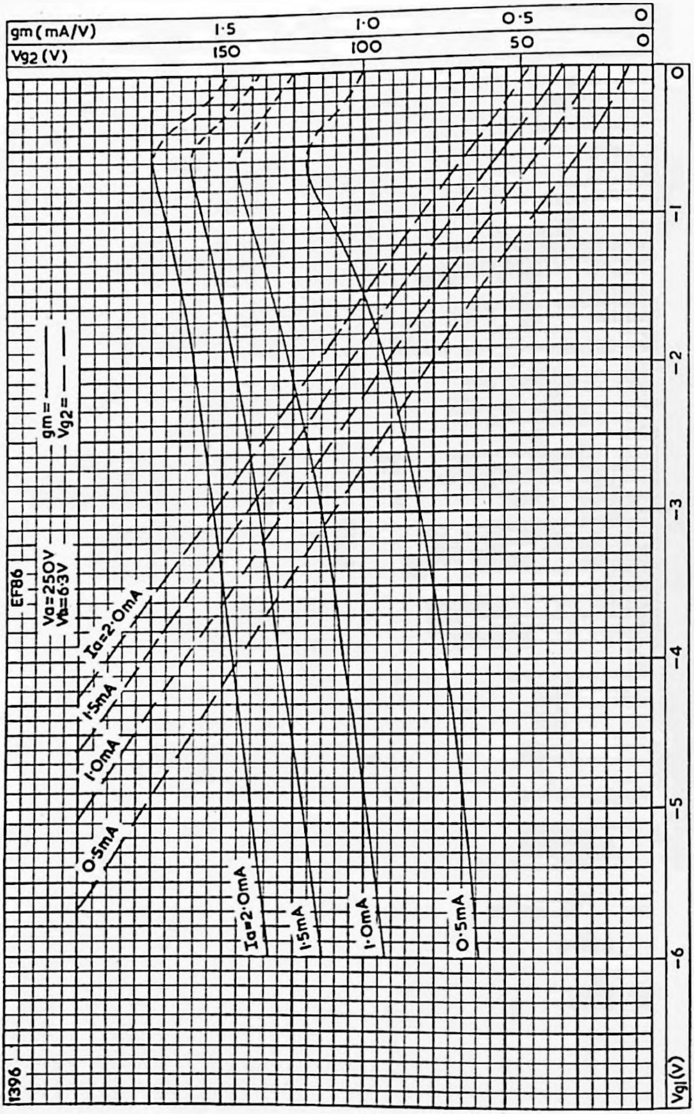


ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE WITH CONTROL-GRID VOLTAGE AS PARAMETER

Mullard EF86

VOLTAGE AMPLIFYING PENTODE

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.



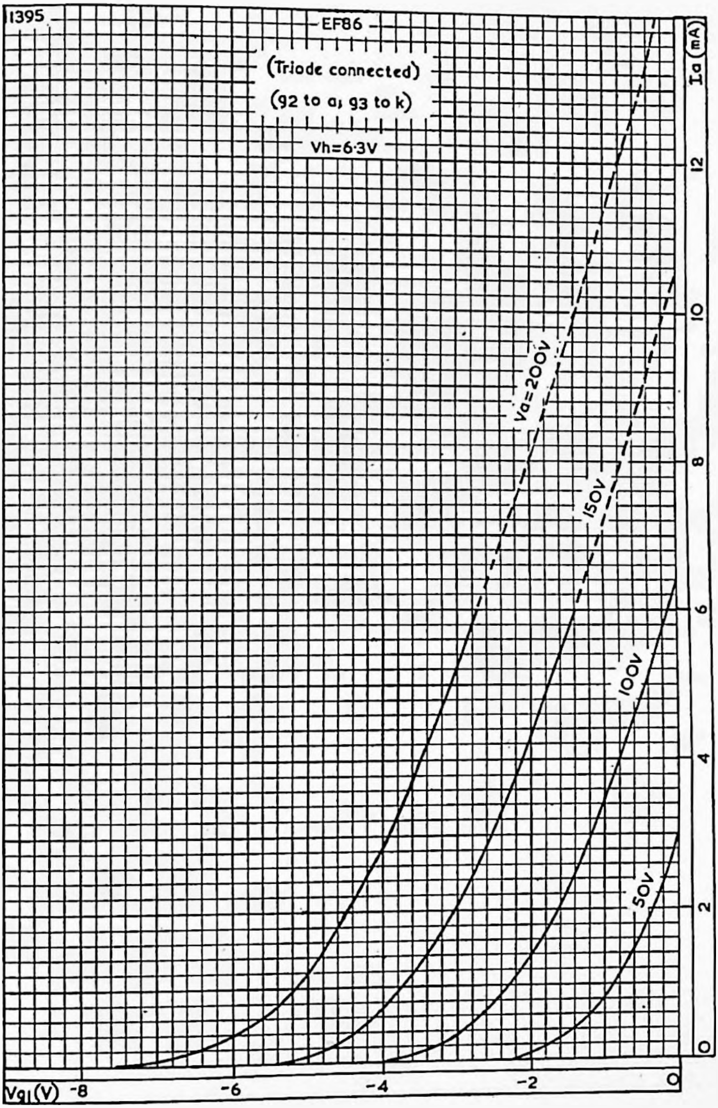
MUTUAL CONDUCTANCE AND SCREEN-GRID VOLTAGE PLOTTED AGAINST CONTROL-GRID VOLTAGE WITH ANODE CURRENT AS PARAMETER.

VOLTAGE AMPLIFYING PENTODE

Mullard

EF86

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.

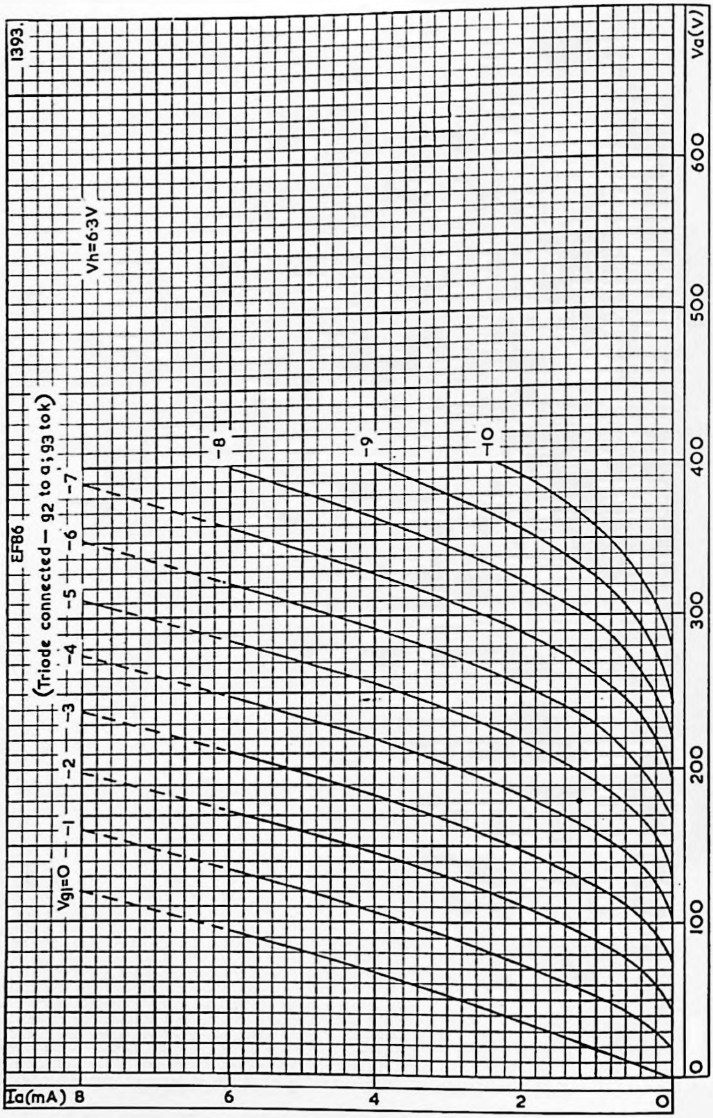


ANODE CURRENT PLOTTED AGAINST GRID VOLTAGE WITH ANODE VOLTAGE AS PARAMETER, WHEN CONNECTED AS A TRIODE.

Mullard EF86

VOLTAGE AMPLIFYING PENTODE

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.

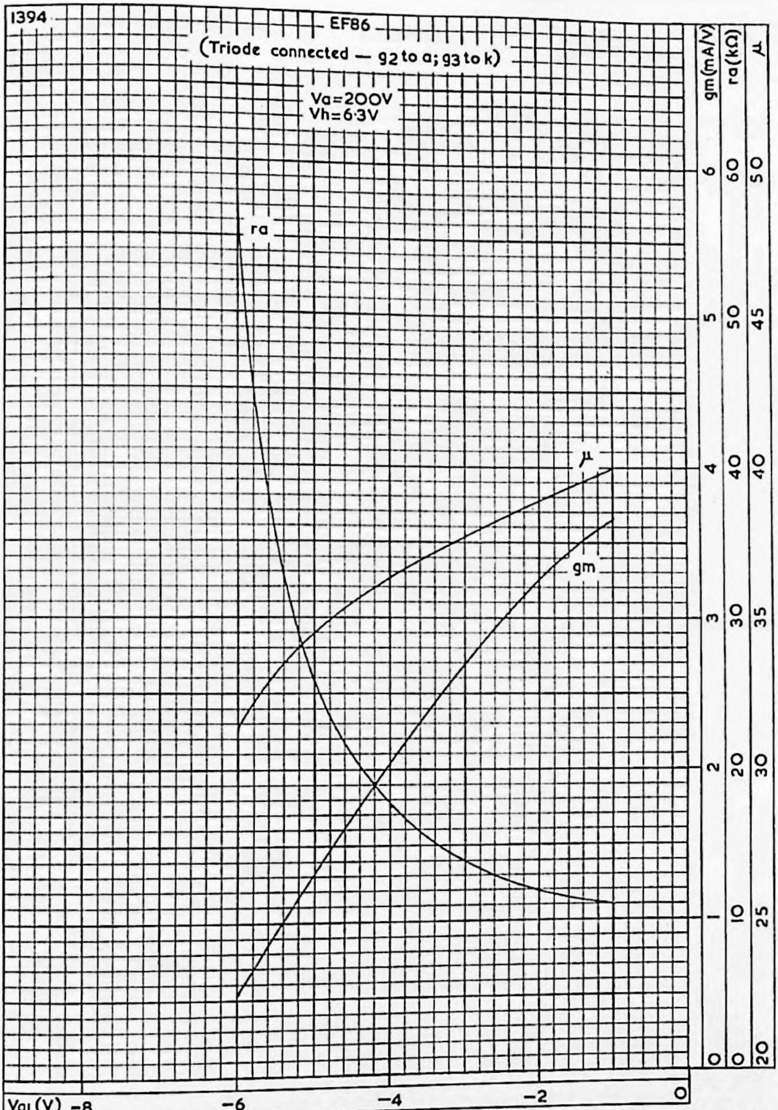


ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE WITH GRID VOLTAGE AS PARAMETER, WHEN CONNECTED AS A TRIODE.

VOLTAGE AMPLIFYING PENTODE

Mullard EF86

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.



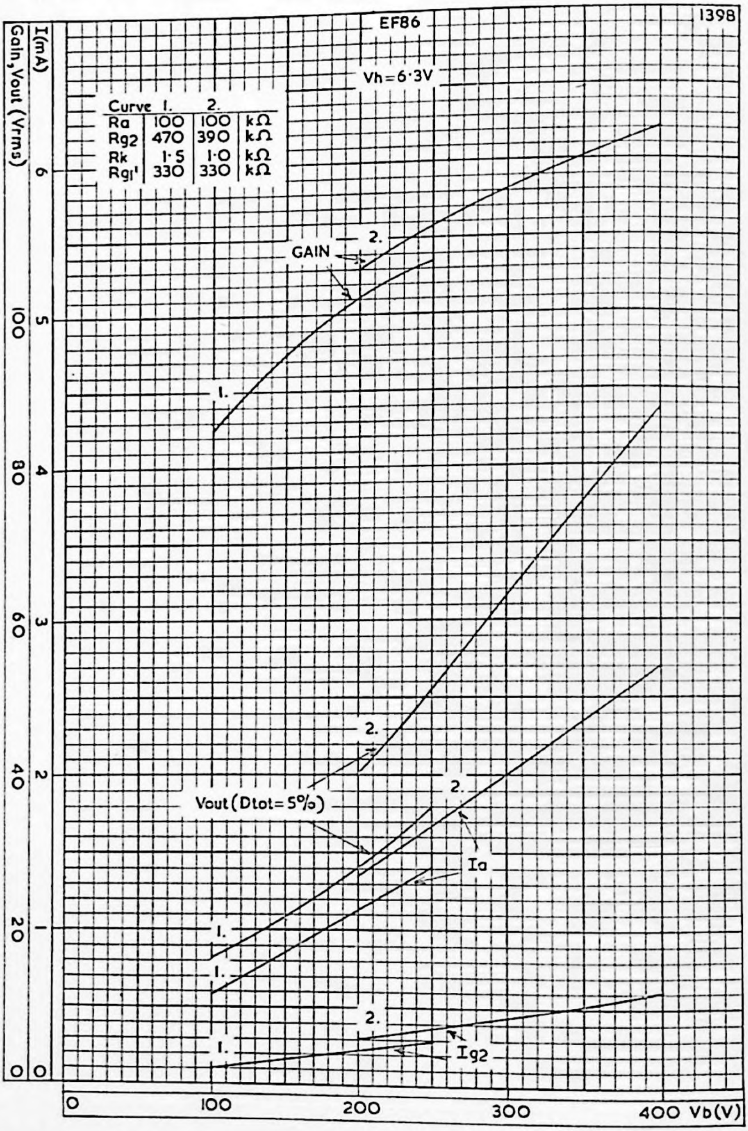
MUTUAL CONDUCTANCE, AMPLIFICATION FACTOR AND ANODE IMPEDANCE PLOTTED AGAINST GRID VOLTAGE, WHEN CONNECTED AS A TRIODE.

Mullard

EF86

VOLTAGE AMPLIFYING PENTODE

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.



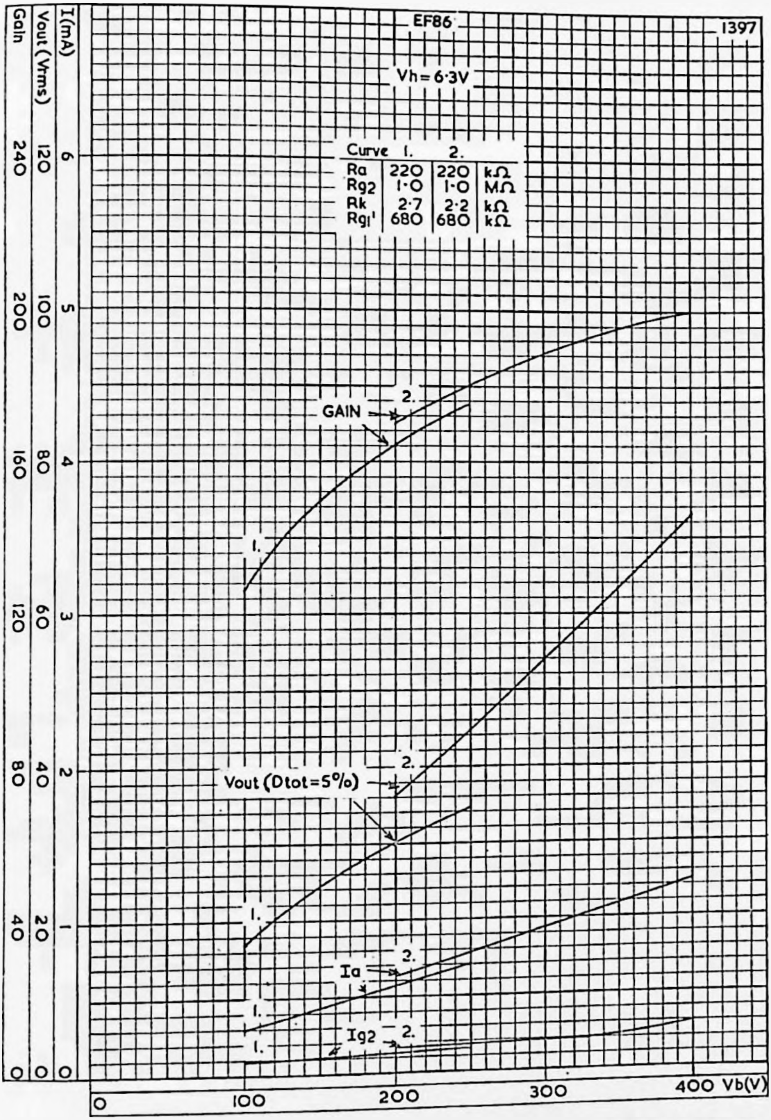
PERFORMANCE OF EF86 AS PENTODE CONNECTED R.C. COUPLED AMPLIFIER PLOTTED AGAINST LINE VOLTAGE, FOR R_a=100kΩ.

VOLTAGE AMPLIFYING PENTODE

Mullard

EF86

Low noise pentode intended for use as R.C. coupled A.F. voltage amplifier, particularly in the early stages of high-gain audio amplifiers, microphone pre-amplifiers and magnetic tape recorders.



PERFORMANCE OF EF86 AS PENTODE CONNECTED R.C. COUPLED AMPLIFIER PLOTTED AGAINST LINE VOLTAGE, FOR R_a=220kΩ.

Mullard

ECC82

DOUBLE TRIODE

Low μ double triode having separate cathodes, primarily intended for use as an amplifier or oscillator.

PRELIMINARY DATA

HEATER

Suitable for series or parallel operation, a.c. or d.c.

The heater is centre-tapped and the two sections may be operated in series or in parallel with one another.

Series — V_h applied between pins 4 and 5

Parallel — V_h applied between pin 9 and pins 4 and 5 connected together

	Series	*Parallel*	
V_h	12.6	6.3	V
I_h	0.15	0.3	A

CAPACITANCES

*c_{a-g}	1.5	μμF
*c_{g-k}	1.6	μμF
$c_{a'-k'}$	0.5	μμF
$c_{a''-k''}$	0.35	μμF

*Each section

CHARACTERISTICS (each section)

V_a	100	250	V
I_a	12	10.5	mA
V_g	0	−8.5	V
g_m	3.1	2.2	mA/V
μ	19	17	
r_a	6.2	7.7	kΩ

LIMITING VALUES (each section)

$V_{a(b)}$ max.	550	V
V_a max.	300	V
p_a max.	2.75	W
I_k max.	20	mA
R_{g-k} max. (cathode bias)	1	MΩ
R_{g-k} max. (fixed bias)	250	kΩ
V_{h-k} max.	180	V
*R_{h-k} max.	20	kΩ

*When used as a phase inverter immediately preceding the output stage, R_{h-k} max. may be 120 kΩ.

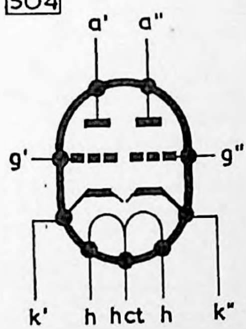
DOUBLE TRIODE

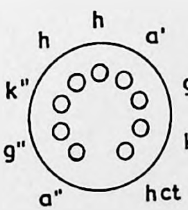
Low μ double triode having separate cathodes, primarily intended for use as an amplifier or oscillator.

Mullard

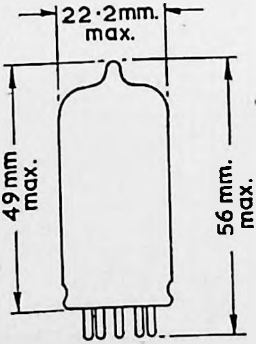
ECC82

504





B9A
Noval Base

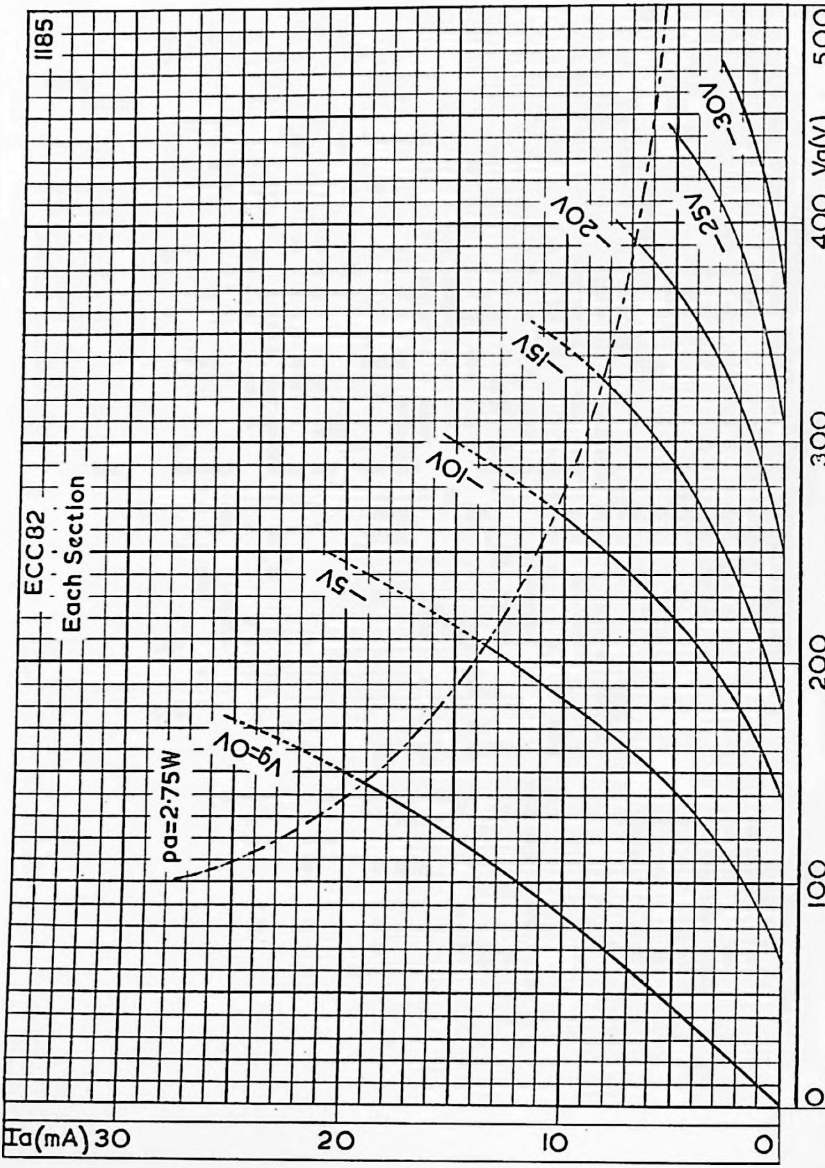


Mullard

ECC82

DOUBLE TRIODE

Low μ double triode having separate cathodes, primarily intended for use as an amplifier or oscillator.



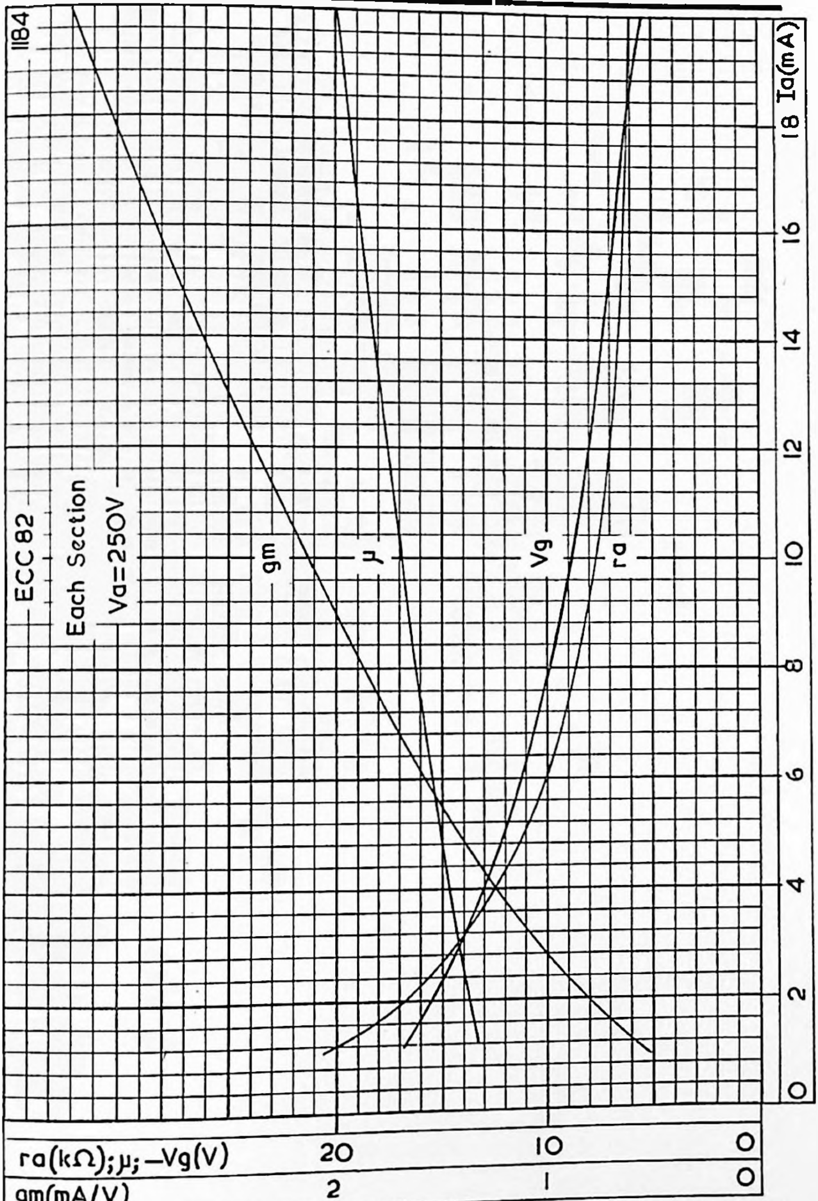
ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE WITH GRID VOLTAGE AS PARAMETER (EACH SECTION)

DOUBLE TRIODE

Mullard

ECC82

Low μ double triode having separate cathodes, primarily intended for use as an amplifier or oscillator.



GRID VOLTAGE, MUTUAL CONDUCTANCE, AMPLIFICATION FACTOR AND INTERNAL RESISTANCE PLOTTED AGAINST ANODE CURRENT, FOR ANODE VOLTAGE OF 250V (EACH SECTION)

Mullard

ECC83

DOUBLE TRIODE

High μ double triode, having separate cathodes, primarily intended for use as a resistance-coupled amplifier or phase inverter.

PRELIMINARY DATA

HEATER

Suitable for series or parallel operation, a.c. or d.c.

The heater is centre-tapped and the two sections may be operated in series or in parallel with one another.

Series	V_h applied between pins 4 and 5
Parallel	V_h applied between pin 9 and pins 4 and 5 connected together

	Series	*Parallel*	
V_h	12.6	6.3	V
I_h	0.15	0.3	A

CAPACITANCES

* $c_{a\text{-}g}$	1.7	μμF
* $c_{a\text{-}h}$	1.6	μμF
$c_{a'\text{-}k'}$	0.46	μμF
$c_{a''\text{-}k''}$	0.34	μμF

*Each section

CHARACTERISTICS (each section)

V_a	100	250	V
I_a	1.2	1.5	mA
V_g	−1	−2	V
g_m	1.25	1.6	mA/V
μ	100	100	
r_a	80	62.5	kΩ

LIMITING VALUES (each section)

$V_{a(b)}$ max.	550	V
V_a max.	300	V
p_a max.	1	W
I_k max.	8	mA
$-V_{g1}$ max.	50	V
* $R_{g\text{-}k}$ max. (cathode bias)	1	MΩ
$R_{g\text{-}k}$ max. (fixed bias)	500	kΩ
$V_{h\text{-}k}$ max.	180	V
** $R_{h\text{-}k}$ max.	20	kΩ

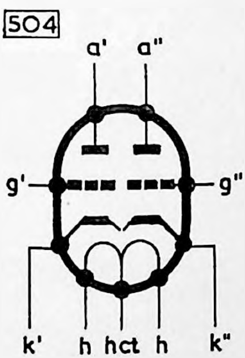
* $R_{g\text{-}k}$ max. may be 2.2 MΩ if $I_a \leq 1$mA.

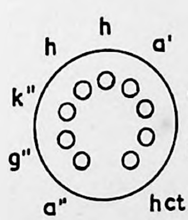
** When used as a phase inverter immediately preceding the output stage, $R_{h\text{-}k}$ max. may be 120 kΩ.

DOUBLE TRIODE

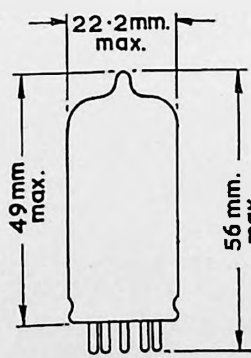
Mullard ECC83

High μ double triode, having separate cathodes, primarily intended for use as a resistance-coupled amplifier or phase inverter.





B9A
Noval Base

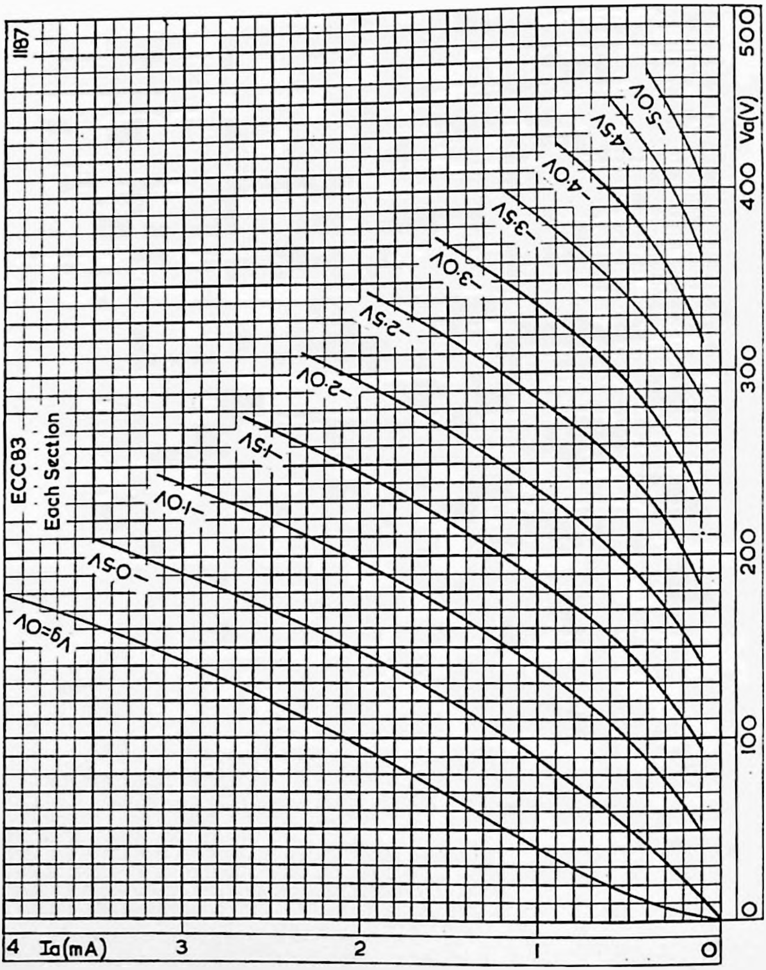


Mullard

ECC83

DOUBLE TRIODE

High μ double triode, having separate cathodes, primarily intended for use as a resistance-coupled amplifier or phase inverter.



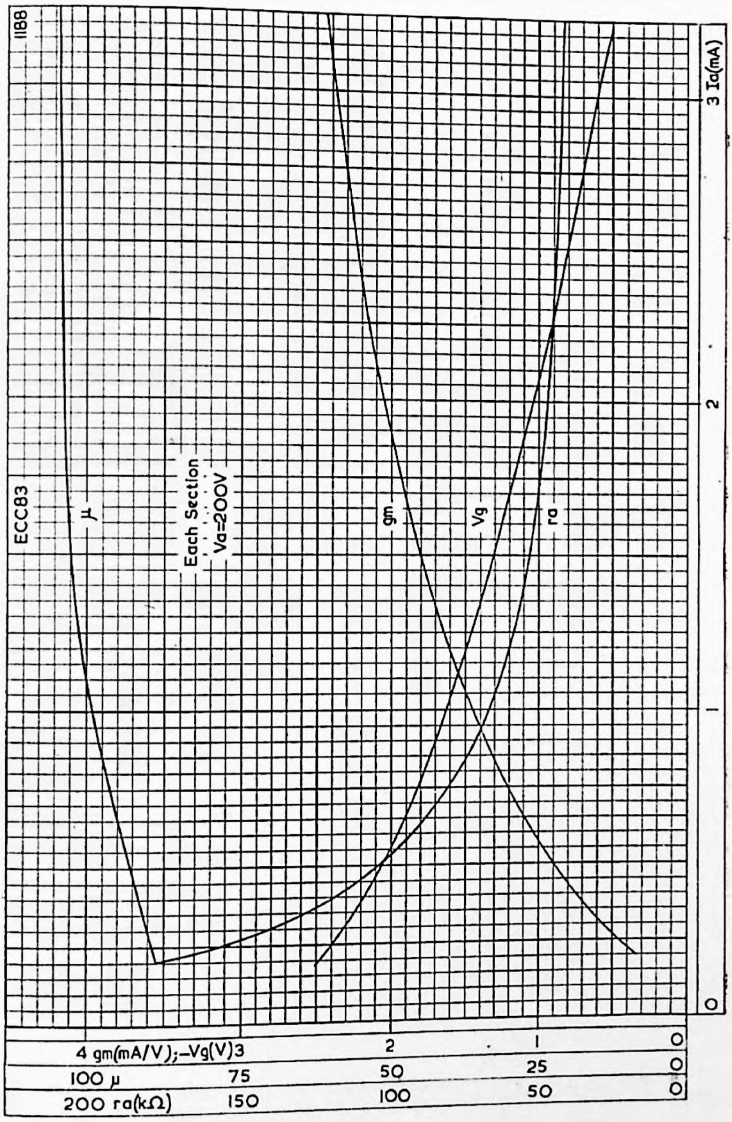
ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE, WITH GRID VOLTAGE AS PARAMETER (EACH SECTION)

DOUBLE TRIODE

High μ double triode, having separate cathodes, primarily intended for use as a resistance-coupled amplifier or phase inverter.

Mullard

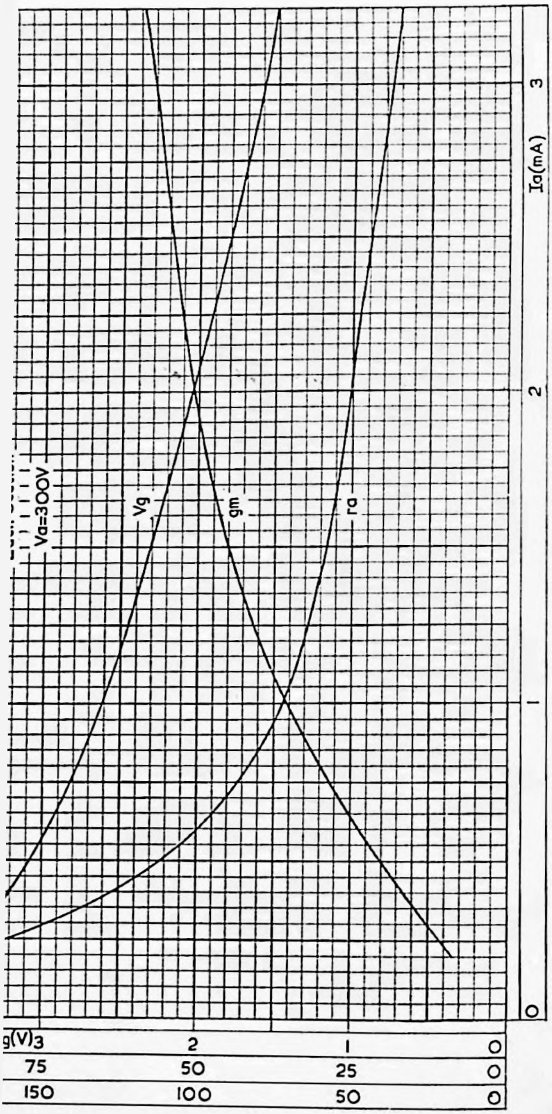
ECC83



GRID VOLTAGE, MUTUAL CONDUCTANCE, AMPLIFICATION FACTOR AND INTERNAL RESISTANCE PLOTTED AGAINST ANODE CURRENT, FOR ANODE VOLTAGE OF 200V (EACH SECTION)

DOUBLE TRIODE

High μ double triode, having separate cathodes, primarily intended for use as a resistance-coupled amplifier or phase inverter.



UTUAL CONDUCTANCE, AMPLIFICATION FACTOR
STANCE PLOTTED AGAINST ANODE CURRENT, FOR
VOLTAGE OF 300V (EACH SECTION)

OUTPUT PENT

Output pentode rated
intended for use in a.c

HEATER

CAPACITANCES

CHARACTERISTIC

OPERATING CC
AMPLIFIER

Pentode Conn

V_a
V_{g2}
R_a
R_k
V_{g1}
I_a
I_{g2}
$V_{in(r.m.}$
*P_{out} (D
$V_{in(r.m.}$
D_3
D_2

† Operation un

* P_{out} and D_{tot}
output availat
sustained sine
resistor will r
grid currents.
output.

OUTPUT PENTODE

Mullard EL84

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.

PRELIMINARY DATA

HEATER

V_h	6.3	V
I_h	0.76	A

CAPACITANCES

C_{out}	6	μμF
C_{in}	11	μμF
$C_{a\text{-}g1}$	<0.5	μμF
$C_{g1\text{-}h}$	<0.25	μμF

CHARACTERISTICS

V_a	250	V
V_{g2}	250	V
I_a	48	mA
I_{g2}	5.5	mA
V_{g1}	–7.3	V
g_m	11.3	mA/V
r_a	38	kΩ
$\mu_{g1\text{-}g2}$	19	

OPERATING CONDITIONS AS SINGLE VALVE CLASS "A" AMPLIFIER

Pentode Connection

			†	†	
V_a	250	250	250	250	V
V_{g2}	250	250	210	250	V
R_a	5.2	4.5	7.0	7.0	kΩ
R_k	135	135	160	210	Ω
V_{g1}	–7.3	–7.3	–6.4	–8.4	V
I_a	48	48	36	36	mA
I_{g2}	5.5	5.5	3.9	4.1	mA
$V_{in(r.m.s.)}$ (P_{out}=50 mW)	0.3	0.3	0.3	0.3	V
*P_{out} (D_{tot}=10%)	5.7	5.7	4.3	4.2	W
$V_{in(r.m.s.)}$ (D_{tot}=10%)	4.3	4.4	3.4	3.5	V
D_3	9.5	8.0	9.3	8.7	%
D_2	2.0	5.0	1.8	1.7	%

† Operation under EL41 conditions.

* P_{out} and D_{tot} are measured at fixed bias and therefore represent the power output available during the reproduction of speech and music. When a sustained sine wave is applied to the control grid the bias across the cathode resistor will readjust itself as a result of the increased anode and screen-grid currents. This will result in approximately 10% reduction in power output.

Mullard

EL84

OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.

TYPICAL OPERATION FOR TWO VALVES IN PUSH-PULL

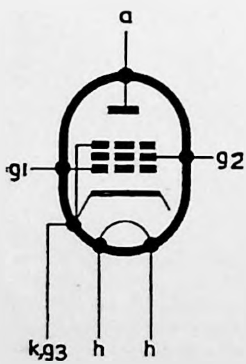
V_a	250	300	V
V_{g2}	250	300	V
R_k	130	130	Ω
R_{a-a}	8.0	8.0	kΩ
$I_{a(o)}$	2×31	2×36	mA
I_a (max. sig.)	2×37.5	2×46	mA
$I_{g2(o)}$	2× 3.5	2×4	mA
I_{g2} (max. sig.)	2× 7.5	2×11	mA
$V_{in\ (g-g)}$ (r.m.s.)	16	20	V
P_{out}	11	17	W
D_{tot}	3	4	%

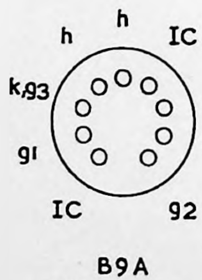
LIMITING VALUES

$V_{a(b)}$ max.	550	V
*V_a max.	300	V
*p_a max.	12	W
$V_{g2(b)}$ max.	550	V
*V_{g2} max.	300	V
p_{g2} (zero sig.) max.	2	W
p_{g2} (max. sig.) max.	4	W
I_k max.	65	mA
$-V_{g1}$ max.	100	V
V_{g1} max. ($I_{g1}=+0.3\ \mu A$)	−1.3	V
R_{g1-k} max. (cathode bias)	1.0	MΩ
R_{g1-k} max. (fixed bias)	300	kΩ
V_{h-k} max.	100	V

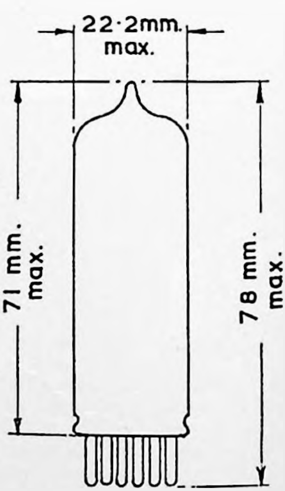
* If the heater, anode, and screen-grid voltages are obtained from an accumulator by means of a vibrator, V_a max.=250V, V_{g2} max.=250V, p_a max.=9W.

1558





B9A
Noval Base

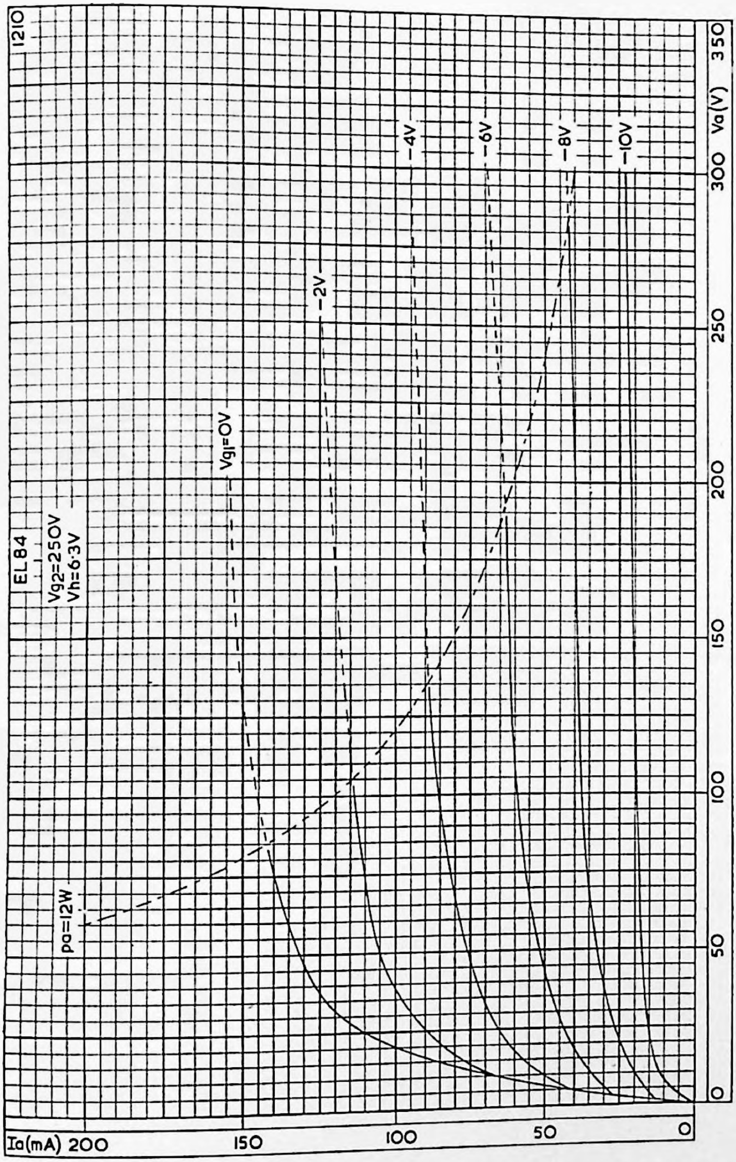


OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.

Mullard

EL84



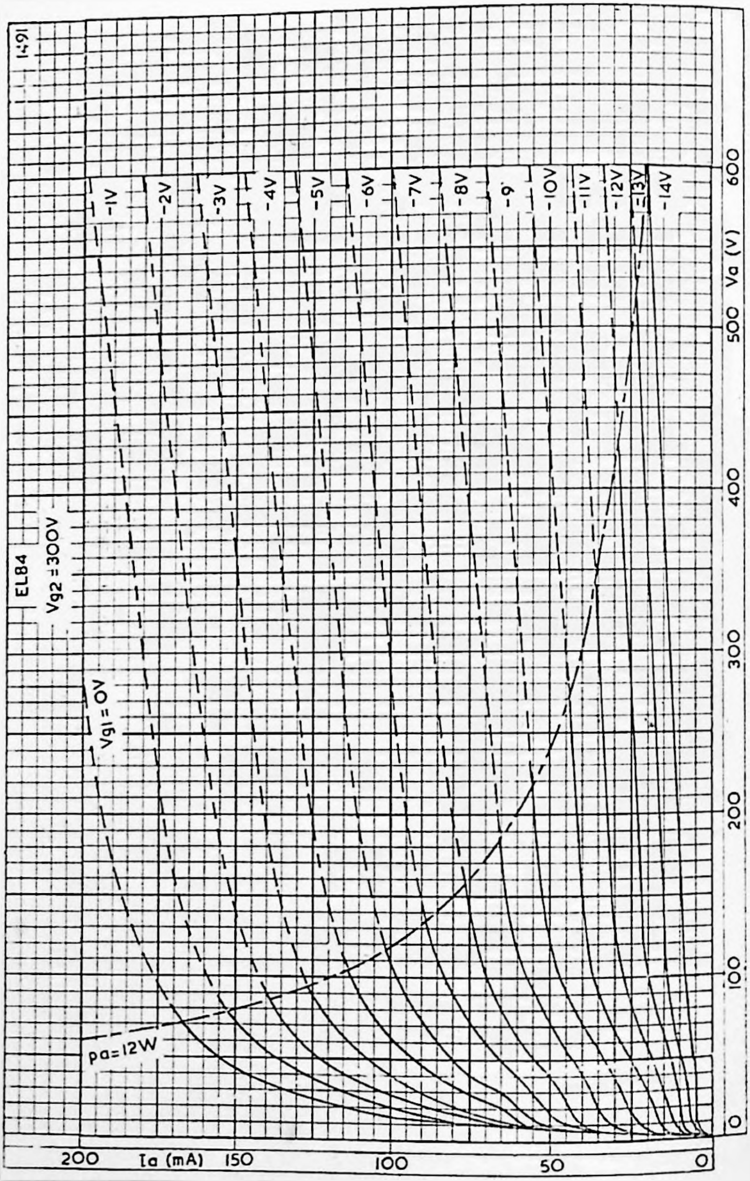
ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE WITH CONTROL-GRID VOLTAGE AS PARAMETER FOR A SCREEN-GRID VOLTAGE OF 250V

Mullard

EL84

OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.

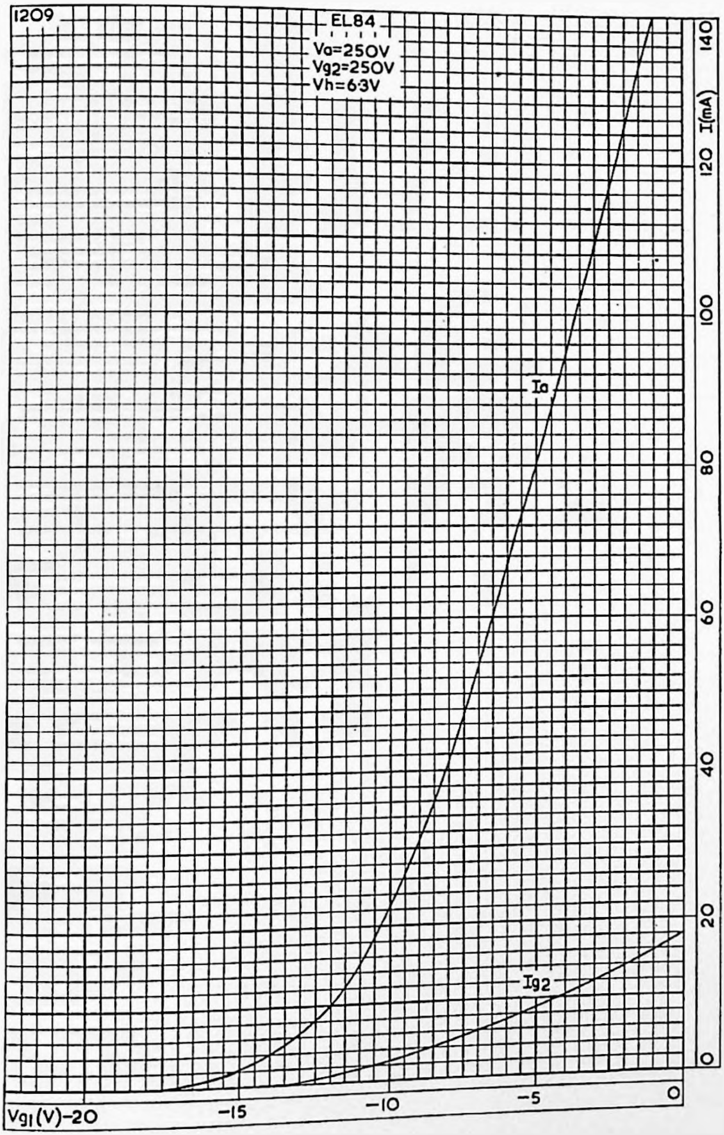


ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE WITH CONTROL-GRID VOLTAGE AS PARAMETER, FOR A SCREEN-GRID VOLTAGE OF 300V.

OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.

Mullard
EL84



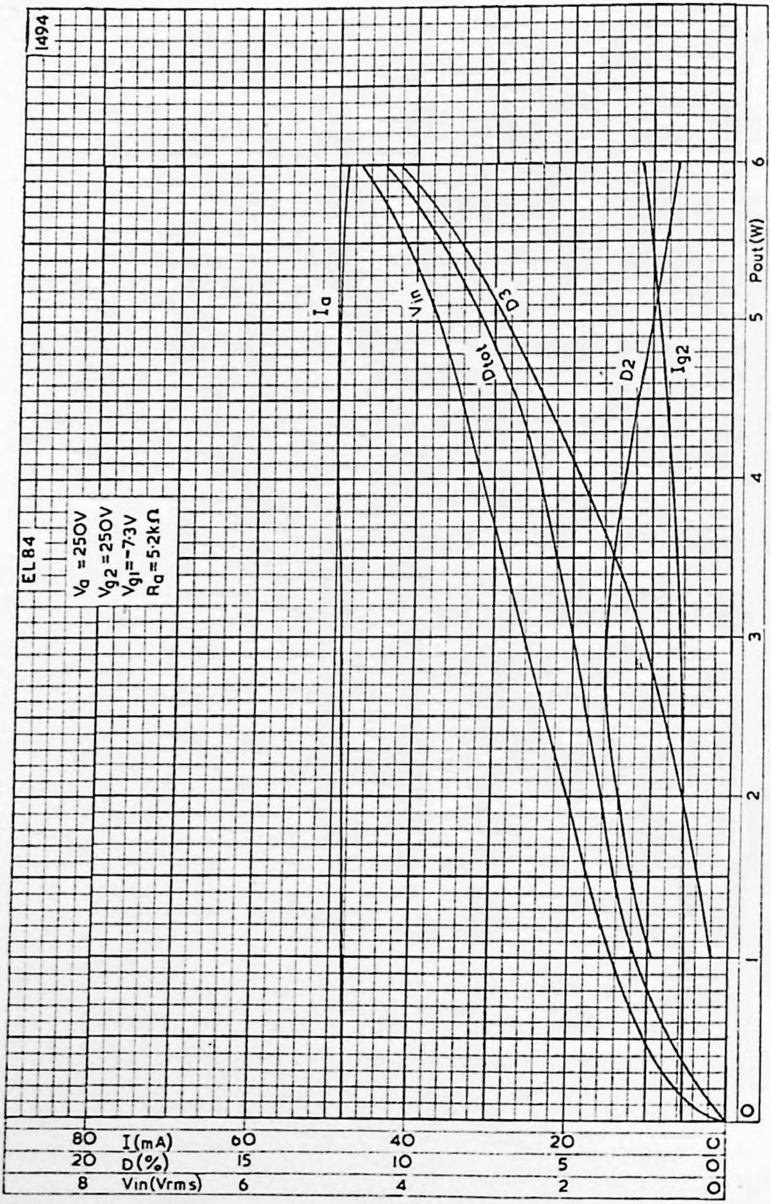
ANODE AND SCREEN-GRID CURRENT PLOTTED AGAINST CONTROL-BIAS

Mullard

EL84

OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.



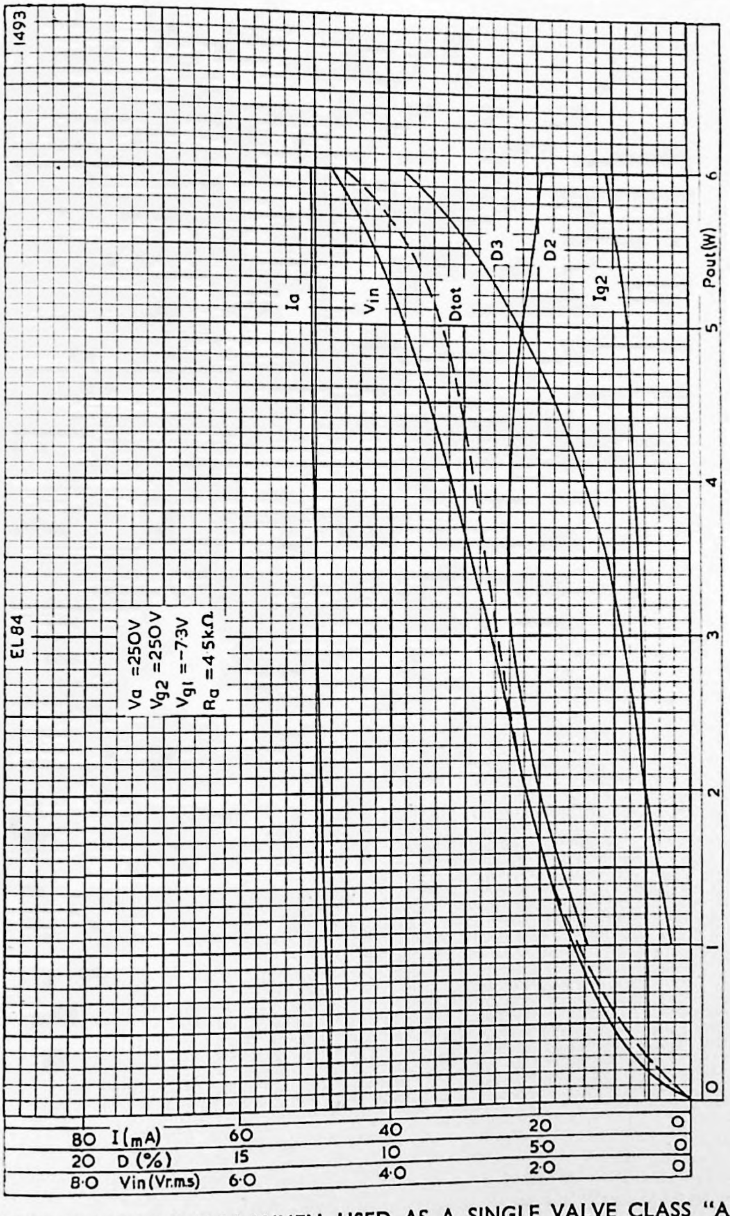
PERFORMANCE OF EL84 WHEN USED AS A SINGLE VALVE CLASS "A" AMPLIFIER WITH A LOAD RESISTANCE OF 5.2 kΩ

OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.

Mullard

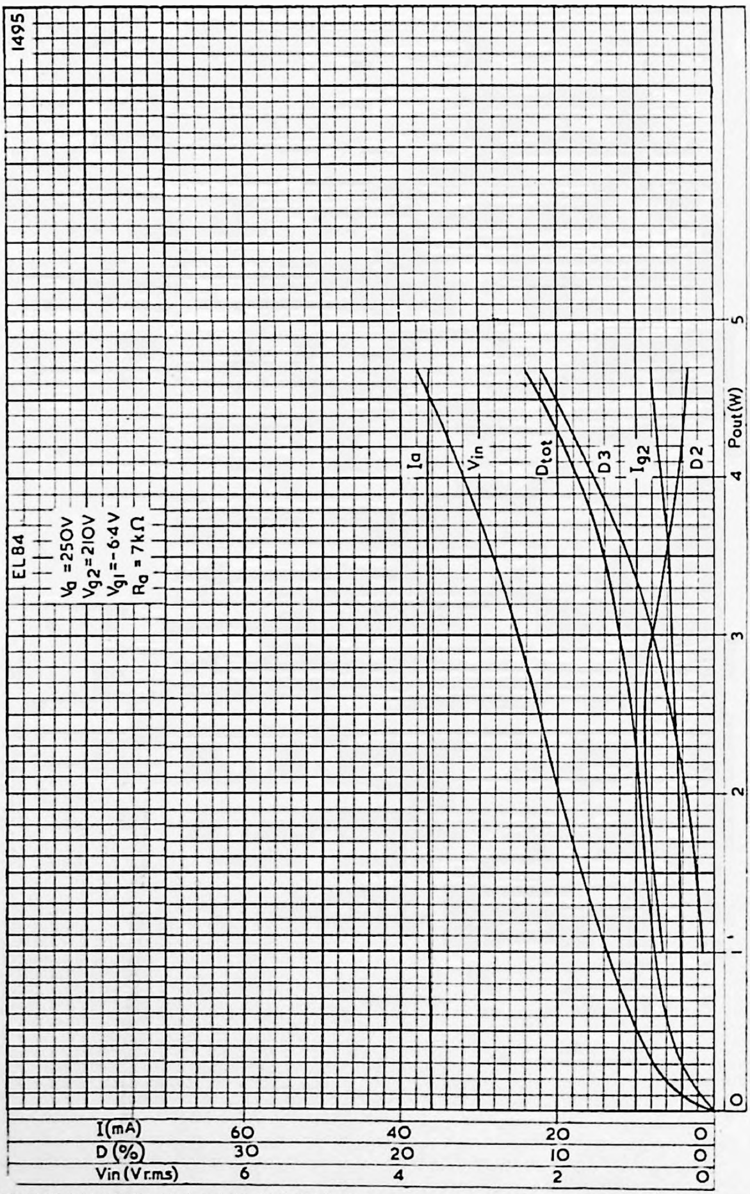
EL84



PERFORMANCE OF EL84 WHEN USED AS A SINGLE VALVE CLASS "A" AMPLIFIER WITH A LOAD RESISTANCE OF 4.5 kΩ.

OUTPUT PENTODE

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.



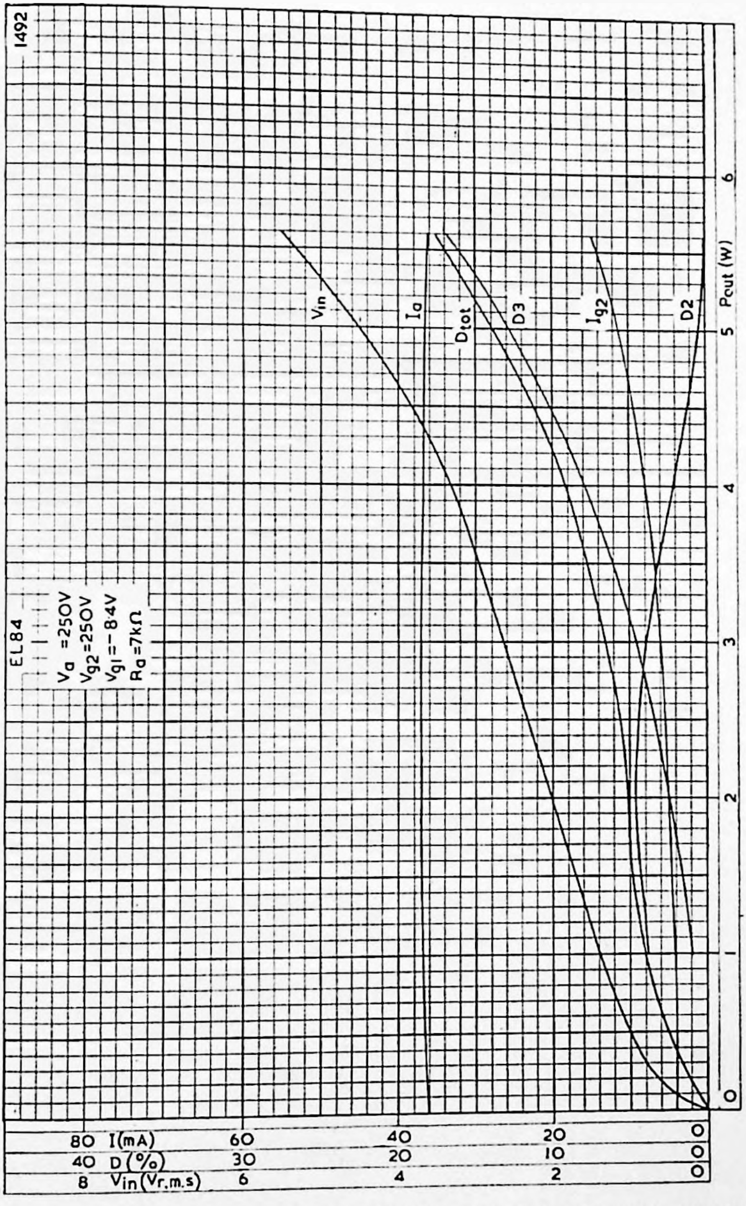
PERFORMANCE OF EL84 WHEN OPERATED UNDER THE SAME CONDITIONS AS EL41 WITH A CONTROL-GRID VOLTAGE OF –6.4V.

OUTPUT PENTODE

Mullard

EL84

Output pentode rated for 12W anode dissipation, primarily intended for use in a.c. mains operated equipment.



PERFORMANCE OF EL84 WHEN OPERATED UNDER THE SAME CONDITIONS AS EL41 WITH A CONTROL-GRID VOLTAGE OF −8.4 V.

Mullard

EL37

OUTPUT PENTODE

25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.

HEATER

V_h	6.3	V
I_h	1.4	A

CAPACITANCES

c_{out}	9.0	μμF
c_{in}	17.5	μμF
$c_{a\text{-}g1}$	1.0	μμF

OPERATING CONDITIONS AS PENTODE

V_a	250	V
V_{g2}	250	V
V_{g1}	−13.5	V
I_a	100	mA
I_{g2}	13.5	mA
R_k	120	Ω
g_m	11	mA/V
r_a	13.5	k Ω
$\mu_{g1\text{-}g2}$	10	
R_a	2.5	k Ω
$V_{in\ (r.m.s.)}$ (P_{out}=50mW)	0.45	V
P_{out} (D_{tot}=10%)	10.5	W
$V_{in\ (r.m.s.)}$ (start of I_{g1})	10.8	V
D_{tot} (start of I_{g1})	13.5	%
P_{out} (start of I_{g1})	11.5	W

OPERATING CONDITIONS FOR TWO VALVES IN PUSH-PULL

Self Bias

V_a	250	325	V
V_{g2}	250	325	V
$I_{a(o)}$	2×59	2×77	mA
I_a (max. sig.)	2×68	2×90	mA
$I_{g2(o)}$	2× 7.5	2× 9.75	mA
I_{g2} (max. sig.)	2×18	2×30	mA
R_k	130	130	Ω
$R_{a\text{-}a}$	4	4	k Ω
P_{out}	20	35	W
$V_{in\ (g1\text{-}g1)\ (r.m.s.)}$	29	43	V
D_{tot}	2.25	4.4	%

Fixed Bias

V_a	350	400	V
V_{g2}	350	400	V
$I_{a(o)}$	2×40	2× 50	mA
I_a (max. sig.)	2×118	2×138	mA
$I_{g2(o)}$	2× 5	2× 6	mA
I_{g2} (max. sig.)	2×29	2× 36	mA
V_{g1}	−31	−36	V
$R_{a\text{-}a}$	3.25	3.25	k Ω
P_{out}	46	69	W
$V_{in\ (g1\text{-}g1)\ (r.m.s.)}$	43.4	49	V
D_{tot}	2.8	2.5	%

OUTPUT PENTODE

Mullard EL37

25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.

OPERATING CONDITIONS AS SINGLE VALVE, TRIODE CONNECTED

(Grid 2 connected to anode by 100 Ω resistor)

V_a	300	400	V
I_a	50	37.5	mA
V_{g1}	–26	–39	V
g_m	6.5	4.5	mA/V
μ	9	9	
r_a	1.4	2	kΩ

OPERATING CONDITIONS AS PUSH-PULL PAIR, TRIODE CONNECTED (Self-Bias)

V_b	350	435	V
V_a	320	400	V
$I_{a+g2(o)}$	2×56	2×70	mA
I_{a+g2} (max. sig.)	2×64	2×80	mA
p_{a+g2}	2×18	2×28	W
R_k	245	245	Ω
R_{a-a}	4	4	kΩ
V_{in} (r.m.s.)	2×21.5	2×27.2	V
P_{out}	12.5	20.6	W
D_{tot}	4.1	4.3	%

LIMITING VALUES — PENTODE CONNECTED

$V_{a(b)}$ max.	800	V
V_a max.	400	V
$V_{g2(b)}$ max.	800	V
V_{g2} max.	400	V
V_{g1} max. ($I_{g1}=+0.3\mu A$)	–1.3	V
V_{h-k} max.	75	V
R_{h-k} max.	5	kΩ
R_{g1-k} max. (cathode bias)	500	kΩ
R_{g1-k} max. (fixed bias)	100	kΩ
p_a max.	25	W
p_{g2} max.	6	W
I_k max.	200	mA

LIMITING VALUES — TRIODE CONNECTED (NORMAL APPLICATIONS)

V_{a+g2} max.	400	V
p_{a+g2} max.	28	W

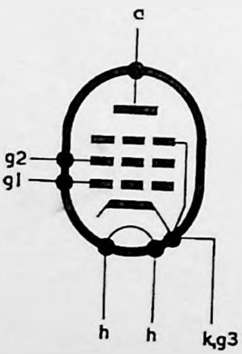
LIMITING VALUES — TRIODE CONNECTED (IN CATHODE-COUPLED PUSH-PULL DRIVER STAGE FOR LARGE POWER TRIODES)

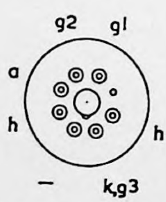
V_{a+g2} max.	500	V
p_{a+g2} max.	12.5	W

Mullard EL37

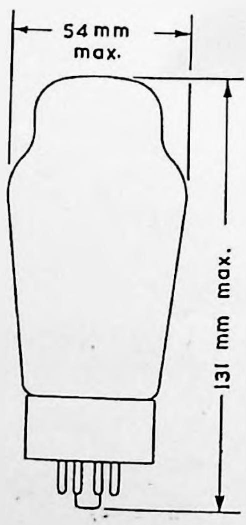
OUTPUT PENTODE

25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.





OCTAL BASE



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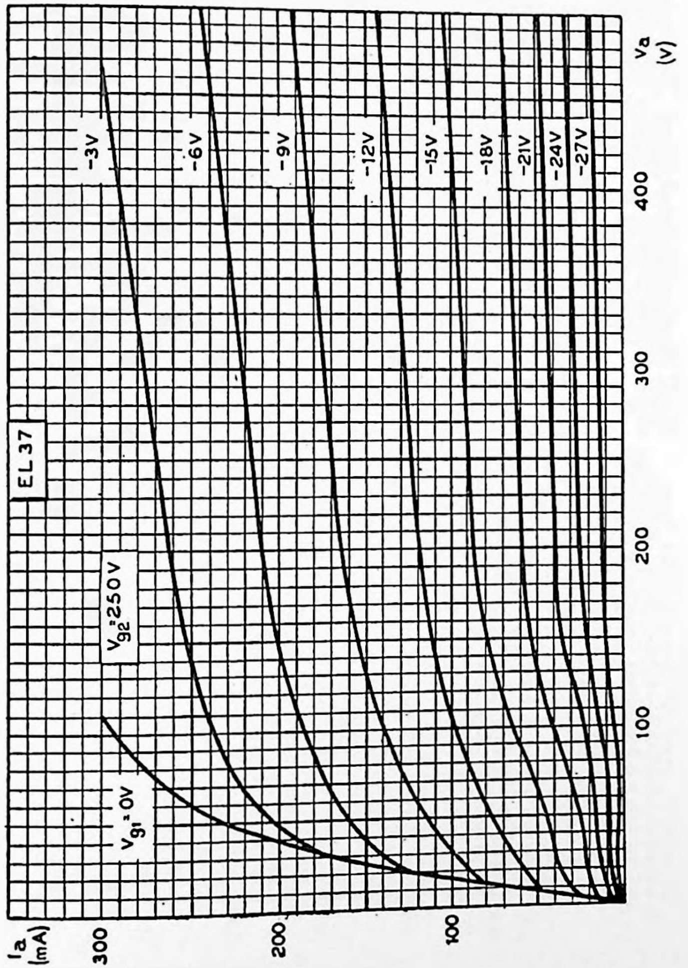
OUTPUT PENTODE

Mullard

EL37

25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.



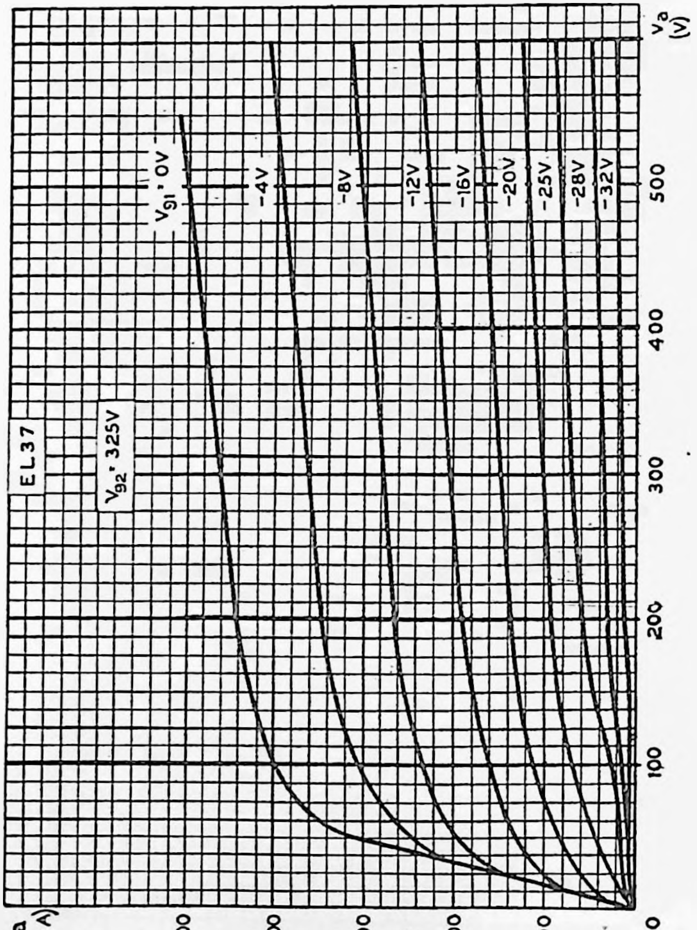
ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE FOR SCREEN-GRID VOLTAGE OF 250V

Mullard

EL37

OUTPUT PENTODE

25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.



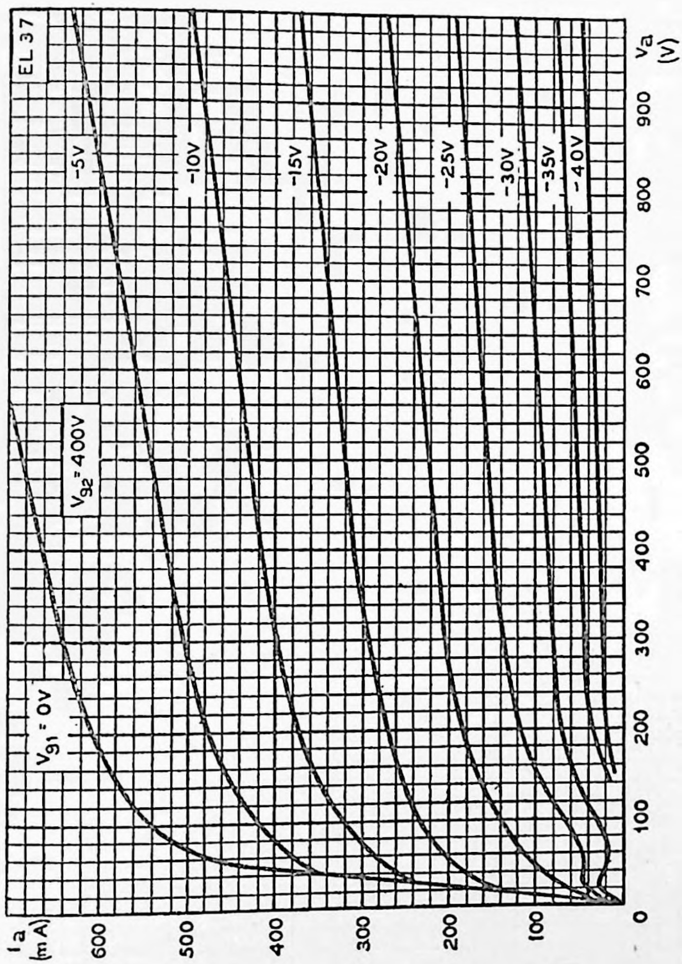
ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE FOR SCREEN-GRID VOLTAGE OF 325V

OUTPUT PENTODE

Mullard

EL37

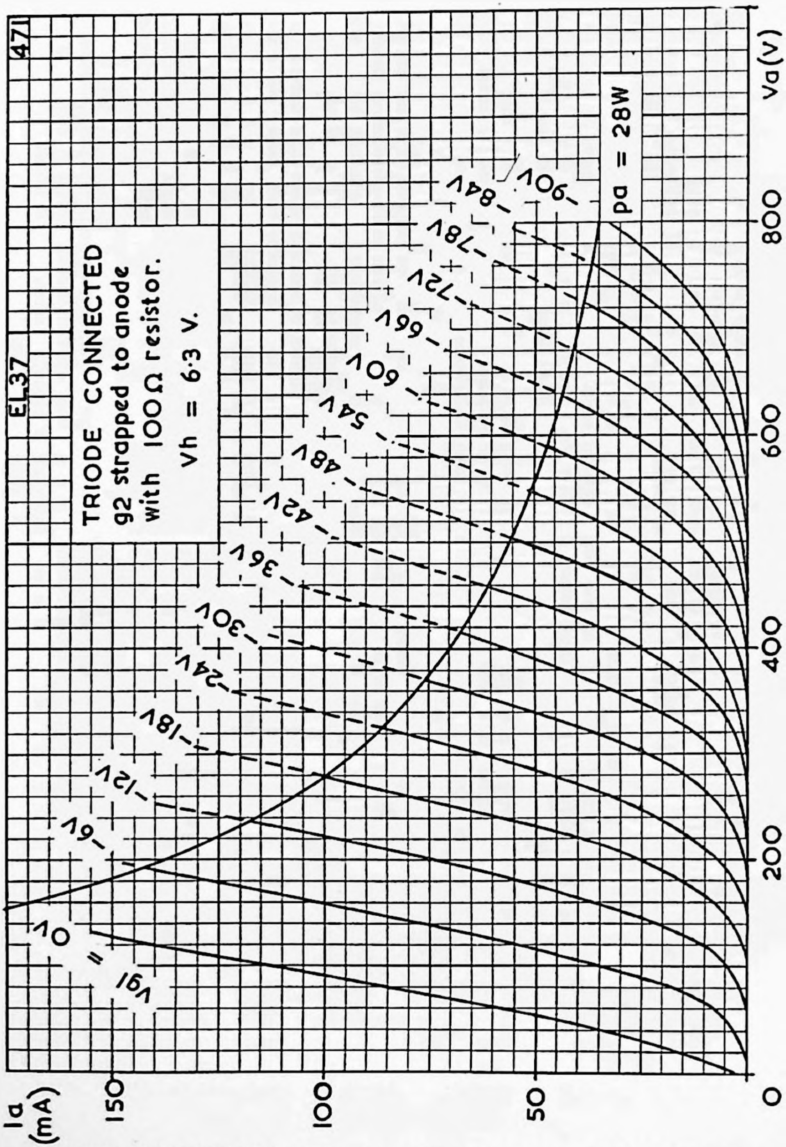
25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.



ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE FOR SCREEN-GRID VOLTAGE OF 400V

OUTPUT PENTODE

25-watt pentode, particularly suitable for use in push-pull combination for outputs up to 69W, or as drivers for large power triode push-pull output stage.



ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE WHEN CONNECTED AS A TRIODE WITH SCREEN-GRID CONNECTED TO ANODE WITH 100 Ω RESISTOR

FULL-WAVE RECTIFIER

Indirectly heated full-wave rectifier, primarily intended for use in a.c. mains-operated equipment.

Mullard

EZ80

PRELIMINARY DATA

HEATER

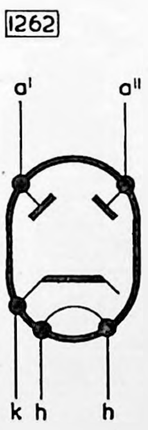
V_h	6.3	V
I_h	0.6	A

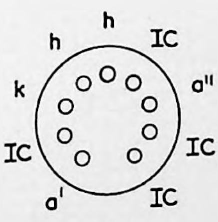
OPERATING CONDITIONS

V_a (r.m.s.)	2×250	2×275	2×300	2×350	V
C	50	50	50	50	μF
R_{lim} min. (per anode)	125	175	215	300	Ω
I_{out}	90	90	90	90	mA
V_{out}	265	285	310	310	V

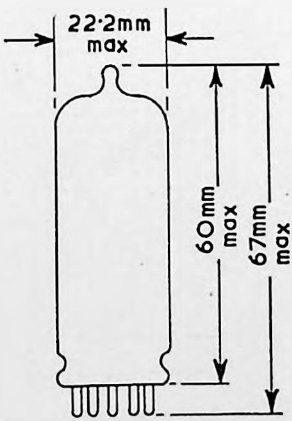
LIMITING VALUES

$V_{a(r.m.s.)}$ max.	2×350	V
I_{out} max.	90	mA
C max.	50	μF
$i_{a(pk)}$ max. (per anode)	270	mA
$v_{h\text{-}k(pk)}$ max.	500	V





B9A
Noval Base

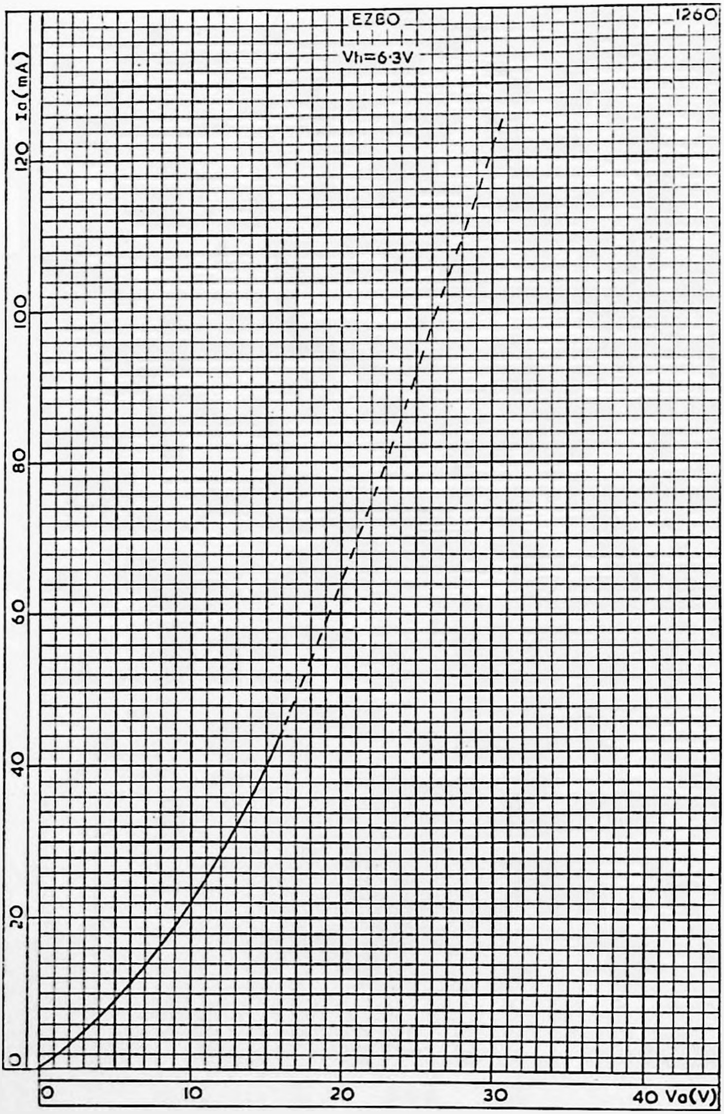


Mullard

EZ80

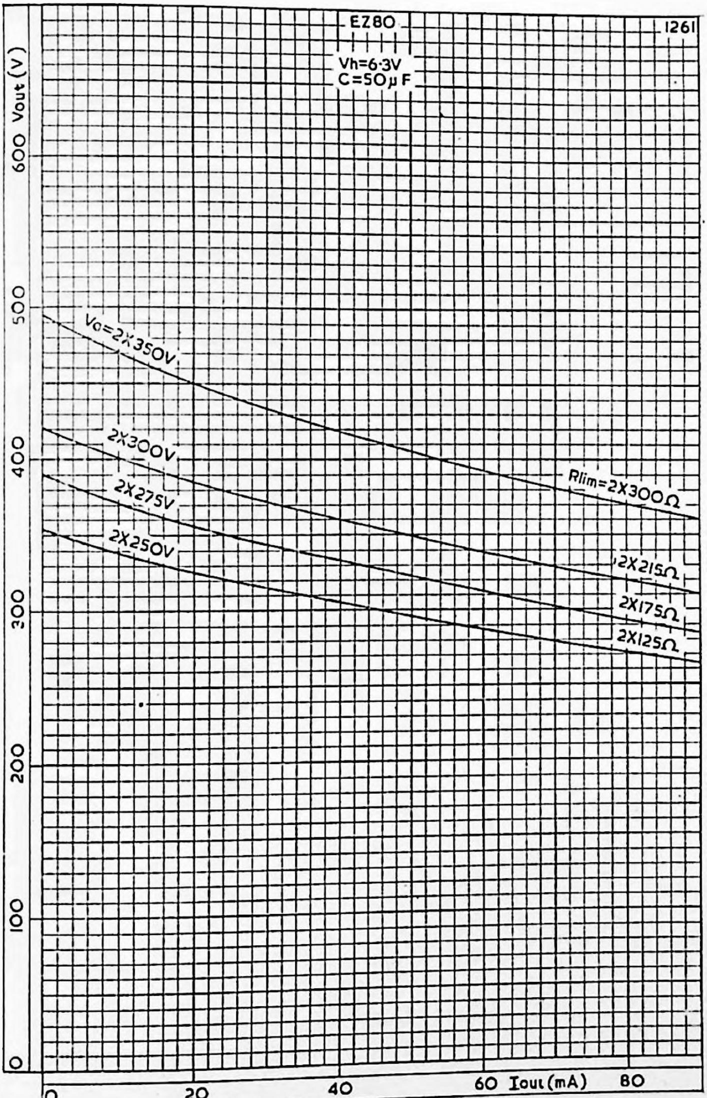
FULL-WAVE RECTIFIER

Indirectly heated full-wave rectifier, primarily intended for use in a.c. mains-operated equipment.



ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE

Indirectly heated full-wave rectifier, primarily intended for use in a.c. mains-operated equipment.



REGULATION CURVES

Mullard GZ30

FULL-WAVE RECTIFIER

Indirectly-heated full-wave rectifier with 5-volt heater.

HEATER

V_h	5.0	V
I_h	2.0	A

LIMITING VALUES

P.I.V. max.	1.4	kV
$i_{a(pk)}$ max.	375	mA
I_{out} max.	125	mA
C max.	32	μF
L min.	5	H

TYPICAL OPERATION

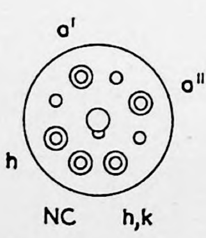
Capacitor Input

$V_{a\,(r.m.s.)}$	350	V
C	32	μF
R_{lim} (each anode)	30	Ω
I_{out}	125	mA

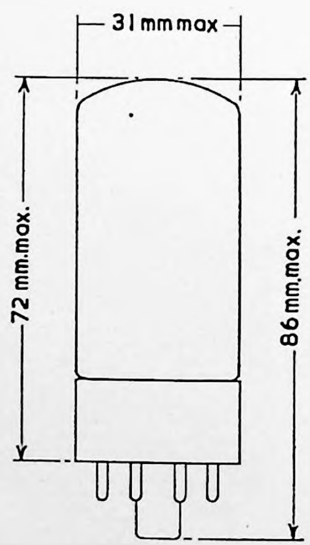
Choke Input

$V_{a\,(r.m.s.)}$	500	V
L min.	5	H
I_{out}	125	mA

1332



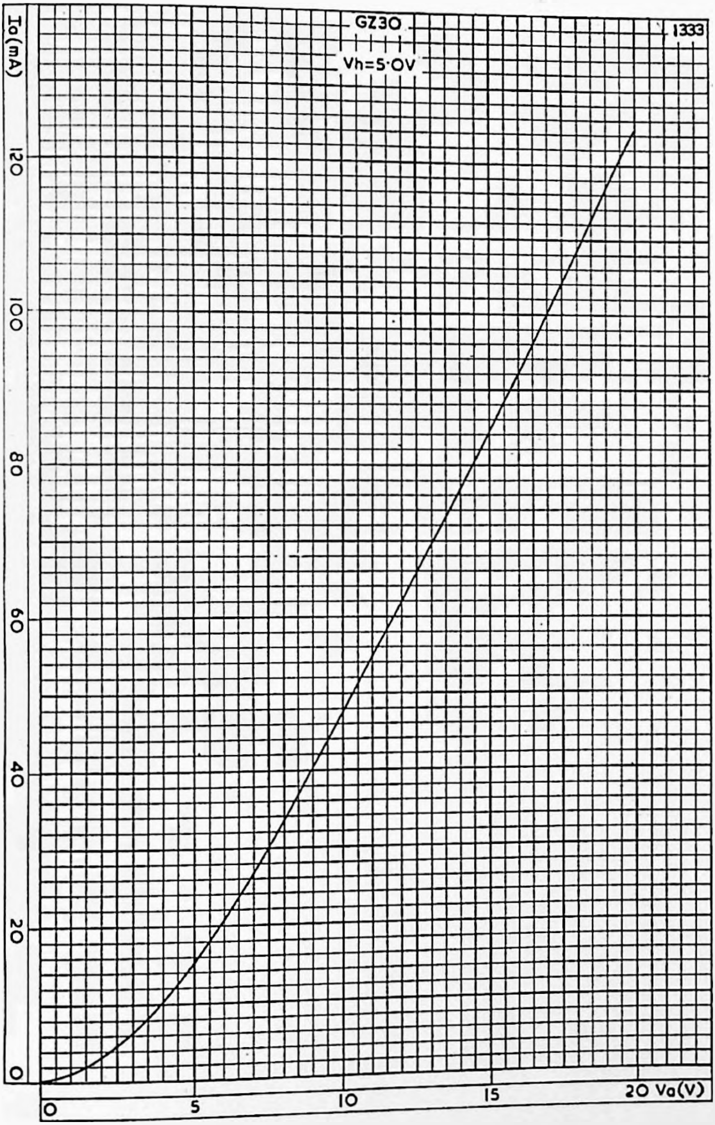
Octal Base.



FULL-WAVE RECTIFIER

Indirectly-heated full-wave rectifier with 5-volt heater.

Mullard GZ30



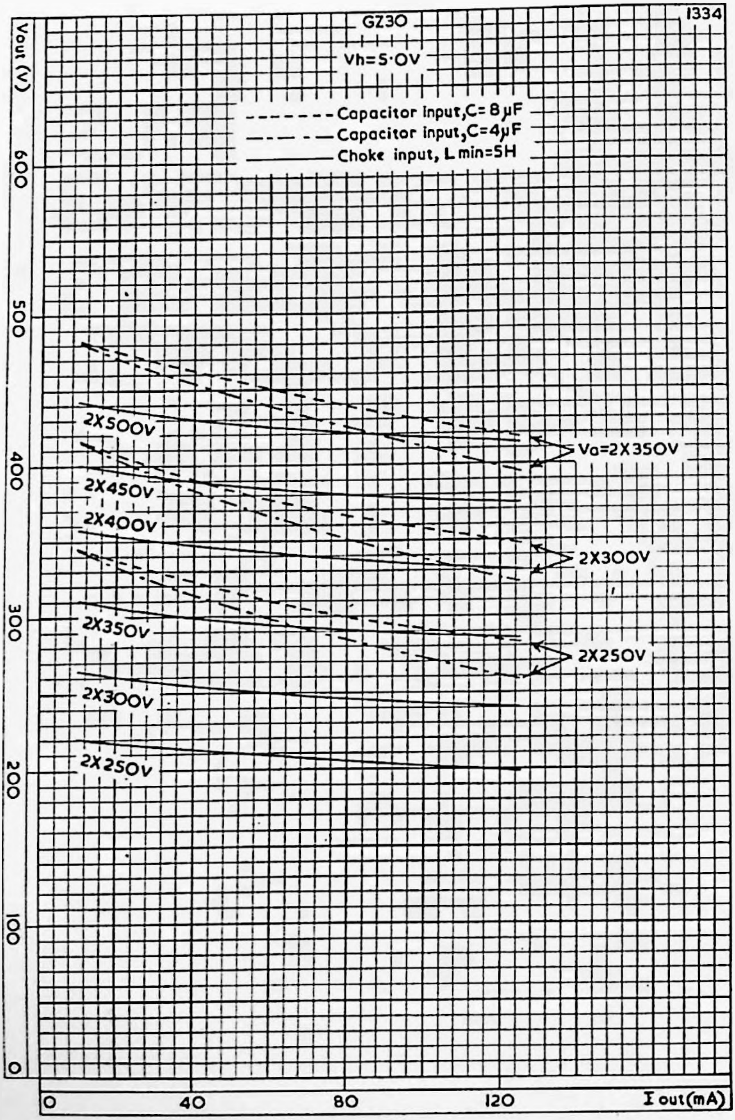
ANODE CURRENT PLOTTED AGAINST ANODE VOLTAGE

Mullard

GZ30

FULL-WAVE RECTIFIER

Indirectly-heated full-wave rectifier with 5-volt heater.



REGULATION CURVES FOR CAPACITOR OR CHOKE INPUT

FULL-WAVE RECTIFIER

Indirectly-heated full-wave rectifier with 5-volt heater.

Mullard GZ32

HEATER

V_h	5.0	V
I_h	2.3	A
Heating Time (approx.)	25	secs.

LIMITING VALUES

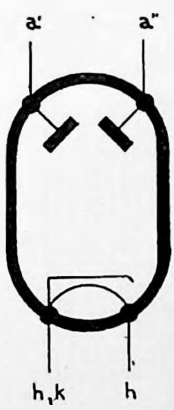
Capacitor Input

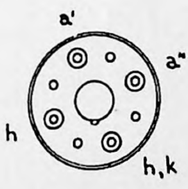
V_a (r.m.s.) max.	2×300	2×300	2×500	V
I_{out} max.	300	250	125	mA

C (μF)	R_{lim} min. (Ω)
60	150
32	100
16	50

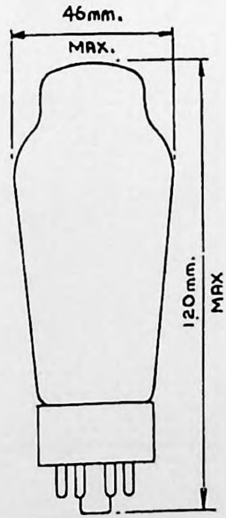
Choke Input

V_a (r.m.s.) max.	2×400	2×500	V
I_{out} max.	300	250	mA



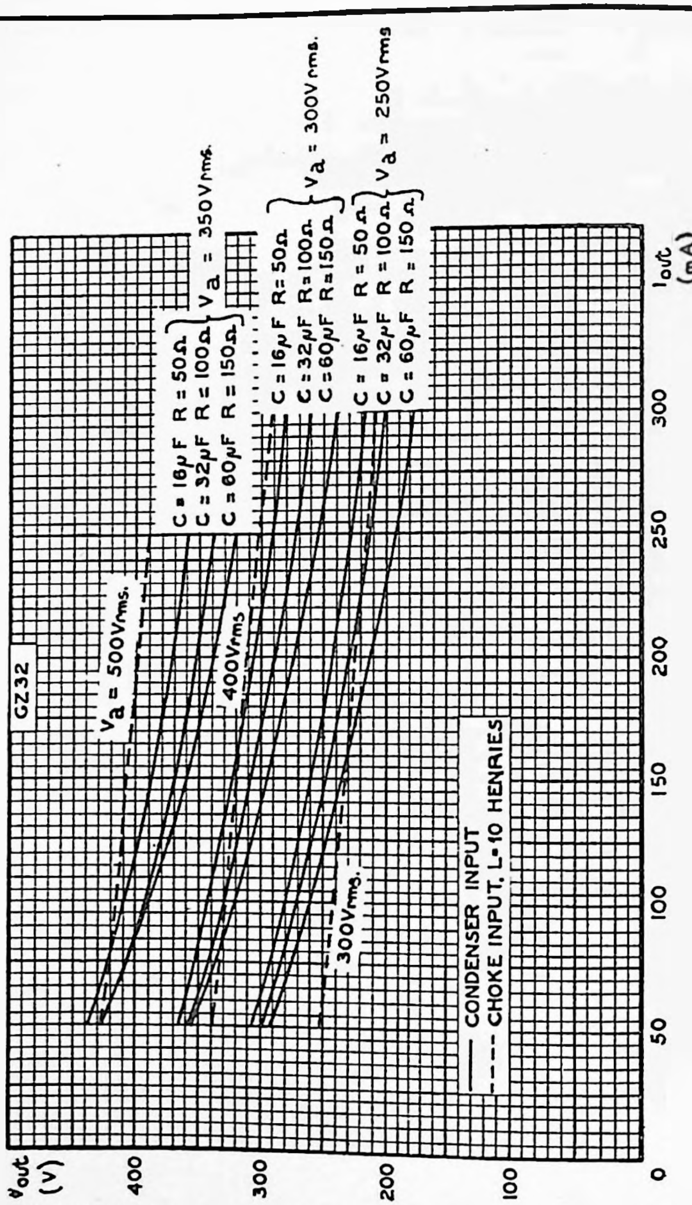


OCTAL BASE



FULL-WAVE RECTIFIER

Indirectly-heated full-wave rectifier with 5-volt heater.



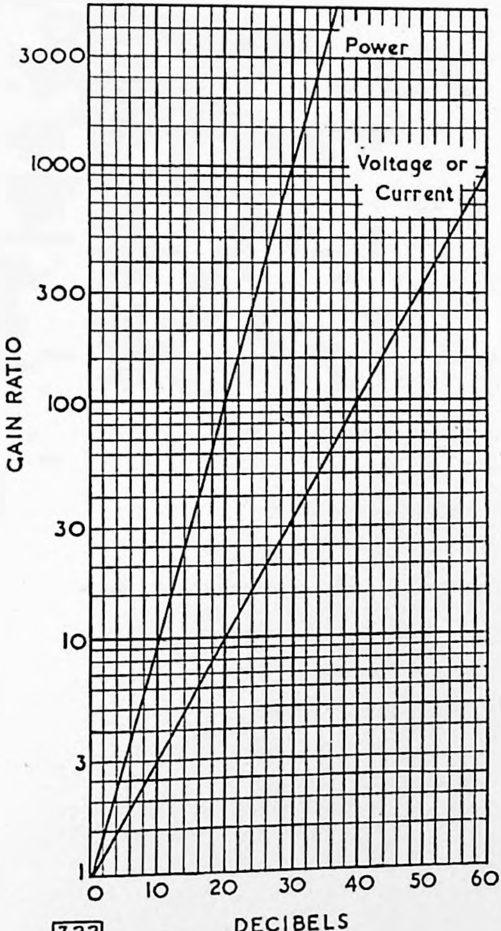
OUTPUT VOLTAGE PLOTTED AGAINST OUTPUT CURRENT

DECIBEL CONVERSION CHART

The relation between Voltage, Current or Power Ratios and Decibels is:—

Voltage	$20 \log \frac{V_1}{V_2}$ = decibels.
Current	$20 \log \frac{I_1}{I_2}$ = decibels.
Power	$10 \log \frac{P_1}{P_2}$ = decibels.

The chart reproduced below enables gain ratios to be converted to decibels direct. The conversion of voltage or current ratios, however, is correct only when the two powers compared are dissipated in equal impedances.



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USEFUL FORMULAE

OHM'S LAW

$$I = \frac{E}{R}$$

where I = current in amperes,
E = voltage in volts, and
R = resistance in ohms.

A convenient method of memorising Ohm's law is by setting it out thus:

$$\frac{\text{Volts}}{\text{Amps} \times \text{Ohms}}$$

when, in order to find the unknown value, the latter should be covered and the remaining calculation performed.

RESISTORS IN PARALLEL

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \frac{1}{R_n}}$$

CAPACITORS IN SERIES

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \frac{1}{C_n}}$$

TIME CONSTANT OF RESISTANCE AND CAPACITANCE IN SERIES

$$T = R \times C$$

where T is the time constant in seconds, R in ohms, and C in farads

STAGE GAIN—VALVE AMPLIFIER

$$M = \frac{\mu R_a}{r_a + R_a}$$

where μ = amplification factor of valve
r_a = impedance of valve in ohms
R_a = anode load resistor in ohms

OUTPUT TRANSFORMER RATIO

$$N = \sqrt{R_a/Z}$$

where N = turns ratio
R_a = optimum load resistance of valve
Z = impedance of loudspeaker

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