

OUTPUT PENTODE PL 82

DESCRIPTION

The PL 82 is an output pentode on Noval base intended for use as audio output or as frame output tube in a television receiver. Special attention has

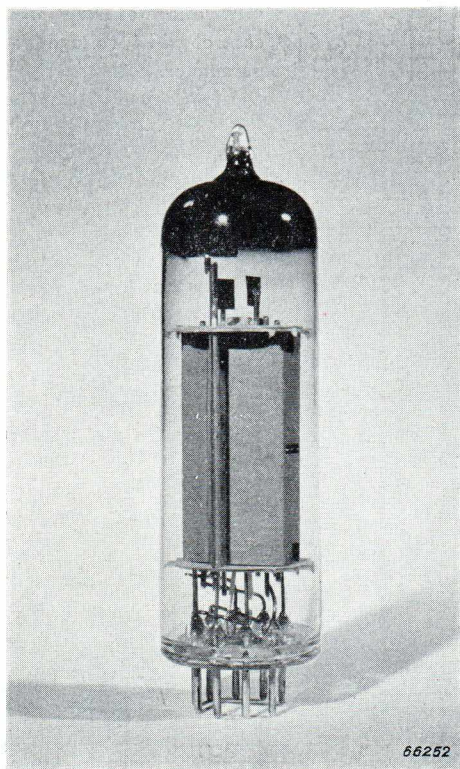


Fig. 56. The output pentode PL 82 (actual size).

been paid to the mechanical design so as to produce a robust and rigid assembly, which minimizes the risk of microphony.

There are a number of cases in which the audio output of the pentode section of an ECL 80 will be considered insufficient. The PL 82, giving an output of 4 W at 10% total distortion and at anode and screen-grid voltages of 170 V, may then be used.

For the same reason, in the frame output stage a PL 82 may be used instead of the pentode section of an ECL 80. The available peak anode current of the PL 82 is three to four times as large as that of the ECL 80, so that the former tube is particularly suitable for use in receivers employing a picture tube with wide-angle deflection.

APPLICATION

1. THE PL 82 AS SOUND OUTPUT TUBE¹⁾

As already indicated above, at a line voltage of 170 V the PL 82 is capable of giving an output of 4 W at 10% total distortion and with a matching resistance of 3 k Ω . The driving voltage required for this output is 6 V_{rms} and the bias 10.4 V. Either fixed or automatic bias may be applied. Automatic bias has the advantage that a higher value of control-grid resistor is permitted, which may increase the gain of the preceding stage. A disadvantage connected with automatic bias, however, is that, due to the voltage drop in the cathode resistor, the voltage between anode and cathode is somewhat reduced, and this also reduces the available output.

At a line voltage of 200 V the output of the PL 82 is the same as that at 170 V, although the operating conditions are somewhat different. These conditions are to be found in the tube data.

2. THE PL 82 AS FRAME OUTPUT TUBE

The PL 82 can deliver a large peak anode current at comparatively low anode and screen-grid voltages. In order to avoid incursion in the knee of the I_a/V_a characteristic, the frame output stage is normally so designed, that the minimum anode voltage, which occurs at the end of the scan, does not become lower than 50 V. From the tube characteristics it may be seen that with a screen-grid voltage of 170 V and an anode voltage of 50 V the anode current of the average tube can greatly exceed 100 mA. In order to allow for inevitable spread between individual tubes and for deterioration during life, the circuit should, however, be designed around a peak anode current not exceeding 90 mA at $V_a = 50$ V and $V_{g2} = 170$ V.

In the design of a frame output stage a choice must be made between an output transformer of small dimensions, which leads to a large peak anode current, and a larger output transformer, with which the peak anode current will be lower. Since

¹⁾ See P. D. van der Knaap and J. Jager, Matching of the Frame Output Stage to the Deflection Coils in Television Receivers, Electr. Appl. Bull. 11, p. 21, 1950 (No. 2).

there are also other important factors to be taken into account, the choice of the output transformer will be dealt with at some length.

The deflection coils used for vertical deflection have resistance and self-inductance, but the rate of change of the deflection current is so low that the voltage occurring across the self-inductance is negligible compared with that across the resistance. It may therefore be assumed that the matching transformer is loaded with a pure resistance, R_d ; see fig. 57.

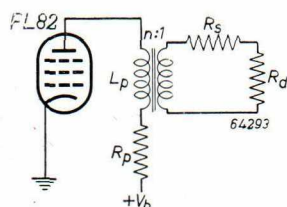


Fig. 57. Basic diagram of a frame output stage.

When it is now assumed that the operating conditions are such that a linear saw-tooth current having a peak-to-peak value I_d flows in the deflection coils, the saw-tooth current in the primary will be I_d/n , whilst a linear saw-tooth voltage occurs across the primary self-inductance L_p . Due to this saw-tooth voltage a current having a parabolic shape is added to the saw-tooth current in the primary. The relative magnitude of this parabolic component depends upon the ratio between the primary self-inductance and the load resistance transformed to the primary, and also upon the fundamental frequency of the saw-tooth current. It will be understood that a relatively low primary self-inductance, as with a transformer of small dimensions, causes a relatively large parabolic component, which considerably influences the shape of the total anode current. In the other extreme case of a very high primary self-inductance, involving a transformer of large dimensions, the parabolic component becomes very small and the total anode current has a linear shape.

The shape of the total anode current required to give a linear saw-tooth current in the deflection coils is depicted in fig. 58 for different values of T_1/T , in which $T_1 = L_p/n^2 (R_d + R_s)$ and T the duration of the frame scan.

It appears from this figure that with $T_1/T = 0.1$ the parabolic component assumes a very high value, resulting in a considerable distortion of the total anode current and a high value of the required peak

anode current. Another important disadvantage is that the minimum in anode current occurs quite a considerable time after the commencement of the scan. In fig. 58 it is assumed that the minimum value of the anode current is just zero, which is, of course, most economical in respect to current consumption. At minimum anode current the tube characteristic shows a strong curvature and it is consequently difficult to distort the driving voltage in such a way that the required shape of anode current is obtained. Non-linearity of the frame scan is therefore apt to occur at about 0.4 of the total picture height, and this is very annoying. A higher value of T_1/T should therefore be employed and this involves a higher value for the primary self-inductance

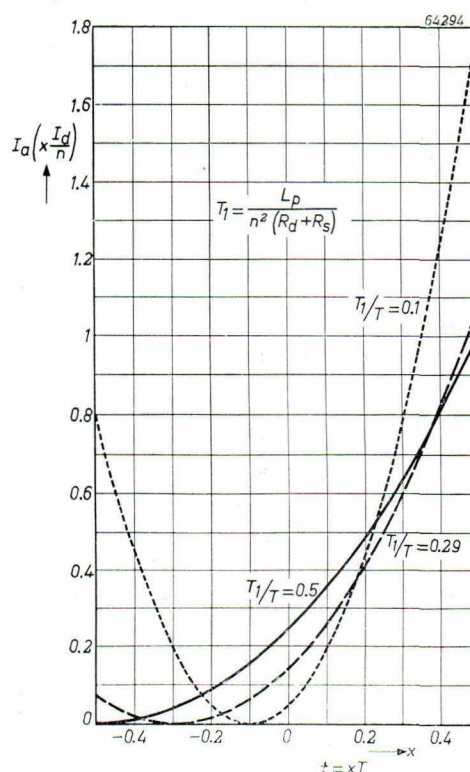


Fig. 58. Shape of the total anode current required to give a linear deflection current, for different values of T_1/T .

With $T_1/T = 0.29$ the shape of the total anode current is much more favourable but the minimum in anode current still occurs at 0.2 of the total picture height. It can be shown that with this value of T_1/T the average anode current is a minimum.

Finally, with $T_1/T = 0.5$ the minimum in anode current coincides with the commencement of the scan, which consequently is the most favourable situation. Moreover, it appears that the shape of the

anode current closely resembles that of the I_a/V_g characteristic of the tube, so that the problem of obtaining a driving voltage of the required shape is considerably simplified. With this value of T_1/T the required peak anode current reaches the minimum. A further increase of T_1/T , i.e. a higher value for L_p , does not decrease the required peak anode current and, although the total anode current assumes a more linear shape, the required average anode current becomes higher.

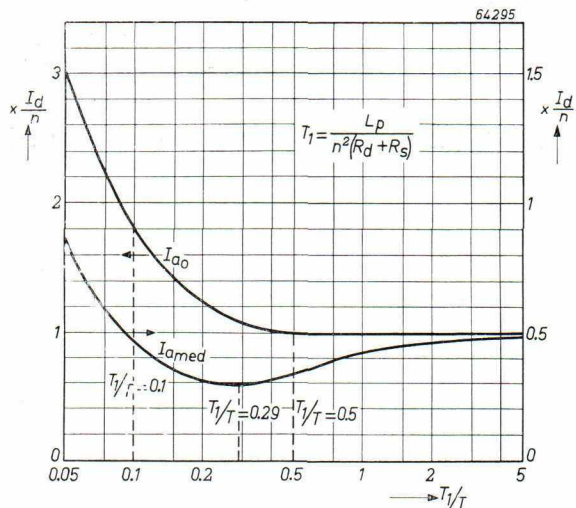


Fig. 59. Peak anode current and average anode current plotted against T_1/T .

The two important characteristics of the anode current, viz. the average anode current $I_{a \text{ med}}$ and the peak anode current I_{a0} , are plotted in fig. 59 against the values of T_1/T . It may be seen that with $T_1/T = 0.29$ the average anode current is a minimum and equal to $0.29 I_a/n$. At $T_1/T = 0.5$ the peak anode current has reached the minimum, which is I_a/n . In this case the average current is only slightly higher than that with $T_1/T = 0.29$.

By way of example an output transformer for use in conjunction with the PL 82 will now be calculated. The influence of the stray self-inductance will be disregarded, and the following practical figures have been chosen:

Supply voltage	$V_b = 170 \text{ V}$
Resistance of the deflection coils	$R_d = 50 \Omega$
Self-inductance of the deflection coils	$L_d = 50 \text{ mH}$
Deflection current peak-to-peak	$I_d = 350 \text{ mA}$
Frame frequency	$1/T = 50 \text{ c/s}$

These data refer to double-D scanning of a picture tube MW 31-16 or MW 22-16 operating with an E.H.T. of 9 kV

In view of the maximum permissible drop of the anode voltage below the H.T. line the turns ratio of the transformer must first be calculated. Assuming that the secondary has a resistance R_s of 15Ω , the drop occurring at the end of the scan across the primary self-inductance is: $\frac{1}{2} I_{dn} (R_d + R_s) = 11.4 n$. In order to avoid incursion in the knee of the I_a/V_a characteristic, and to make allowance for some additional voltage drop caused by the primary resistance and the self-inductance of the deflection coils, the above-mentioned drop must not be chosen too high, a suitable value in this case being 80 V. The turns ratio will therefore be $80/11.4 = 7$.

It must now be checked whether the additional drop, caused by the resistance of the primary and the self-inductance of the deflection coils, does not bring the momentary anode voltage below 50 V. In this example a drop of 40 V is still permissible. If the primary self-inductance is so chosen that $T_1/T = 0.5$ (see figs 58 and 59), the peak anode current occurring at the end of the scan becomes: $I_{a0} = I_d/n = 50 \text{ mA}$. If it is assumed that the primary resistance will be 500Ω , the maximum drop due to this resistance will be 25 V. Owing to the self-inductance of the deflection coils a constant voltage drop occurs during the scan across the primary. When the saw-tooth current is linear this amounts to $n \cdot L_d \cdot I_d/T$. Disregarding the duration of the fly-back, for a system operating with 50 frames per second the duration of the scan $T = 0.02 \text{ sec}$. This gives for the drop due to the self-inductance of the deflection coils, $7 \times 0.05 \times 0.350/0.02 = 6.1 \text{ V}$.

The total drop below the H.T. line now is $80 + 25 + 6 = 111 \text{ V}$, so that the minimum anode voltage at the end of the scan becomes 59 V, which is a sufficiently high value. In fact the anode voltage may be allowed to become as low as 50 V, but it should be realized that in determining $I_{a \text{ med}}$ and I_{a0} the minimum momentary anode current has been assumed to be zero. This condition can hardly be fulfilled in normal practice and the minimum value of the anode current will actually be 1 or 2 mA. This will result in a slightly higher drop in the resistance of the primary winding. As a final check the total voltage drop should again be calculated when the actual resistances of the primary and the secondary are known.

Finally, the required primary self-inductance must be calculated. It has been assumed that

$T_1/T = 0.5$, so that with $T = 0.02$ the value of T_1 becomes $T_1 = 0.01 = L_p/n^2 (R_d + R_s)$, and $L_p = 7^2 \times (50 + 15) \times 0.01 = 32 \text{ H}$.

Summarizing, the transformer data are as follows:

Primary self-inductance	32 H
Turns ratio	7 : 1
Resistance of the primary	500 Ω
Resistance of the secondary	15 Ω
Direct current in the primary	(see fig. 59) $16.5 + 2 \text{ mA}$

From the tube characteristics it may be seen that when the screen-grid voltage is 170 V a bias of about 15 V is required. If this bias is obtained automatically by means of a cathode resistor the

available supply voltage will be reduced by an amount equal to the cathode voltage. This might well bring the momentary anode voltage below the tolerable level but, on the other hand, in most television receivers operating with a transformerless supply system from the 220 V mains the available H.T. line voltage is somewhat higher than 170 V, for example 185 V. With fixed bias there is, of course, no reduction of the available high tension.

The driving voltage for the tube must have a shape that gives the required form of anode current. According to the shape of the available saw-tooth voltage and the figure of T_1/T , provision has to be made for obtaining the required shape of driving voltage. The means employed for this are given in the application notes of the ECL 80.

TECHNICAL DATA

HEATER DATA

Heating: indirect by A.C. or D.C.;
series supply

Heater voltage	V_f	16.5 V
Heater current	I_f	0.3 A

BASE CONNECTIONS AND

DIMENSIONS (in mm)

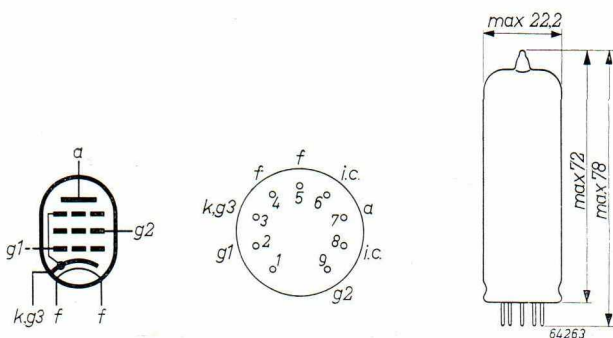


Fig. 60.

Mounting position: any

CAPACITANCES

C_{g1}	11 pF
C_a	8.3 pF
C_{ag1}	< 1 pF
C_{g1f}	< 0.15 pF

TYPICAL CHARACTERISTICS

Supply voltage	V_b	170	200 V
Anode voltage	V_a	170	200 V
Screen-grid voltage	V_{g2}	170	V
Screen-grid resistor	R_{g2}	—	680 Ω
Control-grid voltage	V_{g1}	—10.4	—13.9 V
Anode current	I_a	53	45 mA
Screen-grid current	I_{g2}	10	8.5 mA
Mutual conductance	S	9.5	8 mA/V
Internal resistance	R_i	20	24 k Ω

Amplification factor

between screen grid and

control grid μ_{g2g1} 10 10

OPERATING CONDITIONS FOR SOUND

OUTPUT (one tube in class A)

Supply voltage	V_b	170	200 V
Anode voltage	V_a	170	200 V
Screen-grid voltage	V_{g2}	170	V
Screen-grid resistor	R_{g2}	—	680 Ω
Control-grid voltage	V_{g1}	—10.4	—13.9 V
Anode current	I_a	53	45 mA
Screen-grid current	I_{g2}	10	8.5 mA
Mutual conductance	S	9.5	8 mA/V
Internal resistance	R_i	20	24 k Ω
Matching resistance	R_a	3	4 k Ω
Power output			
($d_{tot} = 10\%$) W_o		4	4 W

Input signal ($d_{tot} = 10\%$) V_i 6 7 V_{rms}

Input signal ($W_o = 50 \text{ mW}$) V_i 0.5 0.55 V_{rms}

OPERATING CONDITIONS FOR SOUND
OUTPUT (two tubes in push-pull)

Anode voltage	V_a	170	200	V
Screen-grid				
voltage	V_{g2}	170	200	V
Common cathode				
resistor	R_k	100	135	Ω
Matching resist-				
ance between				
anodes	$R_{aa'}$	4	4	k Ω
Input signal	V_i	0	9.3	0
Anode current	I_a	2x46	2x50	2x45
Screen-grid				
current	I_{g2}	2x8.7	2x17	2x8.5
Power output	W_o		9	12
Total distortion	d_{tot}		5	5

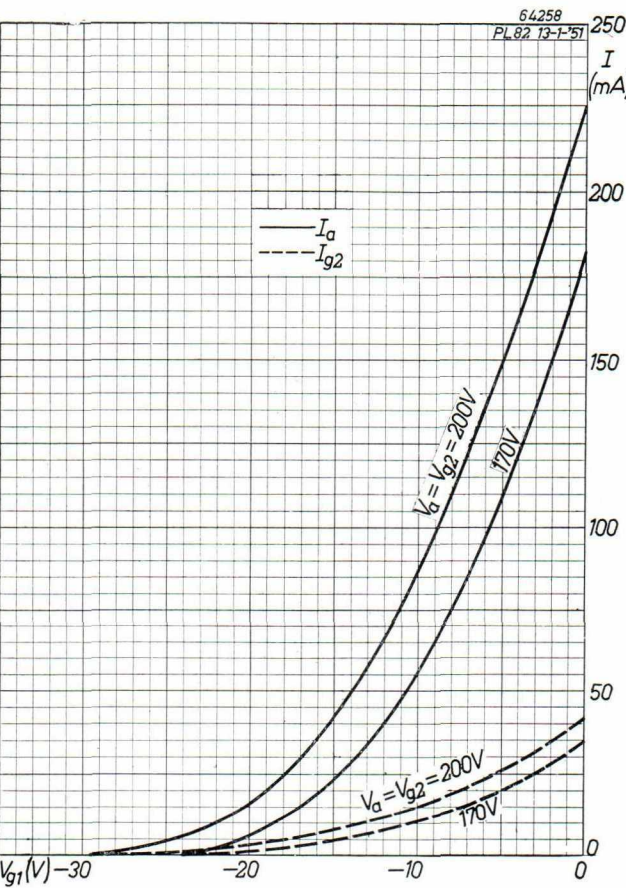


Fig. 61. Anode current and screen-grid current plotted against control-grid voltage with anode and screen-grid voltage as parameter.

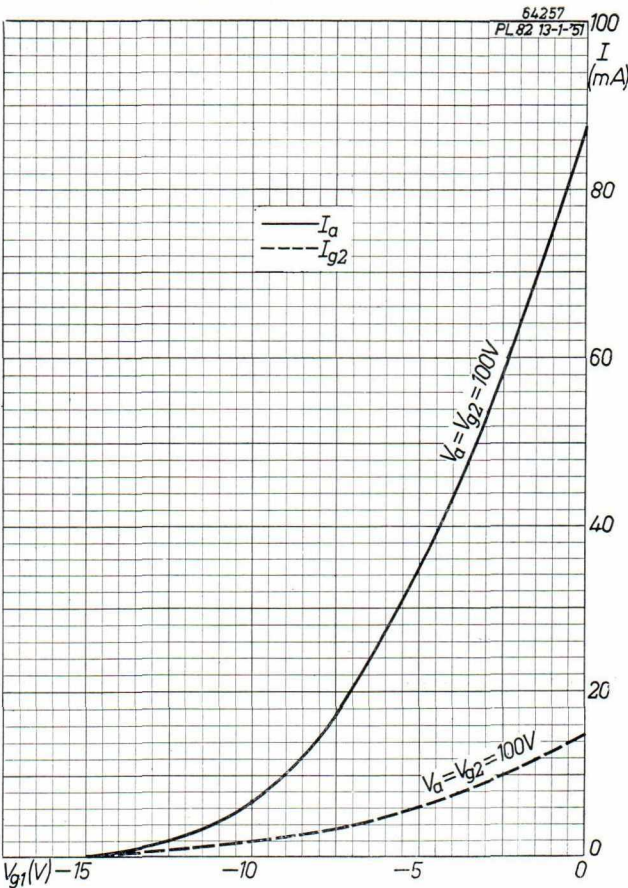


Fig. 62. Anode current and screen-grid current plotted against control-grid voltage for anode and screen-grid voltage of 100 V.

LIMITING VALUES

Anode voltage at zero anode current	V_{a0}	max.	550 V
Anode voltage	V_a	max.	250 V
Positive peak anode voltage (10% of the duration of a cycle with a maximum of 2 m sec.)		max.	2.5 kV
Negative peak anode voltage		max.	500 V
Screen-grid voltage at zero screen-grid current	V_{g20}	max.	550 V
Screen-grid voltage	V_{g2}	max.	250 V
Control-grid voltage (grid current +0.3 μ A)	V_{g1}	max.	-1.3 V
Heater voltage during warming-up period		max.	24.5 V
Voltage between heater and cathode	V_{kf}	max.	200 V
Cathode current	I_k	max.	75 mA
Anode dissipation	W_a	max.	9 W
Screen-grid dissipation	W_{g2}	max.	2.5 W

External resistance between
control grid and cathode

with fixed bias R_{g1} max. 0.4 M Ω

with automatic bias R_{g1} max. 1 M Ω

External resistance between

heater and cathode R_{kf} max. 20 k Ω

To allow for inevitable spread between individual tubes and for deterioration during life in frame output applications, the circuit should be designed around a peak anode current not exceeding 90 mA at $V_a = 50$ V and $V_{g2} = 170$ V.

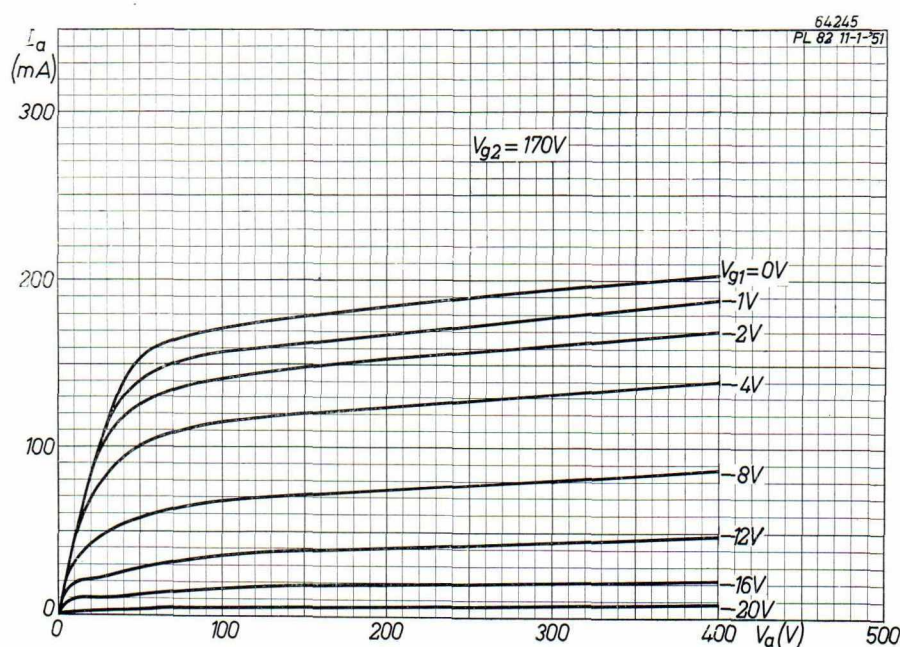
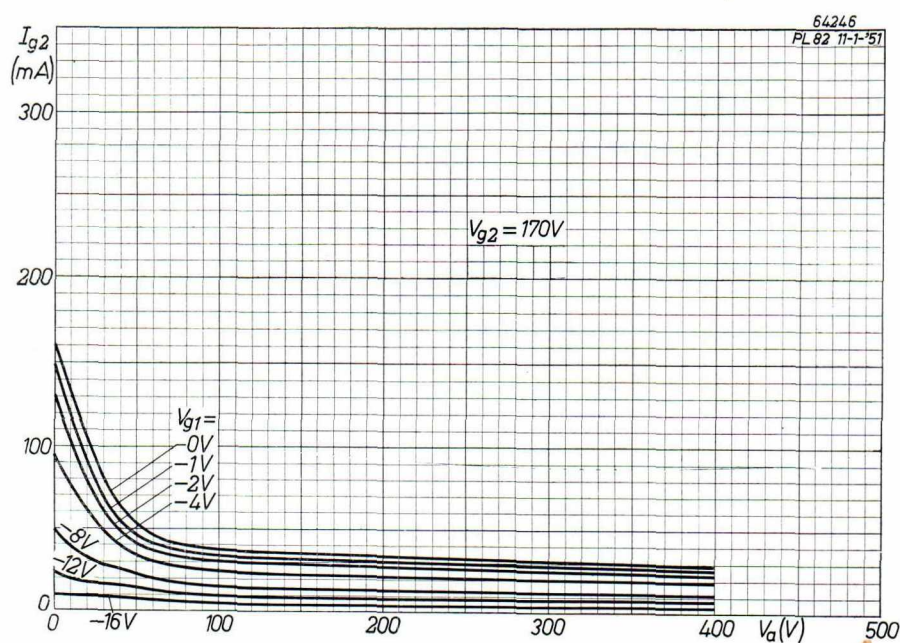


Fig. 63.

Anode current plotted against anode voltage for screen-grid voltage of 170 V, with control-grid voltage as parameter.

Fig. 64.

Screen-grid current plotted against anode voltage for screen-grid voltage of 170 V, with control-grid voltage as parameter.



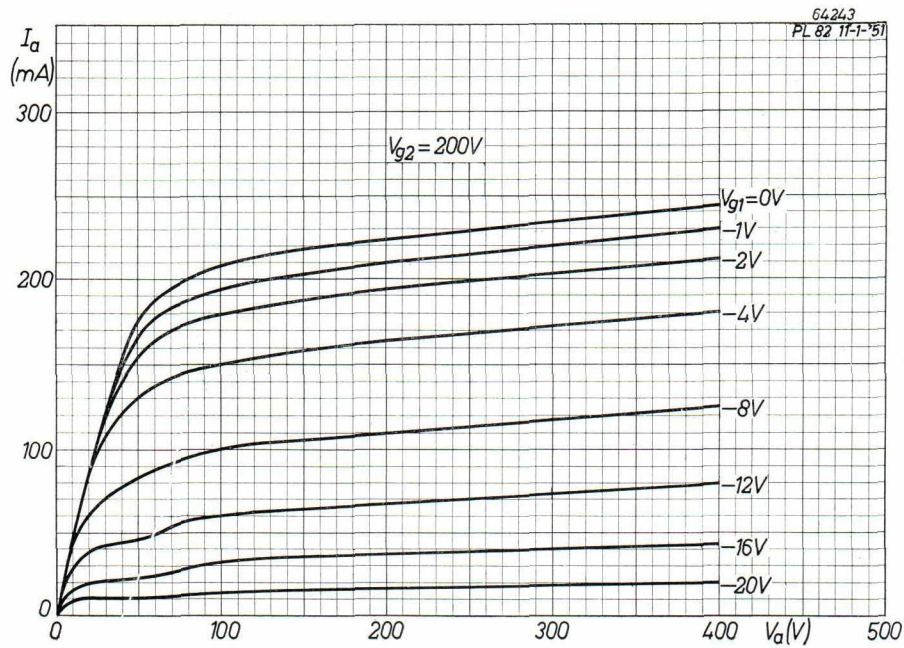
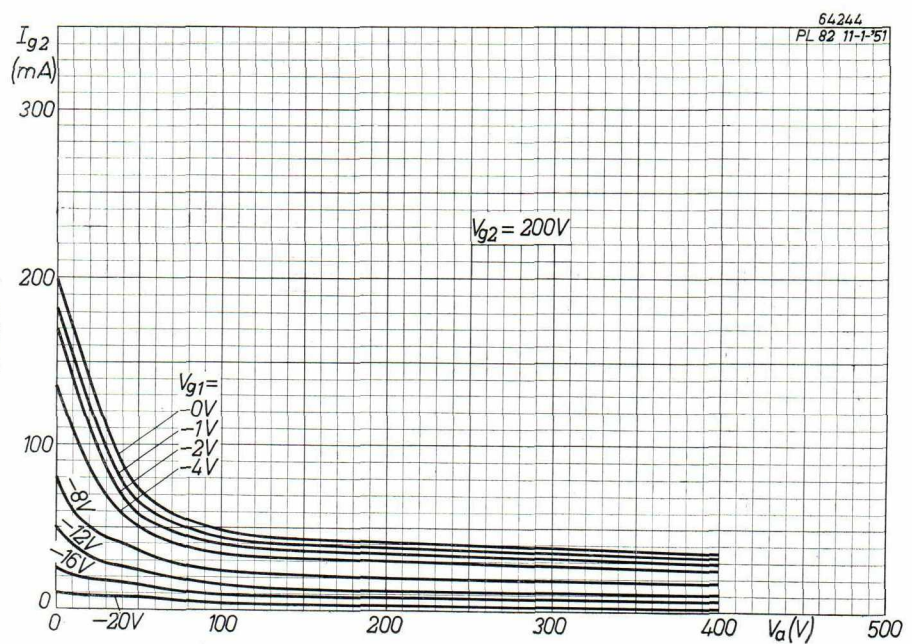


Fig. 65.
Anode current plotted
against anode voltage for
screen-grid voltage of
200 V, with control-grid
voltage as parameter.

Fig. 66.
Screen-grid current plot-
ted against anode voltage
for screen-grid voltage of
200 V, with control-grid
voltage as parameter.



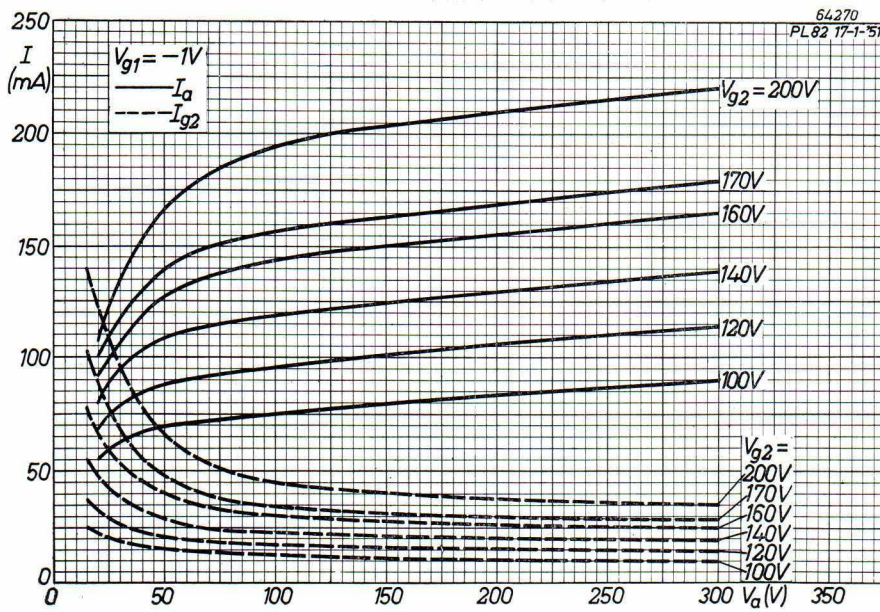


Fig. 67.
Anode current and screen-grid current plotted against anode voltage for control-grid voltage of $-1V$, with screen-grid voltage as parameter.

Fig. 68.
Anode current, screen-grid current, input voltage and total distortion plotted against output power for anode and screen-grid voltage of $170V$.

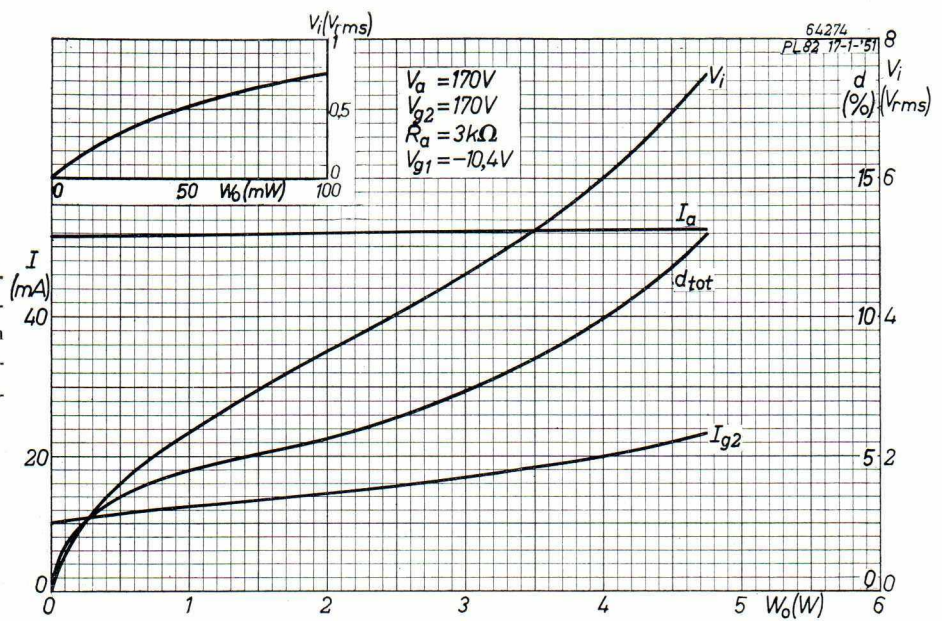


Fig. 69.

Anode current, screen-grid current, input voltage and total distortion plotted against output power for anode and screen-grid supply voltage of 200 V.

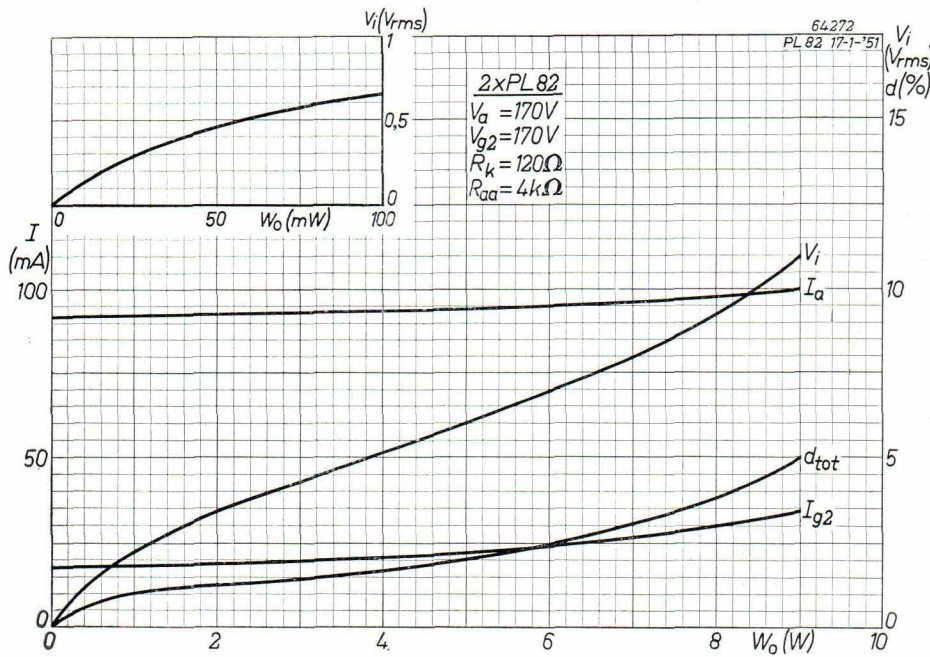
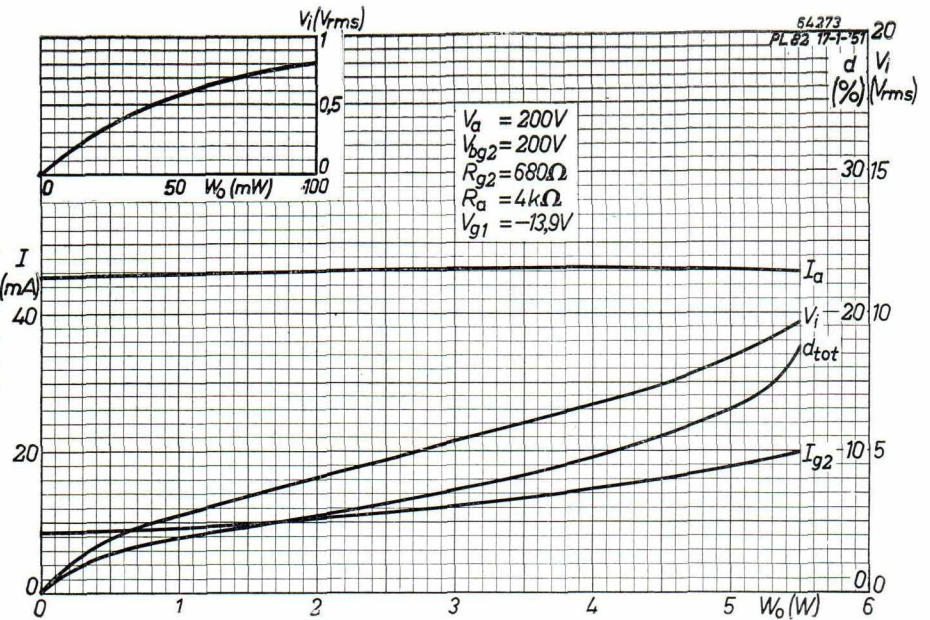


Fig. 70.

Anode current, screen-grid current, input voltage and total distortion plotted against output power of two tubes PL 82 in push-pull for anode and screen-grid voltage of 170 V.

Fig. 71.

Anode current, screen-grid current, input voltage and total distortion plotted against output power of two tubes PL 82 in push-pull for anode and screen-grid voltage of 200 V.

