PHILIPS **PCL 84**

TRIODE - PENTODE
for Video Output Stages

PHILIPS ELECTRON TUBE DIVISION

The construction of the PCL 84 has been developed from the experience obtained with the video tubes used up till now. With the present circuit design this construction features the best compromise between expenditure and efficiency in video output stages.

With a view to the general use of keyed a.g.c., the application of a triode/output pentode in video output stages is very favourable. The advantages of this solution, however, can be fully utilised with completely separated sections only. With the PCL 84 the cathodes of both sections are therefore connected to separate base pins; an additional screen between the sections vouches for an efficient decoupling between the triode and pentode sections.

Owing to its high slope the PCL 84 supplies the necessary video gain already at low anode resistances. The PCL 84 makes possible very economic output stages possessing excellent transfer properties as a result of the small interelectrode capacitances.

The I_a/V_g characteristic of the PCL 84 is practically linear over a wide range, so that there is little non-linear distortion. Moreover, the ample amplification permits the application of negative feedback, thus improving the linearity of the video characteristic.

The ratio of the anode to the screen-grid current, respectively the maximum permissible dissipation of these electrodes, is so chosen that at supply voltages from 170 to 220 V no series resistances are needed in the screen-grid or cathode circuits to limit the dissipation; only with d.c. coupling the screen-grid dissipation can be exceeded at small grid voltages, so that the incorporation of a small protective resistance in the cathode or screen-grid circuit becomes necessary.

In this publication a survey is given on the performance of the PCL 84 in different circuits and applications, together with measurements on two complete video output stages with the PCL 84, viz. one video stage with blanking and contrast control in the cathode of the PCL 84, and another circuit d.c. coupled with the contrast-control in the anode-circuit of the PCL 84.

A. ADJUSTMENT OF THE VIDEO OUTPUT STAGE

1. BLACK-LEVEL CIRCUITS

First of all the circuits with restored black level will be discussed. Fig.1 shows the well-known circuit with a level diode, the signal being applied via an *RC* network. In this circuit the video signal, driving the tube to higher currents from the working point, lies in the lower part of the characteristic. In Table I the performance of the tube at different values of R_a is determined with the aid of the characteristics of Fig.5.

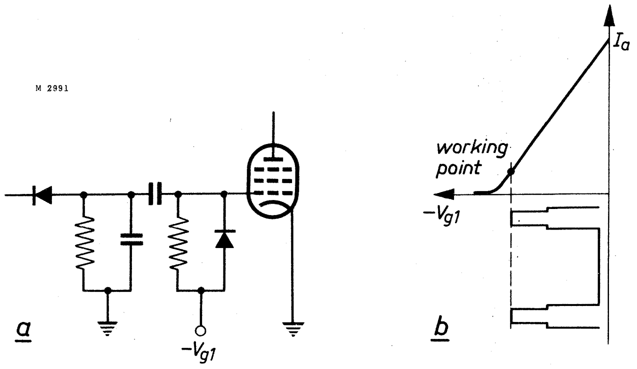


Fig.1. Constant black level by means of a d.c. restorer.

Fig.2 illustrates the principle of a black-level circuit with keyed d.c. restoration in which the switching pulses render the diode bridge circuit, connected to the control grid, temporarily conducting during the black level. In this way the charge of the grid capacitor is reversed once a line period, so that it assumes the potential of the grid biasing source ($-V_{g1}$). Apart from a certain difference of the quiescent current in the working point (this difference corresponds roughly to the distance of the synchronisation peak to the black level), the same driving conditions apply for both circuits.

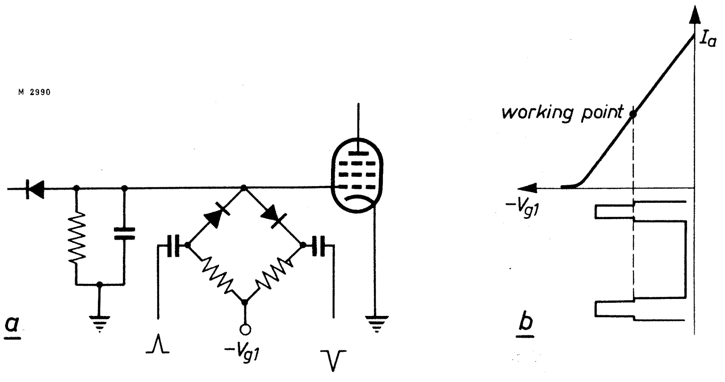


Fig.2. Constant black level with a keyed d.c. restorer.

In the level diode circuit the upper limit of the applicable driving signal is determined by the point of grid current start (V_{g1} = -1.3 V), because the grid capacitor should not be charged by grid current; this would in fact result in undesirable shifting of the black level.

The black-level circuit with keyed d.c. restoration is less liable to disturbances, so that a greater part of the grid base may be used. It may be taken as a guide that in this circuit the PCL 84 may be driven up to V_{g1} = -0.8 V.

With the customary values of the anode load resistor the maximum permissible anode dissipation of the PCL 84 will not be exceeded even at V_{g1} = 0, whilst at V_b = 200 V the maximum permissible screen-grid dissipation, without using R_{g2}, is reached at V_{g1} = -1 V in the case of R_a = 2.7 kΩ or at V_{g1} = -1.15 V in the case of R_a = 3.3 kΩ. In a video output tube in which the black level is kept constant, it is however not necessary to take these static values into consideration, and it is permissible to base the calculation of the tube dissipation on the characteristics corresponding to driving the tube up to 2/3 of the white level. This means that there is no risk of the tube dissipation being exceeded when the tube is driven up to V_{g1} = -1.3 V and V_{g1} = -0.8 V respectively.

The tube should not be operated in the part of the grid base very close to the cut-off point, because the curvature of the characteristic would introduce heavy distortion of the graduation, and moreover, very high demands would have to be imposed on the sync separation due to the compression of the sync-pulses. Table 1 gives the most favourable values of the working point of the black-level circuit for two driving adjustments, one of these based on the video output tube being so driven that it supplies a peak-to-peak voltage of V_{vid} = 55 V at an anode load resistance of R_a = 2.7 kΩ. Good linearisation is, however, still obtainable with an anode load resistance of R_a = 3.3 kΩ; the maximum drive for such a load is also given in Table 1.

Another method of keeping the black level constant, in combination with the A.G.C., is discussed in Section 3.

2. *RC* COUPLING

When connecting the output tube to the video detector via an *RC* filter, so that only the a.c. component of the video signal is transferred, the average value of the input signal coincides with the working point which is determined by the grid bias only. As this average value depends on the picture information, the grid base of the video output tube must be greater than the video signal, for a shift of the video signal to more negative grid voltages at a predominantly white picture will occur, as well as a corresponding shift to more positive grid voltages at the signal "black with narrow white peaks", as is illustrated in Fig.3.

Every possible picture information can be transferred perfectly when the grid base amounts to approx.150 per cent. of the maximum amplitude to be transferred. The working point has to be so situated that about 70 per cent. of the amplitude can lie over and 80 per cent. below the working point.

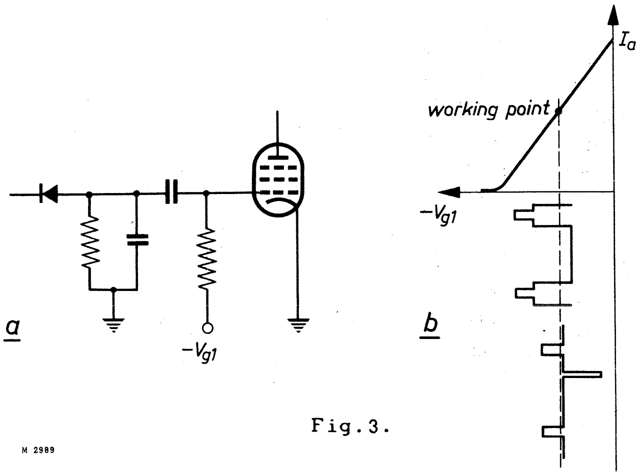


Fig.3.

If strict account is taken of the shape of the television signal, the sync level lies with a white picture approx. 77 per cent.of the maximum amplitude below the working point; the signal peaks of a black picture with narrow white lines drive the video tube up to 67 per cent. over the working point whilst a residual carrier of 10 per cent. at full white should also be considered.

With *RC* coupling the video signal must be kept low compared with the grid base. Table 1 indicates operating conditions both for R_a = 2.7 kΩ and for R_a = 3.3 kΩ. The grid bases and operation values for a white picture and a black one with white peaks are included.

Only the point of grid current start is decisive for the limit of the grid base of the *RC*-coupled PCL 84 (V_{g1} = -1.3 V), the permissible dissipation being of no interest.

3. D.C. COUPLING

With the d.c. coupling, operating with the working point at the extreme right of the I_a/V_g characteristic of the video tube, the highest quiescent current (at no signal) will occur in the working point as compared with other methods of coupling. At normal signal the tube conditions are fully comparable with those occurring with the method of keeping the black level constant.

The arrangement of a d.c.-coupled video output stage is depicted in Fig. 4. For the driving conditions it is assumed that the necessary bias of the video output tube is achieved by means of a cathode resistor.

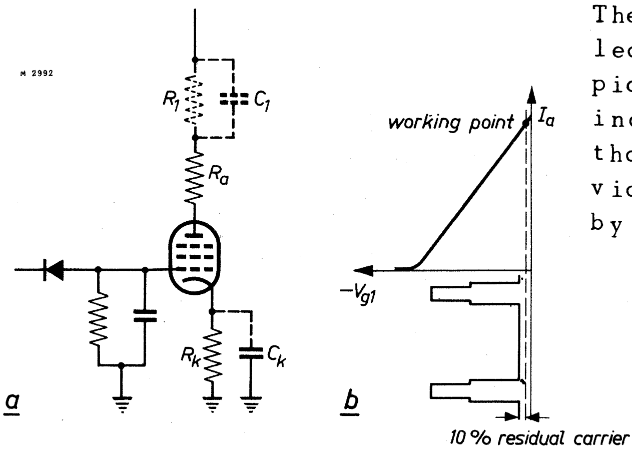


Fig. 4.

Since at d.c. coupling there is no grid capacitor, only the damping of the intercarrier signal by grid current must be taken into consideration, so that the PCL 84 could be driven up to V_{g1} = -0.8 V, were it not that in this case, in the absence of signal, the screen-grid dissipation would be exceeded. Consequently the cathode resistance must have a certain minimum value when the screen grid dissipation is not limited by a screen-grid resistance.

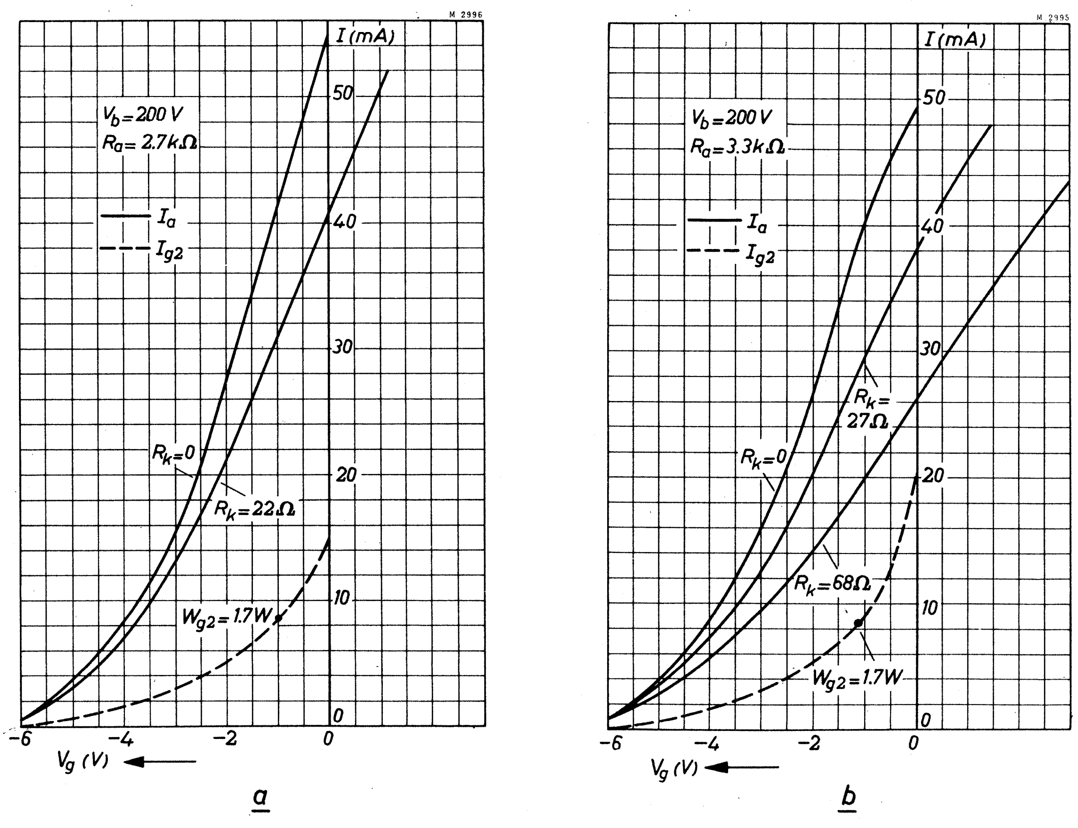


Fig. 5. Load lines of the PCL 84.

With the aid of the characteristics of Fig.5, two maximum driving adjustments have been entered in Table 1, the value of the (not bypassed) cathode resistor being so far reduced that the dissipations reach their maximum permissible value. The largest, not bypassed cathode resistance that may be used when 55 V (peak-to-peak value) video voltage at R_a = 3.3 kΩ should be reached, amounts to R_k = 68 Ω; this adjustment is also given in Table 1. When a larger cathode resistance is used, e.g. for taking off the voltage for keyed A.G.C., the grid circuit can be connected to a tapping of the cathode resistor.

The remarks on the d.c. coupling obviously hold also for circuits in which both d.c. coupling and black-level stabilisation are applied simultaneously, whilst e.g. the contrast control by keyed A.G.C. has been combined with a corresponding shift of the operating characteristics.

4. THE DRIVING CONDITIONS AT NEGATIVE FEEDBACK

(*a*) *Frequency-independent negative feedback*

A video amplifier is preferably supplied with a frequency-independent negative feedback to linearise the characteristic and consequently decrease the non-linear distortions. This feedback, however, necessitates a higher input voltage of the stage.

Table I (page 6) shows the video signals at frequency-independent negative feedback for d.c. coupling between video diode and video tube.

In the cathode lead not-bypassed cathode resistors of R_k = 22, 27 and 68 Ω have been provided for negative current feedback. Apart from the decrease in slope and the linearisation of the characteristic, the same considerations are valid as those for driving without negative feedback.

(*b*) *Frequency-dependent negative feedback*

As a consequence of the stray-capacitances in the anode circuit, the negative feedback is frequency dependent in almost every design, the cathode resistance being bypassed by means of a capacitor. The influence of the negative feedback on the output voltage can be compensated by incorporating an additional *RC*-filter in the anode circuit (cf. R_1C_1 in Fig.4). A complete compensation in the total frequency range is however only attained when the following conditions are satisfied:

$$R_k \cdot C_k = R_1 \cdot C_1.$$

$$\frac{R_k}{R_1} = S \cdot R_a.$$

In this case the function V_a = f(*f*) is very similar to that without cathode resistor. When there is no such compensation and when the cathode member is used for correction of distortion of the amplitude characteristic at the upper end of the frequency band, this will result in an additional decrease of the video signal at high frequencies. Moreover, a larger video signal becomes necessary when driving is achieved by pulses of which the rise-time is short and

TABLE 1. Driving conditions at different connections of the PCL 84 video stage to the video detector (values for $V_b = V_{g2} = 200$ V)

	R_a kΩ	V_{vid} V_{pp}	R_k Ω	V_{bg1} V	$V_{g\sim}$ (video sign.) V_{pp}	I_a (working point) mA	I_{g2} (working point) mA	V_{vid} -	S_{av} mA/V	Remarks
black-level circuits	2.7	55	-	-5.0 sync. level	3.0	3.5 sync. level		25	9.4	
				-4.18 black level		7.2 black level	1.3 black level			
	3.3	80	-	-5.15 sync. level	3.5	3.0 sync. level		32	9.6	max. amplitude
				-4.2 black level		7.0 black level	1.3 black level			
RC-coupling	2.7		-	-3.15		14.5	2.9			
		32			2.3			20	7.2	"white" max. ampl.
		52			2.3			32	11.6	"black with white peaks" max. ampl.
	3.3		-	-3.0		15.6	3.2			
		40			2.2			26	7.8	"white" max. ampl.
		61			2.2			39	11.9	"black with white peaks" max. ampl.
d.c.-coupling	2.7	74	22	0	4.5	40	4.9	22	8.3	$R_{k\,min}$ } max. ampl.
	3.3	85	27	0	4.5	38	4.5	26	7.8	$R_{k\,min}$
	3.3	55	68	0	4.4	26	3.2	17	5.0	$R_{k\,max}$ at V_{vid} = 55 V_{pp}

of which the pulse duration is long with respect to the time constant of the cathode RC-member. The grid-cathode voltage appears to be increased by a factor:

$$\left(1 + \frac{S \cdot R_k}{1 + S \cdot R_k}\right).$$

B. COMPARISON WITH THE VIDEO TUBES USED UP TILL NOW

In the Tables 2, 3 and 4 the corresponding values of the PCL 84 are published which offer a possibility of comparing the new video tube PCL 84 to other tubes used up till now in video stages (the PL 83 and PCF 80). It is shown that the PCL 84 can operate with

TABLE 2. Working point (black level) at 2200 V supply voltage

		PL 83		PCF 80	PCL 84
R_a	kΩ	2.2	2.7	4.3	2.7
R_{g2}	kΩ	-	-	-	-
R_k	Ω	-	-	82	-
I_a	mA	25	15	3.5	7.2
I_{g2}	mA	3.3	2	1.2	1.3
I_k	mA	28.3	17	4.7	8.5
S_{av} (in the video range)	mA/V	11.5	9.3	5.8	9.4
g		25	25	25	25

TABLE 3. Comparison of broadcast amplifier properties

		PL 83		PCF 80	PCL 84
R_a	kΩ	2.2	2.7	4.3	2.7
C	pF	6.6		3.8	4.5
$C_a + C_{cp}$	pF	11.6		8.8	9.5
C_g	pF	11.2		5.5	9
$C_g + C_d$	pF	21.2		15.5	19
$C_a + C_g$	pF	17.8		9.3	13.5
C_{ag1}	pF	< 0.1		<0.025	<0.1
$g.C_{ag1}$ ($25.C_{ag1}$; see table I)	pF	2.5		0.63	2.5
$C_g + g.C_{ag1}$	pF	13.7		6.15	11.5
S_{av}	mA/V	11.5	9.3	5.8	9.4
$S_{av}/(C_a + C_{cp})$	mA/V pF	0.99	0.80	0.66	0.99
$S_{av}/(C_a + C_g)$	mA/V pF	0.65	0.52	0.62	0.7
$S_{av}/(C_a + C_g + g.C_{ag1})$	mA/V pF	0.57	0.46	0.58	0.59
S_{av}/C_a	mA/V pF	1.74	1.41	1.53	2.09
S_{av}/C_g	mA/V pF	1.02	0.83	1.05	1.04
$S_{av}/(C_g + g.C_{ag1})$	mA/V pF	0.84	0.68	0.94	0.82
$S_{av}/I_k(C_g + g \cdot C_{ag1})$ (black level)	1/V pF	0.03	0.04	0.2	0.096

Remarks: C_{cp} = input capacitance of the picture tube (cathode capacitance);
C_d = load capacitance of the video diode;
S_{av} = average mutual conductance in the video range.

TABLE 4. Comparison of the rise time for square-pulse drive.

		PL 83		PCF 80	PCL 84
Anode circuit					
C_{tot} (= C_a + C_{cp} + 10 pF circuit cap.)	pF	21.6		18.8	19.5
R_a (for V_{vid} = 55 V_{pp}', g = 25)	kΩ	2.2	2.7	4.3	2.7
$T_a = 1.2 \cdot R_a \cdot C_{tot}$	ns	57	70	97	63
$B = 0.35/T_a$	Mc/s	6.1	5	3.6	5.56
Grid circuit					
$C'_{g1} = C_2 = C_{g1} + g \cdot C_{ag1}$	pF	13.7		6.15	11.5
$C_1 = C_d + C_{circuit}$	pF	15		15	15
$C_{tot} = C_1 + C_2$	pF	28.7		21.15	26.5
R_1 (equivalent resistance for video detector circuit: $R_i \approx R_1$	kΩ	3		3	3
$T_g = 0.8 \cdot R_1 \cdot C_{tot}$	ns	69		51	63.7
$B = 0.35/T_g$	Mc/s	5.1		6.9	5.5
$T_{vid} = \sqrt{T_a^2 + T_g^2}$	ns	89	98	110	90
p^2 (4 Mc/s) = $S_{max} \cdot \omega C_{agl} \cdot Z_a \cdot Z_g$		0.141	0.149	0.0383	0.182

Remark: p^2 = stabilisation factor, given for f = 4 Mc/s. The grid impedance appears from the parallel connection of R_i and R_1 ($Z_g \simeq 2$ kΩ).

the same low anode resistances as the PL 83 to obtain the same gain figure. When the rise time T_{vid} (at driving with square pulses) of the PL 83 and PCL 84 stages is compared, it can be seen that at the same amplification the obtainable rise time of the PL 83 with R_a = 2.2 kΩ, can be realized with the PCL 84 at R_a = 2.7 kΩ.

C. PROPOSITIONS FOR DIMENSIONING OF VIDEO OUTPUT STAGES

1. Fig.6 shows the circuit of a complete video stage with keyed d.c. restoration and contrast control by means of a variable cathode resistor. The video output tube operates with an anode resistor of 3.3 kΩ and a parallel-series compensation. Moreover, a 5.5 Mc/s sound trap is provided for the suppression of sound in the picture The sound I.F. signal is taken off directly after the video-detector and fed to the sound I.F. amplifier. The grid bias is produced automatically by means of a non-bypassed cathode resistor R_k of 33 Ω. With the low value of the anode resistance used in this case it may be advisable, from the point of view of the step-function characteristic, to apply anode compensation only and to dispense with compensation at the grid side.

   In the grid circuit a series-peaking filter is inserted. The symmetric pulses for the blanking are available in the phase discriminator for horizontal synchronisation, and the correct phase and amplitude of the switching pulses are obtained from adequate differentiation members.

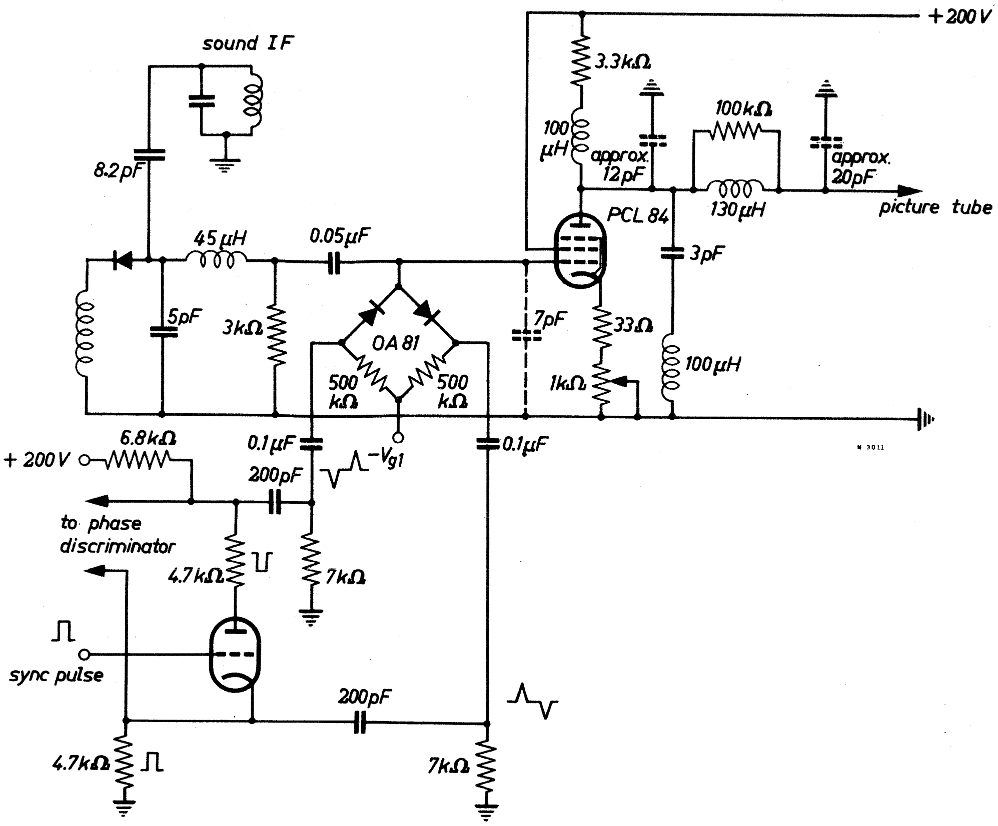


Fig.6.

In the circuit a contrast control in the cathode is provided by means of a 1 kΩ potentiometer.

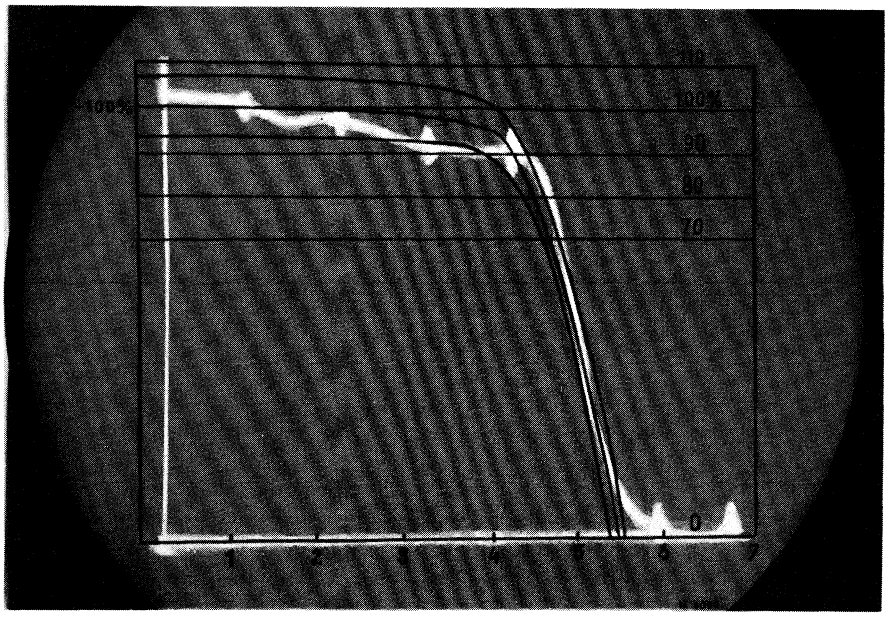


Fig.7.

Fig.7 shows the frequency response obtained in this circuit, with the contrast control turned halfway. Frequency reference marks are indicated at distances of f = 1 Mc/s.

2. Fig.8 shows the circuit of a complete video stage with d.c. coupling and the contrast control included in the anode circuit of the output tube.

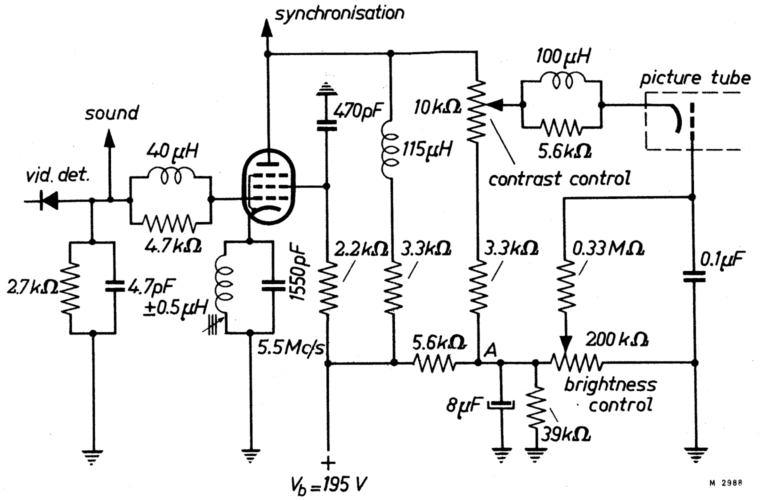


Fig.8.

This video amplifier is also suited for the C.C.I.R. system. The sound signal is taken from the grid circuit, the synchronisation and A.G.C. information from the anode circuit. The amplitudes of these signals do not depend on the position of the contrast control. A suppression of 29 dB of the sound signal is obtained by means of a tuned circuit (f = 5.5 Mc/s) in the cathode lead of the PCL 84.

An inductance ($L \simeq 40$ µH) damped by a resistor of 4.7 kΩ is connected between the detector and the grid of the PCL 84. This correction coil may, in combination with the 5.5 Mc/s trap in the cathode lead, give rise to oscillations if the inductance becomes too high; the resonant frequency of the grid circuit should be slightly higher than 5.5 Mc/s.

In order to avoid that the limiting values of the PCL 84 are exceeded at no-signal condition, a resistor of 2.2 kΩ is inserted in the screen-grid lead at V_b = 195 V.

To prevent a high Miller capacitance, the screen grid must be decoupled, at least for high frequencies. A decoupling capacitor of 470 pF can be used, by which a slight improvement in the response curve is obtained, this being accompanied by a slight loss of gain.

Contrast control is effected by a potentiometer of 10 kΩ. The contrast range is limited to 4 : 1 by a resistor of 3.3 kΩ in series with the potentiometer. In this way the receiver can be tuned at any position of the contrast control. For a high gain and good response curve the anode resistance must be about 2.5 kΩ. Because the dissipation in this resistance would be too high for a normal carbon potentiometer, it is necessary to use a potentiometer of higher value, and a shunt resistor which reduces the total anode load to 2.5 kΩ. The high value of the potentiometer is moreover very useful when the d.c. level of the video signal has to be passed on to the cathode-ray tube. It is then possible to keep the black level automatically constant when the contrast control is operated. This can be done by applying to the lower end of the potentiometer (point A), a fixed direct voltage which is equal to the anode voltage of the video tube at black level. For good operation of this system the load of the chain in which the potentiometer is used must be low compared to the fixed parallel anode load resistance. The voltage at point A is not well fixed, and the black level will depend on the modulation of the video signal, unless the bleeder current (through 5.6 kΩ, 39 kΩ and the brightness control) is high compared to the current flowing through the potentiometer branch. A good A.G.C. action is desirable, since the black level potential in the video tube itself must be kept constant by the A.G.C. Series shunt compensation is used in the anode circuit. The gain of the video stage is about 20 times, and the maximum value of the output voltage is 75 V. At maximum and minimum contrast settings, the rise time is 0.11 μsec; at the intermediate position the rise time increases to 0.135 μsec.

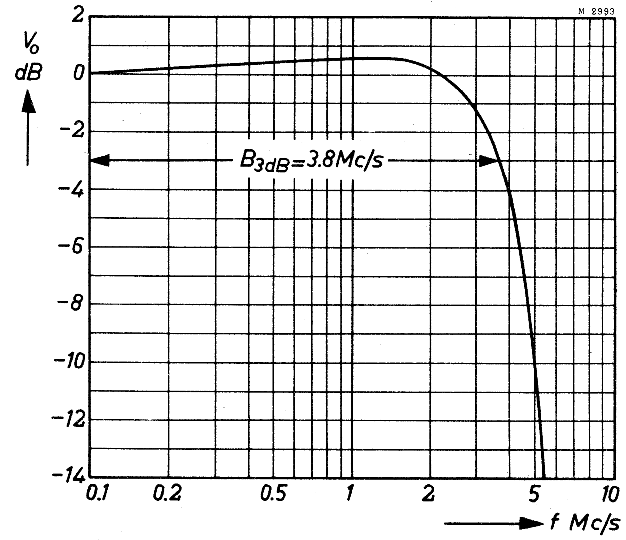


Fig.9.

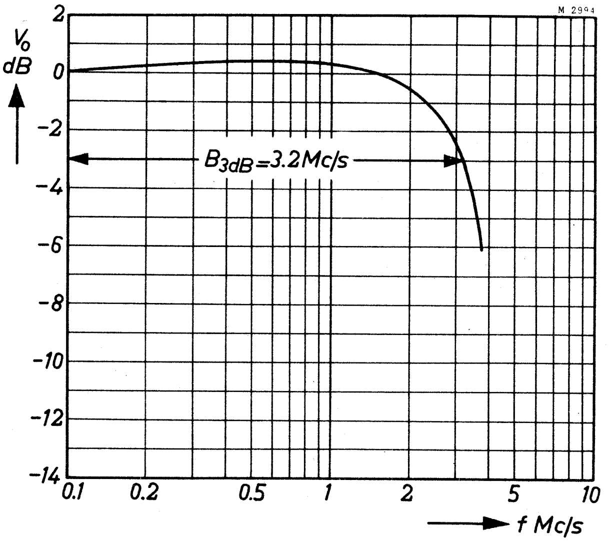


Fig.10.

Figs 9 and 10 show the frequency response curves obtained in this circuit, with the contrast control in the maximum position and with this control turned halfway, respectively. The signal is inserted directly behind the video detector.

Technical Data

The PCL 84 is a triode-pentode with a noval base, and with separate cathodes; its high-slope pentode section is designed for use as video output tube, while the triode section can very well be applied in circuits for keyed A.G.C., synchronisation separation, synchronisation amplification and noise suppression.

GENERAL DATA

Heating: indirect by a.c. or d.c.;
series supply.
Heater voltage V_f = 15 V
Heater current I_f = 300 mA
Base: noval

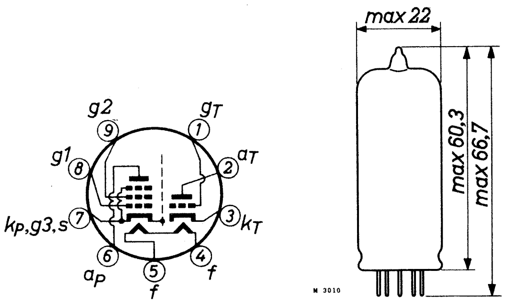


Fig.11. Maximum dimensions (in mm) and electrode connections of the PCL 84.

CAPACITANCES

Pentode section

Control grid to all other electrodes except to the anode	C_{g1}	=	9 pF
Anode to all other electrodes except to the control grid	C_a	=	4.5 pF
Anode to control grid	C_{ag1}	<	0.1 pF
Control grid to heater	C_{g1f}	<	0.1 pF

Triode section

Control grid to all other electrodes except the anode	C_g	=	4 pF
Anode to all other electrodes except the control grid	C_a	=	2.5 pF
Anode to control grid	C_{ag}	=	2.7 pF
Control grid to heater	C_{gf}	<	0.15 pF

Between triode and pentode section

Anode triode to control grid pentode	C_{aTg1P}	<	0.01 pF
Grid triode to control grid pentode	C_{gTg1P}	<	0.01 pF

Between triode and pentode section

Anode triode to control grid section	C_{aTg1p}	<	0.01 pF
Grid triode to control grid pentode	C_{gTg1p}	<	0.01 pF

TYPICAL CHARACTERISTICS OF THE PENTODE SECTION

Anode voltage	V_a	=	170	200	220	V
Screen-grid voltage	V_{g2}	=	170	200	220	V
Control-grid voltage	V_{g1}	=	-2.1	-2.9	-3.4	V
Anode current	I_a	=	18	18	18	mA
Screen-grid current	I_{g2}	=	3.1	3.1	3.1	mA
Mutual conductance	S	=	11	10.4	10	mA/V
Internal resistance	R_i	=	100	130	150	kΩ
Amplification factor of screen grid with respect to control grid	μ_{g2g1}	=	36	36	36	
Control-grid voltage at which grid current starts to flow	$V_{g1}(I_{g1} = +0.3\ \mu A)$	=	max.-1.3	-1.3	-1.3	V

TYPICAL CHARACTERISTICS OF THE TRIODE SECTION

Anode voltage	V_a	=	200	V
Control-grid voltage	V_g	=	-1.7	V
Anode current	I_a	=	3	mA
Mutual conductance	S	=	4	mA/V
Amplification factor	μ	=	65	
Control-grid voltage at which grid current starts to flow	$V_g(I_g = +0.3\ \mu A)$	=	max.-1.3	V

LIMITING VALUES

Pentode section

Anode voltage at zero anode current	V_{ao}	= max.		550	V
Anode voltage	V_a	= max.		250	V
Anode dissipation	W_a	= max.		4	W
Screen-grid voltage at zero screen-grid current	V_{g2o}	= max.		550	V
Screen-grid voltage	V_{g2}	= max.		250	V
Screen-grid dissipation	W_{g2}	= max.		1.7	W
Cathode current	I_k	= max.		40	mA
Control-grid circuit resistance					
with fixed bias	R_{g1}	= max.		1	MΩ
with automatic bias	R_{g1}	= max.		2	MΩ
Heater-cathode voltage	V_{kf}	= max.		200	V
Heater-cathode circuit resistance	R_{kf}	= max.		20	kΩ

Triode section

Anode voltage at zero anode current	V_{ao}	= max.		550	V
Anode voltage	V_a	= max.		250	V
Peak anode voltage	V_{ap}	= max.		400	V
Anode dissipation	W_a	= max.		1	W
Cathode current	I_k	= max.		12	mA
Grid circuit resistance					
with fixed bias	R_g	= max.		1	MΩ
with automatic bias	R_g	= max.		3	MΩ
Heater-cathode voltage					
k neg.; *f* pos.	V_{kf}	= max.		150	V
k pos.; *f* neg.	V_{kf}	= max.	$200\ V_{=}$	+150	V_{rms}
Heater-cathode circuit resistance	R_{kf}	= max.		20	kΩ

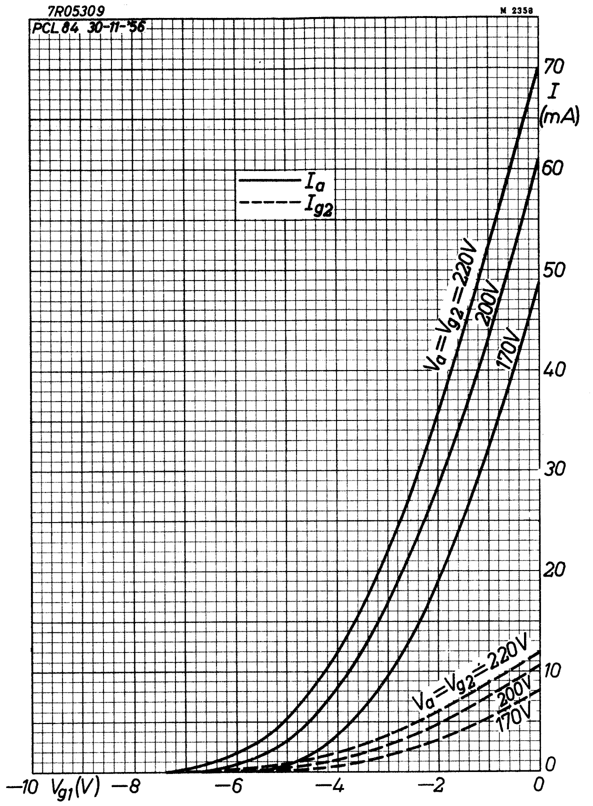


Fig.12. Anode current I_a of the pentode section of the PCL 84 as a function of the control-grid voltage V_{g1} with the anode and screen-grid voltage V_a and V_{g2} respectively, as parameter.

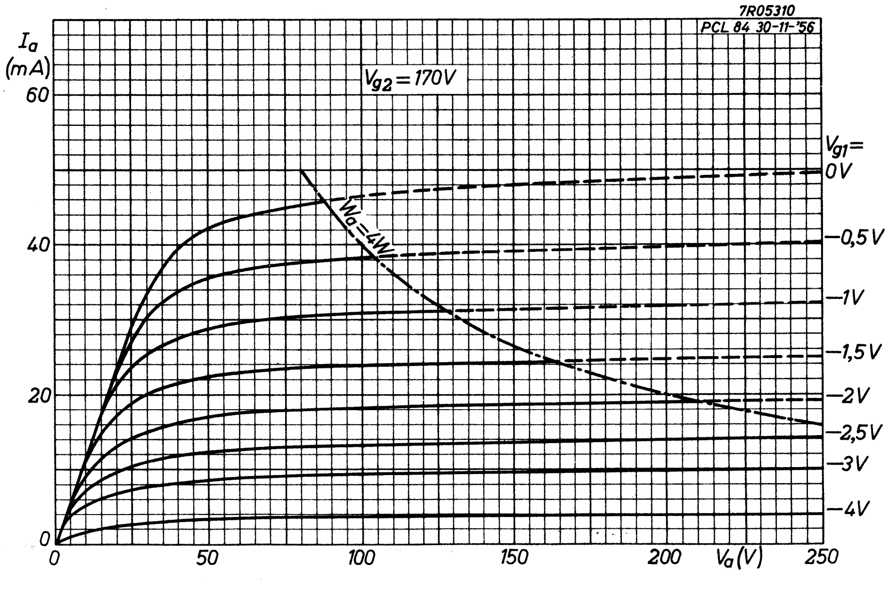


Fig.13. Anode current I_a of the pentode section of the PCL 84 as a function of the anode voltage V_a with the control-grid voltage V_{g1} as parameter. Screen-grid voltage V_{g2} = 170 V.

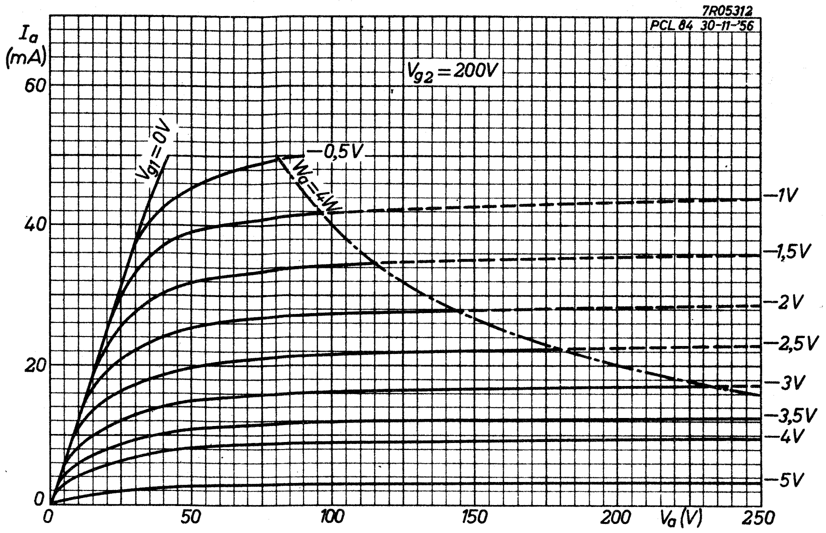


Fig.14. Anode current I_a of the pentode section of the PCL 84 as a function of the anode voltage V_a with the control-grid voltage V_{g1} as parameter. Screen-grid voltage V_{g2} = 200 V.

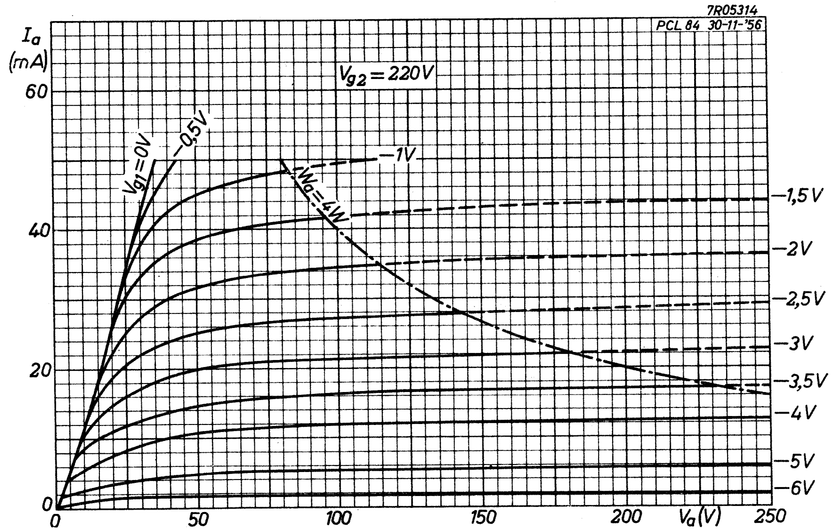


Fig.15. Anode current I_a of the pentode section of the PCL 84 as a function of the anode voltage V_a with the control-grid voltage V_{g1} as parameter. Screen-grid voltage V_{g2} = 220 V.

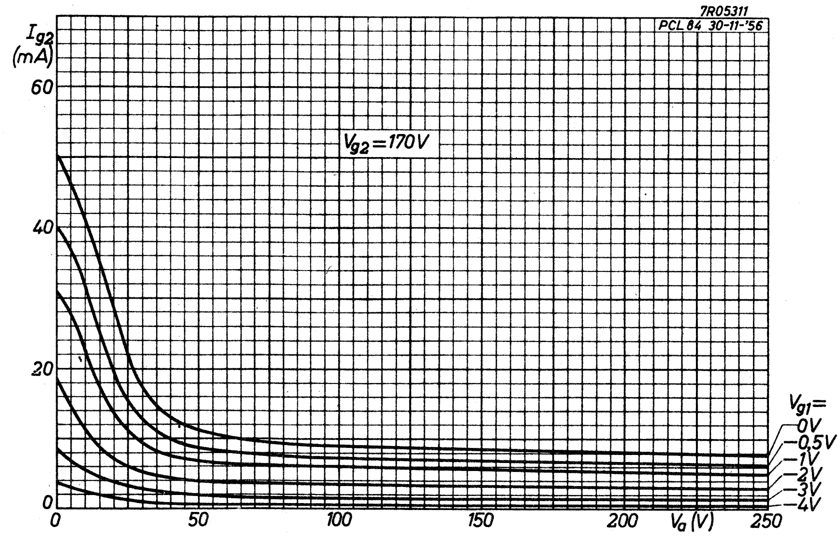


Fig.16. Screen-grid current I_{g2} of the pentode section of the PCL 84 as a function of the anode voltage V_a with the control-grid voltage V_{g1} as parameter. Screen-grid voltage V_{g2} = 170 V.

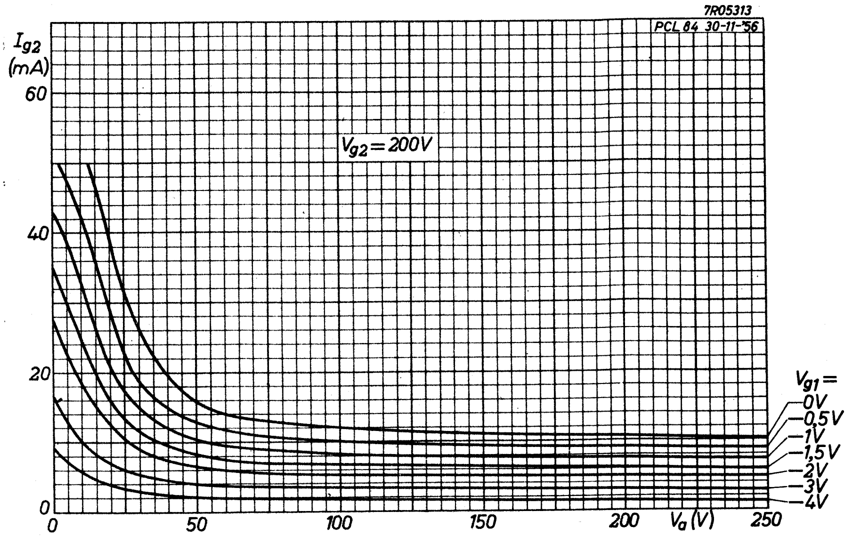
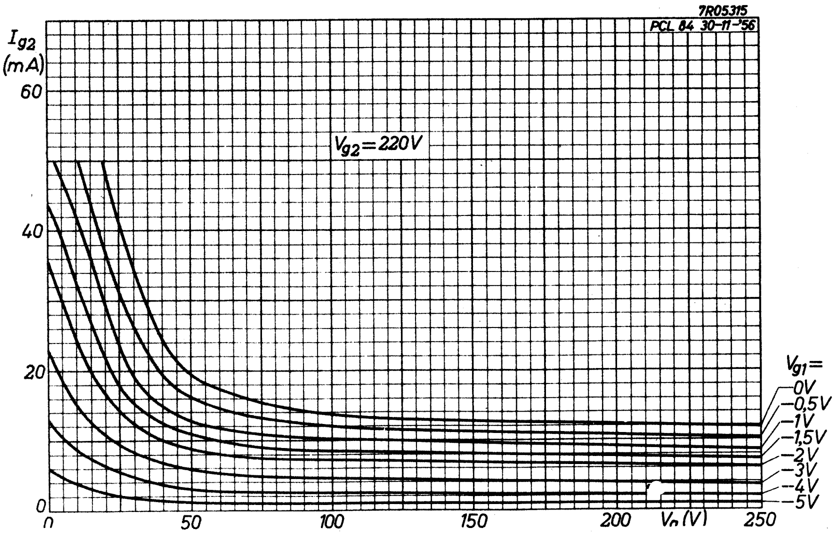


Fig.17. Screen-grid current I_{g2} of the pentode section of the PCL 84 as a function of the anode voltage V_a with the control-grid voltage V_{g1} as parameter. Screen-grid voltage V_{g2} = 200 V.

Fig.18. Screen-grid current I_{g2} of the pentode section of the PCL 84 as a function of the anode voltage V_a with the control-grid voltage V_{g1} as parameter. Screen-grid voltage V_{g2} = 220 V.



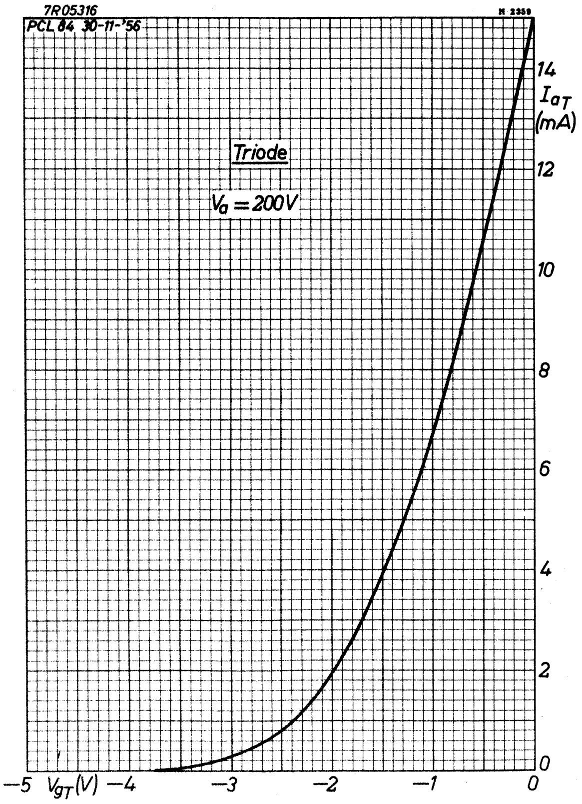


Fig.19. Anode current I_a of the triode section of the PCL 84 as a function of the control-grid voltage V_{g1} with the anode voltage V_a = 200 V.

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