PHILIPS ELECTRON TUBES AND SEMI CONDUCTORS

Information Release

PHILIPS ELECTRON TUBE DIVISION

Eindhoven, March 1958

Dear Sirs,

We are pleased to send you herewith a new documentation dealing with our low-voltage instrument cathode-ray tubes DG 7-31 and DG 7-32.

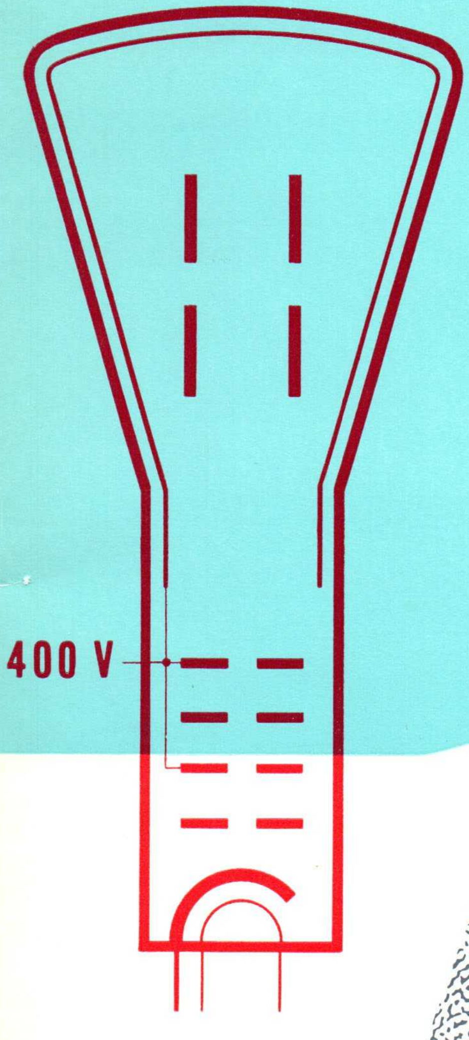
This new brochure contains, apart from technical data on the above tubes, full circuit descriptions for two inexpensive general-purpose oscilloscopes. Therefore, the contents will be of interest not only to setmakers, but also to other circles, such as radio and T.V. service shops, technical schools and possibly amateurs. In view of this, we suggest to have this documentation distributed on a wide scale in the said circles.

We trust that this publication will stimulate the interest in these cathode-ray tubes, and remain,

Yours faithfully,

p/p N.V. PHILIPS' GLOEILAMPENFABRIEKEN p/o

J.N. Schot H.M. Hofstede



PHILIPS

LOW-VOLTAGE CATHODE-RAY TUBES

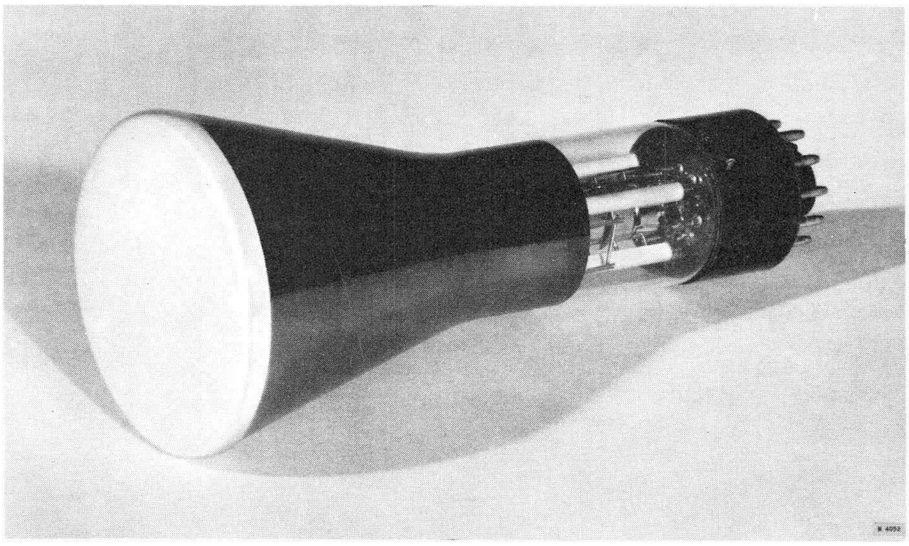
DG 7-31
DG 7-32

PHILIPS ELECTRON TUBE DIVISION

LOW-VOLTAGE CATHODE-RAY TUBES

DG 7-31 AND DG 7-32

PREFACE



In modern science and technology the oscilloscope has become a vital tool. Consequent on the rapid development in various branches of research and industry, improved and specialized oscilloscopes are in growing request, and therefore a range of modern oscilloscope cathode-ray tubes has been developed.

Apart from oscilloscopes used in modern measuring equipment, light-weight oscilloscopes for use in control and maintenance apparatus are meeting with ever growing interest. One of the large fields of application is radio and television servicing, where small portable instruments are needed to enable the service-man to test and repair radio and TV sets "on the spot".

The construction of a type of oscilloscope that is considerably smaller and lighter than conventional types, however, can only be arrived at by reducing the necessary high anode voltage for the cathode-ray tube, since this also implies reduction of the dimensions of the power supply.

In conformity with the above we developed two oscilloscope cathode-ray tubes operating at an anode voltage of only 400 V, which makes for a high deflection sensitivity, so that the signals to be examined need less amplification, and thus a simpler amplifier circuitry suffices. In addition, these tubes are so constructed that no specific low-voltage phenomena as "burn-in" or "sticking-picture" need be feared. These tubes are the DG 7-31 and DG 7-32 which only differ in so far that the former has asymmetric and the latter symmetric deflection.

The excellent properties of the tube types DG 7-31 and DG 7-32 are, amongst others, due to high precision in assembling the electron gun, as well as special methods of composing and applying the phosphor screen, which eliminate the burn-in effect. To make the screen conductive, a very thin, contrast improving tin-oxide layer is provided on the inner side of the glass front plate of the tube envelope, and in this way two great advantages are attained:

(1) The screen can be touched without change in potential (no electrostatic "body-effect");
(2) The screen shows no "sticking-picture" effects.

The electron gun used in the two types of tube is so designed that a high deflection sensitivity is ensured, whilst the focusing and brightness controls can be adjusted independently.

An additional advantage is that, as a consequence of the low anode voltage, the cathode can be earthed and hence no separate filament winding on the power transformer is needed.

For the convenience of our customers some basic circuits have been designed for the DG 7-31 and DG 7-32, and the present documentation contains two thoroughly tested circuit examples which will undoubtedly be of great help to equipment designers.

TECHNICAL DATA OF THE CATHODE-RAY TUBES DG 7-31 AND DG 7-32 [1]

ELECTRICAL

Screen

Fluorescence:green
Persistence: medium

Heating indirect by a.c. or d.c.;
series or parallel supply

Heater voltage	V_f =	6.3 V
Heater current	I_f =	0.3 A

Focusing electrostatic

Deflection double electrostatic — D_1D_1' symmetric; D_2D_2' symmetric [1]

Line width at $V_{(g_2+g_4)}$ = 500 V, I_1 = 0.5 μA = 0.5 mm [2]

Interelectrode capacitances

electrodes	symbol	value (pF) DG 7-31	value (pF) DG 7-32
D_1 to D_1'	$C_{D1D1'}$	1.1	1.0
D_2 to D_2'	$C_{D2D2'}$	1.8	1.7
D_1 to all	C_{D1}	2.5 [3]	2.5 [3]
D_1' to all	$C_{D1'}$	2.5 [3]	2.5 [3]
D_2 to all	C_{D2}	3.4 [3]	3.7 [3]
D_2' to all	$C_{D2'}$	3.0 [3]	3.0 [3]
Grid No.1 to all	C_{g1}	7.6	7.6
Cathode to all	C_k	3.2	3.2

Operating characteristics

Grid No.2 and grid No.4 voltage	$V_{(g2+g4)}$	=	500 V
Grid No.3 voltage	V_{g3}	=	0-120 V [4]
Negative grid No.1 voltage for visual extinction of the focused spot	$-V_{g1}$	=	50-100 V
Deflection sensitivity	D_1D_1'	=	0.35-0.43 mm/V
Deflection sensitivity	D_2D_2'	=	0.24-0.30 mm/V

[1]) Type DG 7-31 is identical to the DG 7-32, but has asymmetric deflection for the D_2D_2' plates. With the DG 7-31, D_2 has to be connected to $(g_2 + g_4)$.

[2]) Measured on a circle of 50 mm diameter.

[3]) Except the opposite deflection plate.

[4]) For calculation of the grid 3 potentiometer a grid 3 current of min. -15 μA and max. +10 μA must be taken into account.

Limiting values (design centre values)

			max.	800 V
Grid No.2 and grid No.4 voltage	$V_{(g2+g4)}$	=	min.	400 V
Grid No.3 voltage	V_{g3}	=	max.	200 V [1]
Grid No.1 voltage (negative value)	$-V_{g1}$	=	max.	160 V
Grid No.1 voltage (positive value)	$+V_{g1}$	=	max	0 V
Peak voltage on D_1D_1'	$V_{D1D1'p}$	=	max	450 V
Peak voltage on D_2D_2'	$V_{D2D2'p}$	=	max.	750 V
Voltage between cathode and heater	V_{kf}	=	max.	125 V
Screen dissipation	W_1	=	max.	3 mW/cm^2
Grid No.2 and grid No.4 dissipation	$W_{(g2+g4)}$	=	max.	0.5 W

Maximum circuit values

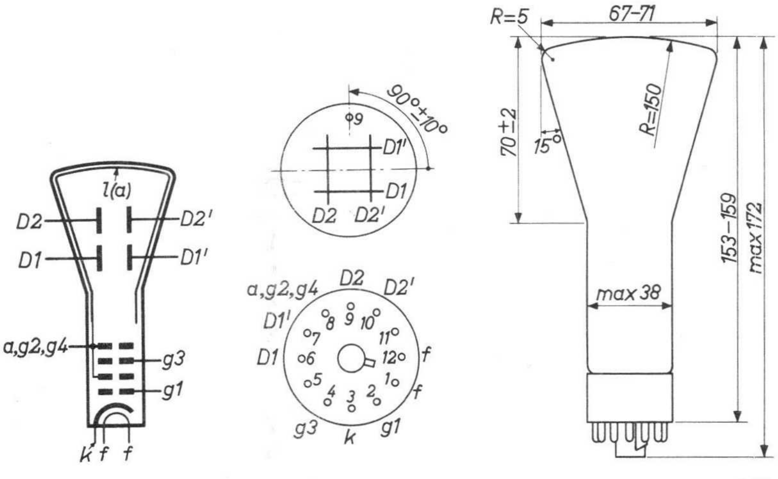
Deflection plate circuit resistance	R_D	=	max.	5 MΩ
Grid No.1 circuit resistance	R_{g1}	=	max.	0.5 MΩ

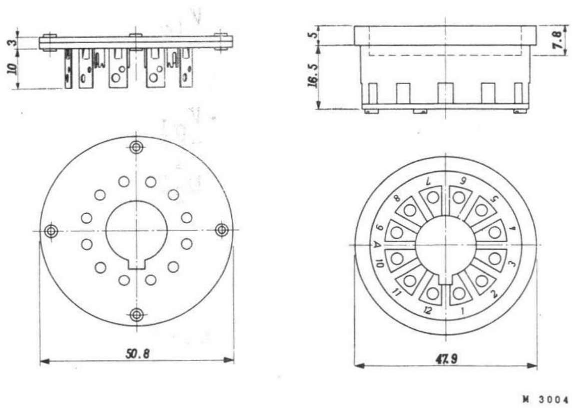
MECHANICAL

Mounting position: any

Net weight: 120 g (4.2 ounce)

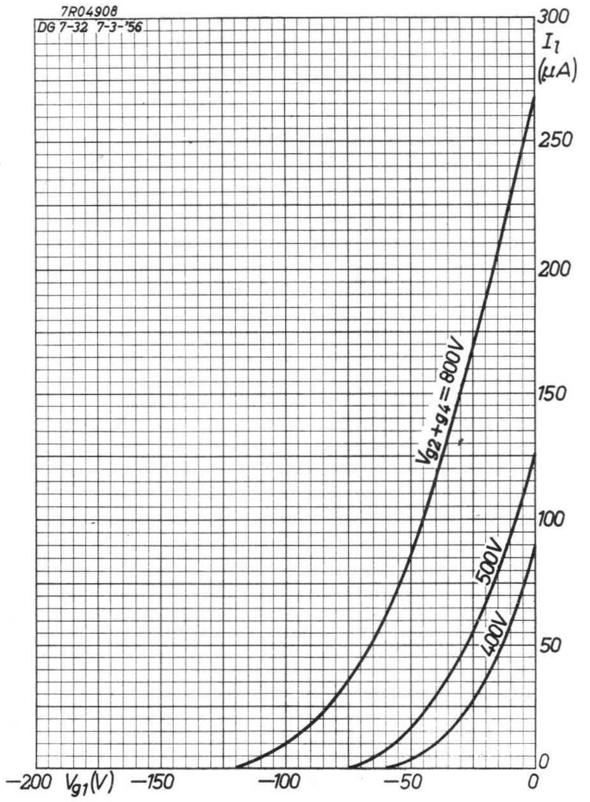
Max. dimensions (in mm) and base connections:



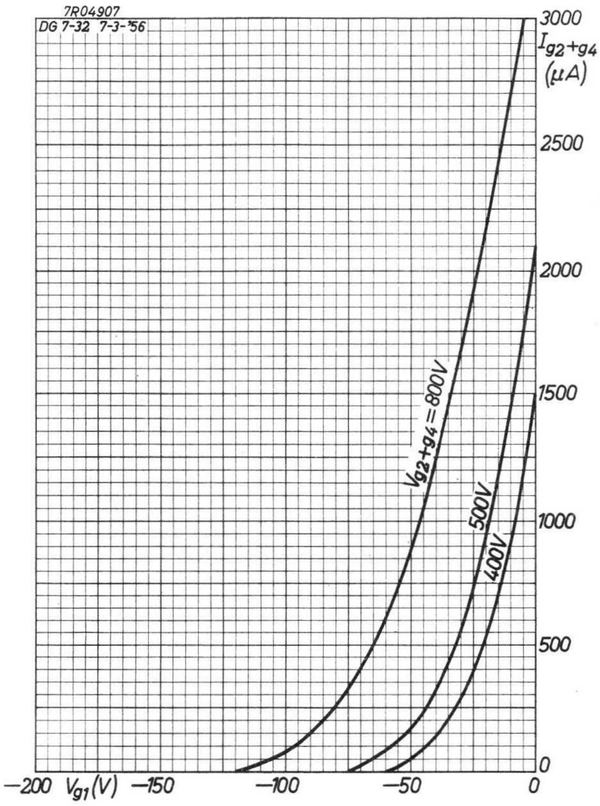


Base: duodecal 12-pins

[1]) For calculation of the grid 3 potentiometer a grid 3 current of min. -15 μA and max. +10 μA must be taken into account.



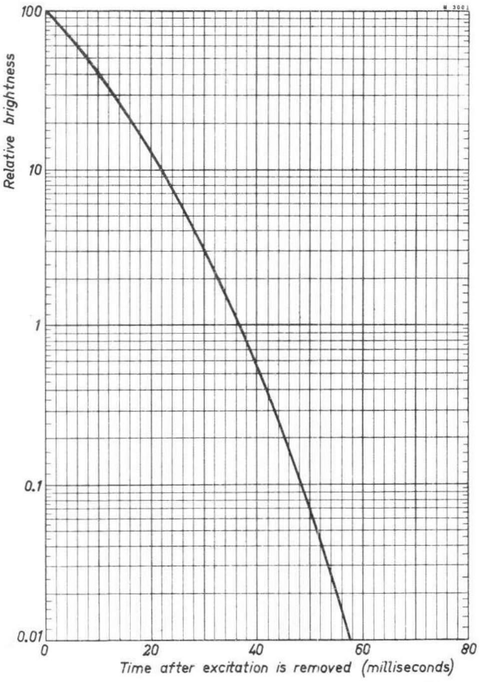
Screen current plotted against negative grid No.1 voltage.



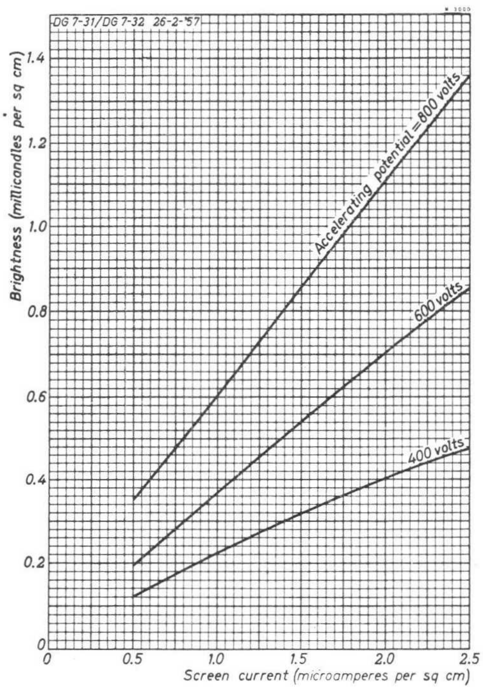
Final anode current plotted against grid cut-off voltage.

G-screen

The green fluorescent G-screen provides high visual contrast under conditions of normal ambient illumination. It has medium persistence and can be used for visual observation of recurrent phenomena in the majority of applications.

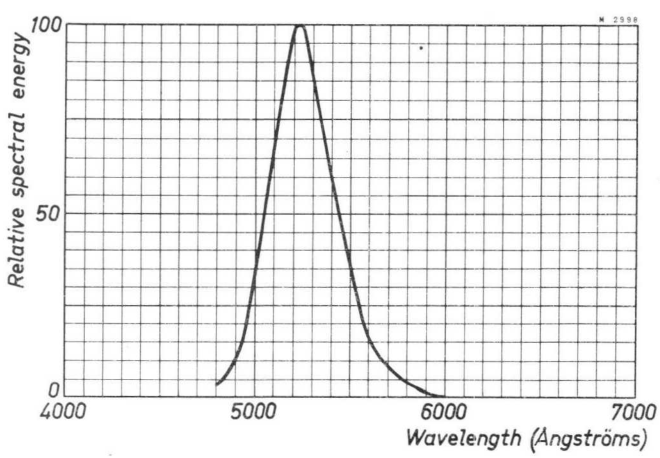


Persistence characteristic of a G-screen.

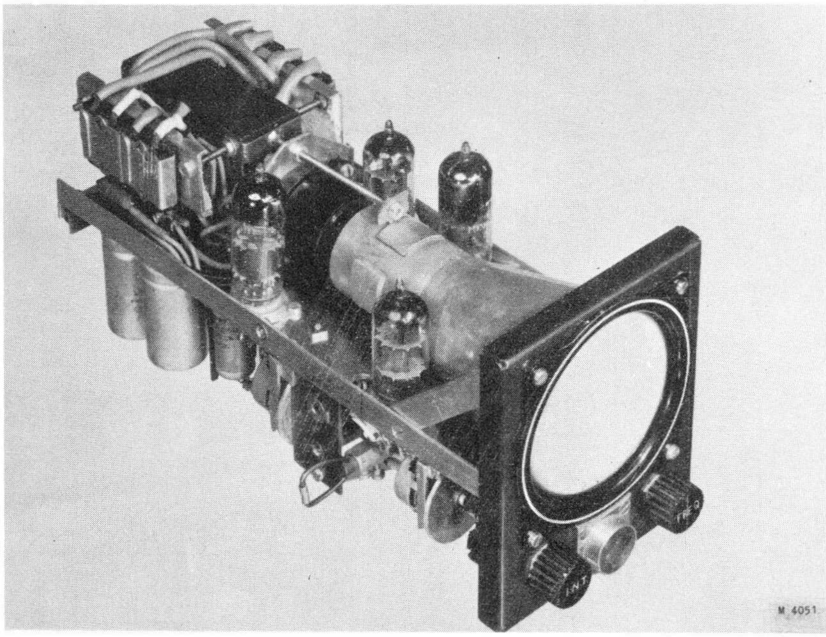


Brightness of a G-screen as a function of the screen current per square cm screen area, with the accelerating potential as a parameter.

Relative spectral energy distribution of a G-screen.



A MINIATURE OSCILLOSCOPE FOR TV SERVICE



INTRODUCTION

The miniature service oscilloscope has been especially designed for the service-man, who on a home service call must be able to repair a television set with a minumum of measuring instruments.

The weight of the apparatus described in this Bulletin has been minimized, the current consumption is kept low with a view to the heat dissipation, and its size is thus that it can easily be carried in a tool-bag.

The essential element of the unit is the Philips Cathode-Ray Tube DG 7-32, which, with an anode voltage of (minimum) 400 V, has a sensitivity of 0.49 mm/V at the vertical plates, and 0.31 mm/V at the horizontal plates. This means that for full deflection 2 x 10 V/cm has to be applied to the vertical deflection plates, 2 x 16 V/cm to the horizontal (time-base) plates. The DG 7-32 has a transparent, contrast-improving and conductive tin-oxide layer between the face and the phosphor; this layer is connected to the final anode, which gives full protection against electrostatic body-effect even at a high operation potential. As a consequence, the heater can be earthed, so that a small supply transformer can be used, no separate heater voltage winding being required.

DESCRIPTION OF THE CIRCUIT

THE VERTICAL AMPLIFIER

The first tube in the amplifier for vertical deflection, the EC 92, is operated as a cathode-follower; it can be incorporated in a measuring head, or built into the oscilloscope.

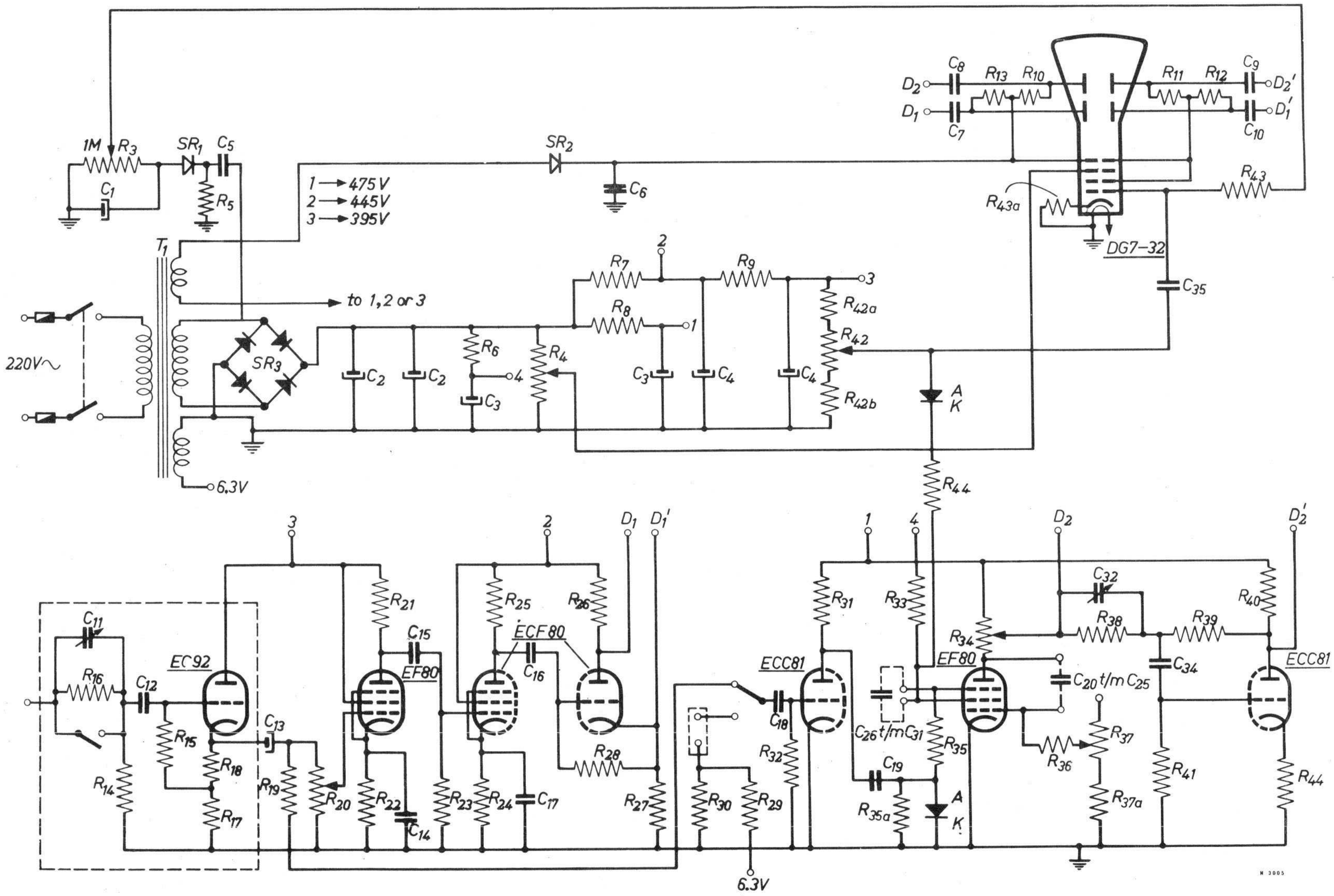


Fig.1.
Circuit diagram with Miller integrator transitron circuit and the EC 92 inserted in the measuring head.

RESISTORS

R_1	=	82 kΩ, ½ W
R_2	=	56 kΩ, ¼ W
R_3	=	1 MΩ, pot.meter
R_4	=	1 MΩ, pot.meter
R_5	=	220 kΩ, ½ W
R_6	=	2,2 kΩ, ½ W
R_7	=	3.3 kΩ, 1 W
R_8	=	2.2 kΩ, ½ W
R_9	=	8.2 kΩ, 1 W
R_{10}	=	4.7 MΩ, ¼ W
R_{11}	=	4.7 MΩ, ¼ W
R_{12}	=	4.7 MΩ, ¼ W
R_{13}	=	4.7 MΩ, ¼ W
R_{14}	=	1.2 MΩ, ¼ W
R_{15}	=	1 MΩ, ¼ W
R_{16}	=	10 MΩ, ¼ W
R_{17}	=	8.2 kΩ, ½ W
R_{18}	=	330 Ω, ¼ W
R_{19}	=	10 kΩ, ¼ W
R_{20}	=	10 kΩ
R_{21}	=	5.6 kΩ, ½ W
R_{22}	=	220 Ω, ¼ W
R_{23}	=	1 MΩ, ¼ W
R_{24}	=	220 Ω, ¼ W
R_{25}	=	5.3 kΩ, ½ W
R_{26}	=	10 kΩ, ½ W
R_{27}	=	10 kΩ, ½ W
R_{28}	=	10 MΩ, ¼ W
R_{29}	=	270 Ω, ¼ W
R_{30}	=	340 Ω, ¼ W (2x680 Ω par.)
R_{31}	=	82 kΩ, ¼ W
R_{32}	=	1 MΩ, ¼ W
R_{33}	=	27 kΩ, ½ W
R_{34}	=	33 kΩ, pot.meter (50 kΩ en 100 kΩ par.)
R_{35}	=	100 kΩ, ¼ W
R_{35a}	=	10 kΩ, ¼ W
R_{36}	=	560 kΩ, ¼ W
R_{37}	=	2 MΩ, pot.meter
R_{37a}	=	2.2 MΩ, ¼ W
R_{38}	=	1 MΩ, ¼ W
R_{39}	=	1.2 MΩ, ¼ W
R_{40}	=	100 kΩ, ¼ W
R_{41}	=	10 MΩ, ¼ W
R_{42}	=	100 kΩ, pot.meter
R_{42a}	=	33 kΩ, ¼ W
R_{42b}	=	33 kΩ, ¼ W
R_{43}	=	2.2 MΩ, ¼ W
R_{43a}	=	100 kΩ, ¼ W
R_{44}	=	1.5 kΩ, ¼ W

CAPACITORS

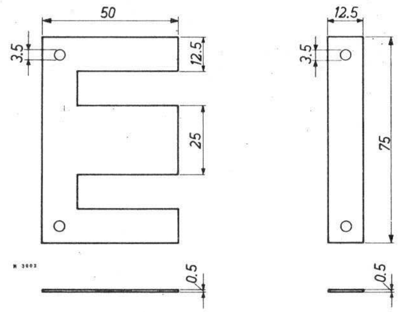
C_1	=	5 µF,	100 V
C_2	=	25+25 µF,	350/400 V
C_3	=	25+25 µF,	350/400 V
C_4	=	25+25 µF,	350/400 V
C_5	=	0.1 µF,	500 V
C_6	=	0.1 µF,	500 V
C_7	=	0.1 µF,	500 V
C_8	=	0.1 µF,	500 V
C_9	=	0.1 µF,	500 V
C_{10}	=	0.1 µF,	500 V
C_{11}	=	2 µF,	trimmer
C_{12}	=	0.1 µF,	500 V
C_{13}	=	25 µF,	50 V
C_{14}	=	220 pF,	350 V
C_{15}	=	0.1 µF,	500 V
C_{16}	=	47 000 pF,	500 V
C_{17}	=	220 pF,	350 V
C_{18}	=	10 000 pF,	350 V
C_{19}	=	10 000 pF,	350 V
C_{20}	=	47 000 pF,	500 V
C_{21}	=	15 000 pF,	500 V
C_{22}	=	4700 pF	500 V
C_{23}	=	1500 pF,	500 V
C_{24}	=	470 pF,	500 V
C_{25}	=	150 pF,	500 V
C_{26}	=	15 000 pF,	500 V
C_{27}	=	4700 pF,	500 V
C_{28}	=	1500 pF,	500 V
C_{29}	=	470 pF,	500 V
C_{30}	=	150 pF,	500 V
C_{31}	=	47 pF,	500 V
C_{32}	=	5 pF,	trimmer
C_{34}	=	47 000 pF,	500 V
C_{35}	=	0.1 µF,	500 V

TRANSFORMER DATA

Primary (S_1): 1430 turns of 0.25 mm enamelled copper wire,
Secondary (S_2): 1000 turns of 0.1 mm enamelled copper wire,
Tertiary (S_3): 1380 turns of 0.16 mm enamelled copper wire,
Quartery (S_4): 2x44 turns of 0.7 mm enamelled copper wire (bifilarly wound)!

Order of windings S_4-S_1-S_3-S_2, (the thickest wire is wound on the core).
Insulation between the layers: Sheets of paper with a thickness of 0.01 mm.
(With S_2 two sheets of 0.01 mm paper.)
Insulation between the windings 3 paper sheets of 0.03 mm.

DIMENSIONAL DRAWING OF THE CORE



Stacking height of core: 26 mm
Material: **silicon iron** sheet 2.6 (annealed)
No-load current: approx 27 mA

TUBES

DG 7-32
1xECC85
1xEC92
1xECF80
2xEF80
2xSelenium rectifier SR250Y50
1xSelenium rectifier SR250B90
2xGermanium diode OA85

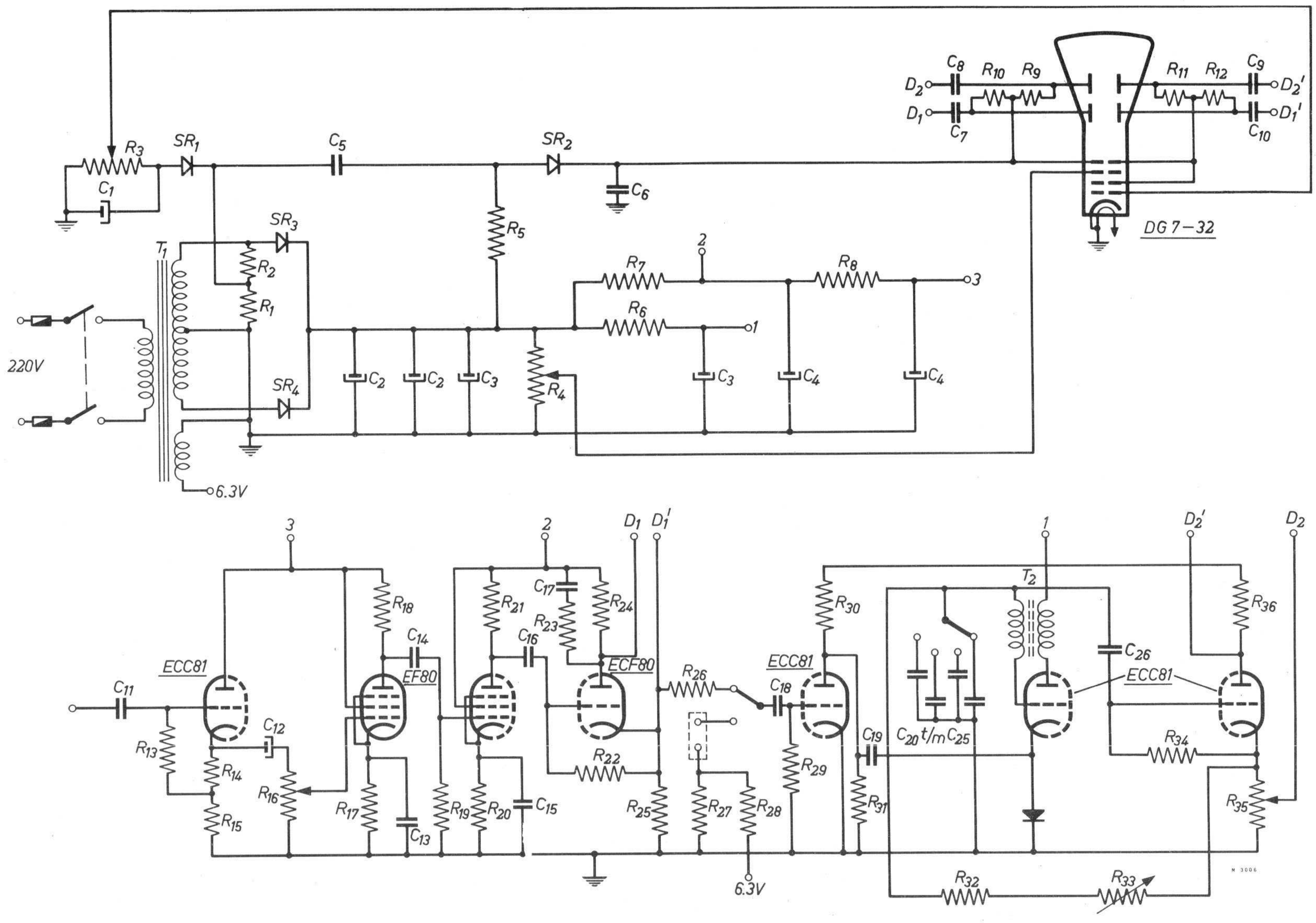


Fig. 2.
Circuit diagram in which the signal of the synchronisation amplifier is fed to a blocking oscillator.

RESISTORS

R_1 =	82 kΩ,	½ W
R_2 =	56 kΩ,	¼ W
R_3 =	200 kΩ,	48 901 30GL
R_4 =	1 MΩ,	48 901 30DL
R_5 =	560 kΩ,	¼ W
R_6 =	2.2 kΩ,	¼ W
R_7 =	3.3 kΩ,	1 W
R_8 =	8.2 kΩ,	1 W
R_9 =	1 MΩ,	¼ W
R_{10} =	1 MΩ,	¼ W
R_{11} =	1 MΩ,	¼ W
R_{12} =	1 MΩ,	¼ W
R_{13} =	1 MΩ,	¼ W
R_{14} =	330 Ω	¼ W
R_{15} =	10 kΩ,	¼ W
R_{16} =	10 kΩ,	48 901 30DL
R_{17} =	220 Ω,	¼ W
R_{18} =	5.6 kΩ,	½ W
R_{19} =	1 MΩ,	¼ W
R_{20} =	220 Ω,	¼ W
R_{21} =	5.6 kΩ,	½ W
R_{22} =	2 MΩ,	¼ W
R_{23} =	12 kΩ,	¼ W
R_{24} =	10 kΩ,	½ W
R_{25} =	10 kΩ,	½ W
R_{26} =	12 kΩ,	¼ W
R_{27} =	2x680 Ω ,	¼ W
R_{28} =	270 Ω ,	¼ W
R_{29} =	1 MΩ,	¼ W
R_{30} =	82 kΩ,	¼ W
R_{31} =	33 kΩ,	¼ W
R_{32} =	470 kΩ,	¼ W
R_{33} =	2 MΩ,	48 901 30DL
R_{34} =	10 MΩ,	¼ W
R_{35} =	50 kΩ,	48 901 30DL
R_{36} =	50 kΩ,	¼ W

CAPACITORS

C_1 =	5 μF	500 V
C_2 =	12½+12½ μF,	350/400 V
C_3 =	25+25 μF,	350/400 V
C_4 =	25+25 μF,	350/400 V
C_5 =	0.1 μF,	500 V
C_6 =	0.1 μF,	500 V
C_7 =	0.1 μF,	500 V
C_8 =	0.1 μF,	500 V
C_9 =	0.1 μF,	500 V
C_{10} =	0.1 μF,	500 V
C_{11} =	0.1 μF,	500 V
C_{12} =	25 μF,	50 V
C_{13} =	220 pF,	350 V
C_{14} =	0.1 μF,	500 V
C_{15} =	220 pF,	350 V
C_{16} =	47000 pF,	500 V
C_{17} =	15 pF,	350 V
C_{18} =	1800 pF,	350 V
C_{19} =	1800 pF,	350 V
C_{20} =	47000 pF,	500 V
C_{21} =	15000 pF,	500 V
C_{22} =	4700 pF,	500 V
C_{23} =	1800 pF,	500 V
C_{24} =	455 pF,	500 V
C_{25} =	150 pF,	500 V
C_{26} =	47000 pF,	500 V

TUBES

DG 7-32

2xECC85

1xECF80

1xEF80

4x selenium rectifier SR250Y50 (SR1-4)

1x germanium diode OA85

TRANSFORMER DATA

Primary (S_1): 1430 turns of 0.25 mm enamelled copper wire,

Secondary (S_2): 1000 turns of 0.1 mm enamelled copper wire,

Tertiary (S_3): 1380 turns of 0.16 mm enamelled copper wire,

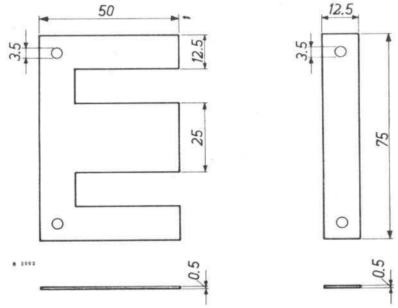
Quartery (S_4): 2x44 turns of 0.7 mm enamelled copper wire (bifilarly wound)

Order of windings S_4-S_1-S_3-S_2, (the thickest wire is wound on the core).

Insulation between the layers: Sheets of paper with a thickness of 0.01 mm. (With S_2 two sheets of 0.01 mm paper.)

Insulation between the windings 3 paper sheets of 0.03 mm.

DIMENSIONAL DRAWING OF THE CORE



Stacking height of core: 26 mm

Material: silicon iron sheet 2.6 (annealed)

No-load current: approx. 27 mA

Data of blocking transformer

Number of turns

Primary S_1: 50 turns of 0.1 mm enamelled copper wire,

Secondary S_2: 50 turns of 0.1 mm enamelled copper wire.

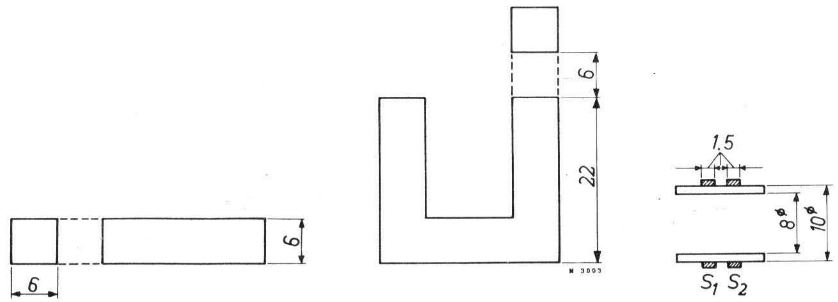


Fig.1 shows the EC 92 inserted in the measuring head. The latter has the advantage of a very low input capacitance, viz. 5 pF with attenuator and 20 pF without. The cylindrical measuring head has a diameter of 25 mm and a length of 140 mm, and weighs 165 g.

The signal from the cathode-follower is taken via a 10 kΩ potentiometer with a 25 μF d.c. blocking capacitor, to prevent the oscillogram from "dancing" when the potentiometer is operated.

The input stage is followed by two amplifier stages. The first amplifier stage is equipped with an EF 80, whilst the second amplifier stage uses the pentode section of the ECF 80. The triode section of the ECF 80 feeds the signal symmetrically to the corresponding plates of the DG 7-32.

In the circuit of Fig.2 the cathode-follower is incorporated in the oscilloscope. In this case the EC 92 and EF 80 can be replaced by one ECF 80, so that the number of tubes of the vertical amplifier is limited to two tubes ECF 80. The measuring head then only contains an attenuator of 1:10, which can be operated by a switch, the input capacitance being 12 pF with attenuator and 50 pF without. The sensitivity of the oscilloscope is 120 mV peak to peak/cm and the bandwidth 1 c/s to 3 Mc/s (measured on the -3 dB points), immaterial which of the two amplifiers is used.

THE TIME BASE

Synchronisation can be established in three ways:
(*a*) internally,
(*b*) externally,
(*c*) with 6.3 V, 50 c/s.

The time base is preceded by a synchronisation amplifier tube, which amongst others has the advantage that distortion of the vertical signal is avoided. Two prototypes of oscilloscope have been developed; in one type the signal of the synchronisation amplifier is fed to a Miller integrator transitron circuit (Fig.1) whereas in the other this signal is passed to a blocking oscillator (Fig.2).

The Miller integrator transitron circuit, which can easily be synchronised, obtains the synchronisation directly from the cathode-follower at the input of the vertical amplifier. Hence the amplitude of the synchronising signal remains constant when the vertical amplifier potentiometer is operated.

This circuit has the following specific features:
- Highly linear saw-tooth.
- Constant amplitude of the saw-tooth for all the frequency ranges.

A drawback is that
- for varying the frequency in steps, two capacitors must be switched over, which necessitates the use of four switch contacts. For this purpose a double-deck wavelength switch with 24 contacts is used, ensuring frequency control in six steps.

At a supply of 250 V the EF 80 delivers a saw-tooth voltage of approximately 130 V, whilst the 130 V saw-tooth voltage for the other deflection plate is supplied by a phase invertor tube.

The specific property of a blocking oscillator is:
- Switching of the frequency can brought about by means of a simpler switch.

Disadvantages:

- The signal at the input of the vertical amplifier often being too weak, the output signal must be used for synchronisation. When changing the vertical amplitude, the amplitude of the synchronising signal is therefore also changed, which may necessitate readjustment of the frequency.
- A very short fly-back which may easily give rise to radiation.
- Variation of the amplitude when the frequency is switched.
- Non-linear saw-tooth which makes the use of a "bootstrap" circuit necessary. If this bootstrap circuit is also operated as a phase invertor, one triode can be dispensed with, which has been done in the experimental type.

Synchronisation may be achieved by means of a diode, in this case the germanium diode OA 85, which is included in the cathode circuit of the blocking oscillator. The resistance in the cathode circuit need be low only during fly-back (about 100 ohms), whereas during the sweep the resistance is about 1 MΩ. Thus the preceding circuit is loaded during fly-back only.

THE SUPPLY

To ensure minimum weight and dimensions of the mains transformer, its design has been kept as simple as possible, i.e. the number of windings and tappings is reduced to a minimum. In order to avoid hum being displayed by the Cathode-Ray Tube, the transformer is positioned on the longitudinal axis of the tube, with the laminations and coil parallel to this axis. Two-phase rectification is applied to reduce the number of electrolytic capacitors required. The high tension supply for the Cathode-Ray Tube is, as can be seen in Fig.1, obtained by an extra voltage in series to that for the tube supply, if necessary this voltage can be stepped up to about 550 V.

TECHNICAL DATA:	transitron circuit	blocking circuit
Input resistance	10 MΩ	10 MΩ with attenuator
	1 MΩ	1 MΩ without attenuator
Input capacitance	5 pF	12 pF with attenuator
	20 pF	50 pF without attenuator
Max. input voltage	300 V peak-to-peak	
Sensitivity	110 mV per cm deflection	
Frequency response	3 db down at 1 c/s and 3 Mc/s (see Fig.3)	
Frequency range time base	20 to 16 000 c/s in six steps	
Power drain	26 W	
Dimensions	100 x 120 x 270 mm	
Weight	2600 g.	

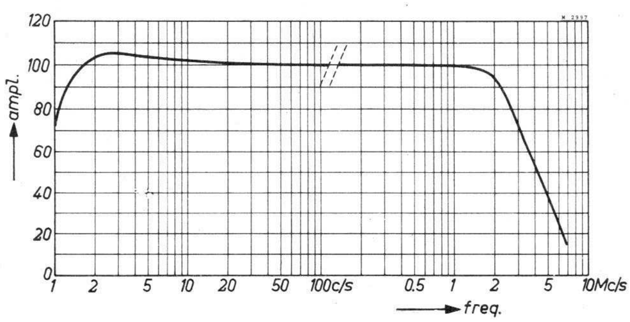


Fig.3. Frequency response curve.

A VERSATILE OSCILLOSCOPE

INTRODUCTION

A modern cathode-ray oscilloscope comprises a number of units, the more important of which are shown in the block diagram of Fig.1. Here, switch S connects the plates for horizontal deflection either to the timebase generator or to the amplifier for horizontal deflection.

In such an arrangement, however, certain tubes, i.e. either those of the horizontal amplifier or those of the timebase generator, although switched to the supply unit, do not perform any useful function. Not only is this uneconomical of power but the provision of separate units as horizontal amplifier and timebase generator results in an expensive construction.

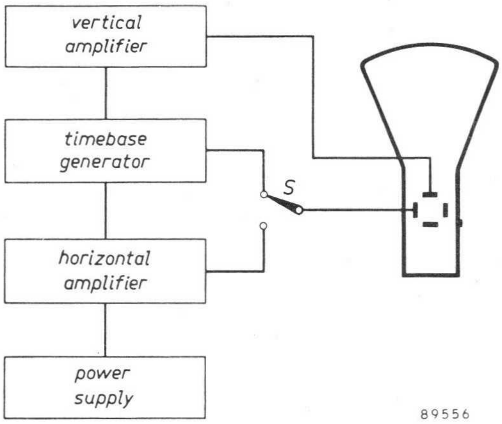


Fig.1. Block diagram of an oscilloscope. By means of switch S either a timebase generator or an amplifier for horizontal deflection is connected to the corresponding deflection plates of the cathode-ray tube.

Moreover, when switch S is in the lower position and the horizontal amplifier is in operation, the oscillator of the timebase generator is not inoperative but continues to operate, thus introducing the risk of interference with the horizontal amplifier.

Below a more economical arrangement is described which is particularly advantageous when incorporated in the design of small oscilloscopes. In this arrangement the horizontal amplifier itself can be converted into a timebase generator by a simple switching operation.

By using double triodes throughout and employing selenium rectifiers instead of thermionic rectifiers, the number of tubes, except the cathode-ray tube, has been limited to four. Nevertheless, the overall sensitivity is high, and push-pull output provides symmetrical deflection voltages for both pairs of plates.

THE OSCILLATOR

In order that the switching arrangements when changing-over from amplifier to timebase generator shall be as simple as possible, a single-tube oscillator should be adopted. Two types suggest themselves: the transitron oscillator and the blocking oscillator.

THE TRANSITRON OSCILLATOR

If combined with the Miller integrator, this oscillator has very good linearity, the error being in the order of only 0.25 %. It has, however, two drawbacks for the application under consideration, namely that it requires a pentode, and that for step control of the frequency it is necessary to switch two elements, namely the discharge capacitor in the control-grid circuit and the coupling capacitor between the grids g_2 and g_3.

THE BLOCKING OSCILLATOR

The above drawbacks do not apply to the blocking oscillator, in which, for step control of the frequency, only one element, namely the charging capacitor in the grid circuit has to be changed. It has, however, the disadvantage that, when operated at normal supply voltages, the linearity error is much greater, amounting to between 5 and 15 % (see section "Linearity of the Timebase Voltage").

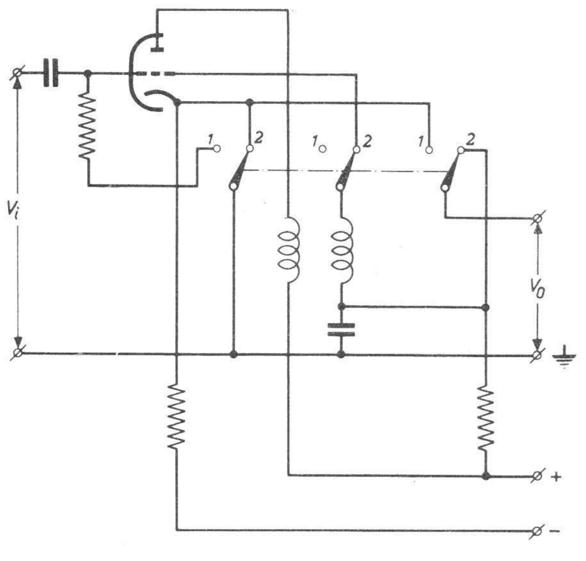


Fig.2. Circuit of a cathode follower that can be switched for operation as a blocking oscillator by changing the switches from position 1 to position 2.

Fig.2 shows how easily an amplifying tube, in this case a cathode follower, can be switched for operation as a blocking oscillator. The grid circuit of the tube is tuned to a frequency of 5 to 10 Mc/s, so that the very small inductance of the feed-back coil in the anode circuit cannot adversely affect the operation of the tube as a cathode follower. The coil may therefore remain permanently in the anode circuit, and need not be short-circuited when the unit is connected as a cathode follower.

SYNCHRONISING THE BLOCKING OSCILLATOR

In principle, a triode blocking oscillator can be synchronised by applying either a positive pulse to the grid or a negative pulse to the anode, the latter ultimately reaching the grid as a positive pulse via the feedback transformer.

Difficulties arise, however, when no pulses are available, for example if the synchronising signal is sinusoidal. Such a signal can hardly be applied to the grid without impairing the operation of the oscillator, and synchronisation via the anode is very insensitive because the feedback transformer has a very poor response at the relatively low signal frequencies. There thus remains only the possibility of synchronising via the cathode circuit. This can be readily achieved by including a resistor in the cathode circuit and applying the synchronising pulses to it. This method has the disadvantage that the resistor introduces a form of feedback which reduces the transconductance of the tube circuit. It is therefore desirable to keep the resistor small, and to obtain the synchronising pulses from a source of low internal resistance.

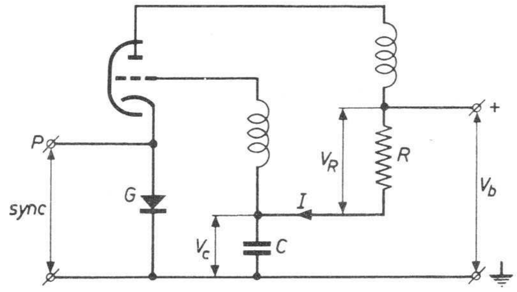


Fig.3. Blocking oscillator in which the synchronizing voltage is applied to a germanium diode G included in the cathode circuit of the oscillator tube.

In the preliminary design, therefore, the synchronising voltage was derived from the cathode of the output stage of the vertical amplifier. Apart from the fact that this is a low voltage, so that synchronisation was not very stable, there was the additional drawback that the flyback pulse appeared at the beginning of the forward sweep.

On the strength of the fact that a low value of cathode resistance is necessary only during the time when the oscillator tube is drawing anode current, and since, during the greater part of the forward sweep no anode current flows so that a high value of cathode resistance is not objectionable, it was decided to substitute a germanium diode for the cathode resistor. During the forward sweep of the sawtooth voltage the diode has an internal resistance of approximately 1 MΩ, but as soon as anode current commences to flow, this resistance decreases, and during the flyback drops to approximately 100 Ω. If the synchronising voltage is applied to point P (Fig.3) the instant at which flyback occurs can be controlled (see Fig.4), and thus the oscillator can be synchronised.

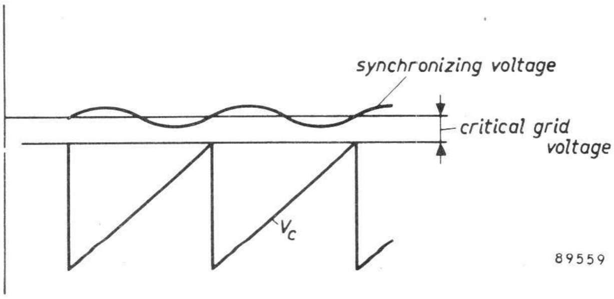


Fig.4. Oscillogram showing how synchronisation can be performed by applying the synchronising voltage to point P of the circuit of Fig.3.

In these circumstances the necessary synchronising voltage can be taken from the anode circuit of the output stage of the vertical amplifier.

LINEARITY OF THE TIMEBASE VOLTAGE

In the case of an *unloaded* blocking oscillator, as represented in Fig.3, the linearity is determined by the difference in discharge current at the beginning and at the end of one cycle, and hence the linearity error $\alpha = (I_1 - I_2)/I_1$. Since $V_r = I.R$, the expression for the linearity may be written:

$$\alpha = \frac{(V_r)_1 - (V_r)_2}{(V_r)_1} = \frac{\Delta V_c}{(V_c)_1 + V_b}, \qquad (1)$$

and since $(V_c)1 < V_b$, this formula may be simplified to:

$$\alpha = \frac{\Delta V_c}{V_b}. \qquad (2)$$

From this follows the well-known conclusion that where α is required to be small, ΔV_c, i.e. the amplitude of the sawtooth voltage, should be kept small compared with the supply voltage V_b.

The voltage ΔV_c is as a rule too large to be applied directly to the grid of the following amplifier tube and must therefore be reduced to a suitable value by means of a voltage divider, represented by $R_2 + R_3$ in Fig.5. This voltage divider constitutes a load on the blocking oscillator, and it is now necessary to examine the effect of this load on the frequency and upon the linearity.

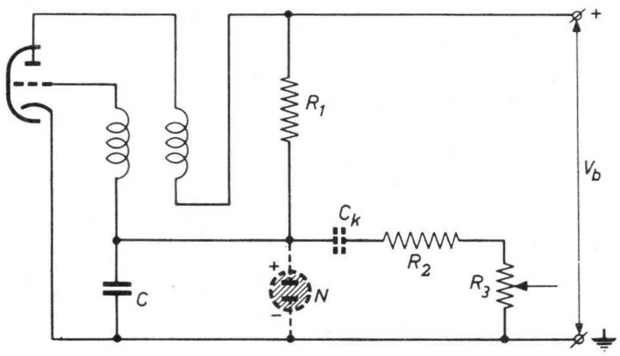


Fig.5. To reduce the output voltage of the blocking oscillator to a convenient value, the voltage divider formed by R_2, R_3 has been provided. The neon lamp N may be connected in parallel with the capacitor C to prevent the voltage across the latter from assuming excessive values in the event of the tube becoming defective. The coupling capacitor C_k may be included to prevent the supply voltage from being reduced due to the presence of the voltage divider R_2,R_3.

In the absence of a load the duration of one cycle is given by:

$$T = \frac{\Delta V_c}{V_b} \cdot R_1 C$$

(see Fig.6), provided $\Delta V_c << V_b$. The repetition frequency is therefore:

$$f = \frac{1}{\frac{\Delta V_c}{V_b} \cdot R_1 C} = \frac{V_b}{\Delta V_c R_1 C}.$$

If the load consisting of $R_2 + R_3$ is now introduced, the supply voltage V_b, according to Thevenin's theorem, will fall to:

$$V_b' = V_b \cdot \frac{R_2 + R_3}{R_1 + R_2 + R_3}$$

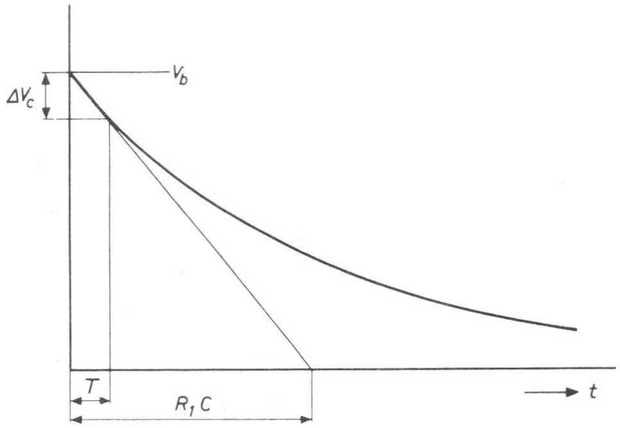


Fig.6. Diagram illustrating the duration T of one cycle.

The charging resistance is now:

$$R_1' = \frac{R_1 (R_2 + R_3)}{R_1 + R_2 + R_3}$$

so that

$$f = \frac{V_b \cdot \frac{R_2 + R_3}{R_1 + R_2 + R_3}}{\Delta V_c C \cdot \frac{R_1 (R_2 + R_3)}{R_1 + R_2 + R_3}} = \frac{V_b}{\Delta V \; R_1 C}.$$

It is therefore seen that the load due to $R_2 = R_3$ does *not* affect the repetition frequency.

There is, however, an increase in the linearity error as a consequence of the reduced supply voltage, since V_b' must be substituted for V_b in eq.(2), so that:

$$a = \frac{\Delta V_C}{V \cdot \frac{R_2 + R_3}{R_1 + R_2 + R_3}} = \frac{\Delta V_C}{V_b} \cdot \left(1 + \frac{R_1}{R_2 + R_3}\right)$$

The value of $R_1/(R_2 + R_3)$ depends upon the desired frequency response curve (which determines R_3) and the available amplification (which determines R_2). This matter will not be pursued further here, because in the design described in this Article a circuit is used in which the attenuator R_2, R_3 is not necessary.

As a matter of interest it can be mentioned that the voltage amplitude of most blocking oscillators is between 15 and 20 V, so that, with a supply voltage of 300 V, the linearity error amounts to about 5 %, which is sufficiently small for simple oscilloscopes.

The coupling capacitor C_k shown in broken line in Fig.5 is often included in order to prevent a reduction in supply voltage due to $R_2 + R_3$. In the time constant C_k $(R_2 + R_3)$ is very large compared with $1/f$, this method may be attractive, but if f is small, C_k must be given a very high value to meet this requirement.

Sometimes the generated sawtooth voltage is deliberately distorted by means of an RC network in order to ensure that a linear sawtooth reappears on the other side of C_k.

Should the oscillator fail to function due to a defective heater, or should the tube be removed, C is charged up to the full supply voltage. Often a neon lamp (N in Fig.5), for example type Z 10, is connected in parallel with C. This lamp becomes conductive at about 70 V and thus functions as a voltage limiter, permitting a charge capacitor of low working voltage rating to be used. It is shown later that the neon lamp can also be made to effect a further considerable improvement in linearity.

IMPROVEMENT OF LINEARITY BY FLOATING SUPPLY VOLTAGE

Eq.(1) for the linearity error,

$$\alpha = \frac{(V_R)_1 - (V_R)_2}{(V_R)_1}$$

may also be written:

$$\alpha = \frac{V_b = (V_C)_1 - \{V_b + (V_C)_2\}}{V_b + (V_C)_1},$$

where V_b is constant. If, however, V_b is caused to increase during the sawtooth period from $(V_b)1$ to $(V_b)2$, the above equation becomes:

$$\alpha = \frac{(V_b)_1 + (V_C)_1 - \{(V_b)_2 + (V_C)_2\}}{(V_C)_1 + (V_b)_1},$$

or

$$\alpha = \frac{(V_b)_1 + (V_C)_1 - \{(V_B)_2 + \Delta V_b + (V_C)_2\}}{(V_C)_1 + (V_b)_1} =$$

$$= \frac{(V_C)_1 - \Delta V_b - (V_C)_2}{(V_C)_1 + (V_b)_1} \simeq \frac{\Delta V_C - \Delta V_b}{V_b}.$$

If, now, $\Delta V_b = \beta \Delta V_C$, this last equation becomes:

$$\alpha = \frac{\Delta V_C \ (1 - \beta)}{V_b}. \quad (3)$$

From this it follows that the nearer the factor β approaches unity, the better will be the linearity.

A circuit in which β can approach unity very closely is shown in Fig.7. Here the blocking oscillator is followed by a cathode follower, so that the oscillator is not loaded. The load output impedance, $1/S$, of the cathode follower permits the use of a low-resistance amplitude control, P. It will also be observed that the neon lamp previously mentioned is not connected in parallel with C but between the discharge resistor R and the cathode of the cathode follower, and is supplied via a resistor R_N from V_b.

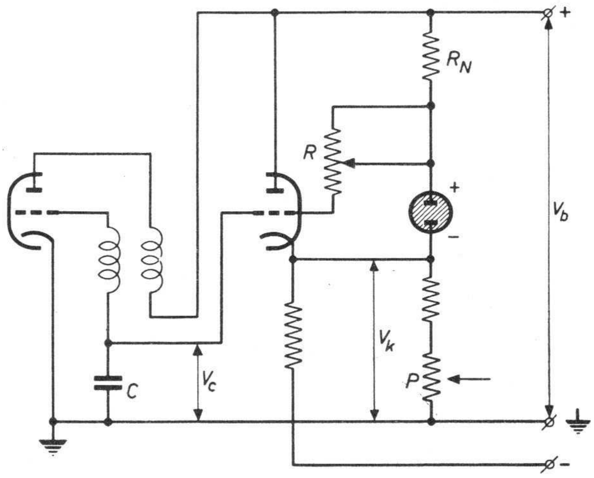


Fig.7. Circuit in which the factor β can be made to approach unity very closely.

The factor β is now determined by the voltage amplification $G = \Delta V_k / \Delta V_g$ of the cathode follower. In the circuit used, G was 0.95, so that for a sawtooth amplitude of 15 V the linearity error becomes:

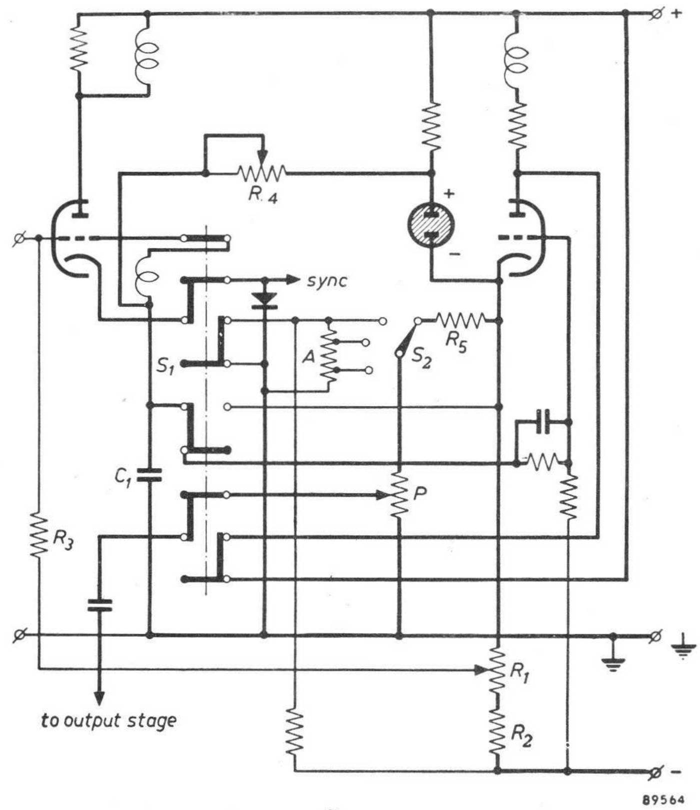
$$a = \frac{15(1 - 0.95)}{85} < 1\ \%.$$

CHANGE-OVER FROM HORIZONTAL AMPLIFIER TO TIMEBASE GENERATOR

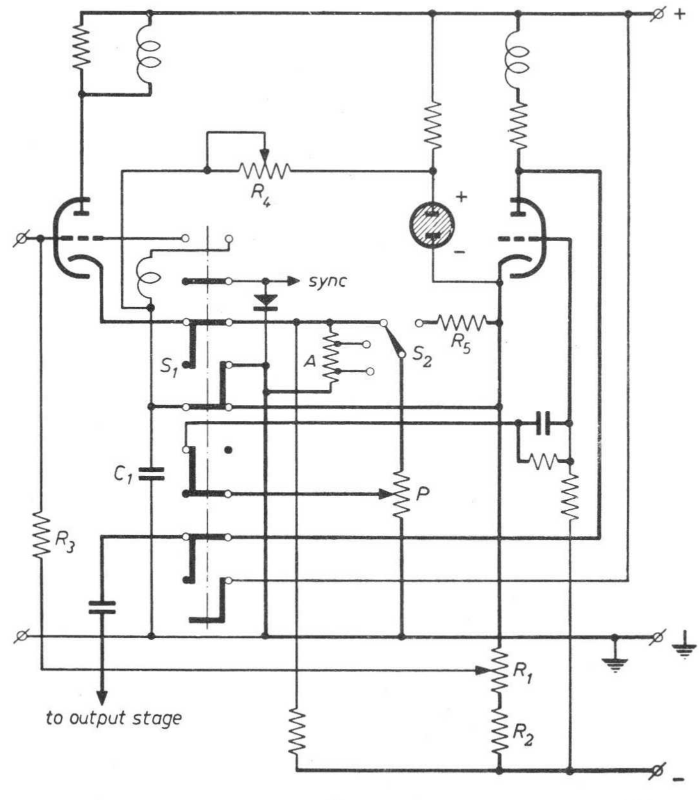
Fig.8 shows the first tube of the horizontal amplifier connected as a timebase oscillator (*a*) and as an amplifier (*b*). The non-essential connections in each case are shown in thin lines.

In Fig.8*a* the left-hand triode is the actual generator, the frequency of which can be adjusted by means of R_4 and by changing C_1. The right-hand triode is the cathode follower, its cathode resistor being $R_1 + R_2$ ($R_2 > R_1$). To prevent R_3 from causing considerable drop in the charging voltage of C_1 at high values of R_4, the resistor R_3 is connected not to earth but to the moving contact of R_1, so that only a small alternating voltage is applied across R_3. R_3 is thus apparently increased by a factor of $1/(1 - \beta)$. The output voltage of the cathode follower is applied via R_5 and R_2 to the attenuator P, and thence, via S_1, to the output stage. S_1 also short-circuits the anode impedance of the cathode follower.

When S_1 is moved to the position shown in Fig.8*b*, this short-circuit is removed, and the alternating voltage at the anode of the right-hand triode is applied to the output stage. The cathode of the right-hand triode and the upper terminal of R_1 are earthed



a



b

Fig.8. Circuit for switching the first tube of the horizontal amplifier as a timebase oscillator (a) or as an amplifier (b).

in this position of S_1. The sliding contact of R_1 should now be so adjusted that the voltage between the cathode of the left-hand triode and earth is zero, thus preventing voltage pulses arising at the right-hand control grid when the step attenuator S_2 is switched over. The capacitor C_1 is also short-circuited to earth in this position of S_1 so that it cannot be charged via R_4.

THE AMPLIFIERS FOR HORIZONTAL AND VERTICAL DEFLECTION

Except for one minor detail which will be noted later, the two amplifiers are identical, so that phase measurements over a wide frequency range can be made. The voltage amplification in both amplifiers is 1000, and the response curve is level within 1 dB from 0.5 to 200 000 c/s (see Fig.9).

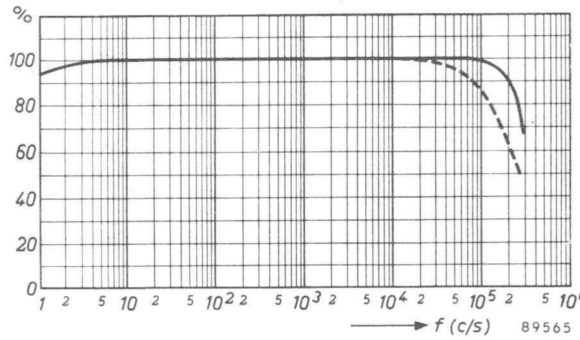


Fig.9. Response curve of the vertical and horizontal amplifiers. The curve in broken line was plotted without the correction coil *L* shown in Fig.10 being included in the circuit.

The circuit diagram is reproduced in Fig.10. As previously mentioned, the first stage is arranged as a cathode follower. A low input capacitance is thus obtained, and low-resistance components may therefore be employed for the step attenuator *A* and the amplitude control R_{12}. Phase correction with parallel capacitors is not necessary.

The cathode of the second stage is directly earthed, thus avoiding the necessity of a decoupled cathode resistor, an important advantage since otherwise a very large capacitance would be necessary to ensure adequate decoupling at the lowest frequencies (about 0.5 c/s). (A non-decoupled cathode resistor reduces the amplification by about 30 %.)

Negative grid bias is obtained from the voltage divider R_{13}, R_{14} (R_{13} = 1 MΩ, R_{14} = 100 MΩ). The lower end of R_{14} is connected to a voltage of approximately -170 V.

The function of capacitor C_3 is to eliminate the influence of the grid capacitance upon the frequency response curve. The capacitance across R_{15} is compensated by a small coil *L* which is included in the anode circuit of the right-hand triode section. Without this coil the response curve is level within 1 dB up to 75 kc/s; with this coil the response is flat up to 200 kc/s.

As is seen from the circuit diagram, the amplifier has a push-pull output stage, thus providing symmetrical deflecting voltages for the cathode-ray tube. This presented one difficulty. If the right-hand control grid of the output tube is earthed, either directly or via a capacitor, any voltage surge at C_{17}, due to a sudden fluctuation of mains voltage, will be applied asymmetrically to the output amplifier, and the image will thus show a temporary shift which will be vertical in the case of the vertical amplifier. In order to prevent this very objectionable effect, C_6 is connected between the positive side of C_{17} and the grid of the right-hand section of the output tube. At frequencies for which $1/\omega C_{17} < R_{15}$, no difficulties need be anticipated in view of the shape of the frequency response curve; but at low frequencies matters are somewhat different.

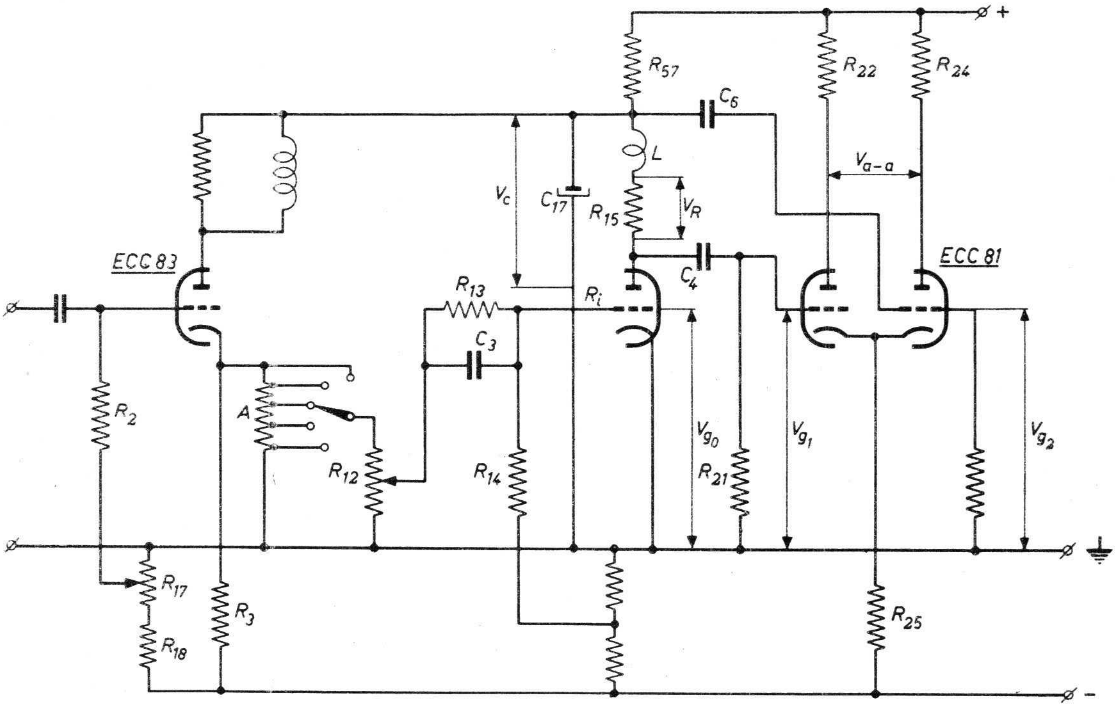


Fig.10. Circuit diagram of the complete amplifier for vertical deflection. The circuit of the amplifier for horizontal deflection is identical to this circuit apart from the fact that the decoupling capacitor (C_7) of the grid of the right-hand section of the output tube is connected to earth instead of to the positive terminal of the smoothing capacitor C_{17}. (For the sake of clarity the components have been given the same numbers as those of the complete circuit diagram, Fig.13.)

This can be investigated by considering the output stage as a differential amplifier for which $\overline{V_{g-g}} = \overline{V_{g1}} + \overline{V_{g2}}$, and disregarding the effect of C_6 and C_4 upon the frequency response curve. At low frequencies the voltage $\overline{V_{g-g}}$ is amplified without phase distortion to $\overline{V_{a-a}}$. The voltage $\overline{V_{a-a}}$ is therefore exactly in phase (or for that matter in antiphase) with $\overline{V_{g-g}}$.

If, now, C_6 is earthed, $\overline{V_{g2}} = 0$, and hence $\overline{V_{g-g}} = \overline{V_C} + \overline{V_R} = \overline{V_{g1}}$. From the vector diagram, Fig.11, it is seen that $\overline{V_{g1}}$ lags by an angle α with respect to μV_{g0} at low frequencies. (For the sake of simplicity the influence of R_{57} and any preceding RC filters upon the frequency response curve has been neglected.)

If, however, C_6 is connected as shown in Fig.10, then $\overline{V_{g-g}} = \overline{V_{g1}} + \overline{V_{g2}} = \overline{V_R}$, which at low frequencies leads μV_{g0} by an angle β. Although α increases towards a maximum with decreasing frequency to become smaller again when the frequency decreases still further, β will show a continuous increase.

By giving C_{17} a high value (50 μF) and by selecting a triode with a high internal resistance (ECC 83), it has been possible for β to be so far reduced that the frequency response curve is flat within 1 dB down to as low as 0.5 c/s.

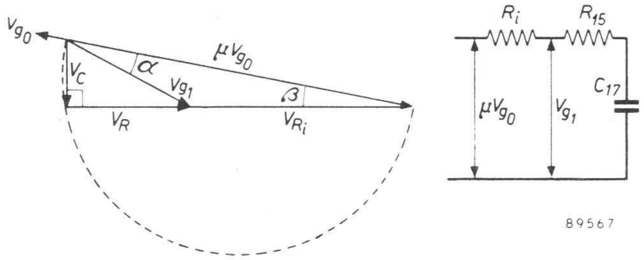


Fig.11. Vector diagram showing that V_{g1} lags by an angle α and that V_R leads by an angle β with respect to $\overline{\mu V_{g0}}$.

In the horizontal amplifier, the corresponding capacitor C_{14} is earthed for the following reasons:

(1) When the device is connected as a timebase generator, R_{15} is short-circuited (see Fig.8*b*), and V_{g1} is derived from a tube now connected as a cathode follower, which functions as a stabiliser since $\Delta V_k = \Delta V_a/\mu$, and μ for the ECC 83 is 100.

(2) When the device is connected as an amplifier, the earthing of C_6 would undoubtedly cause a certain amount of horizontal instability in the event of sudden fluctuations of mains voltage, but the sensitivity of the horizontal deflection system of the cathode-ray tube is considerably less than the vertical sensitivity so that the degree of instability is proportionately less. If desired, the change-over switching can be so arranged that C_6 is connected to the positive terminal of C_{17} in the amplifier position, and to earth in the timebase position of switch S_1 (cf. Fig.8).

THE POWER UNIT

In order to keep the apparatus as simple and compact as possible, selenium rectifiers have been used, thus avoiding the necessity of providing additional windings of the mains transformer for the heaters of the rectifying tubes.

For the amplifiers, two voltages of $+V_b$ and $-V_b$ with respect to earth are required. These can be obtained in two ways:

(1) From a transformer provided with two series-connected secondary windings as shown in Fig.12*a*. Each winding produces, after rectification, a voltage V_b.

(2) From a transformer with only one secondary winding as shown in Fig.12*b*. The required voltages $+V_b$ and $-V_b$ can then be obtained by voltage doubling.

The two circuits are not equally efficient. With the former, the charging current surges occur simultaneously after each cycle; with

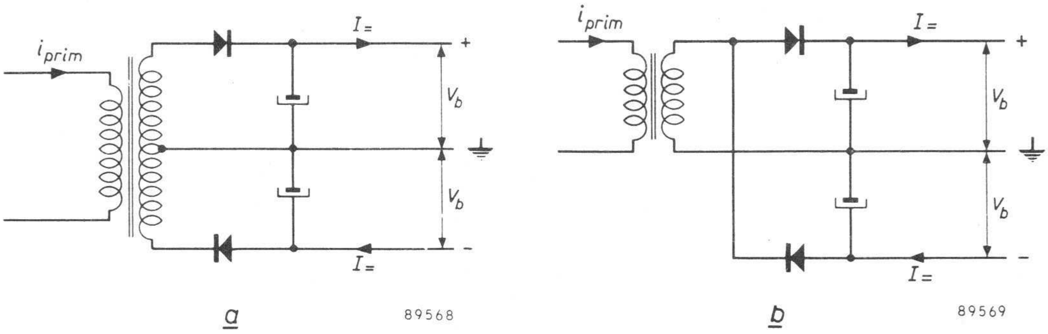


Fig.12. (a) Power unit in which the transformer is provided with two series-connected secondary windings, each of which produces a voltage V_b after rectification. (b) Power unit consisting of a voltage doubler circuit supplying two equal voltages V_b.

the latter they occur alternately after each half cycle. The losses in the first arrangement will thus be greater, and in practice it is found that for the same rectifier output current the alternating current drawn from the mains in the case of the voltage doubler arrangement is the smaller by about 30 %. This arrangement has therefore been adopted on the score of economy, simplicity and compactness.

THE COMPLETE CIRCUIT

The circuit diagram of the complete oscilloscope is shown in Fig.13. Most of the more noteworthy features have been described and explained in previous paragraphs, leaving only a few details for further discussion.

The maximum input signal which may be applied between input terminals I_2 and I_3 for vertical deflection or between terminals I_{11} and I_{12} for horizontal deflection is slightly more than 60 V (r.m.s. value). To permit the application of higher input voltages, resistors R_1 and R_{85} have been included, which allow voltages up to about 300 V (r.m.s. value) to be applied via terminals I_1 and I_3 or I_{10} and I_{12} respectively.

The output voltage of the push-pull output stages is applied directly to the deflection plates in position 2 or switches S_2 for vertical deflection and S_3 for horizontal deflection. Amplitude and phase distortion at very low frequencies are thus avoided, and at the same time parasitic capacitance in parallel with the anode resistance is reduced to a minimum. In position 1 of these switches the deflection plates are connected, via isolating capacitors, to terminals I_4 and I_5 for vertical deflection or I_7 and I_8 for horizontal deflection.

In the horizontal amplifier a neon lamp N, type Z 10, is connected between the right-hand control grid of tube T_4 and earth. This lamp becomes conductive during the change-over from oscillator to amplifier and vice versa, and so prevents excessively high voltages occurring between the grid and cathode of the right-hand section of tube T_4.

Switch S_4 serves for selecting the frequency range of the timebase oscillator. To avoid the risk of T_5 oscillating in the case of a sinusoidal timebase (position 10 of switch S_4), a direct voltage of approximately -3.5 V (taken from R_{62}, R_{63}) is applied to its

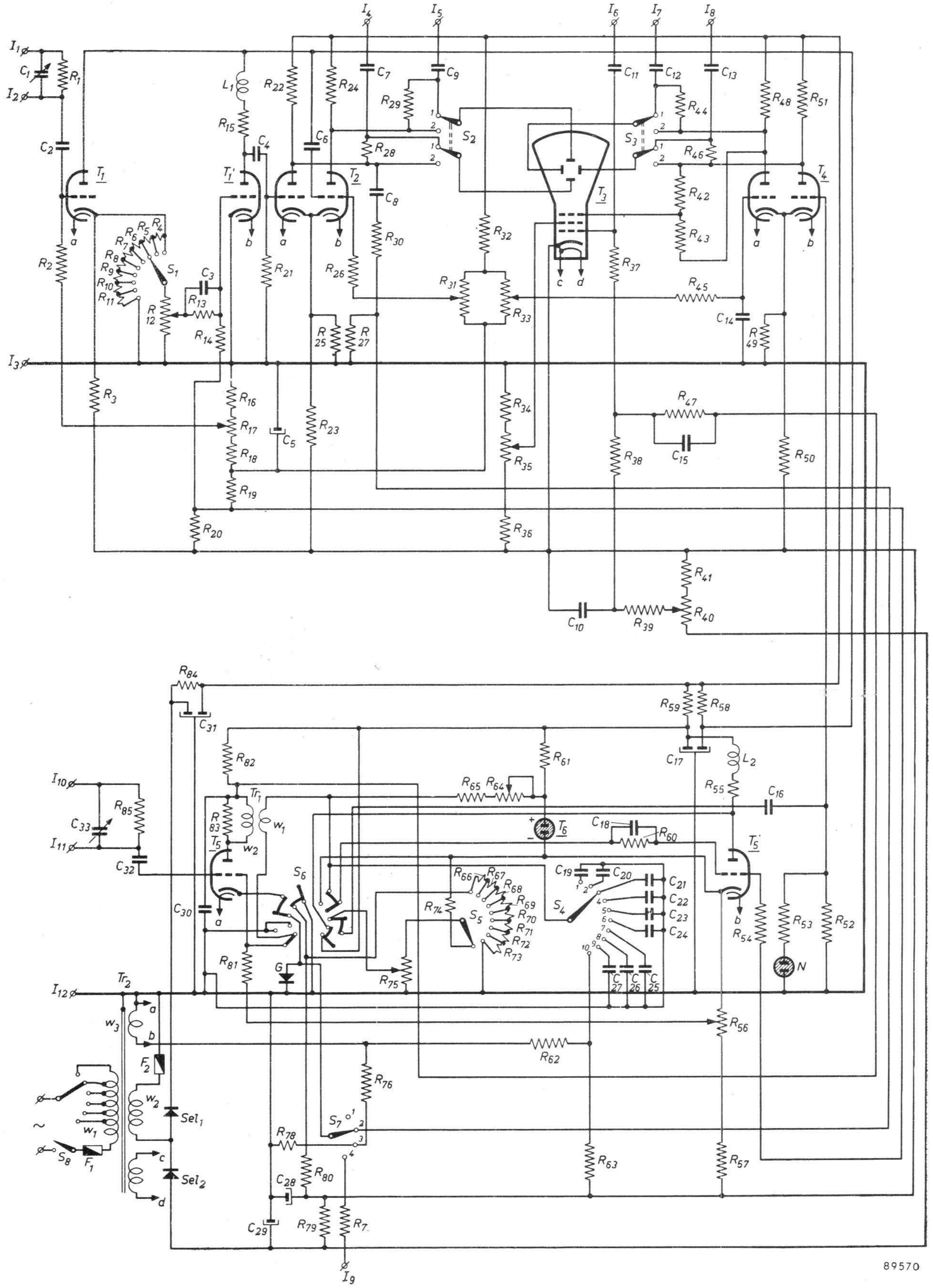


Fig.13. Circuit diagram of the complete cathode-ray oscilloscope with switch S_6 in the timebase position. (For component values, see opposite page.)

RESISTORS

R_1 = 8.2 MΩ, 1 W
R_2 = 2.2 MΩ, ½ W
R_3 = 270 kΩ, 1 W
R_4 = 10 kΩ, ¼ W
R_5 = 33 kΩ, ¼ W
R_6 = 82 kΩ, ¼ W
R_7 = 27 kΩ, ¼ W
R_8 = 1.5 kΩ, ¼ W
R_9 = 390 Ω, ¼ W
R_{10} = 100 Ω, ¼ W
R_{11} = 47 Ω, ¼ W
R_{12} = 5 kΩ, linear wire wound
R_{13} = 1 MΩ, ½ W
R_{14} = 100 MΩ, 1 W
R_{15} = 27 kΩ, ½ W
R_{16} = 4.7 kΩ, ½ W
R_{17} = 1 kΩ, linear carbon
R_{18} = 3.3 kΩ, ½ W
R_{19} = 220 kΩ, 1 W
R_{20} = 220 kΩ, 1 W
R_{21} = 1 MΩ, ½ W
R_{22} = 27 kΩ, 1 W
R_{23} = 47 kΩ, 7 W, wire wound
R_{24} = 27 kΩ, 1 W
R_{25} = 12 kΩ, 1 W
R_{26} = 1 MΩ, ½ W
R_{27} = 12 kΩ, ½ W
R_{28} = 3.3 MΩ, 1 W
R_{29} = 3.3 MΩ, 1 W
R_{30} = 39 kΩ, 1 W
R_{31} = 100 kΩ, linear, carbon
R_{32} = 1.5 MΩ, 1 W
R_{33} = 100 kΩ, linear, carbon
R_{34} = 270 kΩ, 1 W
R_{35} = 100 kΩ, linear, carbon
R_{36} = 82 kΩ, 1 W
R_{37} = 10 kΩ, ¼ W
R_{38} = 220 kΩ, ½ W
R_{39} = 220 kΩ, ½ W
R_{40} = 20 kΩ, linear, carbon
R_{41} = 2.7 kΩ, 3 W
R_{42} = 1 MΩ, ½ W
R_{43} = 1 MΩ, ½ W
R_{44} = 3.3 MΩ, 1 W
R_{45} = 1 MΩ, ½ W
R_{46} = 3.3 MΩ, ½ W
R_{47} = 82 kΩ, ½ W
R_{48} = 27 kΩ, 1 W
R_{49} = 12 kΩ, 1 W
R_{50} = 47 kΩ, 7 W, wire wound
R_{51} = 27 kΩ, 1 W
R_{52} = 1 MΩ, ½ W
R_{53} = 2.2 kΩ, ½ W
R_{54} = 100 MΩ, 1 W
R_{55} = 27 kΩ, ½ W
R_{56} = 1 kΩ, linear, carbon
R_{57} = 56 kΩ, 3 W
R_{58} = 5.6 kΩ, 1 W
R_{59} = 5.6 kΩ, 1 W
R_{60} = 1 MΩ, ½ W
R_{61} = 270 kΩ, 1 W
R_{62} = 68 kΩ, ½ W
R_{63} = 560 kΩ, 1 W
R_{64} = 1 MΩ, anti-log., carbon
R_{65} = 330 kΩ, 1 W
R_{66} = 10 kΩ, ¼ W
R_{67} = 33 kΩ, ¼ W
R_{68} = 27 kΩ, ¼ W
R_{69} = 82 kΩ, ¼ W
R_{70} = 1.5 kΩ, ¼ W
R_{71} = 390 Ω, ¼ W
R_{72} = 100 Ω, ¼ W
R_{73} = 47 Ω, ¼ W
R_{74} = 5.6 kΩ, ½ W
R_{75} = 5 kΩ, linear, wire wound
R_{76} = 2.2 kΩ, ½ W
R_{77} = 2.7 kΩ, ½ W
R_{78} = 1.5 kΩ, ½ W
R_{79} = 2.2 kΩ, 1 W
R_{80} = 270 kΩ, 1 W
R_{81} = 2.2 MΩ, ½ W
R_{82} = 820 Ω, ½ W
R_{83} = 3.3 kΩ, ½ W
R_{84} = 560 Ω, 1 W
R_{85} = 8.2 MΩ, 1 W

CAPACITORS

C_1 = 5 pF max., trimmer
C_2 = 0.27 μF, 500 V
C_3 = 0.047 μF, 300 V
C_4 = 0.47 μF, 500 V
C_5 = 100 μF, 12.5 V
C_6 = 0.47 μF, 500 V
C_7 = 0.27 μF, 500 V
C_8 = 0.27 μF, 500 V
C_9 = 0.27 μF, 500 V
C_{10} = 0.27 μF, 500 V
C_{11} = 0.27 μF, 500 V
C_{12} = 0.27 μF, 500 V
C_{13} = 0.27 μF, 500 V
C_{14} = 0.47 μF, 500 V
C_{15} = 270 pF, 300 V
C_{16} = 0.47 μF, 500 V
C_{17} = 2 x 50 μF, 400 V
C_{18} = 0.047 μF, 300 V
C_{19} = 47 pF, 300 V
C_{20} = 180 pF, 300 V
C_{21} = 820 pF, 300 V
C_{22} = 3300 pF, 300 V
C_{23} = 0.01 μF, 300 V
C_{24} = 0.033 μF, 300 V
C_{25} = 0.1 μF, 300 V
C_{26} = 0.33 μF, 300 V
C_{27} = 1 μF, 300 V
C_{28} = 50 μF, 450 V
C_{29} = 50 μF, 450 V
C_{30} = 1000 pF, 500 V
C_{31} = 2 x 50 μF, 450 V
C_{32} = 0.27 μF, 500 V
C_{33} = 5 pF, max., trimmer

TUBES, ETC.

L_1 = approx. 15 mH
L_2 = approx. 15 mH
T_1 = ECC 83
T_2 = ECC 81
T_3 = DG 7-32
T_4 = ECC 81
T_5 = ECC 83
T_6 = 85A2
N = neon lamp Z 10
F_1 = 1 A fuse
F_2 = 0.1 A fuse
G = germanium diode OA 85

Sel_1 = selenium rectifier 2 x 220C85 in series
Sel_2 = selenium rectifier 2 x 220C85 in series

Tr_1: w_1 = approx. 120 μH, $w_1 : w_2$ = 2.5 : 1

Tr_2: w_1 = 110, 130, 145, 190, 220, 245 V
w_2 = 350 V, 2 x 20 mA
w_3 = 6.3 V, 1.2 A
w_4 = 6.3 V, 0.4 A

control grid, in addition to the 50 c/s voltage, so that this tube is almost cut-off.

S_6 is the switch for changing from timebase generator to horizontal amplifier. It will be observed that the contact connected to the control grid of T_5 is not situated immediately adjacent to the contact connected to the synchronising voltage, but is separated from it by two earthed contacts. This is to prevent part of the synchronising voltage being transferred, either capacitively of by conduction (e.g. via the leakage path between the contacts), to the grid of T_5, which would cause mutual interference between the two amplifiers.

The mains switch, S_8, may be combined with one of the potentiometers. Generally it is coupled to the potentiometer for brightness control, but this has the practical disadvantage that the apparatus may remain switched on unintentionally, no image being visible. It is preferable, therefore, to combine S_8 with the focusing control, R_{35}, since at any setting of this potentiometer an image remains visible on the screen.

TECHNICAL DATA

SENSITIVITY

Between vertical deflection plates, terminals I_4 and I_5	10 V_{rms}/cm
Between horizontal deflection plates, terminals I_7 and I_8	16 V_{rms}/cm
At input of vertical amplifier,	
terminals I_2 and I_3	10 mV_{rms}/cm
terminals I_1 and I_3 (approx.)	50 mV_{rms}/cm
At input of horizontal amplifier	
terminals I_{11} and I_{12}	16 mV_{rms}/cm
terminals I_{10} and I_{12} (approx.)	80 mV_{rms}/cm

FREQUENCY RESPONSE

Vertical amplifier	
from 0.5 c/s to 200 kc/s	-1 dB
at 250 kc/s	-3 dB
Horizontal amplifier	
from 0.5 c/s to 200 kc/s	-1 dB
at 250 kc/s	-3 dB

MAXIMUM INPUT VOLTAGE

Between terminals I_2 and I_3 or between terminals I_{11} and I_{12} (approx.)	60 V_{rms}
Between terminals I_1 and I_3 or between terminals I_{10} and I_{12} (approx.)	300 V_{rms}

INPUT RESISTANCE

0-60 volt input circuits (approx.)	2 MΩ
0-300 volt input circuits (approx.)	10 MΩ

INPUT CAPACITANCE

At terminals I_2 or I_{11} (approx.)	5 pF
At terminals I_1 or I_{10} (approx.)	1 pF

TIMEBASE FREQUENCIES

Position on S_4	Frequency range (c/s)
1	30 000 to 120 000
2	10 000 to 40 000
3	3 000 to 12 000
4	1 000 to 4 000
5	300 to 1 200
6	100 to 400
7	30 to 120
8	10 to 40
9	3 to 12
10	50 c/s sinusoidal

SYNCHRONISATION

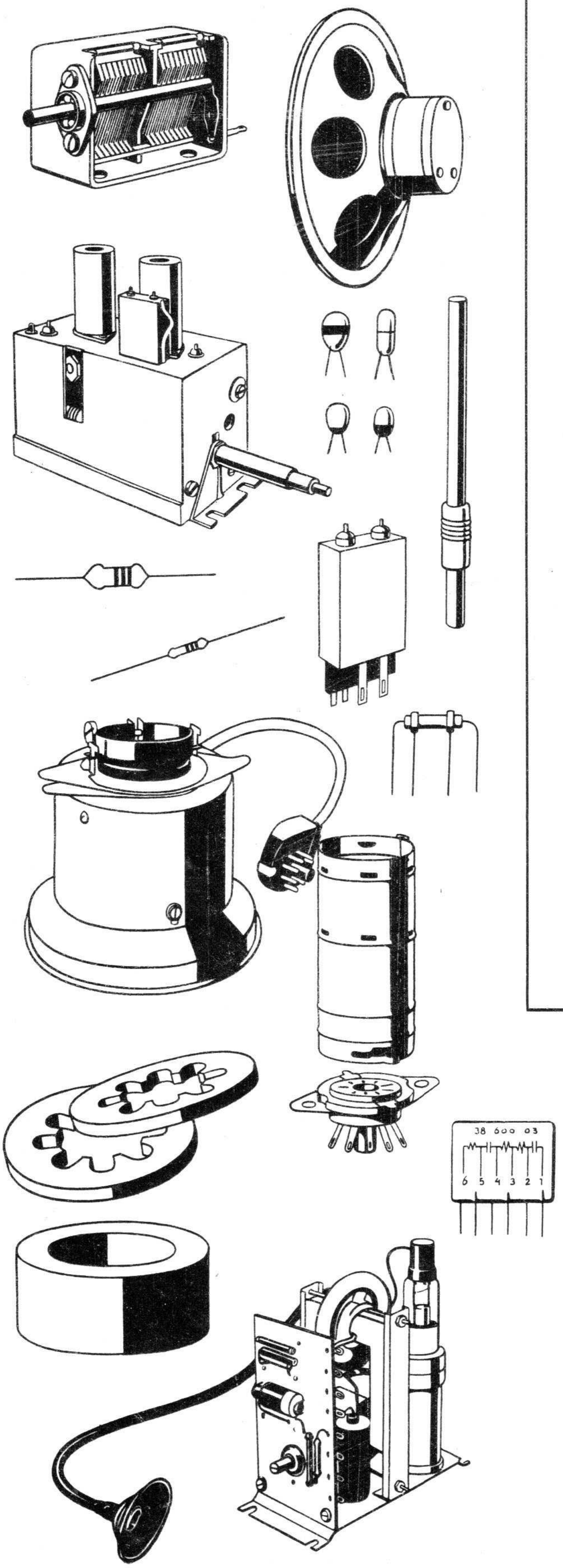
Position 1 on S_7 off
Position 2 on S_7 internal, from vertical amplifier
Position 3 on S_7 internal, 50 c/s
Position 4 on S_7 external via terminal I_9 (0.5 to 5 V)

BEAM MODULATION

Via terminal I_6 0.5 to 3 V

DIMENSIONS AND WEIGHT

Height 20 cm, width 30 cm, depth 17.5 cm; weight 5 kg.

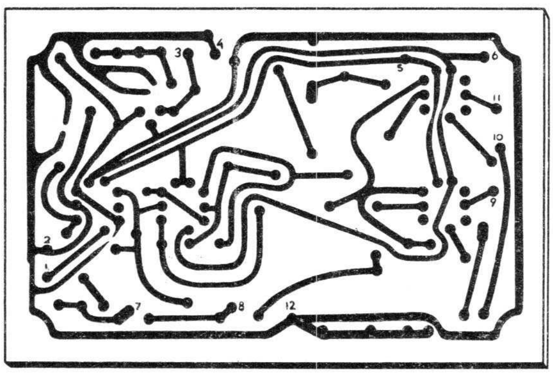


COMPONENTS AND MATERIALS

The electrical as well as mechanical performance of electronic applications depend on the quality of every single component that is used for the assembly of the apparatus. This refers not only to tubes and semi-conductors, but just as much to components and materials.

In this Bulletin no more than a few members of the big family of electron tubes are described, whilst in the parts lists only some components are mentioned. The very important group of mechanical parts, which in fact contributes equally to the success of the final apparatus, could for practical reasons not be indicated in the various circuits.

For all information on the most complete range of high-quality building blocks that can be offered to the Electronic Industry please apply to the address mentioned on the cover.



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