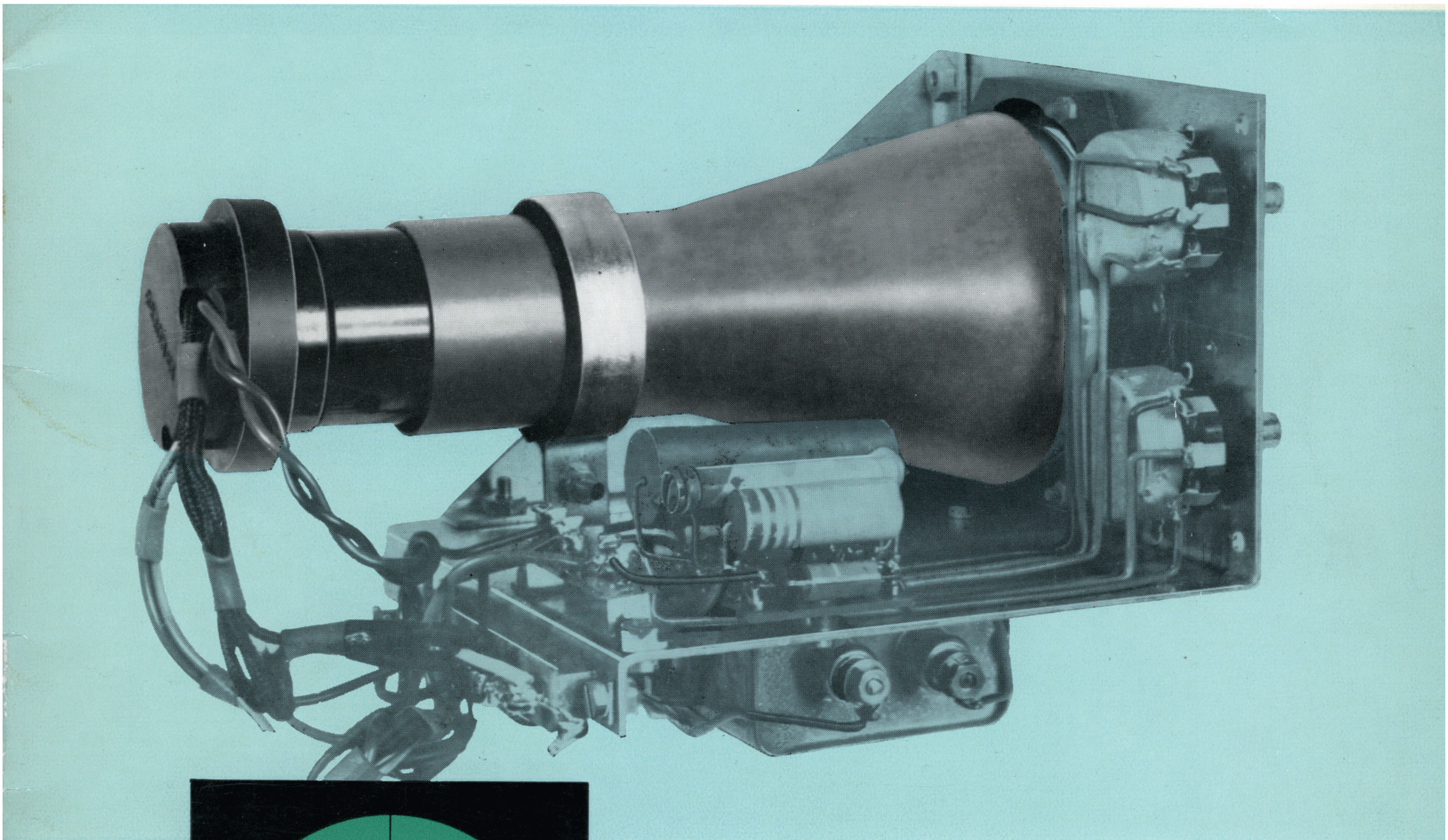
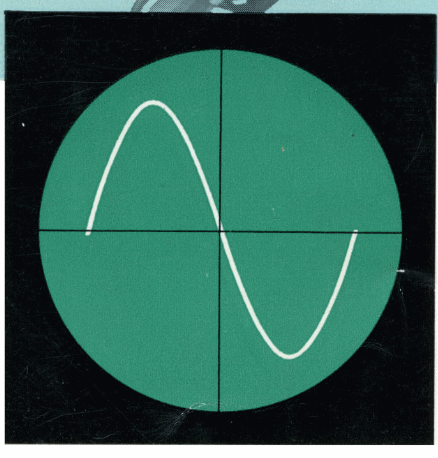
PHILIPS

students' oscilloscope





PHILIPS ELECTRON TUBE DIVISION

Introduction

The oscilloscope described in this publication is a reasonably-priced precision instrument of up-to-date design and robust construction, and gives a performance which adequately meets all the requirements of the demonstration table and the school laboratory.

Unit construction, careful mechanical design and simple layout render assembly and wiring well within the capacity of students under normal supervision, thus not only minimising the overall cost of the instrument but also providing valuable experience in the use of tools and in the wiring and testing of electronic circuits.

Concise building instructions and point-to-point wiring diagrams are given in this booklet, together with explanations of the principles involved and descriptions of some of the experiments, both qualitative and quantitative, which can be conducted with the completed instrument.

Contents

1. General description	3
2. Power supply unit	5
3. Cathode-ray tube unit	9
4. Vertical amplifier	13
5. Timebase generator unit	17
6. Power outlet and waveform panel	22
7. Final assembly	24
8. Testing	26
9. Instructions, exercises and experiments	28

1

General Description

As shown in Fig.1, the instrument comprises four main units, namely the Power Supply Unit; the Vertical (Y) Amplifier; the Cathode-Ray Tube Unit and the Timebase Generator.

Brief details of each are given below; full descriptions will be found in Sections 2 to 6.

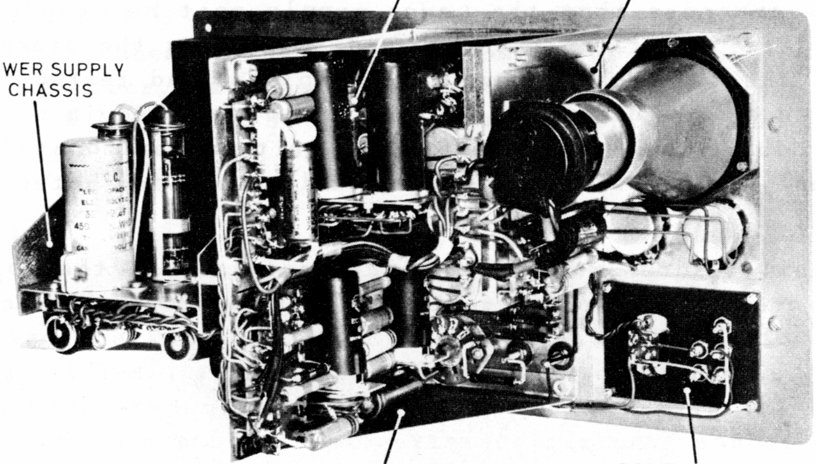


Fig.1. Internal view of oscilloscope.

1.1. POWER SUPPLY UNIT

The power pack has the following outputs:

400 V d.c for cathode-ray tube.
350 V d.c. for amplifier, timebase, etc.
0.1 A at 6.3 V, 50 c/s.
2.0 A at 6.3 V, 50 c/s.
2.5 A at 6.3 V, 50 c/s.

The power pack is generously rated and can supply both h.t. and l.t. for auxiliary apparatus such as a signal generator, for which purpose output sockets are provided on the panel. Additional sockets are provided to permit waveforms originating in the power pack to be displayed on the tube screen for demonstrating a sine wave, half-wave rectification and the effects of the smoothing system, etc.

1.2. VERTICAL AMPLIFIER

Direct-coupled two-stage amplifier with push-pull output for symmetrical deflection. Maximum sensitivity 10 mV_{rms} for 1 cm deflection. Linear response up to 20 kc/s.

1.3. CATHODE-RAY TUBE UNIT

This unit comprises a DG 7-31/01 low-voltage instrument type cathode-ray tube with 3-inch diameter screen giving a green trace. Associated control circuitry includes flyback suppression.

1.4. TIMEBASE GENERATOR

Miller transitron circuit with three frequency ranges, covering frequencies from 12 c/s to 20 kc/s. Synchronisation of the timebase with the vertical amplifier is achieved by a synchronising amplifier stage.

1.5. UNIT CONSTRUCTION

Each of the above units is assembled and wired on a separate sub-chassis, terminal tag strips being provided for the necessary interconnections between the units. This arrangement not only simplifies construction, but permits the units to be built simultaneously by different groups of students.

It is recommended that the power supply unit be completed and tested first, as it can then be used in testing the other units. When all the sub-chassis have been completed and tested, they may be mounted on a front panel and the whole enclosed in a metal or perspex cabinet. Alternatively, each unit may be mounted in its individual cabinet with multi-core cables used for inter-connections.

If the instructions and recommendations given in the following sections are carefully followed, no difficulty should be encountered in completing the instrument. Special emphasis, however, is laid on the need to keep all wiring as short as possible, particularly in the vertical amplifier and the timebase generator in order to reduce to a minimum stray inductances and capacitances which would lower the performance of the instrument.

1.6. COMPONENT LISTS

The components for each unit are listed in the various descriptive sections, and a complete components list is given at the back of this book.

1.7. MECHANICAL DRAWINGS

For each sub-chassis complete mechanical drawings, including drilling templates, are given in the appropriate section. All dimensions in these drawings are in millimetres.

2

Power Supply Unit

This unit provides two H.T. supplies, one at 400 V for the cathode-ray tube, and one at 350 V for the anode circuits of tubes in the timebase generator and vertical amplifier. The output of the 350 V supply is more than sufficient for this load, and up to 20 mA can be drawn from it for such ancillary equipment as a signal generator.

The following 50 c/s low tension supplies are also provided:

1.0 A at 6.3 V for the heater of the cathode ray tube.
2.0 A at 6.3 V for the heater of the e.h.t. rectifier, V_2,
2.5 A at 6.3 V for the heaters of the h.t. rectifier, V_1, the tubes of the time base generator and the vertical amplifier, and the filament of the indicator lamp. Up to 0.6 A can also be drawn from this supply for use in ancillary apparatus.

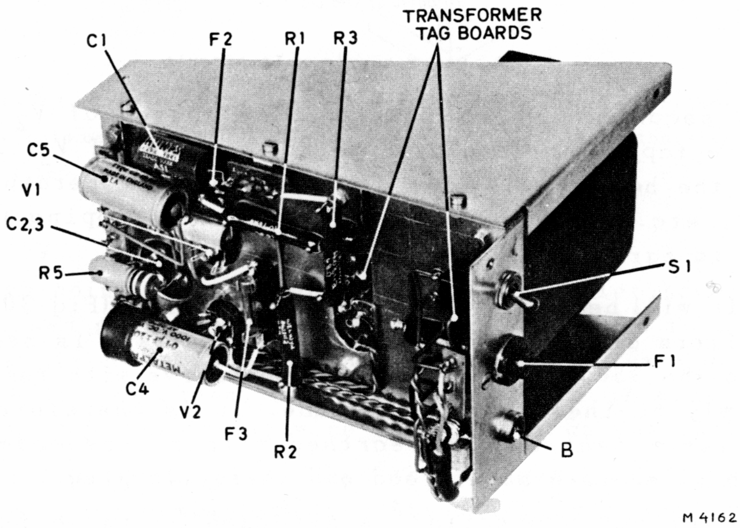


Fig.2. Power supply unit.

2.1. DESCRIPTION OF CIRCUIT

As will be seen from the circuit diagram (Fig.3), the supplies are derived in the first instance from a mains transformer and two EY 84 single-anode rectifier tubes. The transformer primary is designed for 50 c/s mains voltages between 200 and 250 V, and has tappings for different voltages in steps of 10 V.

The h.t. secondary is centre-tapped and wound for 300-0-300 V. V_1, the rectifier for the 350 V h.t. supply, draws current from the centre tapping, and components C_2, R_4 and C_3 form the smoothing filter for the rectified output.

V_2 provides the 400 V e.h.t. supply and is connected across the whole of the 300-0-300 V secondary winding. Smoothing is provided by the components C_4, R_5 and C_5.

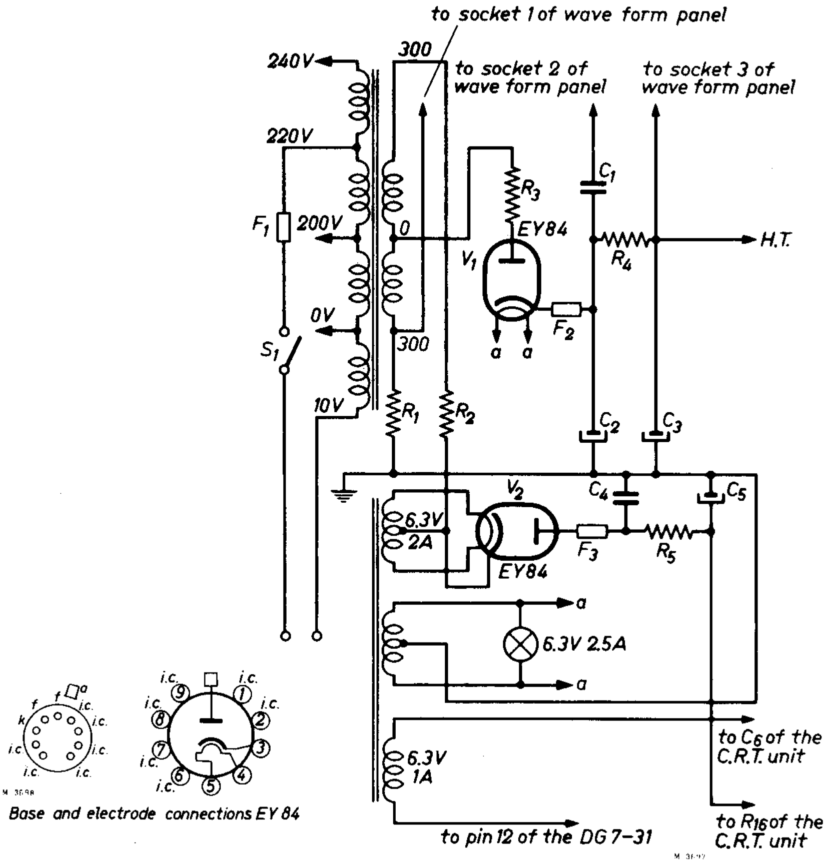


Fig.3. Power supply unit circuit.

The 6.3 V secondary which supplies the heater of V_2 is centre-tapped, the tap being connected to the cathode of V_2. The winding supplying the heaters of tubes in the timebase generator, vertical amplifier, etc., is also centre-tapped, the tapping point being connected to earth through the chassis.

Caution. It will be seen from the master circuit (Fig.30), that the two rectifiers are so connected that the chassis is *negative* with respect to the 350 V h.t. supply, but *positive* with respect to the 400 V supply to the cathode-ray tube. *It is therefore essential that the instrument case is earthed either independently or by means of a three-core mains lead and three-pin plug.*

Adequate overload protection is afforded by three fuses: F_1 in the mains input circuit, and F_2 and F_3 in the two h.t. outputs.

Connections from various points in the circuit are taken to the waveform and power output panel described in Section 6.

2.2. ASSEMBLY

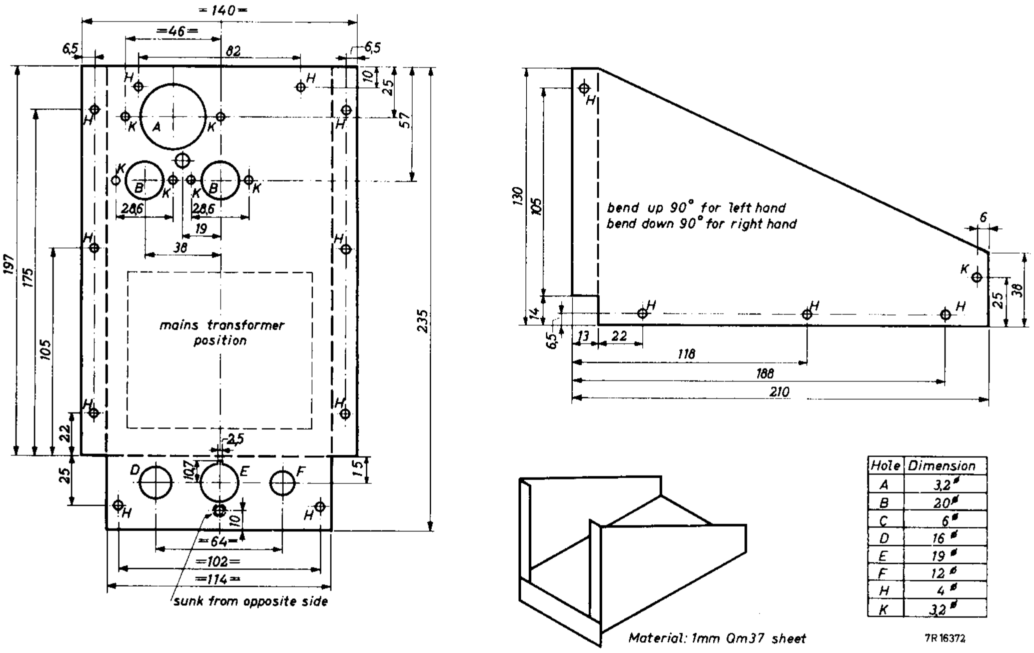
The layout of the components is illustrated in the photograph (Fig.2), and a point-to-point wiring diagram is given in Fig.5.

2.2.1. Chassis

Mechanical details of the chassis are given in Fig.4, which shows how the chassis is made up from three pieces of 1.0 mm Qm 37 sheet, cut and bent to shape, and bolted together. All holes should, of course, be drilled before bending.

2.2.2. Layout

As shown in Fig.2, which is a view of the underside of the completed unit, all components are mounted on the horizontal base of the chassis or included in the run of wiring, with the exception of the mains switch, S_1, the mains fuse, F_1, and the indicator lamp B, which are mounted on the vertical bent-down strip at the front of the chassis. When assembling, it is advisable to locate and secure all fixed components such as tube holders, tag strips, fuses and so forth before commencing the wiring.



Hole	Dimension
A	3,2 ⌀
B	20 ⌀
C	6 ⌀
D	16 ⌀
E	19 ⌀
F	12 ⌀
H	4 ⌀
K	3,2 ⌀

Fig. 4. Power supply unit, mechanical. The chassis sections should be bent up at 90° at all dotted lines unless otherwise stated.

2.2.3. *Wiring*

The point-to-point wiring diagrams in this booklet have been somewhat idealised since this renders them more easy to follow. For example, it is not essential that all the wires should follow exactly the routes shown, but they should, in general, be so arranged that each connecting wire is as short as possible.

The wiring is perfectly straight-forward, and no difficulty should be experienced in completing it. Attention is drawn, however, to the following points:

(1) As stated earlier, the chassis is negative with respect to the 350 V supply. It is imperative therefore that the *negative poles of* C_2 and C_3 and the *positive pole of* C_5 are connected to chassis. The correct polarity is clearly shown in the wiring diagram.

(2) The heater and cathode connections to the tube holders for V_1 and V_2 are indicated by numbers in the wiring diagram. These numbers correspond to the contacts indicated in Fig.5, where the connections are viewed from the *underside* of the tube holder.

(3) The two wires of each heater connection should be twisted together as shown in order to minimise inductive effects.

(4) Resistors R_2 and R_3 are current-limiting resistors and are required only if the mains transformer secondary has a very

low resistance. For any other type of transformer they should be replaced by a straight-through connection.

(5) All points in the circuit from which interconnections must be run to other parts of the instrument and also a certain number of other internal connections are taken to tag boards numbered T_4 and T_5 in Fig.5. Tags 1 and 10 on T_4 and the centre tags of T_5 are permanently connected to the chassis by the tag strip fixing bolts. These connections are part of the instrument circuit and must be *good electrical contacts*.

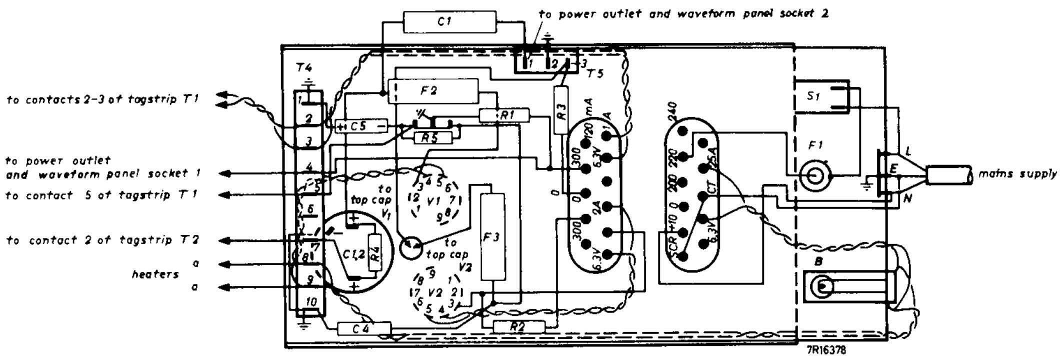


Fig.5. Power supply unit, point-to-point.

2.3. COMPONENTS LIST

A complete list of all components of the oscilloscope will be found on page 35 of this book.

The following list includes only the parts required for building the power supply unit, and is intended to serve as a check list when collecting all the necessary parts before commencing construction.

One chassis, 1 mm Qm 37 sheet, (see Fig.4),
two B9A ceramic tube holders, type number B 9 700 19,
two tube holders with retaining clips for the EY 84,
two base-mounting fuse holders (F_2 and F_3),
one 250 mA cartridge fuse,
one 150 mA cartridge fuse,
one panel-mounting fuse holder (F_1), type number 88082,
one 2 A cartridge fuse,
one indicator lamp, 6.3 V, and holder, type number F 001 AA/02,
one mains switch,
two type EY 84 single-anode rectifier tubes and top-cap connectors,
three 3-way terminal tag strips, type number B 8 708 20/03,
one 10-way terminal tag strip, type number B 8 708 20/00
one 6 mm rubber grommet.

Resistors	*Capacitors*
R_1 = 10 Ω, 6 W wire-wound	C_1 = 0.1 μF polyester 400 V d.c.
R_2 = 68 Ω, 6 W wire-wound	C_2, C_3 = 32+32 μF electrol. 450 V d.c.
R_3 = 47 Ω, 6 W wire-wound	C_4 = 0.1 μF paper, 1000 V d.c.
R_4 = 1 kΩ, 1 W	C_5 = 8 μF electrol. 500 V d.c.
R_5 = 220 kΩ, 1 W	

All resistors are 20% tolerance. R_2 and R_3 are required only with transformers having a secondary with low resistance.

3

Cathode-Ray Tube Unit

The cathode-ray tube unit comprises a Type DC 7-31/01 cathode-ray tube and its associated circuitry, i.e., the resistor chain which supplies the potentials to the various electrodes of the cathode-ray tube, including the potentiometers forming the focusing and brightness controls.

3.1. DESCRIPTION OF CIRCUIT

As will be seen from the complete circuit diagram of the oscilloscope (Fig.30), the negative pole of the 350 V d.c. supply provided by rectifier tube V_1 and the positive pole of the 400 V d.c. supply provided by rectifier tube V_2 are earthed to chassis. The two supplies are, therefore, effectively in series. The e.h.t. supply for the cathode-ray tube is taken between the junction of R_{26} and R_{30} in the Y-amplifier (Fig.11) which is at a potential of about 240 V positive with respect to the chassis, and the lower end of R_{16} in the cathode-ray tube unit (Fig.6), which is at approximately 300 V negative with respect to the chassis.

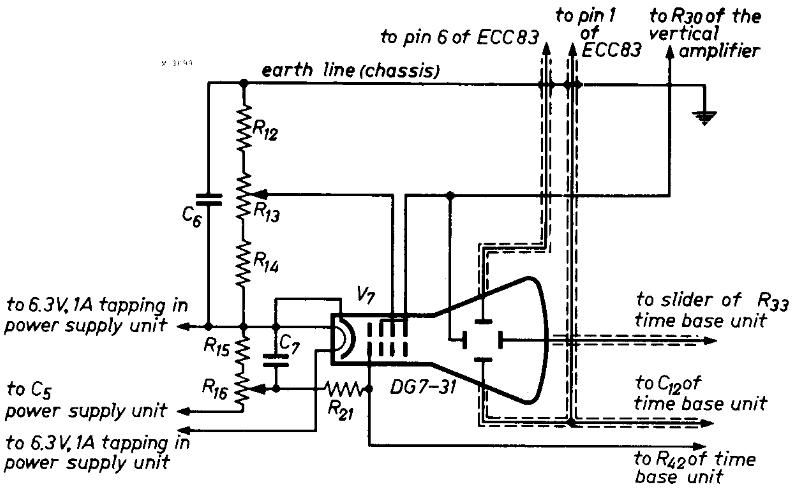


Fig.6. Cathode ray tube circuit.

The final anode of the cathode-ray tube is connected to the junction of R_{26} and R_{30}, and the potentials of the other electrodes are derived from a resistor chain comprising R_{12}, R_{13}, R_{14}, and R_{15} and R_{16}.

The cathode of the tube is connected to this chain at the junction of R_{14} and R_{15}, so that, by means of R_{13} and R_{16}, variable potentials, one positive and one negative with respect to the cathode, can be obtained.

Thus adjustment of R_{16} varies the negative potential of the grid of the tube with respect to the cathode and so serves as the brightness control, while R_{13} supplies a variable positive potential to the second anode and forms the focusing control.

It should be noted that one side of the tube heater is connected directly to the cathode, which is decoupled to chassis via C_6. The brightness control is decoupled to cathode via C_7.

As the horizontal deflection system is arranged for asymmetric operation, one of the horizontal deflection plates, D_2, is connected to the final anode, i.e., pins 8 and 9 of the cathode-ray tube are connected together.

3.2. ASSEMBLY

The photograph (Fig.8) indicates the layout of the components, and Fig.7 is a point-to-point wiring diagram.

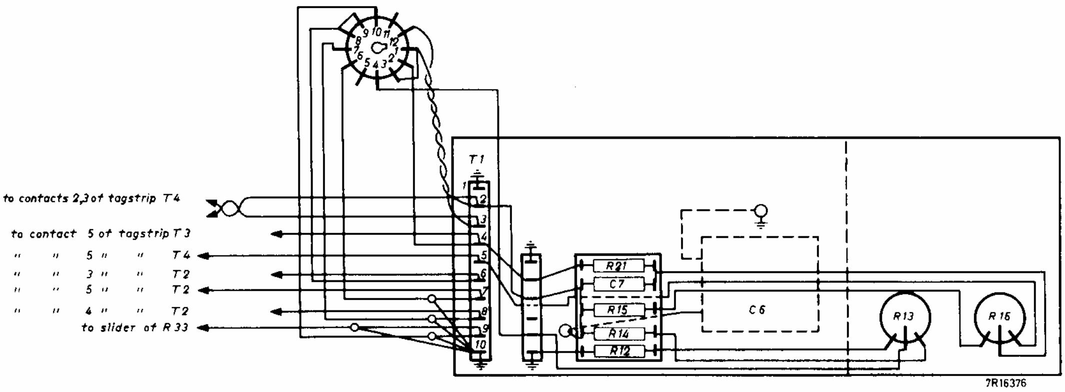


Fig.7. Cathode ray tube, point-to-point.

Note: Contact 1 of tubeholder must be connected to contact 2 of tagstrip T_1 and contact 12 of tubeholder to contact 3 of tagstrip T_1.

3.2.1. *Chassis*

From the mechanical drawing reproduced in Fig.9, it will be seen that the chassis consists of a main member and one side bracket of Qm 37 sheet, cut and bent to shape: a ringshaped support for the neck of the cathode-ray tube also made of Qm 37, and padded with felt; and a heptagonal fuller board plate having a central hole padded with felt to support the face plate of the cathode-ray tube.

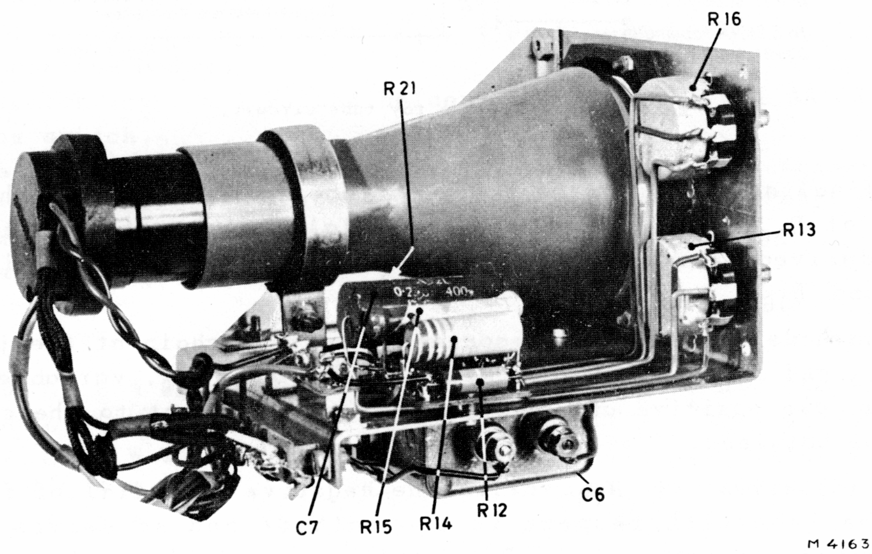


Fig.8. Cathode ray tube unit.

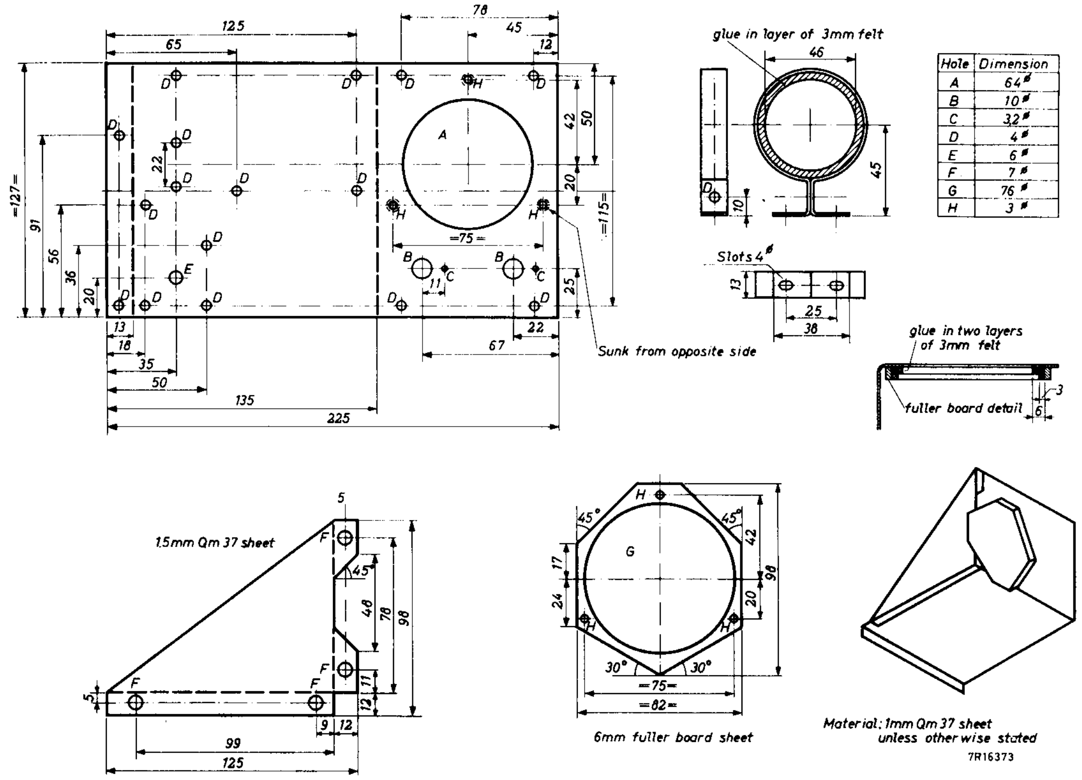


Fig.9. Cathode-ray tube, mechanical.
Note: Bend up at 90° at dotted lines unless otherwise stated.

3.2.2. *Layout*

Components C_6, R_{13} and R_{16} are mounted on the chassis itself. All other components are wired to terminal tag boards with the exception of the tube holder, connections to which are made by flying leads.

It is recommended that all fixed components be secured to the chassis before commencing the wiring, but the terminal tag board carrying resistors and capacitors should not be finally bolted down until those wires which are run under the board have been connected.

3.2.3. *Wiring*

This chassis is the simplest of all the units to wire, and no difficulty should be experienced in following the point-to-point wiring diagram (Fig. 7).

The following points, however, should receive special attention:

(1) Where screened wires are shown, either for incoming connections or for wiring between the terminal tag strip and the tube holder, the metallic screening sheaths must be earthed as indicated, by soldered connections to terminal 10 on tag strip *T1*. This terminal is earthed to chassis via one of the outer tags of the tag strip fixing bolts, and care must be taken that this makes a good electrical connection.

(2) One end of R_{12} is earthed to chassis via one of the outer tags of an intermediate tag strip, and a good electrical connection to chassis at this point through the fixing bolt is essential.

(3) All wires, including flying leads, should be kept as short as possible to minimise stray pick-up. In order to determine the lengths of the flying leads to the tube holder, it is advisable to fit the cathode-ray tube with its holder temporarily in its supports, and then cut each lead to length.

(4) The connections between contact *1* on the tube holder and terminal *2* on strip *T1*, and that between contact *12* on the tube holder and terminal *3* on strip *T1* should be twisted together in order to avoid inductive effects. These two leads should be colour-coded, say one red and one black, to prevent them being interchanged.

3.3. COMPONENTS LIST

The following is a check list of all parts required to build the cathode ray tube unit. The complete components lists will be found on page 35.

One chassis, 1 mm and 1.5 mm Qm 37 sheet, 6 mm fuller board sheet and 3 mm felt (see Fig.9),
one Type DG 7-31/01 cathode-ray tube,
one 10-way terminal tag strip,
one 6-way terminal tag strip,
one 2 x 5-way terminal tag board,
one mu-metal can for cathode-ray tube DG 7-31/01, type number 55530,
one tube holder for the DG 7-31/01, type number 5912/22,
two control knobs.

Resistors

R_{12} = 82 kΩ, 1 W, 20%
R_{13} = 100 kΩ, linear potentiometer, 10%
R_{14} = 22 kΩ, 1 W, 20%
R_{15} = 47 kΩ, 1 W, 20%
R_{16} = 50 kΩ, linear potentiometer, 10%
R_{21} = 100 kΩ, ½ W, 20%

Capacitors

C_6 = 2 μF, paper, 500 V d.c.
C_7 = 0.27 μF, polyester, 250 V d.c.

4

Vertical Amplifier

The amplifier for the vertical deflection voltage comprises a pentode voltage amplifier stage directly coupled to a double triode which supplies two antiphase outputs to the Y-plates of the cathode-ray tube.

The amplifier gives a linear response over the audio frequency range, and has a maximum sensitivity of 10 mV r.m.s. per cm of deflection at 1 kc/s.

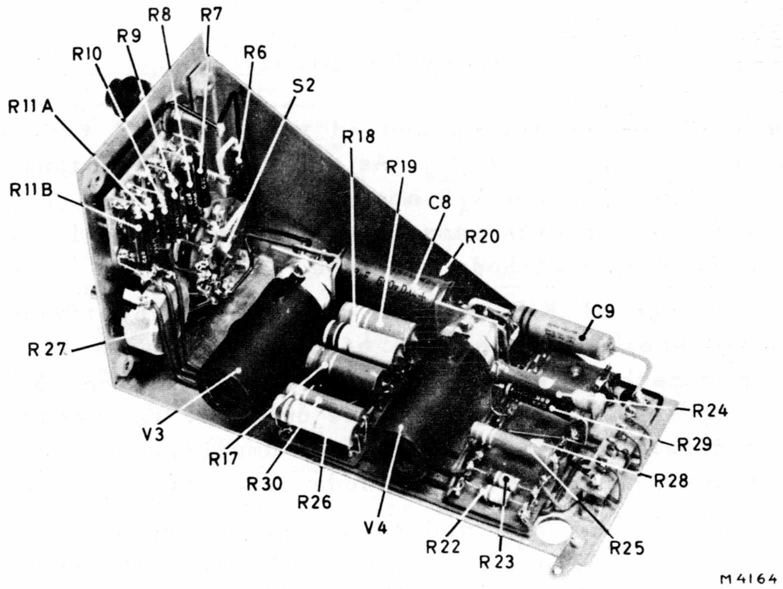
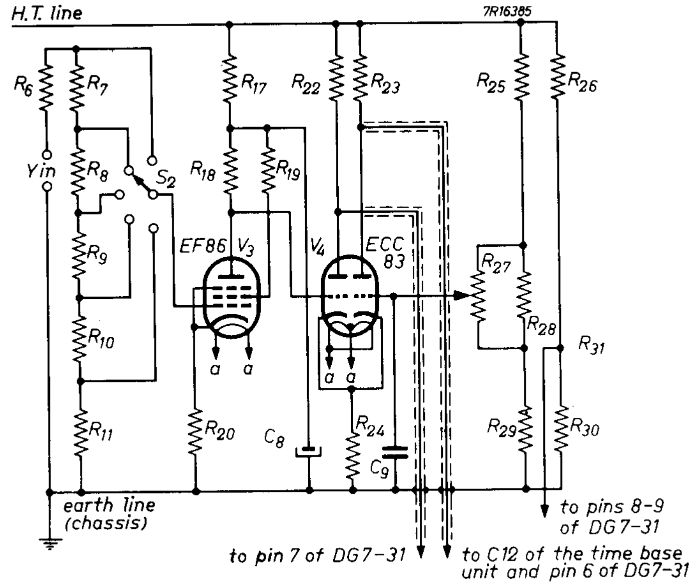


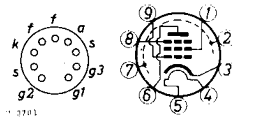
Fig.10. Vertical (Y) amplifier unit.

4.1. DESCRIPTION OF CIRCUIT

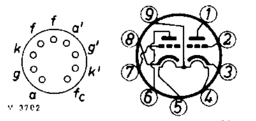
The circuit of the amplifier is shown in Fig.11. The input signal is applied to the grid circuit of the voltage amplifying pentode V_3, via a stepped attenuator system comprising the resistors R_6, R_7, R_8, R_9, R_{10} and R_{11}, thus giving a choice of five sensitivities, namely 10 mV, 100 mV, 1.0 V, 10 V and 100 V per centimetre of deflection, which can be selected by switch S_2. This system permits quantitative measurements to be made when using a calibrated graticule. If desired, however, the fixed-step attenuator can be replaced by the simpler variable potentiometer. In this case R_6 and R_{11} should be retained, and R_7, R_8, R_9 and R_{10} replaced by a logarithmic potentiometer of 1 MΩ.

The amplified signal voltage appearing at the anode of V_3 is applied directly to the grid of V_4A, the left-hand section of the double triode ECC 83 (V_4). The grid of V_4B, the right-hand triode section of V_4, is maintained at a pre-set positive potential equal to the positive potential at the grid of V_4A (and anode of V_3) via the voltage divider formed by R_{25}, R_{28}, R_{29} and R_{27}. Of these, R_{27} is a potentiometer for fine adjustment of the standing voltage at the grid of V_4B, and serves as the vertical (Y) shift control.





Base and electrode connections EF 86



Base and electrode connections ECC 83

Fig.11. Amplifier circuit.

The two cathodes of V_4 are connected together and thence to the chassis via a common resistor R_{24}. As a result, the output voltages from the anodes of V_4A and V_4B are in antiphase, and it is these two voltages which form the symmetrical deflection voltage applied to the Y plates of the cathode ray tube.

The output voltage of V_4B is also applied to the timebase generator circuit where a proportion of the voltage is used to synchronise the time base with the vertical deflection. The filter circuit R_{17}, C_8 serves to decouple the anode of V_3. Negative feedback is introduced in both stages of the amplifier by the emission of decoupling capacitors in the cathode circuits of V_3 and V_4.

Capacitor C_9 decouples R_{27} and thus ensures smooth operation of the Y-shift control. In order to reduce the risk of stray pick-up, the output connections from the anodes of V_4 consist of screened leads, the screening being earthed to chassis.

The heater of V_4 is centre-tapped, and the two halves can be connected in series and operated at 12.6 V (as in d.c./a.c. equipments) or in parallel and operated at 6.3 V. In this instrument, of course, the latter arrangement is adopted, for which purpose pins 4 and 5 are connected together as shown.

It should be noted that a tapping is taken from the junction of R_{26} and R_{30} to the final anode of the cathode-ray tube as explained in Section 3, "The Cathode Ray Tube Unit". The potential at this point also serves as the reference potential for the horizontal deflection plate D_2'.

4.2. ASSEMBLY

The layout of the components is illustrated in the photograph (Fig.10), and a point-to-point wiring diagram is given in Fig.13.

4.2.1. Chassis

Mechanical details of the chassis are given in Fig.12, which shows how the chassis is fabricated from two main members of Qm 37 sheet cut and bent to shape, and two small tube holder brackets of the same material.

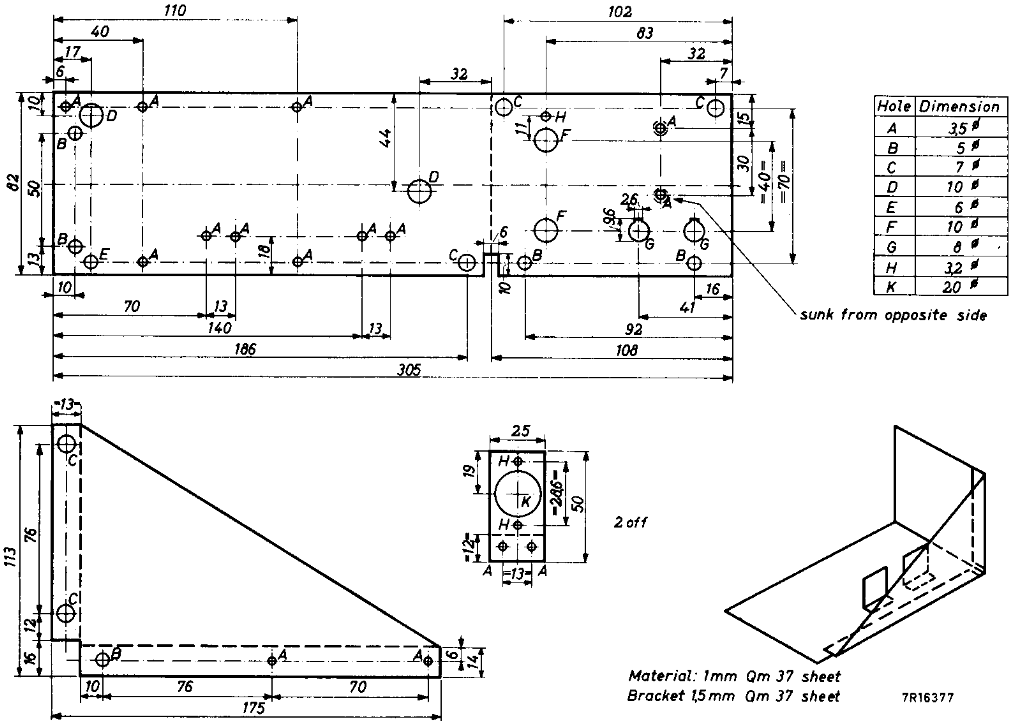


Fig.12. Amplifier, mechanical.
Note: Bend up 90° at all dotted lines.

4.2.2. *Layout*

As shown in Fig.13, most of the components are either mounted on the chassis or on terminal tag boards, only R_6 and C_9 being included in the run of wiring. Those points in the circuit from which connections have to be taken to other units are brought out to a terminal tag strip *T2*, with the exception of the heater circuit leads which are anchored to a pair of contacts on one of the tag boards.

As in the case of the other units, it is advisable to locate and secure the fixed components before commencing the actual wiring. However, in some cases, connecting wires pass under the tag boards, and these should not be finally secured until the chassis wiring is completed.

4.2.3. *Wiring*

Owing to the high sensitivity of the amplifier any stray signals picked up by the wiring of the first stage will appear, greatly

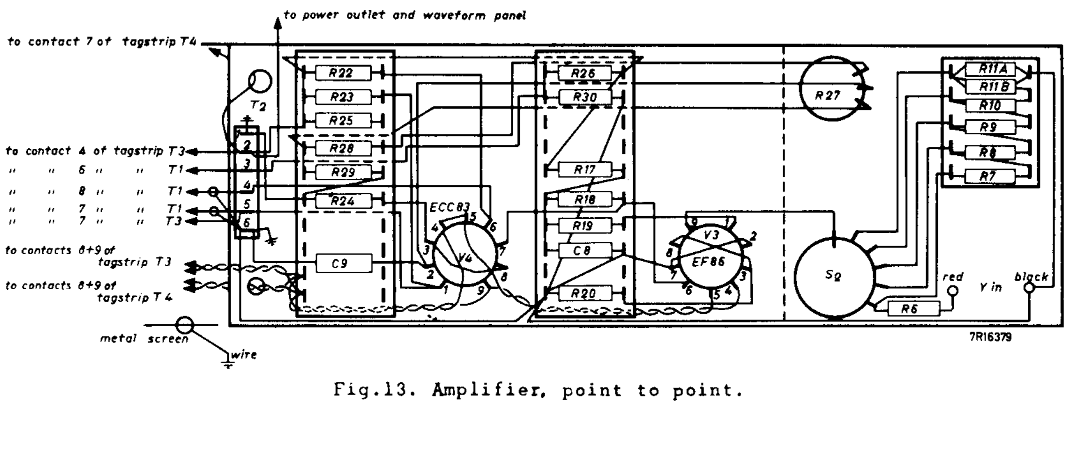


Fig.13. Amplifier, point to point.

magnified, in the output. It is therefore essential to keep the length of all wires in the grid circuit of V_3 to a minimum, and to locate the heater leads as far away from the grid connections as possible.

The contacts on the tube holders for V_3 and V_4 are numbered to correspond with the internal connections shown in Fig.13 which also gives the connections for the EF 86 pentode and the ECC 83 double triode, viewed from the underside of the tube holder.

Notes on Earthing

I) Where screened leads are indicated, these should be kept as short as possible and the screening must be earthed at both ends.

II) Terminals *1* and *6* of terminal tag strip *T2* are earthed to the chassis by the tag strip fixing bolts. These connections are part of the instrument circuit and must be *good electrical connections*. It should be noted that terminal *1* on the strip provides the earth connection for the earthy ends of R_{24} and R_{29}, while terminal *6* provides the earth connections for C_9, R_{20}, C_8, the screening of V_3, R_{11}, and R_{30} and also for the sheathing of the screened anode leads of V_4.

4.3. COMPONENTS LIST

The parts required for building the Y amplifier are given in the following list which forms a check list for use when collecting assembly. As mentioned elsewhere, a complete list of all the parts for the oscilloscope will be found at the back of this book.

One chassis, 1 mm Qm 37 sheet (see Fig.12),
two B9A ceramic tube holders, type number B 9 700 19,
one type EF 86 pentode,
one type ECC 83 double triode,
two tube screening cans, type number B 8 700 55,
two terminals, one black, one red, type number B 8 708 10/01,
three rubber grommets (10 mm, 10 mm, 6 mm),
one one-wafer, single-pole 5-way rotary switch,
two 2 x 10-terminal tag boards,
one 2 x 5-terminal tag board,
one 6-way terminal tag strip,
two control knobs.

RESISTORS

R_6	= 680 kΩ,	½ W,	± 5%
R_7	= 1 MΩ*,	½ W,	± 5%
R_8	= 100 kΩ*,	½ W,	± 5%
R_9	= 10 kΩ*,	½ W,	± 5%
R_{10}	= 1 kΩ*,	½ W,	± 5%
R_{11A}	= 220 Ω*,	½ W,	± 5%
R_{11B}	= 220 Ω*,	½ W,	± 5%
R_{17}	= 82 kΩ,	1 W,	± 20%
R_{18}	= 100 kΩ,	1 W,	± 10%
R_{19}	= 390 kΩ,	1 W,	± 10%
R_{20}	= 1.2 kΩ*,	1 W,	± 5%
R_{22}	= 180 kΩ,	½ W,	± 10%
R_{23}	= 180 kΩ,	1 W,	± 10%
R_{24}	= 68 kΩ*,	1 W,	± 10%
R_{25}	= 330 kΩ*,	1 W,	± 10%
R_{27}	= 200 kΩ,	linear potentiometer,	± 20%
R_{28}	= 22 kΩ,	½ W,	± 10%
R_{29}	= 68 kΩ,	½ W,	± 5%
R_{30}	= 330 kΩ,	1 W,	± 10%

CAPACITORS

C_8 = 8 μF, electrolytic, 500 V d.c.
C_9 = 0.1 μF, polyester, 400 V d.c.

NOTE

R_7, R_8, R_9 and R_{10} may be replaced by a single 1 MΩ logarithmic potentiometer if desired.

5

Timebase Generator Unit

The time base generator unit comprises two pentodes and their associated circuitry, one tube providing a voltage of sawtooth waveform and variable frequency and amplitude for application to the horizontal deflection system of the cathode-ray tube, and the other operating as a synchronising pulse amplifier. Other features of the unit are arrangements for beam suppression in the cathode-ray tube during the flyback period, and provision for using an external source of horizontal deflection voltage when desired; and for using the output of the internal time base generator in other equipment.

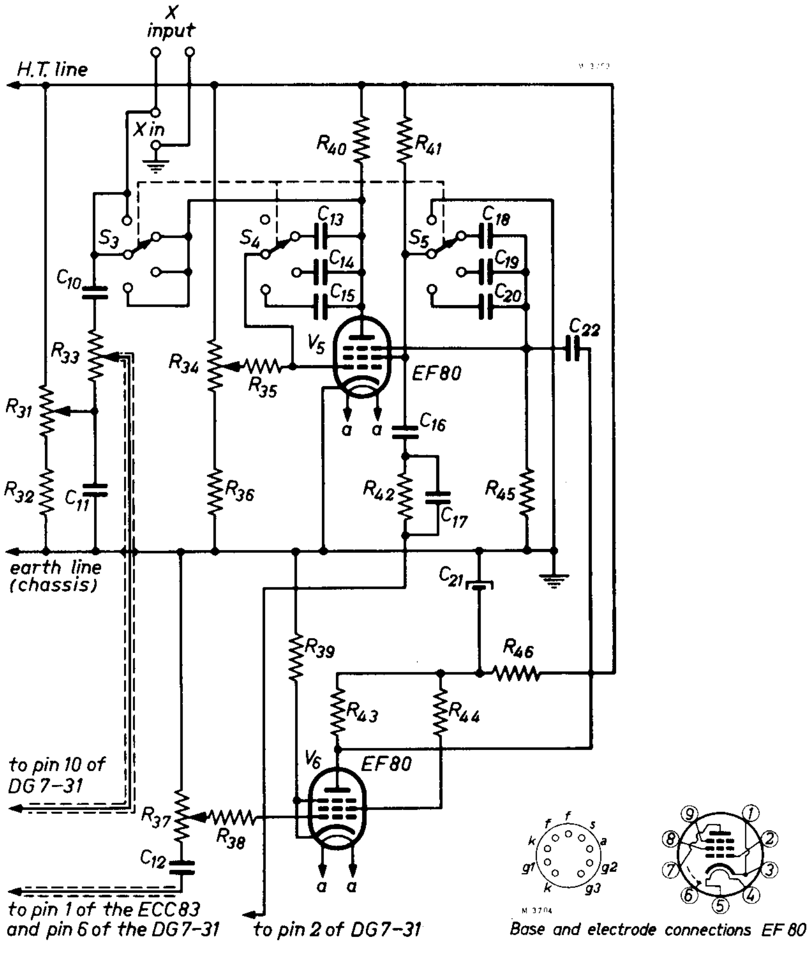


Fig.14. Timebase circuit.

5.1. DESCRIPTION OF CIRCUIT

The theoretical circuit is shown in Fig.14, from which it will be seen that the timebase generator, V_5 and its associated circuits, is an example of the miller transitron circuit.

5.1.1. Oscillator

In this arrangement, capacitor C_{13}, C_{14} or C_{15}, as selected by switch S_4; gives a choice of three frequency ranges, namely 13 c/s to 130 c/s; 125 c/s to 1.3 kc/s; or 1.25 kc/s to 20 kc/s. Resistor R_{34} provides fine adjustment of the frequency in each range.

Capacitor C_{18}, C_{19} or C_{20}, selected by switch S_5, determines, in conjunction with R_{45}, the shape of the sawtooth waveform.

5.1.2. Amplitude and X-shift Controls

The sawtooth output variations at the anode of V_5 are applied, via C_{10}, to a resistor-capacitor network comprising R_{33}, C_{11} R_{31} and R_{32}. Of these, R_{33} is the timebase amplitude control, while R_{31}, which supplies an adjustable direct voltage upon which the sawtooth voltage is superimposed, is the *X*-shift control.

5.1.3. Flyback Suppression

During the flyback period a strong voltage pulse is produced at the screen grid of the oscillator tube, V_5. This pulse is applied via the network C_{16}, R_{42} and C_{17} to the grid of the cathode-ray tube in such a sense that the beam is cut off and the trace therefore suppressed during the flyback.

5.1.4. Synchronisation

The signal applied by the *Y*-amplifier to one of the vertical deflection plates is also applied via C_{12} to the potentiometer R_{37} from which a part of the signal is taken to the control grid of the synchronising amplifier tube V_6. The anode of V_6 is connected via C_{22} to the suppressor grid of the oscillator tube V_5. The result is that the "run-down" of the sawtooth waveform is triggered off by the pulse reaching the screen grid of V_5 from the synchronising amplifier, that is to say by pulses derived from the input signal to the *Y* amplifier.

If, therefore, the frequency of the time base voltage is so adjusted that it is equal to, or a multiple or submultiple of, the frequency of the vertical voltage, and if the synchronising pulse amplitude control (R_{37}) is suitably adjusted, the time base voltage will be pulled into phase with the vertical deflection voltage, and synchronisation will be maintained.

5.1.5. External Time Base Connections

The coarse frequency control switch $S_{3,4,5}$, has a fourth position to which it should be turned when a horizontal deflection voltage from an external source is applied via terminals marked "*X IN*". The same terminals also serve as output terminals, when the local time base generator is used, to supply a sawtooth voltage to some other piece of apparatus In which case switch $S_{3,4,5}$ must be turned to the appropriate range.

5.1.6. Decoupling

To reduce the risk of positive feedback between the synchronising amplifier in the timebase unit and the vertical amplifier via the positive h.t. line, the anode and screen-grid supply to V_6 is decoupled by R_{46} and C_{21}.

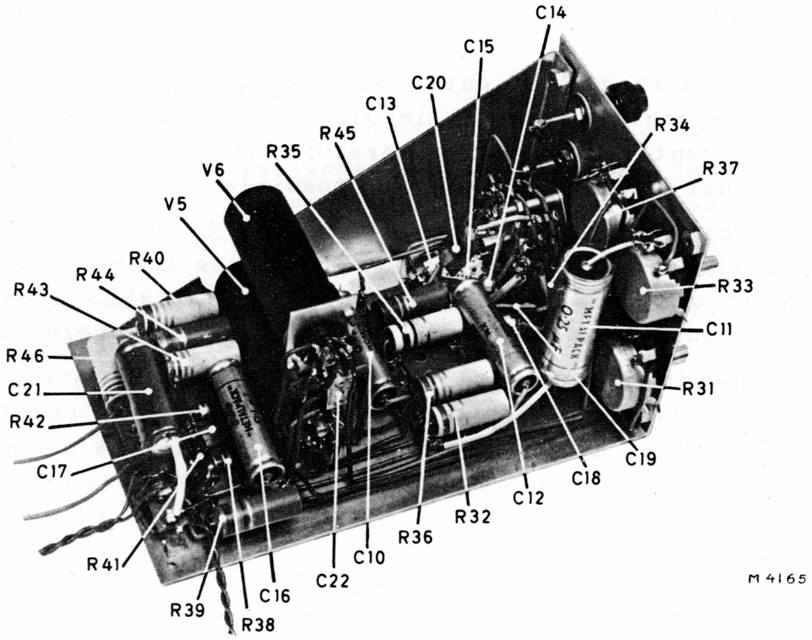


Fig.15. Timebase generator unit.

5.2. ASSEMBLY

The layout of the components is illustrated in the photograph (Fig.15) and the point-to-point wiring diagram is given in Fig.16.

5.2.1. Chassis

The mechanical drawing (Fig.17) shows how the chassis is fabricated from a main rectangular member and one side bracket of Qm 37 sheet cut and bent to shape. There is also a small bracket of the same material to accommodate the two tube holders and screening cans.

5.2.2. Layout

Figs 15 and 16 indicate that, with the exception of C_{11}, C_{13}, C_{14}, C_{15}, C_{18}, C_{19} and C_{20}, which are connected in the run of wiring, all the components are either mounted direct on the chassis or on terminal tag boards or strips.

The recommendation that all fixed components should be located and secured to the chassis before commencing wiring applies with particular force to the time base unit, which contains rather more components than the others, and in which the positions of some of the smaller components are somewhat critical.

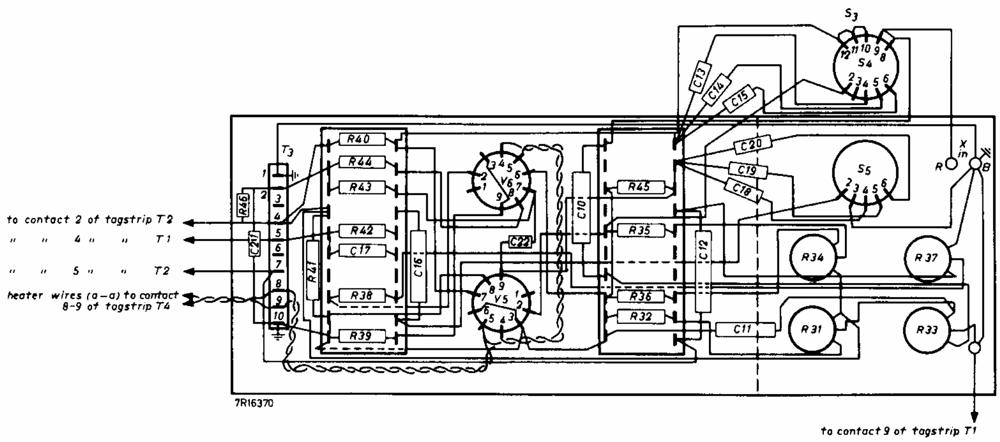


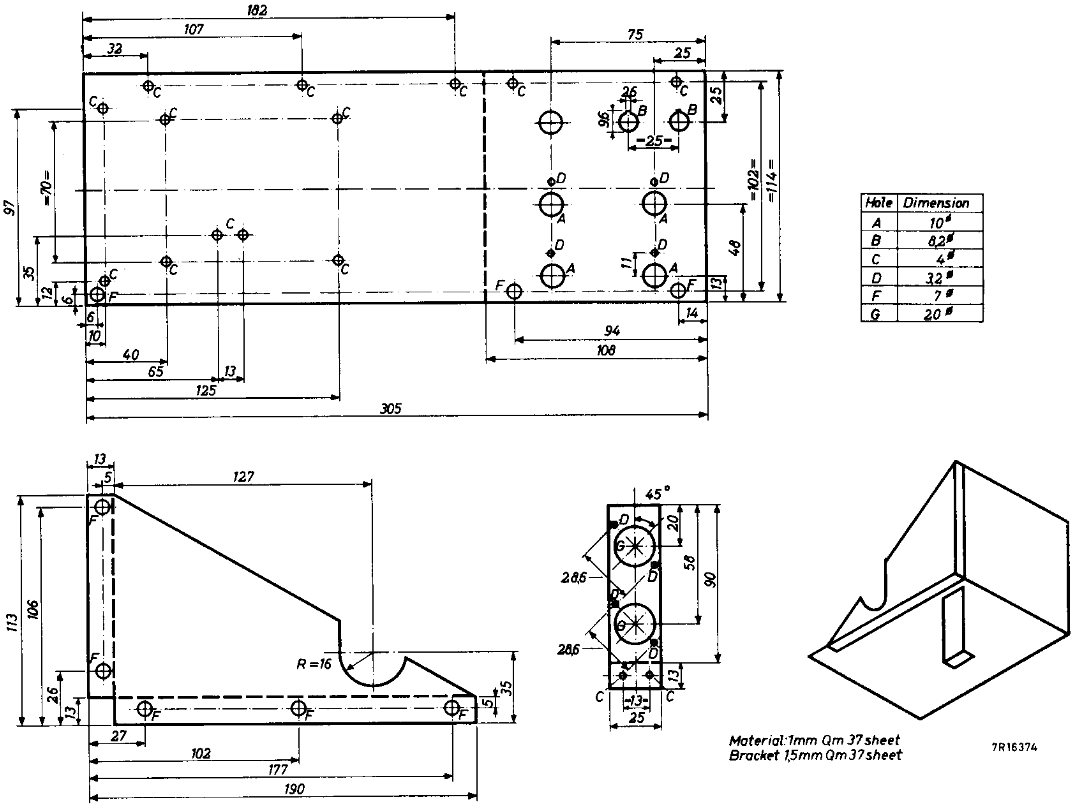
Fig.16. Timebase, point-to-point.

5.2.3. *Wiring*

The timebase unit is the one most likely to produce any stray signals which could seriously impair the performance of the completed instrument. Once again, therefore, it is stressed that every connection must be kept as short as possible.

The six capacitors wired to wafers S_4 and S_5 must not be allowed to lie parallel to each other or to any wires in the same part of the circuit; otherwise the stray capacitances thus produced may cause deterioration of the shape of the sawtooth waveform.

It is also important to note that the screened time base output lead from the slider of R_{33} must be taken direct to terminal 9 of tagstrip T1 on the cathode-ray tube unit. *It must on no account be allowed to pass near any part of the sensitive vertical amplifier circuit.*



Hole	Dimension
A	10 ø
B	8,2 ø
C	4 ø
D	3,2 ø
F	7 ø
G	20 ø

Fig.17. Timebase, mechanical

Note: bend down at 90° at all dotted lines, unless otherwise stated.

5.3. COMPONENTS LIST

The check list given below includes only the parts required for building the timebase unit. For a complete list of all the components of the oscilloscope see the pages 34 and 35 of this book.

One chassis, 1 mm and 1.5 mm Qm 37 sheet (see Fig.17),
two B9A ceramic tube holders, type number B 9 700 19,
two tube screening cans, type number B 8 700 55,
two type EF 80 tubes,
two terminals, one black, one red, type number B 8 708 10/01,
two 2 x 10-way terminal tag boards,
one 10-way terminal tag strip,
one two-wafer, three pole, four-way rotary switch,
five control knobs.

RESISTORS

R_{31}	= 250 kΩ,	linear potentiometer,	± 10%
R_{32}	= 180 kΩ,	1 W,	± 20%
R_{33}	= 2 MΩ,	linear potentiometer,	± 10%
R_{34}	= 2 MΩ,	logarithmic potentiometer,	± 10%
R_{35}	= 470 kΩ,	1 W,	± 20%
R_{36}	= 27 kΩ,	1 W,	± 10%
R_{37}	= 200 kΩ,	linear potentiometer,	± 10%
R_{38}	= 1 MΩ,	½ W,	± 20%
R_{39}	= 180 Ω,	1 W,	± 20%
R_{40}	= 68 kΩ,	1 W,	± 20%
R_{41}	= 56 kΩ,	6 W, wire-wound,	± 20%
R_{42}	= 1 MΩ,	½ W,	± 20%
R_{43}	= 22 kΩ,	1 W,	± 20%
R_{44}	= 82 kΩ,	1 W,	± 20%
R_{45}	= 270 kΩ,	1 W,	± 20%
R_{46}	= 22 kΩ,	1 W,	± 20%

CAPACITORS

C_{10}	= 0.1 μF,	polyester,	400 V d.c.
C_{11}	= 0.27 μF,	polyester,	400 V d.c.
C_{12}	= 0.1 μF,	paper,	600 V d.c.
C_{13}	= 6800 μF,	silver mica,	± 5 %
C_{14}	= 680 pF,	ceramic,	± 5 %
C_{15}	= 68 pF,	ceramic,	± 5 %
C_{16}	= 0.1 μF,	paper,	800 V d.c.
C_{17}	= 8.2 pF,	ceramic,	± 10 %
C_{18}	=22.000 pF,	polyester,	400 V d.c.
C_{19}	= 1800 pF,	silver mica,	± 5 %
C_{20}	= 180 pF,	ceramic,	± 5 %
C_{21}	= 8 μF,	electrolytic,	450 V d.c.
C_{22}	= 47 pF,	ceramic,	± 10 %

6

Power Outlet and Waveform Panel

This unit, which is mounted on the main front panel of the instrument, performs two functions. In the first place it permits both h.t. and l.t. supplies to be taken from the oscilloscope power pack for driving such auxiliary equipment as a low-power amplifier or a signal generator. The outputs thus available are 20 mA at 350 V d.c., and 0.6 A at 6.3 V a.c., 50 c/s.

Secondly, by means of five sockets marked *1* to *5*, various voltages and waveforms originating in the power pack are made available for application to the input of the vertical amplifier, so that the oscilloscope can be used to analyse its own power supply, thereby demonstrating the corresponding waveforms and the processes of half-wave rectification, smoothing, etc.

6.1. DESCRIPTION OF CIRCUIT

As can be seen from the master circuit reproduced in Fig.30, the positive and negative h.t. power output sockets are connected respectively to the h.t. positive line and to earth (chassis), while the l.t. is connected across the 6.3 V secondary of the power transformer which also supplies the heaters of tubes in the Y amplifier and timebase generator.

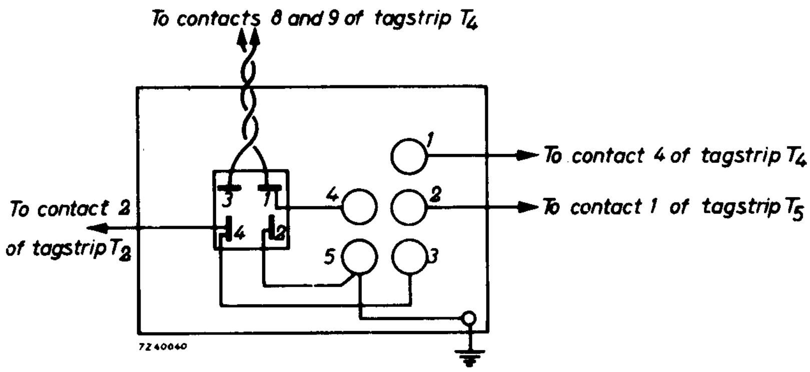


Fig.18. Power outlet and waveform panel, point-to-point.

Of the waveform sockets, No.5 is the common earth terminal. Connections between one or other of terminals *1* to *4* and terminal *5* provide the following voltages:

Between sockets *1* and *5*:

Voltage drop (approximately 1 V) across resistor R_1 in the anode circuit of V_1, and thus showing the effect of half-wave rectification.

Between sockets *2* and *5*:

The ripple voltage at the cathode of V_1, showing the effect of the reservoir capacitor C_2. It should be noted that the direct components of the voltage at this point is blocked by capacitor C_1 .

Between sockets 3 and 5:

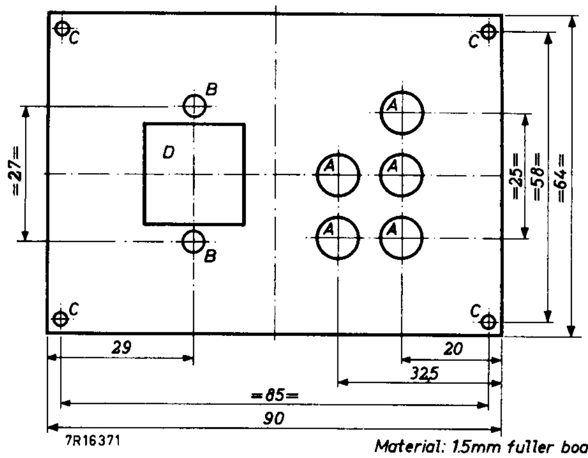
The potential at the positive h.t. line (350 V d.c.), showing the effect of the smoothing filter R_4, C_3.

Between sockets 4 and 5:

The voltage (3.15 V_{rms}) across one half of one of the 6.3 V secondaries of the power transformer.

6.2. ASSEMBLY

The connections between these sockets and the various sub-units of the oscilloscope are indicated in the point-to-point wiring diagram of Fig.18. A dimensioned drawing and drilling template for the fuller board panel on which are mounted one 4-pin non-reversible socket and five single sockets is given in Fig.19.



Hole	Dimension
A	8ø
B	4ø
C	3ø
D	20ø

Fig.19. Power outlet and waveform panel mechanical.

7

Final Assembly

When the various units have been assembled and wired, the whole should be mounted to form the complete oscilloscope. As suggested in an earlier section, there are several alternative arrangements. The one described in this section is the one adopted for the prototype instrument and has also been used in a number of oscilloscopes, some built for demonstration purposes and some actually constructed by students.

In this arrangement the various sub-chassis are bolted to a substantial mild steel front panel. After all the inter-connections between the units have been made and the complete instrument tested and found to work satisfactorily, the whole is mounted in a sheet steel case. Alternatively the case can be fabricated from perspex sheet, and the edges reinforced with metal angle-strips.

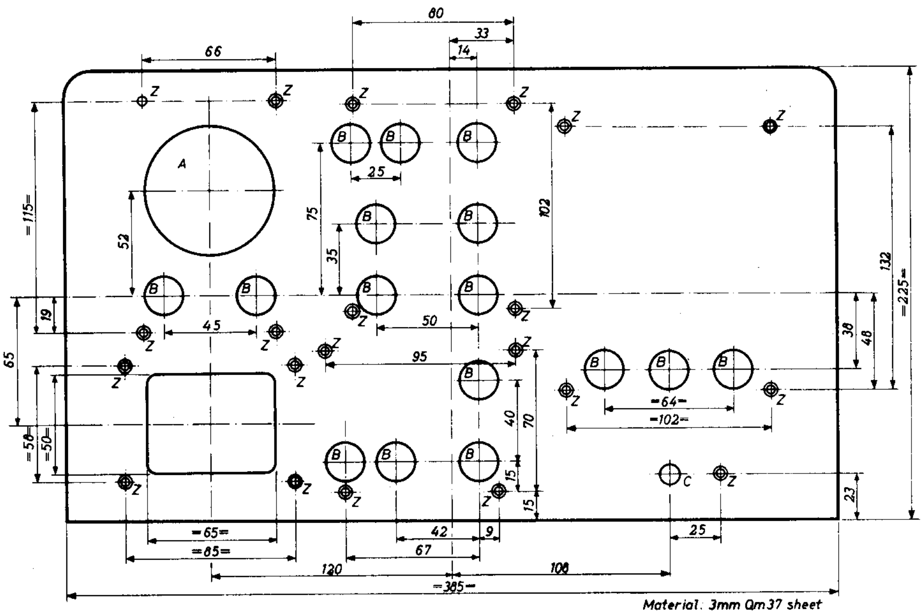
The photographs reproduced in Figs 1 and 21 show views of the complete instrument before and after being mounted in its case.

7.1. PANEL

A dimensional drawing for the sheet steel panel is given in Fig.20. The countersunk holes marked Z are the fixing holes for the various sub-units, all other holes being clearance holes through which project the terminals, control knobs, etc., already mounted on this units.

7.2. CONNECTIONS

The interconnections between the terminal tag strips of the various sub-units are indicated in the schematic diagram of Fig.22.



Hole	Dimension
A	64 ø
B	20 ø
C	10 ø
Z	4 ø

7R16375

Fig.20. Front panel layout, mechanical.

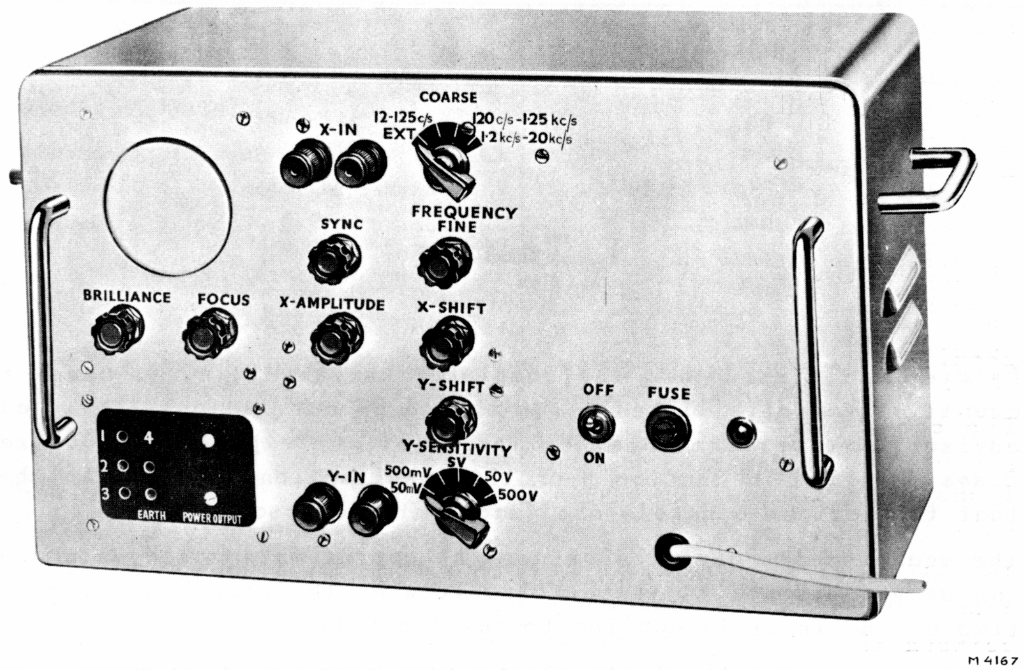


Fig.21. External view of oscilloscope.

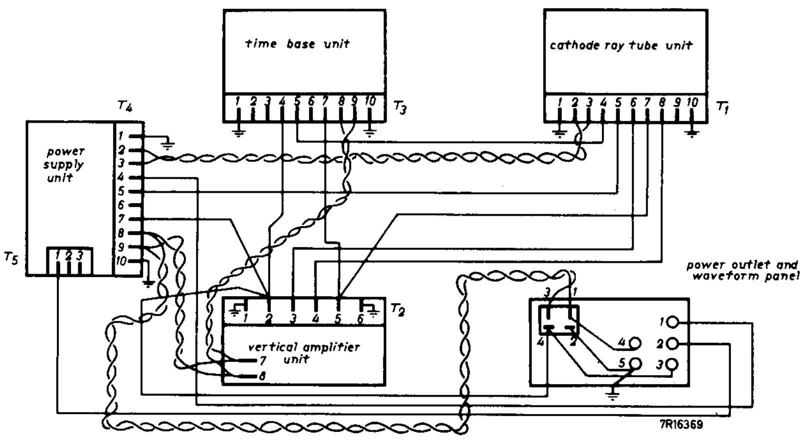


Fig.22. Schematic diagram showing inter-chassis connections (viewed from the rear).

Note that

- contact 9 of tagstrip T_3 is connected to contact 8 of T_2.
- contact 8 of T_4 is connected both to contact 7 of T_2 and to contact 3 of waveform panel.
- contact 2 of T_4 is connected to contact 3 of T_1.

8

Testing

Before finally mounting the complete instrument in its case, the quantitative tests listed below should be carried out. It is also advisable to perform some, at least, of the experiments or exercises detailed in Section 9 of this publication in order to check that the various controls are functioning correctly.

The measurements given below are the approximate voltages appearing at various points in the circuit when the time base is operating but *no input* is applied to the Y amplifier.

Before commencing the tests the primary winding of the mains transformer must be correctly connected to suit the voltage of the local 50 c/s mains supply. Instructions for this will be found in Section 9.

The coarse frequency control of the time base generator should now be set to any one of the three ranges (not to "*EXT*"), and the mains switch closed. In about a minute a horizontal luminuous trace corresponding to the timebase voltage should appear on the screen. After allowing about ten minutes to elapse from the time of switching on, the voltages between the pairs of points indicated in Column 1 of the Table below should be measured, and the readings should be in fair agreement with the values given in Column 2.

TEST MEASUREMENTS

Test Points	Approximate Readings
POWER SUPPLY UNIT	
Contacts 2 and 3 of tagstrip T_4	6.3 V a.c.
Contact 4 of tagstrip T_4 and chassis	1 V a.c.
Contact 5 of tagstrip T_4 and chassis	-300 V d.c.
Contact 7 of tagstrip T_4 and chassis	+380 V d.c.
Contacts 8 and 9 of tagstrip T_4	6.3 V a.c.
VERTICAL AMPLIFIER	
Contact 2 of tagstrip T_2 and chassis	+380 V d.c.
Contact 3 of tagstrip T_2 and chassis	+240 V d.c.
Contact 4 of tagstrip T_2 and chassis	+160 V to +290 V d.c. according to setting of Y shift control.
Contact 5 of tagstrip T_2 and chassis	+140 V to +280 V d.c. according to setting of Y shift control.

continued on opposite page

Test Points	Approximate Readings
TIME BASE UNIT	
Contact 2 of tagstrip T_3 and chassis	+250 V d.c.
Contact 4 of tagstrip T_3 and chassis	+370 V d.c.
Contact 5 of tagstrip T_3 and chassis	-200 V to -260 V d.c. according to setting of brilliance control.
Contact 7 of tagstrip T_3 and chassis	+140 V to +280 V d.c. according to setting of Y shift control.
Contacts 8 and 9 of tagstrip T_3	6.3 V a.c.
C.R.T. UNIT	
Contacts 2 and 3 of tagstrip T_1	*6.3 V a.c.
Contact 4 of tagstrip T_1 and chassis	-200 V to -260 V d.c. according to setting of brilliance control.
Contact 5 of tagstrip T_1 and chassis	-300 V d.c.
Contact 6 of tagstrip T_1 and chassis	+240 V d.c.
Contact 7 of tagstrip T_1 and chassis	+140 V to +280 V d.c. according to setting of Y shift control.
Contact 8 of tagstrip T_1 and chassis	+160 V to +290 V d.c. according to setting of Y shift control.
Contact 9 of tagstrip T_1 and chassis	+ 50 V to +370 V d.c. according to setting of X shift control and X amp control
Pin 4 C.R.T. and chassis	- 100 V to - 190 V d.c. according to setting of focus control.

* *Care should be taken when making this measurement as these tags are at a potential of -260 V with respect to chassis.*

9

Instructions, Exercises and Experiments

The following pages provide general instructions for setting up and operating the oscilloscope, followed by a series of graduated exercises and experiments designed to give the student practice in connecting up and using the instrument, to demonstrate the effects of the various controls and adjustments, and to provide examples of a few typical traces.

9.1. GENERAL INSTRUCTIONS

Mains Supply

This oscilloscope is designed for operation on a 50 c/s supply at voltages between 200 and 250 V. Before putting the instrument into service, connections to the primary tappings of the mains transformer must be made in accordance with the following table:

Supply voltage	*Primary connections*
200 V	tags 0 and 200
210 V	tags 10 and 200
220 V	tags 0 and 220
230 V	tags 10 and 220
240 V	tags 0 and 240
250 V	tags 10 and 240

Caution

The cathode-ray tube must never be operated continuously with the spot stationary, as this may cause local burning of the screen and destroy its luminescent properties. Either the *X* or the *Y* or both deflection systems should therefore be operated by periodic voltages. If, however, a particular experiment involves a stationary spot, a switch must be included in the input circuit and the signal applied only during the short time required for making the observation.

AMPLITUDE CONTROLS

Before switching on the mains supply, the *Y* amplifier should be adjusted for *minimum* sensitivity (500 V range) and the timebase amplitude control to about mid-position. Both controls can be subsequently adjusted to give a trace of convenient size and proportions.

FOCUS ADJUSTMENT

To adjust the focus, switch on the instrument with the timebase running (i.e., with the coarse frequency control switched to one of the three ranges and *not* to "*EXT*"). Turn *focus* control until the horizontal trace gives the most sharply defined line.

BRIGHTNESS CONTROL

To adjust the brightness of the trace, switch on the instrument with the timebase running as in the previous paragraph, thus giving a horizontal trace. turn *brightness* control knob to the lowest setting which gives a trace of adequate brightness. This adjustment is not constant, and depends upon the tracing speed at which the light spot travels over the surface of the screen, and this, in turn, is governed by the amplitudes and frequencies of the deflecting voltages. It may therefore be necessary to reset the brightness control for different demonstrations or investigations.

WARMING-UP TIME

In addition to the normal warming-up time of the tube and tube cathodes, a matter of minutes only, at the expiration of which a trace should be visible on the screen, it takes a further period for all the components - resistors, transformer windings, etc. - to settle down to the steady temperature which represents balance between heat generation and heat dissipation. In order to ensure constant readings, therefore, a period of at least ten minutes should be allowed to elapse after switching on before taking quantitative observations.

9.2. EXERCISES AND EXPERIMENTS

The following demonstrations can be performed with the minimum amount of additional apparatus and serve to indicate the capabilities of the instrument and to give practice in its use. As indicated in the final paragraph, availability of a signal generator or oscillator enables the number of experiments to be extended almost indefinitely.

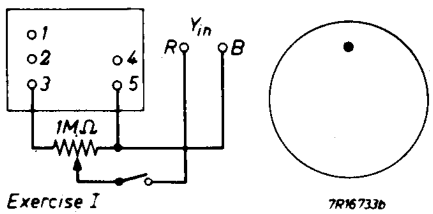


Fig.23.

Exercise 1 - Demonstration of vertical deflection

Setting-up, see Fig.23

(*a*) Switch timebase coarse adjustment to "*EXT*" (no deflecting voltage applied to *X* plates).
(*b*) Set *Y* sensitivity (attenuator) to 500 V range.
(c) Connect a 1 MΩ potentiometer between sockets *3* and *5* of waveform panel (350 V d.c.)
(*d*) Connect slider of potentiometer via a switch to *red Y* input terminal and lower end of potentiometer to *black Y* input terminal.
(e) Switch on mains.

Observations

(*a*) Note variation of vertical deflection of spot as potentiometer is adjusted.
(*b*) Adjust potentiometer to give a small deflection, and then reset *Y* sensitivity to 50 V range. Note increased deflection.
(c) Adjust potentiometer to give a convenient deflection, and then operate the *Y* shift control. Note change of position of light spot.

Exercise 2 - Demonstration of vertical deflection due to a continuously varying deflecting voltage

Setting-up, see Fig. 24

(*a*) Switch timebase coarse adjustment to *"EXT"* (no deflecting voltage applied to *X* plates).
(*b*) Set *Y* sensitivity control to 5 V range.
(*c*) Connect terminals *4* and *5* of waveform panel (3.15 V, 50 c/s) to *red* and *black* *Y* input terminals respectively.
(*d*) Switch on mains.

Observations

(*a*) Note that the trace is a vertical line, representing twice the amplitude of the voltage sine wave, i. e. the peak-to-peak value of the voltage.
(*b*) Operate *Y* shift control and note that the trace is shifted bodily upwards or downwards.
(*c*) Note the effect upon the sharpness of the trace when the focus control is adjusted.

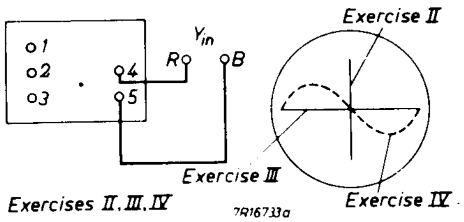


Fig. 24.

Exercise 3 - Demonstration of horizontal deflection due to a continuously varying deflecting voltage

Setting up

(*a*) Set timebase coarse frequency control to the 12-125 c/s range.
(*b*) Apply no input to *"Y IN"* terminals.
(*c*) Switch on mains.

Observations

(*a*) Note that the trace is a horizontal line, the length of which can be varied by adjusting the *X* amplitude control.
(*b*) Adjust the *X* shift control, and note that the horizontal trace is shifted bodily to the right or to the left.
(*c*) Increase the timebase frequency gradually to the maximum of 20 kc/s and note the reduction in the brightness of the trace as the writing speed is increased. Readjust brightness by means of the brightness control,

Exercise 4 - Demonstration of a sine wave

Setting-up, see Fig. 24

(*a*) Connect sockets *4* and *5* on the waveform panel (3.15 V, 50 c/s) to *red* and *black* *Y* input terminals respectively.
(*b*) Set timebase coarse frequency control to the 12-125 c/s range.
(*c*) Set *Y* sensitivity control to 5 V range.
(*d*) Switch on mains.

Observations

(*a*) Note that a complex pattern of waves appears and moves across the luminescent screen.

(*b*) Adjust the fine frequency control of the timebase until one complete sine wave appears on the screen and moves slowly across the screen. The timebase is now running at the frequency of the *Y* input signal, i.e., 50 c/s.
(*c*) Adjust synchronising control until the trace is held steady. The timebase is now not only running at the same frequency as the *Y*-input, but is also locked in synchronism with it.
(*d*) Adjust the fine frequency control until two complete sine waves appear on the screen. The timebase frequency is now half that of the *Y* input signal, i.e., the timebase is running at 25 c/s.
(*e*) Note the effects of adjusting the *X* amplitude and the *X* and *Y* shift controls.

Exercise 5 - Demonstration of half-wave rectification

Setting-up, see Fig.25

(*a*) Connect sockets *1* and *5* of the waveform panel to red and black *Y* input terminals respectively.
(*b*) Set *Y* sensitivity control to the 500 mV range.
(*c*) Set timebase coarse frequency control to 12-125 c/s range.
(*d*) Switch on mains.

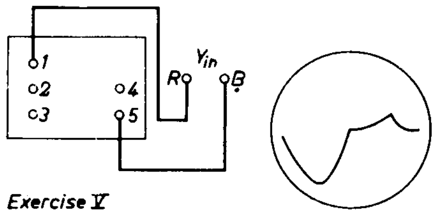


Fig.25.

Observations

(*a*) Adjust timebase fine frequency control until a trace corresponding to one complete cycle at 50 c/s appears on the screen. As shown in Fig.25 the trace consists of a conductive half cycle corresponding to conduction of V_1, and a non-conductive half cycle.

Note. The conductive half cycle represents the voltage drop (approx. 1.0 V) resulting from the flow of the anode current of V_1 through resistor R_1. The "blip" appearing during the non conductive half cycle of V_1 is the voltage drop across R_1 caused by the small anode current (approximately 1 mA) of V_2. R_1 being common to the anode circuits of both tubes.

(*b*) Re-adjust frequency of timebase to 25 c/s so that two complete cycles are shown on the screen.
(*c*) Note the effects of varying the timebase amplitude and of adjusting the *X* and *Y* shift controls.

Exercise 6 - Demonstration of effect of reservoir capacitor

Setting up, see Fig.26

(*a*) Connect sockets *2* and *5* to the red and black *Y* input terminals respectively.
(*b*) Set *Y* amplifier to 5 V range.
(*c*) Set timebase coarse frequency control to the 12-125 c/s range.
(*d*) Switch on mains.

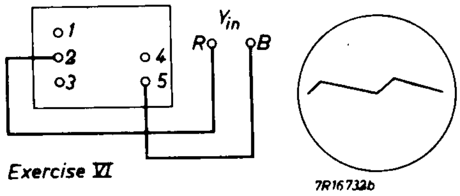


Fig.26.

Observations

Adjust timebase frequency to 25 c/s so that two complete cycles of approximately sawtooth waveform appear on the screen, and adjust synchronising control until the trace is held steady. The waveform shown is the ripple component of the output of V_1 prior to smoothing by the filter circuit R_4. C_3.

Exercise 7 - Demonstration of the effect of the smoothing network on the H.T. supply.

Setting-up, see Fig.27

(*a*) Connect sockets *3* and *5* (smoothed h.t. voltage of 350 V) to red and black *Y* input terminals respectively.
(*b*) Set *Y* sensitivity control to the 500 V range.
(*c*) Switch on mains.
(*d*) Adjust timebase frequency to 25 c/s as before.

Observations

Note substantially constant amplitude of the high tension voltage.

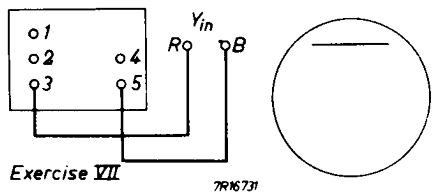


Fig.27.

Exercise 8 - Demonstration of the effect of applying sinusoidal voltages of equal frequency and in phase simultaneously to the vertical and horizontal deflecting systems

Setting-up, see Fig.28

(*a*) Transformer *T* is a standard mains transformer with a centre-tapped secondary winding giving 250-0-250 V. This transformer is also used for Exercises 9 and 10 and will be found to be a most useful component for other experiments and demonstrations.
(*b*) Connect two potentiometers of 1 MΩ in parallel across one of the 250 V halves of the transformer secondary.

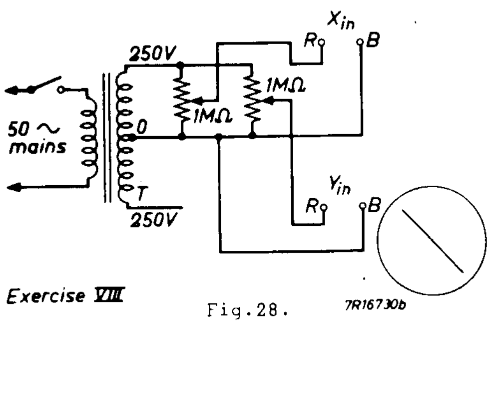


Fig.28.

(c) Connect the slider of one potentiometer to the red *Y* input terminal and the lower end of the same potentiometer to the black *Y* input terminal.
(d) Set *Y* sensitivity control to the 500 V range.
(e) Connect the slider of the second potentiometer to the red *X* input terminal, and the lower end of the same potentiometer to the black *X* input terminal.
(f) Set coarse timebase frequency control to "*EXT*".
(g) Switch on mains.

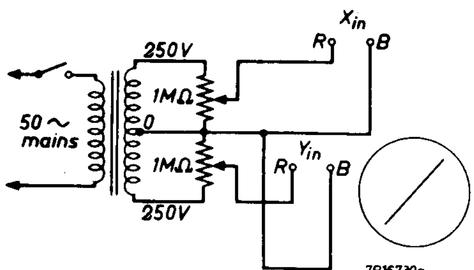
Observations

(a) Note that the trace is a straight sloping line.
(b) Vary the adjustments of the two potentiometers, and note that the slope of the trace depends upon the relative amplitudes of the two deflecting voltages.

Exercise 9 - Demonstration of the effect of two sinusoidal deflection voltages of equal frequency but of opposite phase (180° out of phase)

Setting-up, see Fig.29

(a) Connect one 1 MΩ potentiometer across each of the two halves of the transformer secondary winding.
(b) Connect the slider of one potentiometer to the red *Y* input terminal and the mid-point of the transformer secondary to the black *Y* input terminal.
(c) Set *Y* sensitivity control to the 500 V range.
(d) Connect the slider of the second potentiometer to the red *X* input terminal, and the mid-point of the transformer secondary to the black *X* input terminal.
(e) Set the coarse timebase frequency control to "*EXT*".
(f) Switch on mains.



Exercise IX

Fig.29.

Observations

(a) Note that the trace is again a straight sloping line but that it now has a reverse slope.
(b) Vary the adjustments of the two potentiometers, and note that the slope of the line depends upon the relative amplitudes of the two deflecting voltages.

Exercise 10 - Demonstration of complex waveforms

Setting up

(a) Connect a microphone to the *Y* input terminals of the oscilloscope.
(b) Set *Y* sensitivity control to the 5 V range, and coarse time base frequency control to, say, the 125 c/s to 1.25 kc/s range.
(c) Switch on mains.

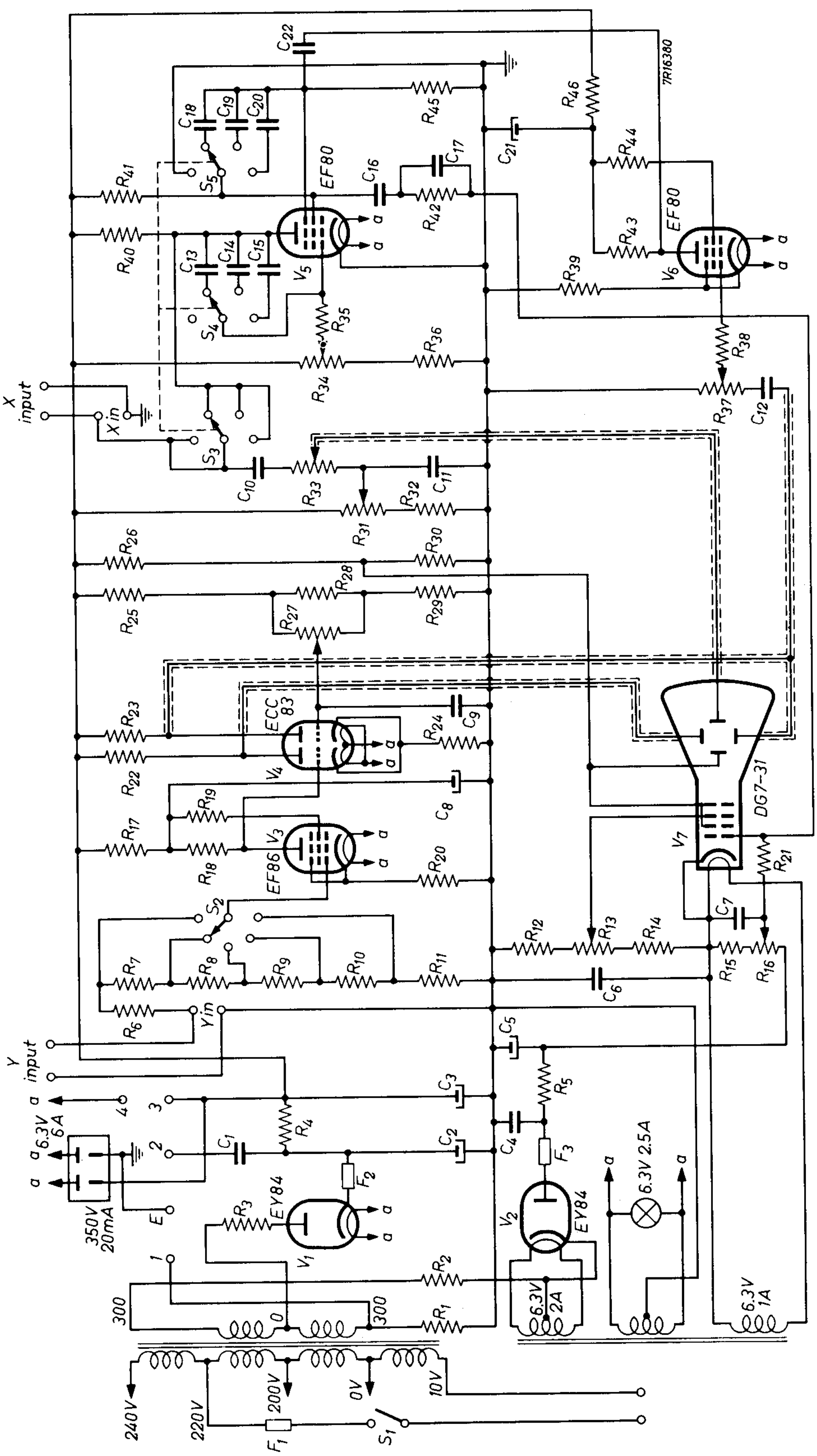


Fig.30 Main circuit diagram.

RESISTORS

R_1	= 10 Ω,	6 W wire wound		83541 B 10 E
R_2	= 47 Ω,	6 W wire wound		83541 B 47 E
R_3	= 68 Ω,	6 W wire wound		83541 B 68 E
R_4	= 1 kΩ,	1 W	10 %	B 8 305 07 A/1 K
R_5	= 220 kΩ,	1 W	10 %	B 8 305 07 A/220K
R_6	= 680 kΩ,	½ W	5 %	B 8 305 06 B/680K
R_7	= 1 MΩ,	½ W	5 %	B 8 305 06 B/1 M
R_8	= 100 kΩ,	½ W	5 %	B 8 305 06 B/100K
R_9	= 10 kΩ,	½ W	5 %	B 8 305 06 B/10K
R_{10}	= 1 kΩ,	½ W	5 %	B 8 305 06 B/1 K
R_{11}	= 220 Ω,	½ W	5 %	B 8 305 06 B/220E
	220 Ω,	½ W	5 %	B 8 305 06 B/220E
R_{12}	= 82 kΩ,	1 W	10 %	B 8 305 07 A/82K
R_{13}	= 100 kΩ,	linear pot.	10 %	E 098 CG/60 C 08
R_{14}	= 22 kΩ,	1 W	10 %	B 8 305 07 A/22K
R_{15}	= 47 kΩ,	1 W	10 %	B 8 305 07 A/47K
R_{16}	= 50 kΩ,	linear pot.	10 %	E 098 CG/60 C 06
R_{17}	= 82 kΩ,	1 W	10 %	B 8 305 07 A/82K
R_{18}	= 100 kΩ,	1 W	10 %	B 8 305 07 A/100K
R_{19}	= 390 kΩ,	1 W	10 %	B 8 305 07 A/390K
R_{20}	= 1.2 kΩ,	1 W	5 %	B 8 305 07 B/1K2
R_{21}	= 100 kΩ,	½ W	10 %	B 8 305 06 A/100K
R_{22}	= 180 kΩ,	½ W	10 %	B 8 305 06 A/180K
R_{23}	= 180 kΩ,	½ W	10 %	B 8 305 06 A/180K
R_{24}	= 68 kΩ,	1 W	10 %	B 8 305 07 A/68K
R_{25}	= 330 kΩ,	1 W	10 %	B 8 305 07 A/330K
R_{26}	= 120 kΩ,	1 W	10 %	B 8 305 07 A/120K
R_{27}	= 200 kΩ,	linear pot.	10 %	E 098 CG/60 C 10
R_{28}	= 22 kΩ,	½ W	10 %	B 8 305 06 A/22K
R_{29}	= 68 kΩ,	½ W	5 %	B 8 305 06 B/68K
R_{30}	= 330 kΩ,	1 W	10 %	B 8 305 07 A/330K
R_{31}	= 200 kΩ,	linear pot.	10 %	E 098 CG/60 C 10
R_{32}	= 180 kΩ,	1 W	10 %	B 8 305 07 A/180K
R_{33}	= 2 MΩ,	linear pot.	10 %	E 098 CG/60 C 18
R_{34}	= 2 MΩ,	log.pot.	10 %	E 098 CG/60 C 19
R_{35}	= 470 kΩ,	1 W	10 %	B 8 305 07 A/470K
R_{36}	= 27 kΩ,	1 W	10 %	B 8 305 07 A/27K
R_{37}	= 200 kΩ,	linear pot.	10 %	E 098 CG/60 C 10
R_{38}	= 1 MΩ,	½ W	10 %	B 8 305 06 A/1 M
R_{39}	= 180 Ω,	1 W	10 %	B 8 305 07 A/180E
R_{40}	= 68 kΩ,	1 W	10 %	B 8 305 07 A/68K
R_{41}	= 56 kΩ,	8 W wire wound		83541 A/56 E
R_{42}	= 1 MΩ,	½ W	10 %	B 8 305 06 A/1 M
R_{43}	= 22 kΩ,	1 W	10 %	B 8 305 07 A/22K
R_{44}	= 82 kΩ,	1 W	10 %	B 8 305 07 A/82K
R_{45}	= 270 kΩ,	1 W	10 %	B 8 305 07 A/270K
R_{46}	= 22 kΩ,	1 W	10 %	B 8 305 07 A/22K

CAPACITORS

C_1	= 0.1 μF,	400 V	polyester	C 296 AC/A 100 K
C_2, C_3	= 32+32 μF,	400 V	electrolytic	AC 5309/32+32
C_4	= 0.1 μF,	1 kV	paper	C 101 AD/A 100 K
C_5	= 8 μF,	400 V	electrolytic	AC 8109/8
C_6	= 2 μF,	500 V	paper	82280 A/E 2 M
C_7	= 0.27 μF,	250 V	polyester	C 296 AC/A 270 K
C_8	= 8 μF,	400 V	electrolytic	AC 8109/8
C_9	= 0.1 μF,	400 V	polyester	C 296 AC/A 100 K
C_{10}	= 0.1 μF,	400 V	polyester	C 296 AC/A 100 K
C_{11}	= 0.27 μF,	400 V	polyester	C 296 AC/A 270 K
C_{12}	= 0.1 μF,	600 V	paper	5326 P/100 K
C_{13}	= 6800 pF,	5 %	silver mica	82058 B/6 K 8
C_{14}	= 680 pF,	5 %	ceramic	C 304 AH/B 680 E
C_{15}	= 68 pF,	5 %	ceramic	C 304 AB/A 68E
C_{16}	= 0.1 μF,	800 V	paper	5828 P/100 K
C_{17}	= 8.2 pF,	10 %	ceramic	C 304 AB/L 8 E 2
C_{18}	=22.000 pF,	10 %	400 V pol.	C 296 AC/A 22 K
C_{19}	= 1800 pF,	5 %	silver mica	82058 B/1 K 8
C_{20}	= 180 pF,	5 %	ceramic	C 304 AC/B 180 E
C_{21}	= 8 μF,	400 V	electrolytic	AC 8109/8
C_{22}	= 47 pF,	10 %	ceramic	C 304 AB/A 47 E

MAINS TRANSFORMER

Primary	10-0-200-220-240 V
Secondary	300-0-300 V, 120 mA
	3.15-0-3.15 V, 2 A
	3.15-0-3.15 V, 2.5 A
	6.3 V, 1 A

TUBES

V_1 = EY 84
V_2 = EY 84
V_3 = EF 86
V_4 = ECC 83
V_5 = EF 80
V_6 = EF 80
V_7 = DG 7-31/01

Observations

(*a*) When the horizontal timebase trace has appeared, excite the microphone by means of a tuning fork, and note the waveform corresponding to the note produced.

(*b*) It will be necessary to adjust the two timebase frequency controls to the fundamental frequency of the tuning fork, when the departure of the waveform from a true sine wave will be visible.

(*c*) Repeat the experiment with a flute, a violin, the human voice, etc., as sources of sound, making any necessary adjustments to the timebase frequency and the *Y* sensitivity control to give the best display of the waveform. Note that while a flute gives a reasonably pure sine wave, other sources produce complex waves due to the inclusion of overtones.

CONCLUSION

The number of experiments and demonstrations which can be performed is limited only by the ancillary apparatus available. For example, a network whereby a variable phase shift can be introduced between two sinusoidal inputs of equal frequency would greatly increase the scope of Exercise 9, while the availability of a signal generator such as a beat frequency oscillator or a simple transistor oscillator would enable sinusoidal voltages of different frequencies to be applied to the two deflecting systems and thus demonstrate the formation of Lissajous figures.

Printed in Holland

20/836/D/E-1-'60