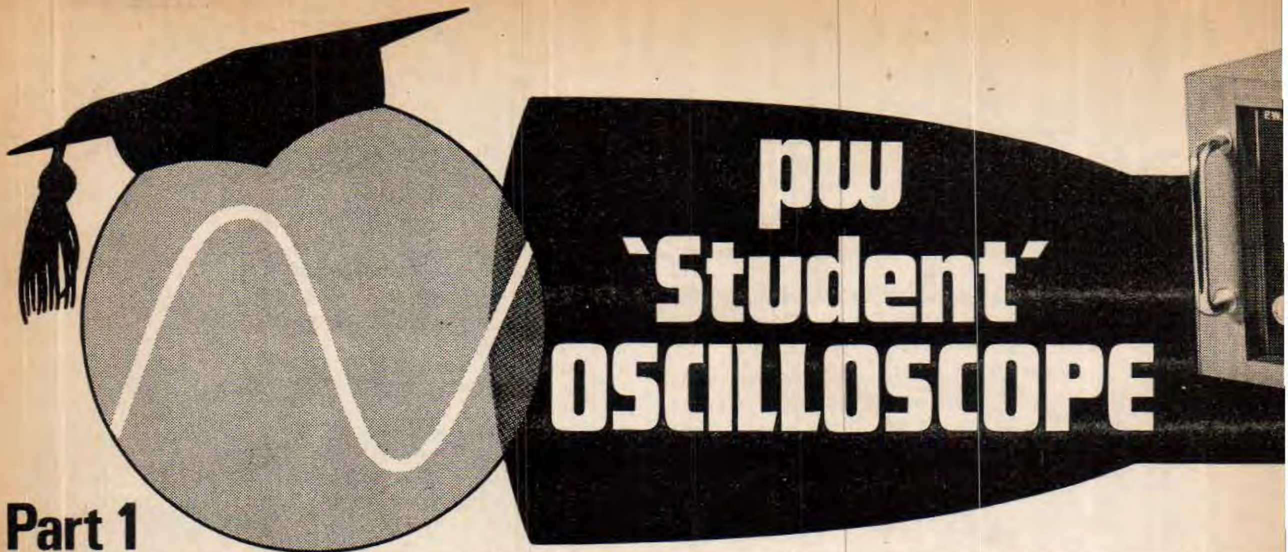


PW 'Student' OSCILLOSCOPE

Part 1

SIMPLE TO BUILD • INEXPENSIVE • ONE

IT occurred to the writer that many readers, being 'brought up' on transistors, would not have had the opportunity to learn about the oscilloscope from the 'bottom up' and that a basic transistorised design, with modern construction methods, would be welcomed.

An oscilloscope should be a substantial piece of equipment, and in view of the high voltages employed (700V for the e.h.t. and 300V for the deflection amplifiers) it must be emphasised that the rather solid nature of the model is deliberate.

Another feature is the simplification of the controls on the front panel, these being; brilliance, focus, Y attenuation (Y amp), Y shift, timebase coarse control in 6 ranges, timebase fine control (fine), timebase amplitude (X amp), and sync on/off.

There is a Y input socket and an external timebase input socket.

The writer has noticed that it is usually necessary to attenuate the input signal rather than amplify it, and with transistorised equipment the signal which is being examined can be dealt with quite effectively by an attenuator of the 'volume control' type. This makes it necessary to turn the Y attenuator down to zero before connecting a signal to the Y input socket but once this habit has been formed, the simplification of having just one continuously variable gain control with a d.c. amplifier is evident. The d.c. amplifier is necessary to maintain a good low frequency response, especially with square wave signals.

The Cathode Ray Tube

The cathode ray tube (c.r.t.) itself is a form of valve, having a heater and a cathode, a control grid and anode—which must be at a high positive potential (e.h.t.) with respect to the cathode.

For a 3in. c.r.t. the e.h.t. should be of the order of 900/1000V.

Between the control grid and the final anode are the first and focusing anodes. There are also two pairs of deflection plates, one pair—the Y plates—for vertical deflection, and the other pair—the X plates—for horizontal deflection. The deflection plates are usually operated in push-pull and with 1000 volts across the c.r.t. the push-pull voltage swing needs to be about 150V. This makes it necessary to have a 300V supply to the deflection amplifiers and the deflection transistors must be able to withstand this voltage.

The design utilises the 3BP1, c.r.t. which has a heater requirement of 6·3V at 0·6A. The c.r.t. has a 14 pin base with a locating spigot and the base connector should be obtained (if possible) when purchasing the c.r.t.

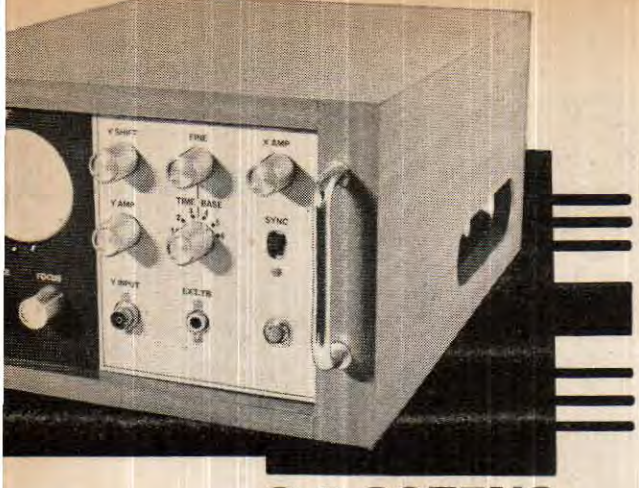
The tube gives a green trace of medium short persistence and a useful trace height is 5cms. The c.r.t. is approximately 10 inches in length including the base.

Cathode ray tubes are sensitive to stray magnetic fields, such as those produced by mains transformers, and even when a mu-metal shield is utilised to screen the c.r.t., transformers on the same chassis usually cause some interference to the spot. Mu-metal shields are quite expensive (when available).

In the present design, the mains transformers are fitted on a separate chassis, connected together by a multiway lead. By using this method, the problem of interference from the mains transformers was eliminated.

The Y (Vertical) Amplifier

The input to the Y amplifier is through a 'volume control' type attenuator VR1, and it is taken directly to the base of Tr1, which with Tr2 forms a boot-



G.A.COZENS

ASSEMBLY BOARD

strapped amplifier with an input impedance of about 1mΩ. If the reader wishes, a $0 \cdot 1 \mu F$ capacitor (Cx) can be inserted in the lead from the slider of VR1 to the base of Tr1, with a shorting switch across it, to give a.c./d.c. facilities, but it must be pointed out that this is a sensitive part of the circuit, and all leads must be kept as short as possible to avoid stray pick up.

The output from the signal amplifier is passed through a resistor network to the long tailed pair which form the vertical deflection amplifier Tr3 and Tr4. This stage performs two functions:

1. To give two outputs which are 180° out of phase and supply the push-pull voltages to the vertical deflection plates.

2. To provide a voltage swing of 150V at each deflection plate.

When the base of Tr3 goes positive its collector goes negative. That is, the signal is inverted at Tr3 collector.

Also Tr3 emitter goes positive. This means that Tr4 emitter goes positive. The base bias of Tr4 is held at a fixed level by the bias network VR2 R15. As the potential difference between Tr4 base and emitter is decreasing the base of Tr4 is in effect going negative.

This causes the collector of Tr4 to move in a positive direction, which is the same as the original signal at Tr3 base. Thus Tr3 collector is the inverting output and Tr4 collector is the non inverting output.

The network R7, R8, R9 is designed to bias the base of Tr3 and prevent overloading, and the base bias of Tr4 is made variable to balance with Tr3 base and centre the trace on the screen. VR2 is therefore the Y shift. C2 by-passes any a.c. signals present at Tr4 base.

The collectors of Tr3 and Tr4 are connected directly to the Y plates. The values of the collector resistors were chosen by trial to balance the collector outputs, and the emitter resistors R11 and R14, and the coupling resistor R12, which controls the gain of the stage, may also be altered to match the transistors. When the trace is centred and no signal is present the collector voltages shoud be 180V. The maximum height of the Y trace when using a 100mV input signal (VR1 at maximum) is 3cms.

SPECIFICATION

Y Signal

Input via co-axial lead
Attenuator continuously variable
Input Impedance 1MΩ
Sensitivity on full gain 100mV r.m.s. gives trace height of 3cms p. to p.
Bandwidth d.c. to 1MHz.
Useful trace height 5cms.

X Deflection

Sensitivity on external timebase 100mV r.m.s. gives trace width of 1cm p. to p.
Useful trace width 5 cms.
Timebase in 6 ranges.
Range;
1. 10—100Hz
2. 32—170Hz
3. 150—550Hz
4. 520Hz—3·5·kHz
5. 3·0—20kHz
6. 6·0—40kHz

Controls

Front Panel

Brilliance	*Y gain*
Focus	*Y shift*
Timebase fine frequency	*X Signal*
Timebase range (course)	*X Signal*
Timebase amplitude	*X Signal*
Sync on/off	

Side of Chassis

X linearity	*Astigmatism*
X shift	

The Timebase Generator and X Amplifier

The timebase waveform generator Tr7 is a unijunction transistor (TIS43) with Tr6 acting as a constant current device to regulate the charging of the timing capacitors (C5, C6, C7, C8, C9 and C10) and to give a linear rise time.

The fine frequency control (VR3) should be wirewound and it should be possible to steady the trace at any part of the frequency range without using synchronisation. There is some loss of amplitude on the upper timebase range.

The sawtooth signal is taken from the emitter of Tr7 to the base of Tr8, via a closed circuit jack JK1 and a $0 \cdot 1 \mu F$ capacitor C12. The output signal from Tr8 collector is fed via capacitor C13 to the timebase amplitude control VR4.

The horizontal deflection amplifiers Tr9 and Tr10 are a long tailed pair with a common emitter resistor R31. Bias for Tr9 is by potentiometer network R28 R29 and as in the Y amplifier, the base bias of the second transistor Tr10 is made variable to act as a shift control to centre the trace on the c.r.t. screen. C17 by-passes any a.c. signals and stabilises the trace.

Synchronising

The purpose of synchronisation is to lock the time-base frequency to the Y signal and so hold a given number of complete waveforms steady on the screen.

The Y signal is taken from the emitter of Tr3 and is passed via C4 to the base of Tr5. Tr5 is driven hard by the Y signal and this produces a square wave at the collector of Tr5.

C3 and R16 form a pulse shaper and the diode D1 passes the positive going pulse to b2 of the uni-junction sawtooth generator Tr7.

The d.c. potential to b2 is stabilised by the zener diode D2. R24, C11 and the decoupling resistor R23 all contribute to improved synchronisation of the timebase.

The Power Supplies

Five a.c. supplies are required from the mains transformers, they are:

1. 6·3V at 0·6A for the c.r.t. heater (T2)
2. 250V at 2mA for the e.h.t. multiplier circuit (T2)
3. 15 to 22V at 500mA for the low voltage line (T3)
4. 250V at 50mA for the high voltage 300V d.c. line (T1)
5. 6·3V 0·6A for indicator lamps (T1)

The leads from the oscilloscope chassis are taken to the transformer subchassis and terminate in a multiway plug. It is suggested that constructors utilise a 10 way Jones plug and socket, for the inter-connection.

★ components list

Resistors

R1	4·7kΩ	R25	10MΩ
R2	2·2kΩ	R26	12kΩ
R3	47kΩ	R27	12kΩ
R4	100Ω	R28	3·3MΩ
R5	8·2kΩ	R29	18kΩ
R6	1kΩ	R30	47kΩ 1W
R7	8·2kΩ	R31	120Ω
R8	2·2kΩ	R32	47kΩ 1W
R9	1·8kΩ	R33	3·3MΩ
R10	68kΩ	R34	2·2MΩ
R11	390Ω	R35	2·2MΩ
R12	56Ω	R36	10kΩ 1W
R13	82kΩ	R37	10kΩ 1W
R14	470Ω	R38	1·2kΩ 1W
R15	5·6kΩ	R39	390Ω 1W
R16	1MΩ	R40	1·2kΩ 1W
R17	22kΩ	R41	1·2kΩ 1W
R18	1·5MΩ	R42	390kΩ 1W
R19	10kΩ	R43	8·2kΩ
R20	82kΩ	R44	1MΩ
R21	8·2kΩ	R45	680kΩ
R22	47Ω	R46	100kΩ
R23	470Ω	R47	100kΩ
R24	680Ω		

All ± 10% ½W carbon except where stated otherwise.

Transistors:
- Tr1, Tr2, Tr5, Tr8 BC109
- Tr3, Tr4, Tr9, Tr10 MJE340
- Tr6 ASY26
- Tr7 TIS43

Diodes:
- D1 1N4148 or 1N914
- D4, D5, D6 1N5054 or PL4007
- D7, D8 400 p.i.v. 1A
- D2 12V 1W
- D3 18V 1W

Transformers:
- T1, T2 Primary 200–250V 50Hz
  Sec. 250V 60mA, 6·3V 2A
- T3 Primary 200–250 50Hz
  Sec. 18V 1·25A

Capacitors:
- C1 100μF elect 25V
- C2 0·47μF 250V
- C3 0·1μF
- C4 0·022μF
- C5 0·68μF
- C6 0·1μF
- C7 0·02μF
- C8 0·005μF
- C9 0·001μF
- C10 0·0005μF
- C11 100μF elect 25V
- C12 0·1μF
- C13 100μF elect 25V
- C14 100μF elect 25V
- C15, C16, C17 0·47μF 250V
- C18, C19, C24 50μF + 50μF + 50μF elect 350V
- C20, C26 32μF + 32μF elect 350V
- C21, C22 500μF elect 25V
- C23, C25 250μF elect 50V
- C27, C28, C29, C30 0·47μF 1000V
- Cx see text

Potentiometers:
- VR1 2MΩ carbon
- VR2 2·5kΩ w.w. linear
- VR3 50kΩ w.w. linear
- VR4 25kΩ w.w. linear
- VR5 25kΩ w.w. linear
- VR6 250kΩ carbon
- VR7 250kΩ carbon
- VR8 250kΩ carbon
- VR9 50kΩ carbon

(VR6–VR9: good quality well insulated)

CRT: 3BP1

Switches:
- S1 2 pole c/o slide
- S2 1 or 2 pole 6 way rotary. Only 1 pole used
- S3 On/off mains toggle switch
- JK1 Closed circuit p.o. type jack

Miscellaneous:
Veroboard, 0·15in matrix 3¾ins. x 17ins. Veropins. 2, 4, 6BA screws, nuts, washers and spacers, panel lamps, coaxial sockets, systoflex, cleats, grommets, chipboard, laminated plastic sheet, 4 instrument handles, 8 rubber feet, aluminium for metalwork.

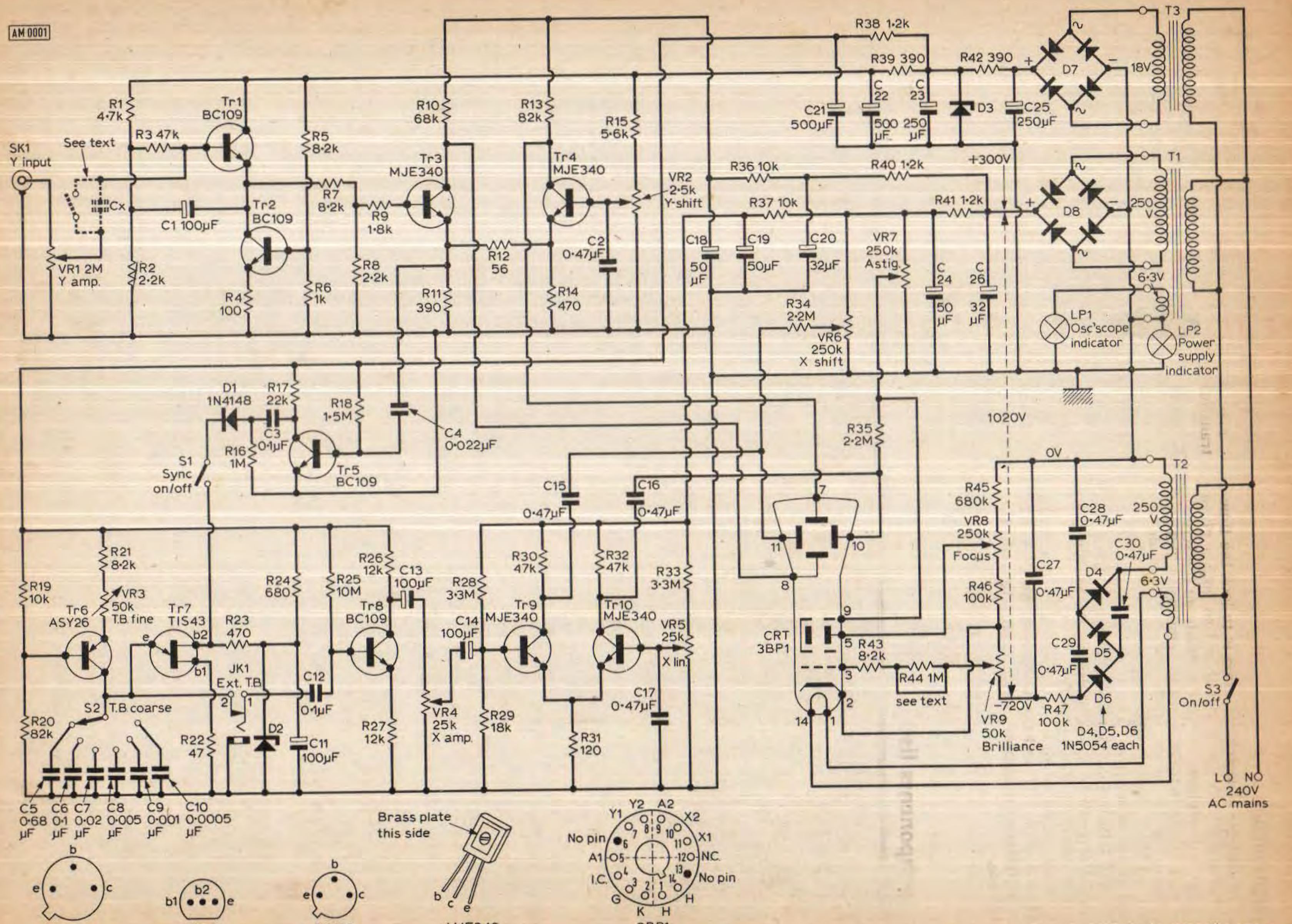


Fig. 1 : Complete circuit of the **P.W. Student Oscilloscope.**

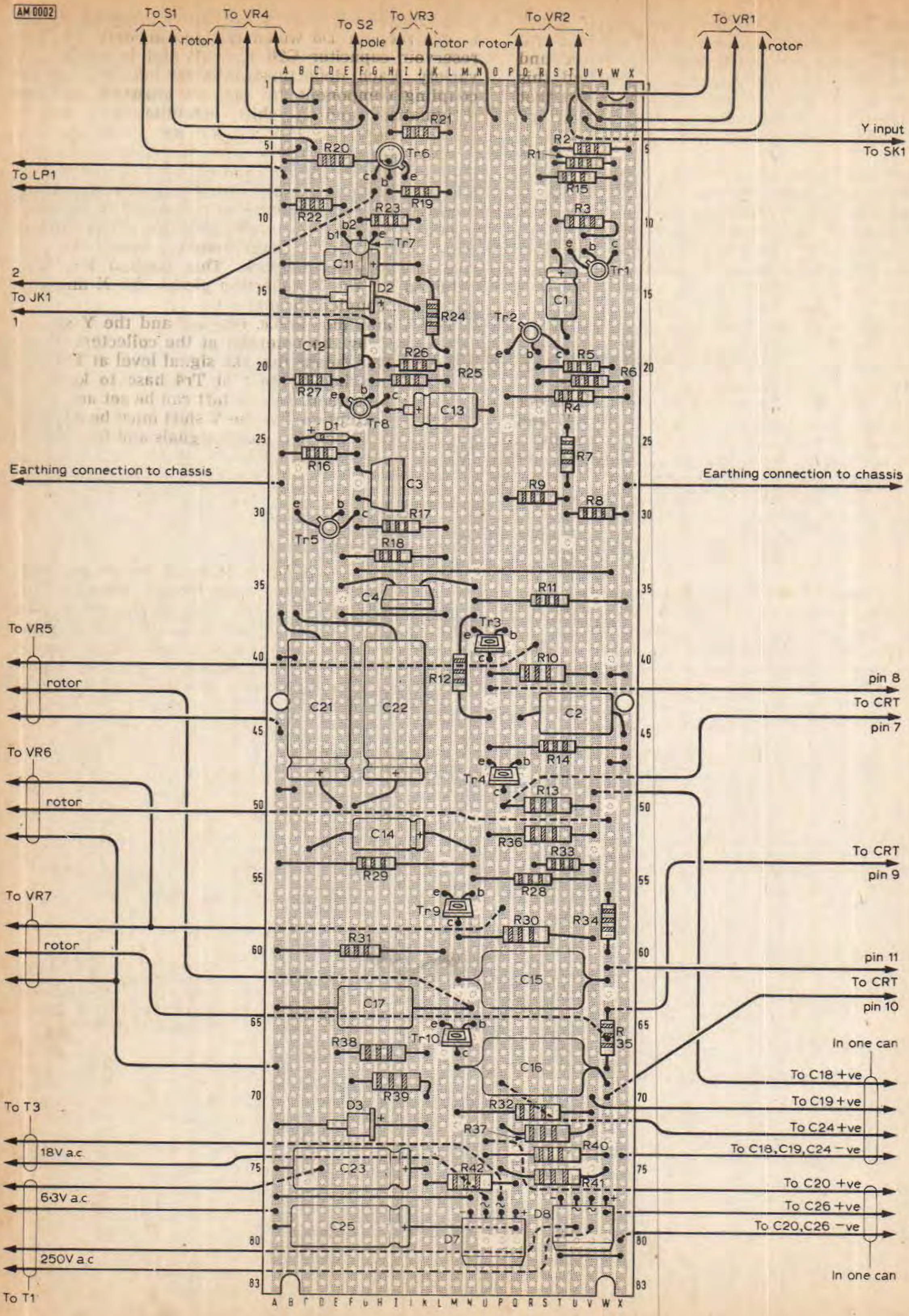


Fig. 2: The complete Veroboard layout for the oscilloscope.

The tube heater winding must withstand 1000V to the chassis. If the insulation breaks down it will put the whole e.h.t. voltage between heater and cathode of the c.r.t. The writer has not had this fault occur on any standard mains transformers that he has used. Well insulated twin flex of the type used for mains wiring is suitable for the c.r.t. heater leads.

Three rectifier diodes are used in the e.h.t. multiplier circuit. Although this type of circuit suffers from poor regulation, in this case, where the current required is only about 1mA it is quite stable.

The capacitors C28, C29 C30 help to maintain good regulation. The diodes are arranged to give a negative output, the positive end of the chain is at earth potential.

The circuit is so arranged that the 700V e.h.t. supply and the 300V line are in series. Therefore the voltage across the c.r.t. from the grid to the final anode, is equal to the sum of the two voltages.

The c.r.t. resistance network acts as a bleeder across the e.h.t. and the smoothing resistor R47 and the network should be fitted before the circuit is tested. It will limit the e.h.t. voltage and prevent possible damage to the smoothing capacitor C27.

The 1MΩ resistor R44 may be included in the circuit if flyback blanking is to be added later. Because of the unusual layout of the e.h.t. multiplier circuit extra care must be taken in layout and wiring.

The low voltage line is supplied from transformer T3 which gives an output of between 15 and 22 volts, the bridge rectifier being rated at 400V p.i.v. at 1A and the reservoir and smoothing capacitors at 50V. The smoothing resistor R42 has a value of 390Ω and the zener diode D3 stabilises the line at 18V. The Y amplifier and the timebase circuit have separate smoothing components to reduce inter-action.

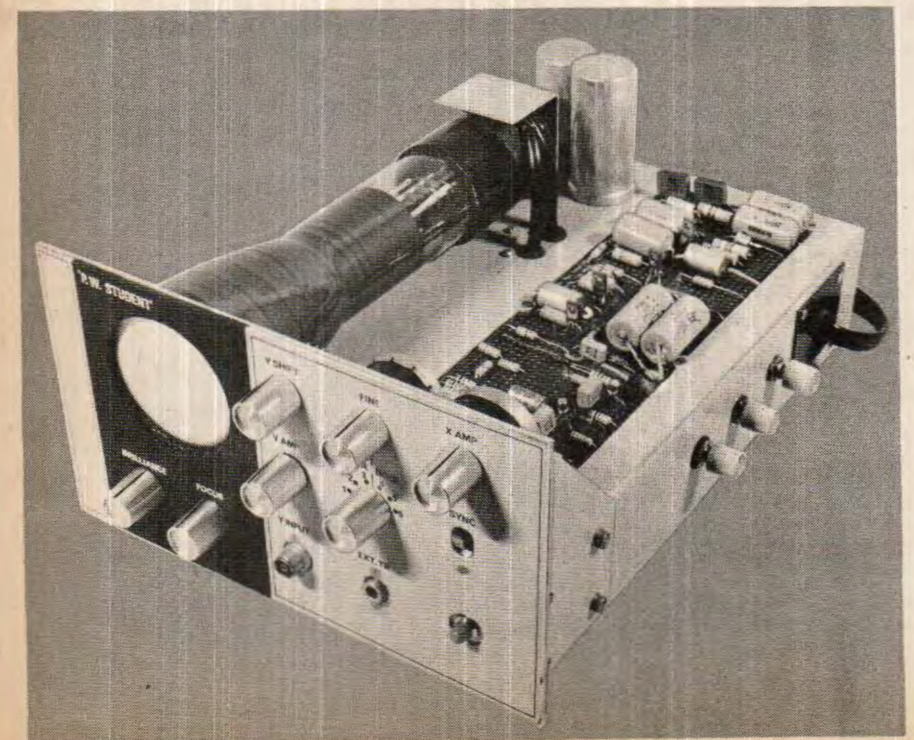
The high voltage 300V d.c. line is supplied by the bridge rectifier D8 which is rated at 400V 1A. The reservoir capacitor C26 is 32μF and is of the can variety. Each deflection amplifier has its own decoupling components to prevent crosstalk and the astigmatism and X shift potentiometers are in parallel across the 300V d.c. line and act as bleeders.

When the writer commenced his experiments with this oscilloscope, the method used for X and Y shift was similar to that employed in valved instruments, where the deflection plates were coupled to the valve anodes through capacitors and the shift voltages were determined by potentiometers across the positive end of the network. This method has been retained for the X deflection plates, the X amplifier being a.c. coupled throughout.

The Y amplifier is d.c. coupled and the Y shift is determined by the potential at the collectors of Tr3 and Tr4. This means that the signal level at Tr3 base must be matched by that at Tr4 base to keep the trace on the screen. The X shift can be set and needs no further attention, but the Y shift must be adjusted for positive or negative going signals and for changes in amplitude.

The Veroboard Panel

The Veroboard panel is 24 holes (or strips) wide and 83 holes long. This is cut from a standard 17in. x 3¾in. Veroboard panel. The matrix is 0·15in. When working on the panel it is essential to make all joints with the minimum of solder. Where flexible leads are taken to components on the Veroboard, Veropins or the wire ends of components already attached to the copper strips should be used as anchoring points.



Photograph showing the completed oscilloscope. The three controls on the right hand side of the chassis are X linearity, X shift and astigmatism.

—to be continued—