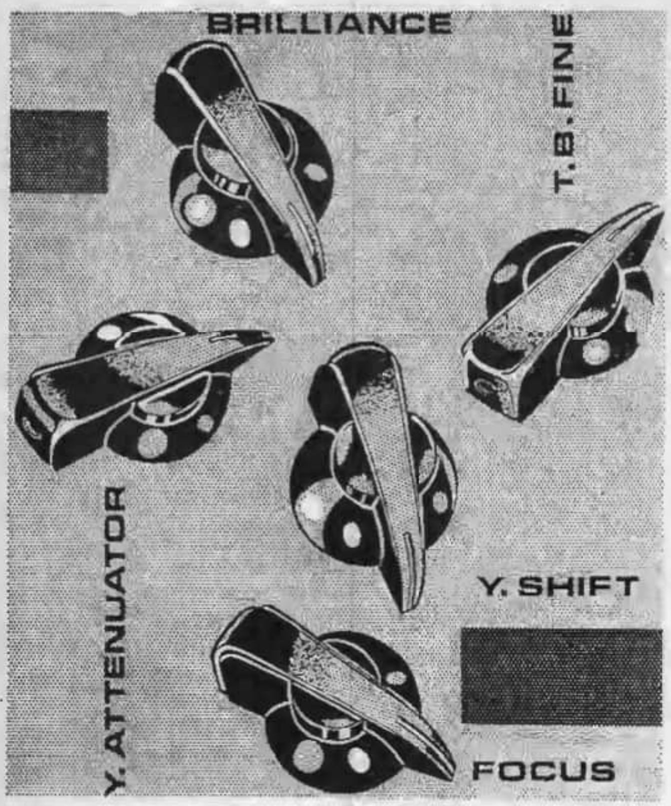


INEXPENSIVE OSCILLOSCOPE

PART THREE

By P. Cairns

After completing the construction as described in last month's article, all wiring should be re-checked to ensure that it is in accordance with the circuit diagram. Particular care should be taken when checking the h.t. and e.h.t. circuit wiring.

The testing and setting up procedure will now be described.

Set the oscilloscope controls as follows: X shift, Y shift, focus, brilliance, astig., time base fine, X gain, and Y gain all at approximately half scale.

The Y attenuator should be set to position 1 (X1) and a short circuit link connected across the Y input sockets.

Set the time base switch (S5) to position 2 and the sync control (VR6) to zero, the cal. switch (S2) off and the sync switch (S4) to the internal position.

Now switch on the oscilloscope.

The neon V2 gives indication when the h.t. supply is present, and after a short period the time base line should appear horizontally across the tube face. When this appears set the brilliance to a reasonable viewing level and adjust the focus for as fine a trace as possible. With the focus correctly adjusted the trace should be under one millimetre thick.

CHECKING THE TIME BASE

Now reduce the X gain to zero, thus reducing the time base line to a spot. This spot should be centred on the screen by means of the X and Y shifts; these controls will move the spot horizontally and vertically respectively. The X gain is then increased once more until the time base line just overlaps each side of the screen.

The time base switch should now be switched through positions 1 to 4 and the fine control swung over its entire range at each position. The trace length may vary slightly between ranges but this can be easily compensated for by the appropriate adjustment being made on the X gain.

On the slowest range on both time base controls the trace should appear as a spot travelling from left to right across the tube face as the time base scan here is about 100ms/cm, the spot taking over half a second to scan the tube face. No flyback sweep should be visible and as the tube is of relatively short persistence little or no afterglow will be visible.

CHECKING THE X AMPLIFIER

Having checked that the time base is working satisfactorily on all ranges, set X gain to zero and then the time base switch to position 5 (X Amp.). Now inject an external signal of between one and ten volts into the X input sockets. The internal calibration can be used for this purpose by simply connecting a shorting link between the cal. output socket and the X input socket, the earth return being internal to the oscilloscope.

The cal. switch is then switched on. After centring the spot by means of the X shift, the X gain should be increased to maximum, when the injected signal will appear as a horizontal line on the screen whose length will be dependent upon the amplitude of the injected signal. If the internal cal. is used whose output is one volt peak to peak, the line should be about 1·25cm long with maximum X gain as the X amplifier has a maximum sensitivity of approximately 800mV/cm.

Having ensured that the X amplifier and associated circuit are working correctly, reset the time base switch to position 2, the X gain to zero, recentre the spot if necessary by means of the shift controls, and then increase the X gain until the time base line is again just over one screen diameter in length.

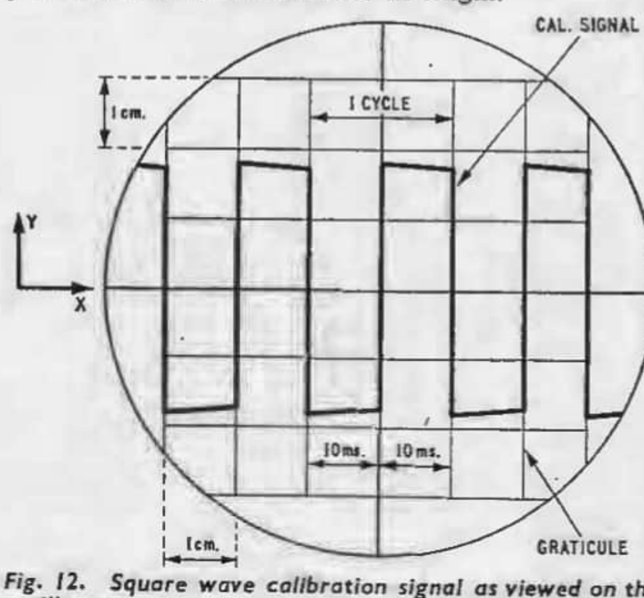


Fig. 12. Square wave calibration signal as viewed on the oscilloscope

ADJUSTING THE SIGNAL TRACE

The short circuit link can now be removed from the Y amplifier and a signal injected into the input. Again the internal cal. signal may be used, the cal. output being linked to the Y input socket and the cal. signal switched on. The Y gain should then be adjusted until the signal amplitude occupies about three centimetres of the screen height. The time base fine control is then adjusted until about two or three complete cycles of the square wave occupy the screen width. At the same time the sync control is also increased from zero until the trace is locked steady and does not tend to "run" across the screen.

In practice it will always be found an advantage to adjust the fine time base control and the sync control simultaneously to achieve optimum and positive synchronisation.

The screen trace should now appear as in Fig. 12, assuming that the internal cal. signal is being used. The slight slope on the upper and lower edges is due to the l.f. response of the Y amplifier and is not a function of the signal. No over- or undershoot should be present nor should any of the corners be rounded, all corners and edges should be sharp and clean cut. (Such defects would be due to incorrect h.f. compensation and in this case C13 and C15 would be the most likely offenders. However, no such troubles should normally be encountered.)

The signal can be examined in more detail if required by simply increasing the time base speed until only one or less cycles occupy the screen width (the sync control being readjusted to suit, of course). The trace can also be expanded by increasing the X gain which at maximum should give at least the equivalent of six screen diameters, i.e., the signal is "stretched" in a horizontal direction by a factor of six. By such methods very small portions of a composite signal may be expanded to large dimensions for more detailed analysis.

THE BASE CALIBRATION

Referring back to the trace as previously described and as shown in Fig. 12, such a trace may be used for time, as well as amplitude or voltage, calibration.

With each pulse or half cycle occupying exactly 1cm as shown, the time base calibration at that point is 10ms/cm, i.e. as the cal. signal is derived from the 50c/s mains, one cycle of this frequency is equivalent to 20ms and therefore each half cycle equals 10ms.

If the time base is expanded until one half cycle occupies say 4cm the time calibration is then 2·5ms/cm. Faster time base speeds can be calibrated by means of an audio oscillator, e.g. if a signal input to the Y amplifier of 5kc/s is set so that one cycle occupies exactly 1cm, the time base calibration is then 0·2ms or 200μs/cm.

The approximate ranges of sweep speeds covered by the time base is shown in the specification given in the first article of this series.

In some instances a slight non-linearity at the start or finish of the time base scan may be noticed, particularly on the slower sweep speeds. This can easily be offset by increasing the X gain slightly until the non-linear portion of the trace "falls" outside the tube diameter.

ASTIGMASTISM ADJUSTMENT

Before going on to the Y amplifier, the preset astigmatism control (VR1) may be set up.

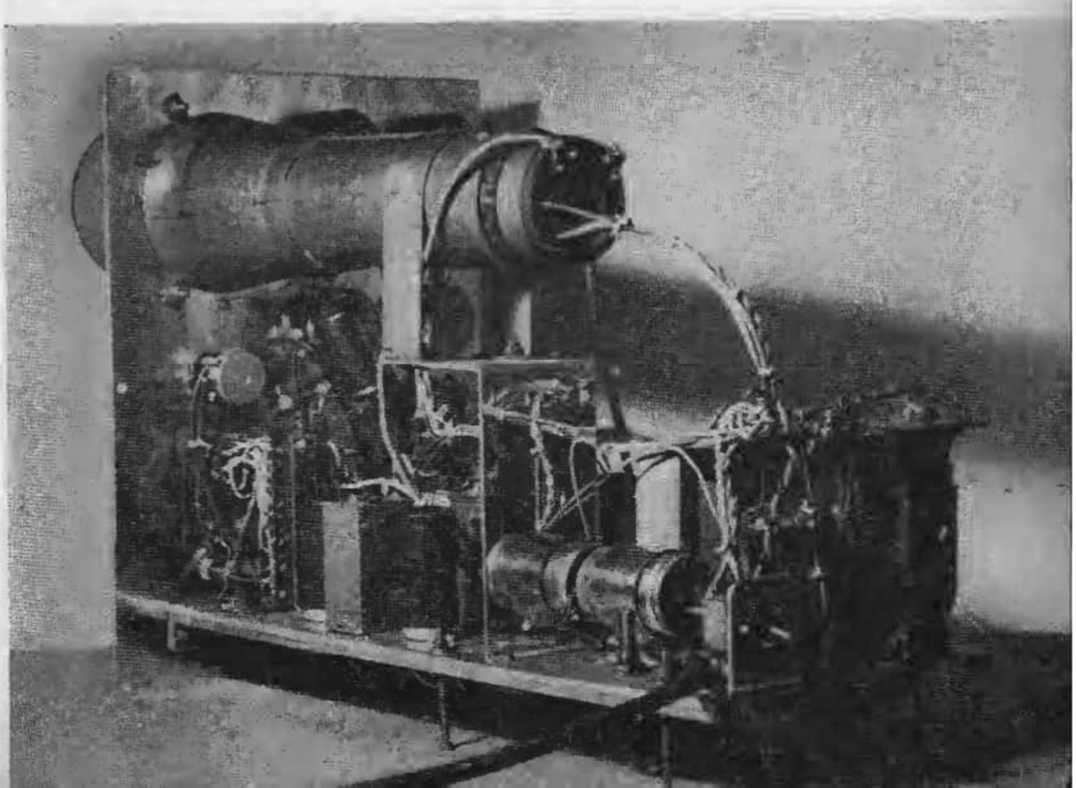
With the oscilloscope set up as just described and with a trace similar to Fig. 12 on the screen, connect a d.c. voltmeter between the slider of VR1 and the chassis. This preset control is then adjusted to give a voltage of about 260 on the meter.

The focus control should then be adjusted to give optimum focus over the whole of the trace in both horizontal and vertical directions.

The purpose of the astig. control is to give optimum focus over the whole useful screen area which is usually achieved when the A3 voltage is near in value to the deflection plate voltages.

The astig. control should then be varied by a reasonable amount above and below the figure quoted, the focus being adjusted at each setting until the best results are obtained. The object is to get an equally fine focus at both the edges and centre of the trace

An incorrectly adjusted control could show up as a slightly defocused trace at the edges with a very fine focus in the centre, or a fine focus on the vertical edges of the trace and slight defocusing on the horizontal edges, or vice versa. The best compromise between



A general view of the inexpensive oscilloscope. This completed assembly should be housed in a case made either of plywood or aluminium sheet. Ventilation holes should be provided along the top and bottom edges of the side panels these extremes should be found by experimenting with the astig. and focus controls.

Once the astig. is set it should seldom require any further adjustment. Any change in focus necessary due to a change in brilliance is compensated for by adjusting the focus control in the normal manner.

It may be mentioned at this point that the centre portion of the tube is normally used for signal analysis and measurement as a certain amount of defocusing occurs at the extreme edges in all but the most expensive tubes. This is principally due to the curvature of the glass which becomes more pronounced at the edges of the screen and is unavoidable.

X AMPLIFIER CALIBRATION

We now come to the calibration of the Y amplifier. While the method to be described uses the internal cal. signal, any external signal in the audio range may be used—provided the output level is known or is measurable.

The output level of the cal. signal should be one volt peak to peak, the accuracy depending principally upon the divider network R4, R5, R6. The signal level can be checked by connecting a low range d.c. voltmeter of the multirange type between the cal. output and one of the common earth sockets. With

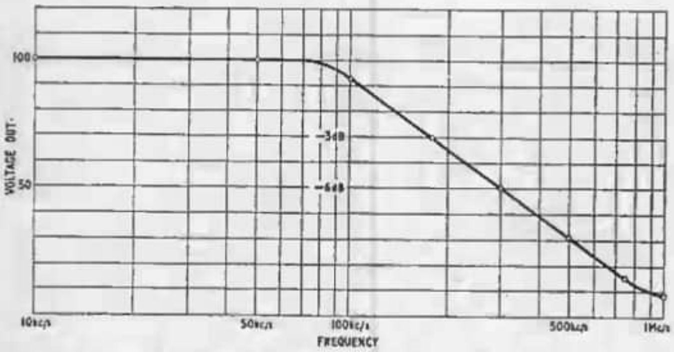


Fig. 13. This curve shows how the response of the Y amplifier falls of at the higher frequencies

the cal. switch on this should read 0·5 volts, this being the average voltage of a one volt peak to peak square wave having a 1:1 mark space ratio.

The oscilloscope is set up again to the same conditions as previously described with a trace similar to that in Fig. 12 and the Y attenuator still being in position 1 (x1).

The Y gain is now adjusted until the peak to peak amplitude of the signal occupies exactly 5cm. This point can now be marked on the Y scale as 200 or 0·2 (the scale being Y sensitivity in millivolts or volts per centimetre).

The signal amplitude can now be reduced by means of the Y gain to exactly 2·5cm peak to peak, this point being marked on the scale as 400 or 0·4. This method is continued until the main points of the scale are calibrated; e.g., 2cm = 500 or 0·5. 1cm = 1,000 or 1. 3·3cm = 300 or 0·3, etc. The intermediate points can be calibrated later if required.

The measurements can be carried out by means of the graticule or with a fine pair of dividers. Once this scale is calibrated these sensitivity factors may be increased by the various attenuation factors obtainable by means of the Y attenuator.

For example, if a signal is measured with an amplitude of 2·5cm with the Y gain reading 300mV/cm and the Y attenuator set in position 4 ($\times$30) then the actual peak to peak voltage would be (300 $\times$ 30) $\times$ 2·5 = 22·5 volts. If the signal is a sine wave this can be converted to r.m.s. value if required by dividing by $2\sqrt{2}$ = 7·95 volts r.m.s.

As the Y calibration is carried out on the basic amplifier (position 1 on the attenuator) any inaccuracy on the other ranges will be simply due to the tolerance of the attenuator resistors, and as 5 per cent high stability types are specified any such errors are reduced to practicable proportions.

Another advantage of the attenuator is that the various multiplying factors choosen ($\times$3, $\times$10, $\times$30, etc.) correspond to very near 10dB steps, this often being of use when taking characteristics on audio power amplifiers.

As previously mentioned, the Y amplifier has quite a good frequency response but when working up at the h.f. end of the characteristic the Y gain calibration will become increasingly inaccurate. To help offset this a typical frequency response curve for the amplifier is shown in Fig. 13. Though this curve will tend to vary somewhat between amplifiers due to differences in tube capacitance, valves, wiring, and stray circuit capacitance, etc., it will give an approximate value of any correction factor which may be required at the h.f. end of the amplifier characteristic.

The gradual fall off in h.f. response also shows that the amplifier is correctly compensated and will have a good square wave response. An over compensated amplifier will have a pronounced "hump" at the h.f. end of its characteristic.

VOLTAGE READINGS

A final test worth carrying out is to check the voltages at various points in the circuit and also the h.t. current drain. A complete list of all the relevant voltages together with the conditions under which they were taken is given in Table 1.

Table 1
VOLTAGE READINGS

All voltages are with respect to earth and measured on AVO Model 8 (20,000 ohms/volt). Measured under following conditions: no signal input, time base on fastest sweep speed, brilliance, focus and astig. controls set for normal viewing brightness and optimum focus, X and Y shift controls in mid position.

Valve	*Anode*	*Cathode*
V1	—	325V
V4b	220V	1·6V
V5a	245V	21·5V
V5b	245V	
V6a	115V	5V
V6b	310V	150V
V7a	315V	150V
V7b	215V	12V
V8a	190V	19·5V
V8b	190V	

C.T.R. (V3):
Grid −660V Anode 2 −380V Anode 3 260V

H.T. (junction L1/R2): 315V

E.H.T. (junction C7/VR3): −750V

Calibration Unit Supply (junction R5/S2): 11V

Total H.T. current 45mA

While the voltages shown were measured on an AVO Model 8, 20,000 ohms/volt instrument, a meter of lower impedance can be used providing the necessary correction is allowed for.

The voltage levels listed are not in any case the criterion as the individual voltages will vary between instruments due to differences in component tolerances, h.t. level, valve efficiencies, etc. They are provided here principally as a guide when fault finding or servicing.

With all the above tests satisfactorily completed the oscilloscope may be considered ready for use and should prove invaluable in all aspects of amateur experimental work. While the many and varied uses to which an oscilloscope may be put, together with its few limitations, is beyond the scope of this particular article, the variety of applications for which it can be used will increase as the operator becomes more familiar with the various controls and test procedures involved. The advantages of the oscilloscope in all branches of electronic work are immense, and once the operator becomes fully conversant with the various techniques involved, he will find it an invaluable, and even indispensable, instrument.

MAINS TRANSFORMER

The Radiospares "Heavy Duty" type mains transformer meets the requirements of this oscilloscope *without any modification.* If a "normal" type mains transformer with only two 6·3V windings is used it is then necessary to wind on one additional heater secondary. The information in the components list (p. 331, March issue) should be amended accordingly.

ALTERNATIVE TUBE TYPES

A type 3BP1 c.r. tube is used in the author's original model. If either of the alternatives are used the minor differences in specification and the difference in base and pin connections should be noted.

The pin connections of the 3EP1 and 3GP1 tubes are identical and are shown in Fig. 11.

3EP1—The Y plate sensitivity will be decreased by about 8 per cent. The X plate sensitivity will be decreased by about 10 per cent. These slight differences will be automatically compensated for when the instrument is calibrated. The specification and circuit should therefore remain unchanged.

3GP1—The Y plate sensitivity will be increased by about 6 per cent. The X plate sensitivity will be increased by about 20 per cent. It may be necessary to increase the value of R15 by about 20 per cent (up to 390 kilohms) to allow for the lower value of A2 voltage required by this tube. The minor difference in Y sensitivity will be compensated for when the instrument is calibrated. The only difference in specification will be an increase in the X sensitivity of about 20 per cent, i.e. 7X trace expansion instead of a 6X trace expansion. The only circuit change may be R15 which can be increased should the correct focus not be obtained.

TUBE ORIENTATION

In order to obtain proper aligment of the trace it may be necessary to rotate the 3EP1 and 3GP1 tubes slightly away from the position indicated in Fig. 11 (p. 415, April issue). Once this adjustment has been performed, lock the base clamp to secure the tube. ★

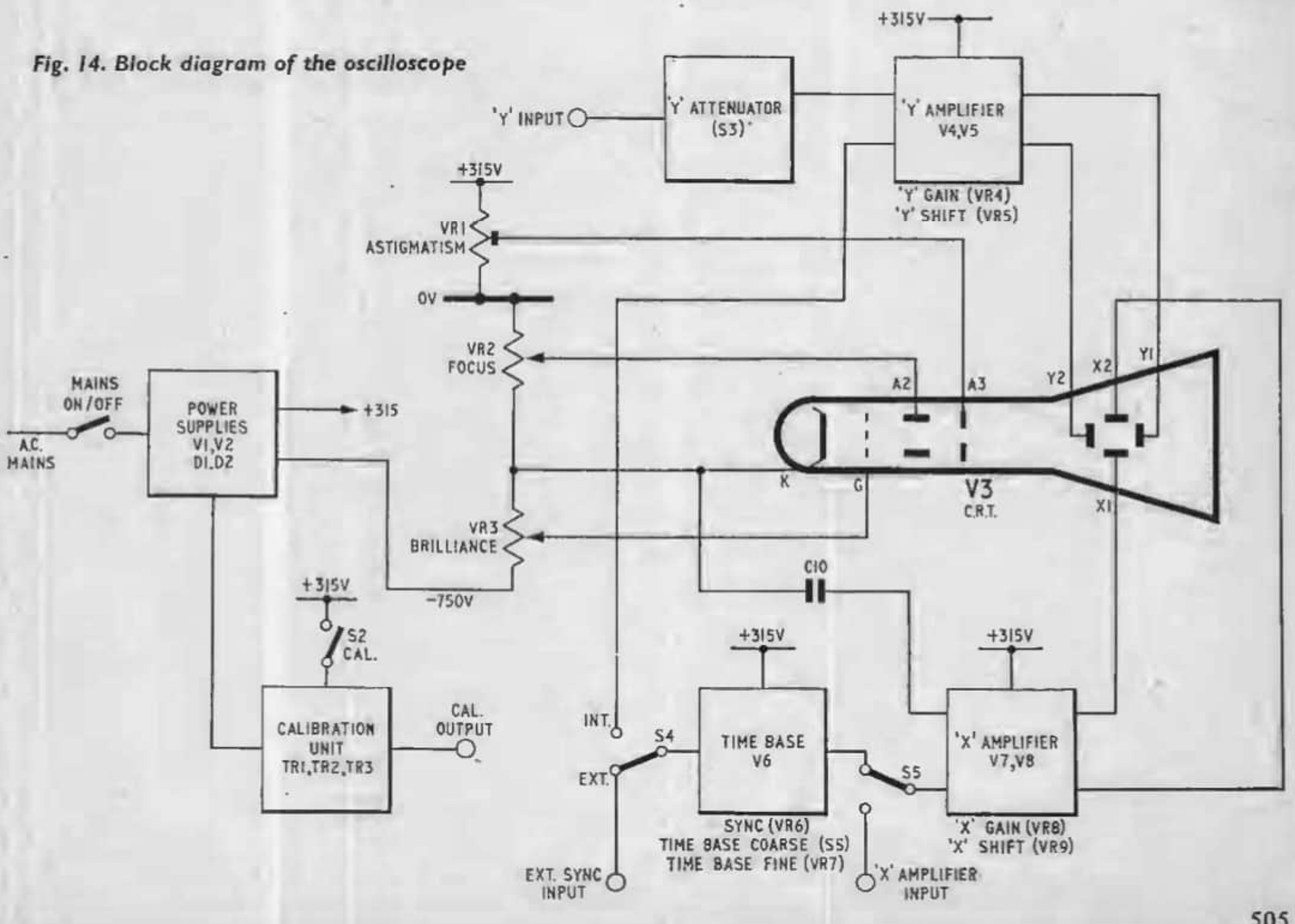


Fig. 14. Block diagram of the oscilloscope