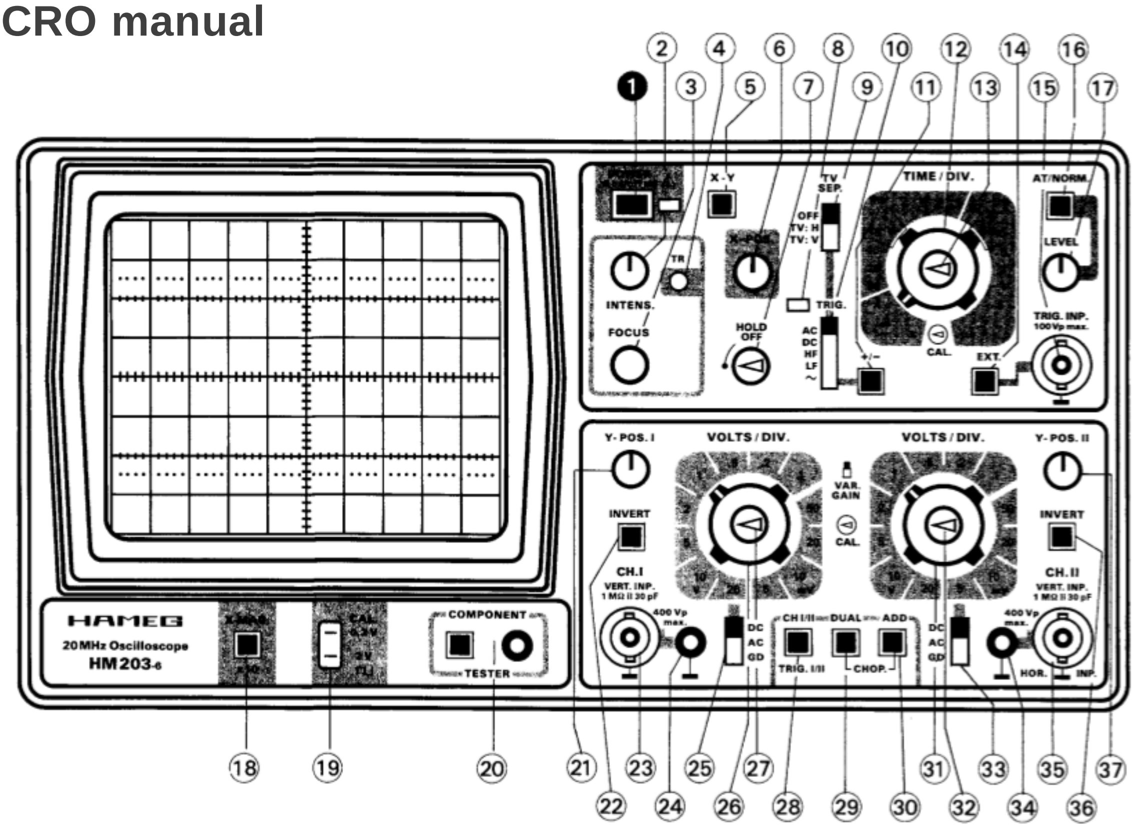
The CRO – Cathode Ray Oscilloscope

A cathode ray oscilloscope (CRO) is a device that measures potential differences and how they vary over time. It is typically used to measure the time period and peak p.d. of repeated waveforms, and to determine the shape of the waveform.

A CRO allows up to two inputs (“channels”) to provide separate p.d. traces on the screen. This allows two waveforms to be compared on the same screen.

A description of the internal structure of a CRO and how they work is given after the operation manual below.

CRO manual



The above diagram shows the Hameg HM-203 CRO, and the HM303 is very similar. The Scopex 14D-15 CRO is simpler and while the controls mentioned below are not in the same places, they should be more easily found.

1. **Power:** insert the power cable into the back of the CRO and connect to the mains.

2. **Check settings:**

   i) ensure that all buttons are in the OUT position before switching the CRO on,

ii) Ensure that the Y-gain fine control [27, 32] adjustment is turned to the extreme anti-clockwise position.

3. **Powering up the CRO**: plug the CRO into a wall socket and switch it on using button [1]. The CRO will take a few moments to boot up, and will display the manufacturer's logo while it does so.

4. **Connect the input channel(s):** take the black coaxial cable and push the circular end onto the TV aerial-style end to input channel 1, labelled CH I [23] and twist to lock it in place.

   The other end of the cable should have standard 4mm red and black plugs that can be connected into standard laboratory equipment.

   If your experiment requires you to compare two inputs, connect a second coaxial cable to input channel 2, labelled CH II [35].

5. **CRO screen:** the electron beam will create a trace on the screen for each input channel in use. A grid is printed on the screen, with a 1 cm major divisions on both the horizontal (time) and the vertical (potential difference) axes. On the central axis, finer 2mm minor tick marks are placed to allow more precise readings.

   The CRO controls refer to divisions, but exam papers refer to cm. These are the same thing.

   e.g. a CRO time base will be set to 10 ms/div, which in an exam question will appear as 10 ms/cm or 10 ms.cm^{-1},

   a CRO y-gain will be set to 2V/div, which in an exam question would appear as 2V/cm or 2 V.cm^{-1}.

6. **Time base:** the time base is the time it takes the electron beam to scan horizontally across one division on the CRO screen, typically measured in ms/div or μs/div.

   Use the knob labelled **TIME/DIV** [12] to set the time base to a value that give a steady, recognisable waveform with *at least* one full repeat of the waveform visible on the screen.

   If the CRO trace is moving across the screen or there are too many closely-packed vertical lines, the time base needs to be adjusted to a finer setting, *i.e.* smaller time period per division.

   If the CRO trace is a horizontal or a sloping line, or you cannot see *at least* one complete waveform, the time base needs to be adjusted to a coarser setting.

   Both inputs (channels 1 and 2) share the same time base.

7. **Y-Gain:** this determines the vertical deflection of the electron beam for a given input potential difference, and labelled as **VOLTS/DIV** [26,31]. Values are given in V/div or mV/div.

   Each input channel has a separate Y-gain control.

   If either the top or bottom of the waveform is not visible on the screen at the same time then the Y-gain needs to be adjusted to courser setting (i.e. more volts per division). Reduce the amplitude of the trace to bring all of it within the screen.

   If the waveform looks horizontal or the waveform only occupies a small proportion of the y-axis, then the Y-gain needs to be adjusted to a finer setting (i.e. fewer volts per division). Increase the amplitude such that both peaks **and** troughs are *just* within the limits of the CRO screen.

8. **Beam adjustment:** to maximise the degree of precision in your readings you should adjust the beam in two ways:

   INTENSITY [2] will allow you to increase/decrease the brightness of the trace. You want to have the lowest intensity that still allows you to see the trace.

   FOCUS [3] will allow you to adjust the beam to produce the finest trace line possible on the CRO screen.

   Note that the greater the intensity (brighter trace) the worse the focus (thicker trace line). Some models only have a single control **INTENS/FOCUS** for these two parameters.

9. **Measuring pd:** reading peak to peak pd from a waveform is difficult, as neither peak nor trough will necessarily lie close to the y-axis. To make your reading more accurate take the following steps:

   i) Time base: switch the time base off, with some models this is done using the button labelled **XY** [5], in others pressing and holding the DUAL button switches to XY mode. XY mode stops the electron beam scanning horizontally and collapses the trace into a single vertical straight line.

   ii) X-shift: move the trace horizontally to sit **on** the y-axis using the x-shift knob, labelled **X-POS** [6].

   iii) Y-shift: move the trace vertically so that one end lies exactly on a y-axis major or minor tick mark using the y-shift knob, labelled **Y-POS** [21,37]. You may want to adjust the y-gain to ensure the line is as long as possible on the screen with both ends still visible (see 5 above). Each input channel has its own Y-POS control.

   iv) Reading: you will need to find the distance on the CRO screen between the two ends of the line; your answer should be to a precision of ± 0.2 div.

This should then be *multiplied* by the y-gain (VOLTS/DIV setting) to get the peak-to-peak p.d.

This should then be divided by 2 to get the peak pd, V_0.

v) Remember: to re-start the time base once you have taken your readings to avoid "burn in" – the electron beam will damage the CRO screen if left for too long.

10. **Measuring period:** there are a couple of point to note:

i) Centring: ensure that the waveform is centrally placed in the vertical.

Switch the time base off (see 7i) and adjust the y-shift (see 7iii) to place the vertical trace line symmetrically across the x-axis, with as much trace line above as below. Remember to restart the time base once this is done.

ii) X-shift: find the left-most point on the CRO screen where the trace crosses the x-axis. X-shift the CRO trace (see 7ii) such that this point sits *exactly* on a major or minor tick mark on the x-axis.

Find the right-most point on the CRO screen where the trace crossed the x-axis and find the number of divisions between these two points; your answer should be to a precision of ± 0.2 div.

Count the number of **half wavelengths** between these two points.

Multiply the distance between the two points by 2 and then divide by the number of half wavelength to get the wavelength in divisions.

Multiply the wavelength in divisions by the time base setting (TIME/DIV) to get the period of the waveform.

Exercises

1. A waveform is observed as shown in Fig.1 below on an oscilloscope with a time base of 50 $ms.cm^{-1}$ and a y-gain of 20 $mV.cm^{-1}$.

   Calculate the peak and rms p.d. and the time period and frequency of the signal.

Fig.1

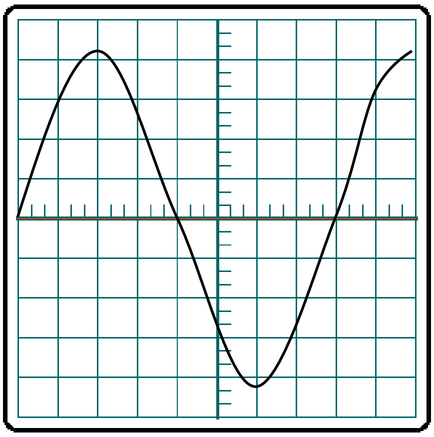
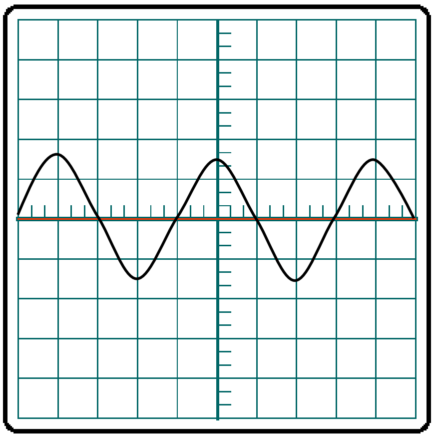


Fig.2

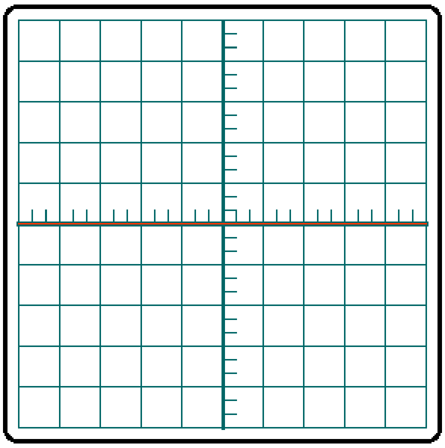


2. The waveform shown in Fig. 2 has a frequency of 12.5 kHz and V_{rms} of 0.21 V. Estimate the time-base and y-gain setting used.

3. A p.d. source is expected to have a frequency of 50 Hz and a peak p.d. of 0.57 V

   What time-base and y-gain settings would you used from the options listed to fit one full waveform on the screen in Fig.3.

Fig. 3

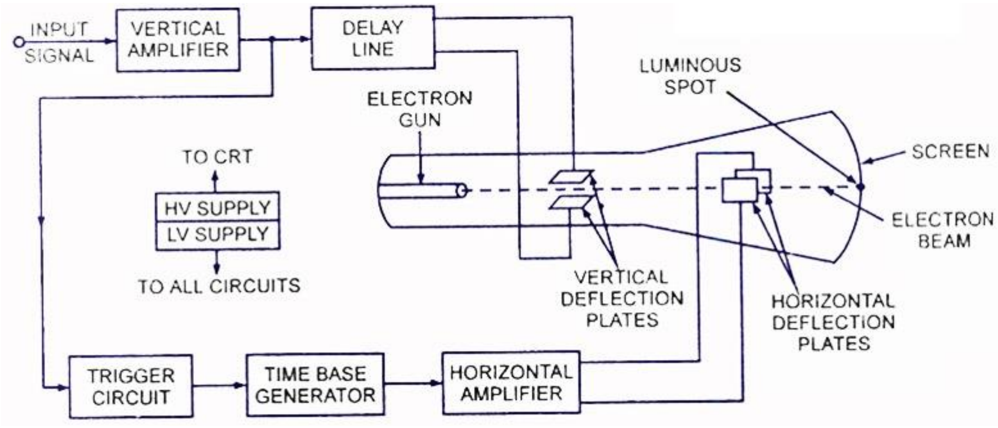


Time base	y-gain
50 $ms.cm^{-1}$	5 $V.cm^{-1}$
20 $ms.cm^{-1}$	2 $V.cm^{-1}$
10 $ms.cm^{-1}$	1 $V.cm^{-1}$
5 $ms.cm^{-1}$	0.5 $V.cm^{-1}$
2 $ms.cm^{-1}$	0.2 $V.cm^{-1}$
1 $ms.cm^{-1}$	0.1 $V.cm^{-1}$
0.5 $ms.cm^{-1}$	50 $mV.cm^{-1}$
0.2 $ms.cm^{-1}$	20 $mV.cm^{-1}$
0.1 $ms.cm^{-1}$	10 $mV.cm^{-1}$

4. A experiment is to use a CRO to display the capacitor charge/discharge curve where the value of RC is 8.5 ms. The capacitor is charged/discharged using a 1.5 V dc supply. A signal generator controls a reed switch, which flips the circuit from charge to discharge and back gain repeatedly.

   If the capacitor is to be fully charge/discharged at the end of each phase, state the maximum frequency the signal generator can be set to. What CRO time base and y-gain settings should be used to display the waveform on Fig.3 ?

Inside the CRO



Functions of the components:

1. Cathode Ray Tube (CRT)

It is the heart of the oscilloscope, an evacuated glass tube with a phosphor screen at one end and an electron gun at the other. When the electrons emitted by the electron gun strike the phosphor screen of the CRT, a visual signal is displayed on the CRT.

2. Vertical Amplifier

The input p.d. (signal) is amplified by the vertical amplifier. The level of amplification is determined by the y-gain setting (see below).

3. Delay Line

As the name suggests that, this circuit is used to, delay the signal for a period of time. This is done to ensure that the beam is scanning the screen when the signal reaches the vertical deflection plates.

4. Time Base Circuit

Time base circuit produces a “saw-tooth” p.d. required to deflect the beam in the horizontal direction. The spot is deflected by the saw tooth p.d. at a constant time-dependent rate.

5. Horizontal Amplifier

The saw tooth voltage produce by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates. The level of amplification is deteremined by the time-base.

6. Trigger Circuit

The signals which are used to activate the trigger circuit are converted to trigger pulses for the precision sweep operation whose amplitude is uniform. Hence input signal and the sweep frequency can be synchronized.

7. Power supply:

The voltages require by CRT, horizontal amplifier and vertical amplifier are provided by the power supply block. Power supply block of oscilloscope is classified in to two types

(1) Negative high voltage supply (-1000 to -1500 V)

(2) Positive low voltage supply (300-400 V)