Experiment: 4

AIM: To study cathode ray oscilloscope and perform measurements.

- **Introduction:**

The cathode ray oscilloscope is a versatile laboratory instrument. If a laboratory has only CRO in it, other measuring instruments may not be required. This is the importance of CRO in scientific laboratories. With it we can measure, AC/DC voltage, AC/DC current, resistance, phase and phase difference between two or more waveforms, relative frequency of a waveform, observe the amount of noise present on a signal, etc. CRO is also useful to observe the shape of waveform or signal and observe its real time progression on time axis. The waveform displayed on it, is observed with respect to x-y axes or co- ordinate system. The screen of CRO is plotted in terms of a measuring scale, known as graticule. Using this scale, the amplitude and wavelength of waveform can be accurately measured in centimetres and then converted into required unit.

4.1 Basic working principle of CRO

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) and accelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, and accelerating anode (positive electrode) is called an electron gun. Its purpose is to generate the electron beam and control its intensity and focus. Between the electron gun and the fluorescent screen are two pair of metal plates - one oriented to provide horizontal deflection of the beam and one pair oriented to give vertical deflection to the beam. These plates are thus referred to as the horizontal and vertical deflection plates. The combination of these two deflections allows the beam to reach any portion of the fluorescent screen. Wherever the electron beam hits the screen, the phosphor is excited and light is emitted from that point. This conversion of electron energy into light allows us to write with points or lines of light on an otherwise darkened screen. Some important terms before going into the details of functional block diagram of CRO.

- **Input:** It is the main input of CRO, to which the input signal is connected. The waveform of this input signal is displayed on the screen of CRT.
- **Vertical attenuator1:** It consists of RC voltage divider, which is marked on the CRO front panel as Volt/div control knob. Thus the 'gain' of CRO can be controlled with Volt/div knob.
- **Vertical amplifier:** It is a set of preamplifier and main vertical amplifier. The input attenuator sets up the gain of vertical amplifier.
- **Delay line:** The delay line delays the striking of electron beam on the screen. It synchronizes the arrival of the beam on screen when time base generator signal starts sweeping the beam horizontally. The propagation delay2 produced is about 0.25 msec.
- **Trigger circuit:** It takes the sample of input voltage connected at y-input of CRO and feeds it to the input of time base generator. So, the TBG starts only when input signal is present at y-input.

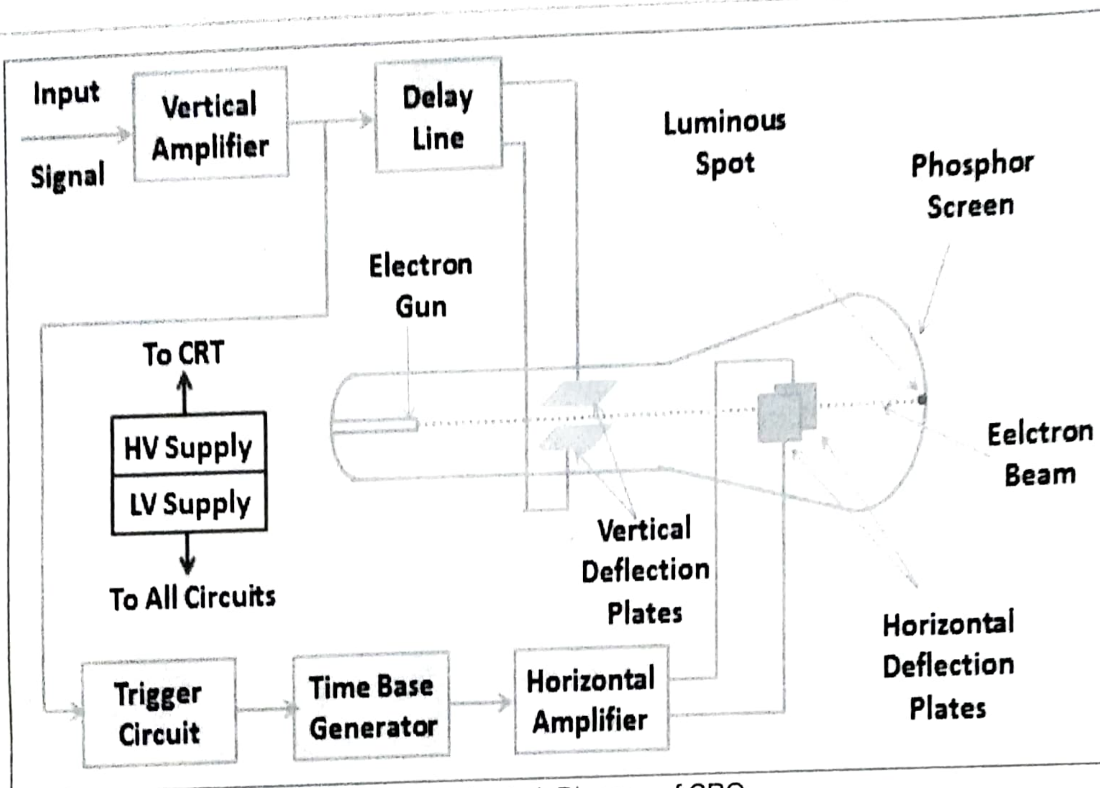

Figure 4.1 Block Diagram of CRO

- **Time base generator:** It produces a saw tooth wave. The waveform is used to sweep (move) the electron beam horizontally on the screen. The rate of rise of positive going edge of saw tooth wave- form is controlled by Time/div control knob. Thus, the saw tooth wave controls the horizontal deflection of electron beam along x-axis. A switch known as INT/EXT is also connected after the output of TBG. When the switch is in INT position, the output of TBG is connected to H-plates through horizontal amplifier. When it is in EXT position, internal saw tooth is cut-off and some external signal can be connected to horizontal plates.
- **Horizontal amplifier:** It amplifies the saw tooth waveform coming from TBG. It contains phase inverter circuit also. Due to this circuit, two outputs are produced. One output produces positive going saw tooth and other output produces negative going saw tooth. The first output is connected to right side H-plate and the second output is connected to left side H-plate. So, the electron beam moves properly from left to right of the screen.
- **HV/LV power supply:** The high voltage section is used to power the electrodes of CRT and the low voltage section is used to power the electronic circuits of the CRO.

8	AUTO/NORM	AUTO mode enables trace when no signal is fed at the trigger input. In NORM position, the trigger level can be varied using LEVEL control.
9	LEVEL	It allows setting of the trigger level between peak to peak amplitude of the input signal.
10	TRIG IN	A socket that is used to feed external trigger signal in EXT mode.
11	EXT	Switch that allows External triggering signal to be fed from the socket marked TRIG IN.
12	*X*-POS	This knob controls the horizontal position of the beam trace.
13	VAR	Controls the time base speed in-between two steps of TIME/DIV switch.
14	+/-	This switch selects the slope of triggering.
15	INV CH. II	This switch when pressed inverts the signal at CH.II.
16	INTENS	It controls the trace brightness.
17	FOCUS	It controls the sharpness of the trace.
18	DC/AC/GND	Coupling switch for each panel. In AC mode, the signal in coupled through 0.1μF capacitor.
19	CH-I (*Y*) and CH-II (*X*)	BNC connectors serve as *Y*-input connections for CH-I and CH-II. CH-II input connector also serves as Horizontal external signal on using *X*-*Y* control.
20	Volts/Div.	A switch to select the sensitivity of each channel.
21	*Y*-Pos I and II	These controls are provided for vertical deflection of trace for each channel.

4.3 Features of a typical analog CRO are as under:

1. Dual channel
2. Bandwidth up-to 30MHz.
3. Invert facility in both channels.
4. Vertical deflection coefficients: 5mV to 20 V / div.
5. Time base: 20ns-0.2 s / div.
6. Variable Hold –Off.
7. X10 magnification.
8. Triggering capability.
9. Saw tooth output (5Vpp approx.)

4.4 Measurements using CRO

The primary uses of the cathode ray oscilloscope (CRO) are to measure voltage, to measure frequency and to measure phase.

- **Measuring voltage:**

Because of its effectively infinite resistance, the CRO makes an excellent voltmeter. It has a relatively low sensitivity, but this can be improved by the use of an internal voltage

4.2 Front Panel Control:

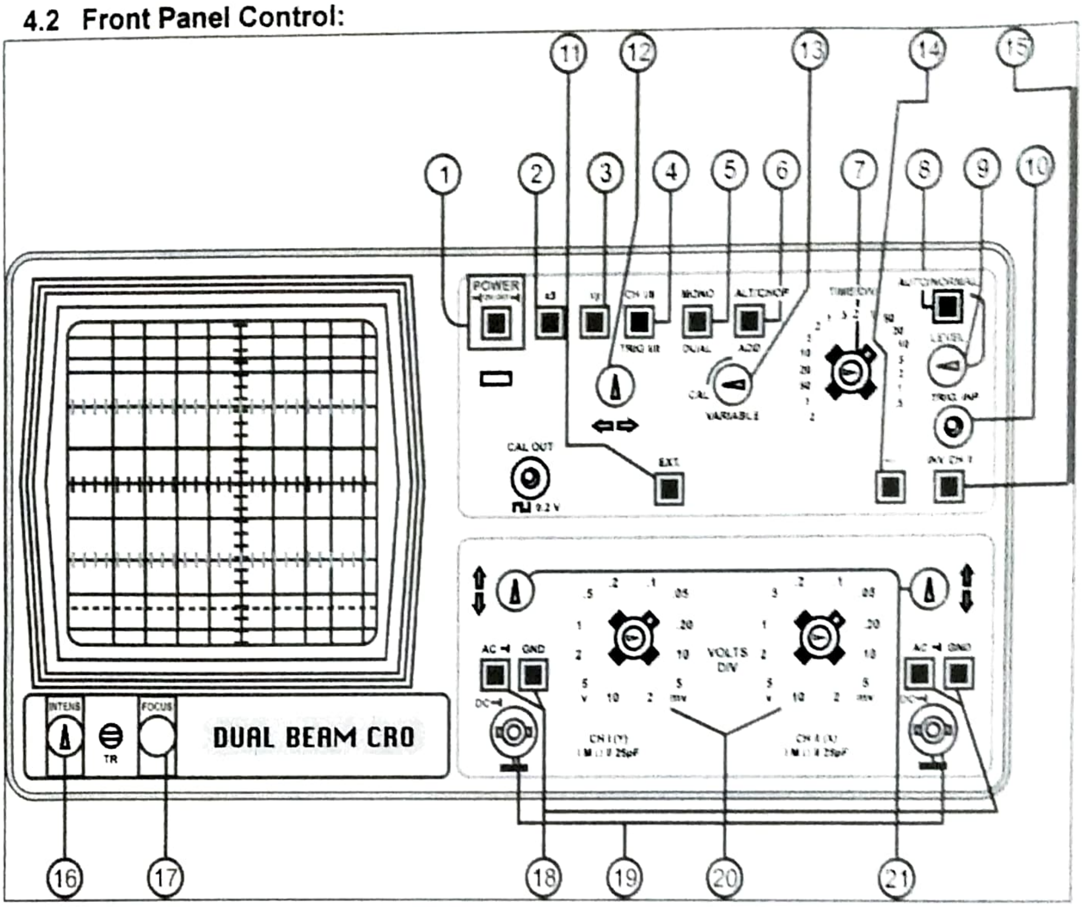

Figure 4.2 Front Panel of CRO

Sr. No.	Control	Function
1	Power	Turns mains power on/off.
2	X5	When pressed, gives five times magnification of the signal.
3	XY	It cuts off the time base fed to the horizontal plates when pressed and allows access to the horizontal signal fed through CH-II. It is used for *X-Y* display.
4	CH-I/CH-II/Trig I/Trig II	It selects and triggers CH-I when it is out. On pressing, it selects and triggers CH-II.
5	Mono/ Dual	Switch selects Mono or Dual trace operation.
6	Alt/ Chop/Add	Switch selects alternate or chopped in Dual mode. If Mono is selected then this switch enables addition or subtraction of channel i.e.CH1 ± CH2.
7	Time/Div.	It selects time base speeds.

amplifier. The oscilloscope must first be calibrated by connecting a d.c. source of known e.m.f. to the Y-plates and measuring the deflection of the spot on the screen. This should be repeated for a range of values, so that the linearity of the deflection may be checked. The known e.m.f. is then connected and its value found from the deflection produced. Most oscilloscopes have a previously calibrated screen giving the deflection sensitivity in volts per cm or volts per scale division. In this case a calibration by a d.c. source may be considered unnecessary.

- **Measuring frequency:**

Using the calibrated time base the input signal of unknown frequency may be 'frozen', and its frequency found directly by comparison with the scale divisions. Alternatively, the internal time base may be switched off and a signal of known frequency applied to the X-input. If the signal of un- known frequency is applied to the Y-input, Lissajous figures are formed on the screen. Analysis of the peaks on the two axes enables the unknown frequency to be found.

- **Measuring phase:**

The internal time base is switched off as above and two signals are applied as before. The frequency of the known signal is adjusted until it is the same as that of the unknown signal. An ellipse will then be formed on the screen and the angle of the ellipse will denote the phase difference between the two signals.