UNIT-V: STORAGE AND DISPLAY INSTRUMENTS: Cathode Ray Oscilloscopes– CRT Circuit, Vertical Deflection System, Delay Line, Horizontal Deflection System, Oscilloscope Techniques, Special Oscilloscopes, Recorders -XY & Magnetic Tape Dot Matrix Display. .

CATHODE RAY OSCILLOSCOPE (CRO):

The major block circuit shown in Fig. 7.4, of a general purpose CRO, is as follows:
1. CRT
2. Vertical amplifier
3. Delay line
4. Time base
5. Horizontal amplifier
6. Trigger circuit
7. Power supply

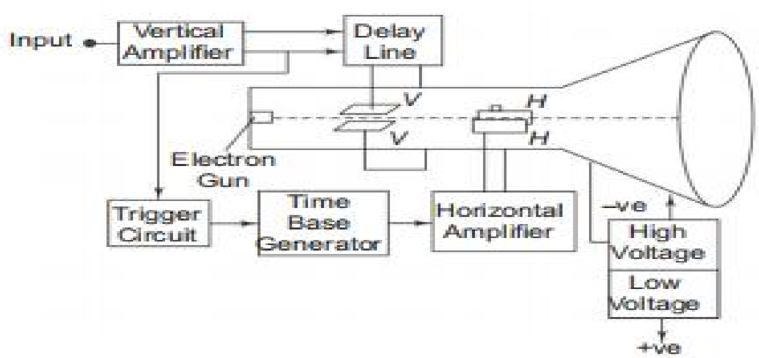


Fig. 7.4 Basic CRO block diagram

The function of the various blocks are as follows.

1. **CRT** This is the cathode ray tube which emits electrons that strikes the phosphor screen internally to provide a visual display of signal.

2. **Vertical Amplifier** This is a wide band amplifier used to amplify signals in the vertical section.

3. **Delay Line** It is used to delay the signal for some time in the vertical sections.

4. **Time Base Generator** It is used to generate the sawtooth voltage required to deflect the beam in the horizontal section.

5. **Horizontal Amplifier** This is used to amplify the sawtooth voltage before it is applied to horizontal deflection plates.

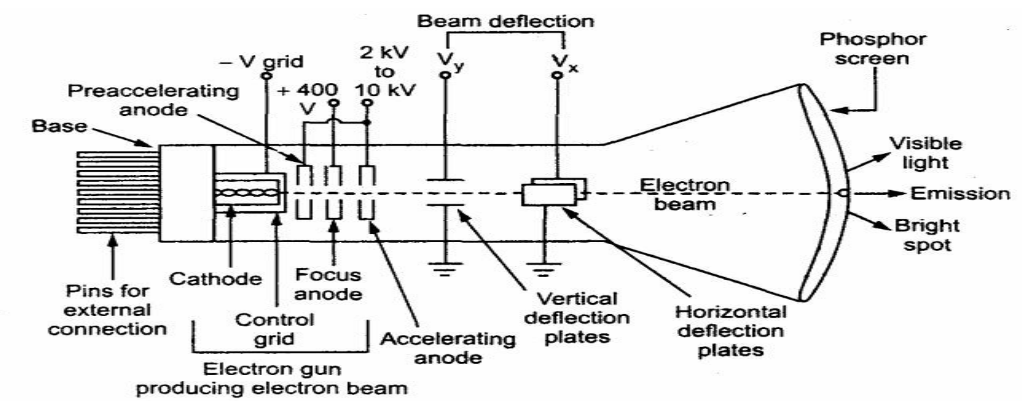
6. **Trigger Circuit** This is used to convert the incoming signal into trigger pulses so that the input signal and the sweep frequency can be synchronised

7. Power Supply There are two power supplies, a –ve High Voltage (HV) supply and a +ve

Low Voltage (LV) supply. Two voltages are generated in the CRO. The +ve volt supply is from + 300 to 400 V. The –ve high voltage supply is from – 1000 to – 1500 V. This voltage is passed through a bleeder resistor at a few mA. The intermediate voltages are obtained from the bleeder resistor for intensity, focus and positioning controls.

CRT (CATHODE RAY TUBE)

This tube, illustrated in figure , is commonly used to obtain a visual display of electronic information in oscilloscopes, radar systems, television receivers, and computer monitors. The CRT is a vacuum tube in which a beam of electrons is accelerated and deflected under the influence of electric or magnetic fields. The electron beam is produced by an assembly called an electron gun located in the neck of the tube. These electrons, if left undisturbed, travel in a straight-line path until they strike the front of the CRT, the "screen," which is coated with a material that emits visible light when bombarded with electrons.



In an oscilloscope, the electrons are deflected in various directions by two sets of plates placed at right angles to each other in the neck of the tube. (A television CRT steers the beam with a magnetic field) An external electric circuit is used to control the amount of charge present on the plates. The placing of positive charge on one horizontal plate and negative charge on the other creates an electric field between the plates and allows the beam to be steered from side to side. The vertical deflection plates act in the same way, except that changing the charge on them deflects the beam vertically.

VERTICAL DEFLECTION SYSTEM

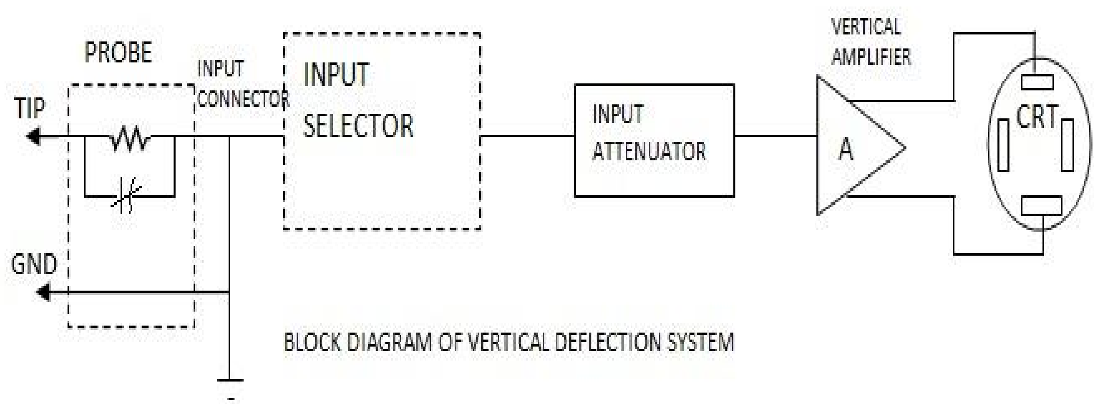
The vertical deflecting system of a cathode ray oscilloscope has critical requirements. The functions and requirements are listed below: The vertical deflecting system has to provide the following facilities :

1. Amplify and reproduce the input signal. The amplifier must have good fidelity That is it must amplify the input signal within the limits of its bandwidth, without effecting the amplitude, frequency and phase.

2. It has to isolate the cathode ray tube from the input signal. That is it has to act as a buffer.

3. It must have provisions for the different modes of operation.

The functional block diagram of the vertical deflecting system of a general purpose oscilloscope is shown in figure.



BLOCK DIAGRAM OF VERTICAL DEFLECTION SYSTEM

The vertical deflecting system consists of the following elements:

1. Probe.
2. Selector for input signal.
3. Attenuator to adjust the gain of amplifier.
4. The vertical amplifier that amplifies the signal.

Probe

This passive probe has a resistor which acts as the attenuator for the signal. The capacitor is to act as the compensator. These two components are used in the probe Tip of the probe connects the circuit. Ground connection is established through a clip connector. The other end of the probe will be connected to the vertical input terminals of the cathode ray oscilloscope using a BNC connector or the like.

Input Selector

The input selector is nothing but a single pole three way switch. It's pole is connected to the input terminals of the vertical amplifier. The two extreme positions namely way one and way three are connected to the attenuator through the capacitor and directly, respectively. The middle position of the 'switch that is the second way is connected to earth. In the first position of the switch the input is directly connected to the input attenuator. This position is marked as DC. The d.c input signals will directly appear at the attenuator. In this position both and d.c and a.c components are available after due attenuation at the input of the amplifier. This mode is convenient for measurement of total instantaneous valued of signal voltages.

Input Attenuator

The input attenuator consists of number of RC potential dividers controlled on the CRO front panel. This control is done by the VOLTS/DIV selector. This selector will be calibrated in terms of the deflection factor (V/div). The sequence of attenuation commonly used with the CROs is 1-2-5. For example the range of the attenuator setting can be 0.1. 02, 0.5, 1, 2, 5, 10, 20 and 50 volts per division with a maximum attenuation of 50 v/div setting. There are attenuators that have 12 settings.

The vertical amplifier

Vertical amplifier consists of the following stages.
1. Pre-amplifier.
2. Phase inverter.
3. Driver amplifier.
4. Output amplifier.

With all the above stages, its fixed overall sensitivity or gain is expressed in terms of the deflection factor, V/div. Fixed gain amplifier will only be used as the design is easier to offer the required standard of stability.

DELAY LINE IN TRIGGERED SWEEP

Figure 7.13 shows a delay line circuit.

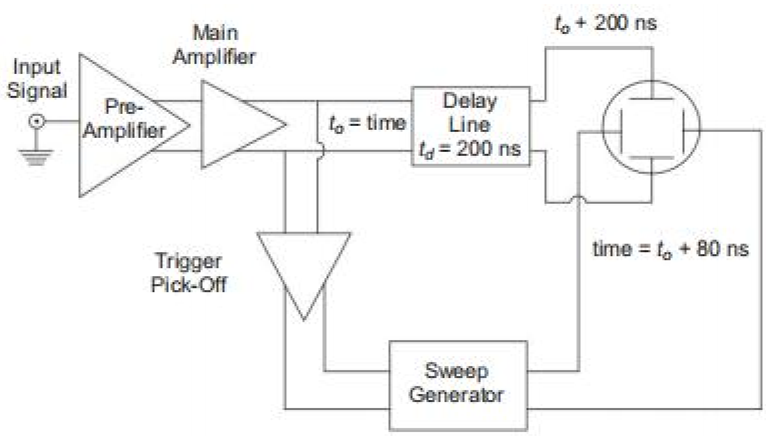


Fig. 7.13 Delay line circuit

Figure 7.14 indicates the amplitude of the signal wrt time and the relative position of the sweep generator output signal. The diagram shows that when the delay line is not used, the initial part of the signal is lost and only part of the signal is displayed. To counteract this disadvantage the signal is not applied directly to the vertical plates but is passed through a delay line circuit, as shown in Fig. 7.13.

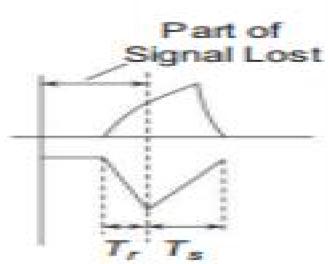


Fig. 7.14 Delay line waveform

This gives time for the sweep to start at the horizontal plates before the signal has reached the vertical plates. The trigger pulse is picked off at a time to after the signal has passed through the main amplifier. The sweep generator delivers the sweep to the horizontal amplifier and the sweep starts at the HDP at time t_o + 80 ns. Hence the sweep starts well in time, since the signal arrives at the VDP at time t_o + 200 ns.

HORIZONTAL DEFLECTION SYSTEM

The horizontal deflecting system consist of a Time Base Generator and an output amplifier.

Sweep or Time Base Generator A continuous sweep CRO using a UJT as a time base generator is shown in Fig. 7.8. The UJT is used to produce the sweep. When the power is fi rst applied, the UJT is off and the CT charges exponentially through RT. The UJT emitter voltage VE rises towards VBB and when VE reaches the peak voltage VP, as shown in Fig. 7.9, the emitter to base ‘1’ (B1) diode becomes forward biased and the UJT triggers ON. This provides a low resistance discharge path and the capacitor discharges rapidly.

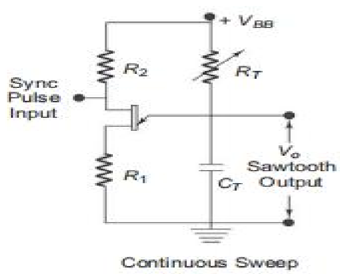


Fig. 7.8 Continuous sweep

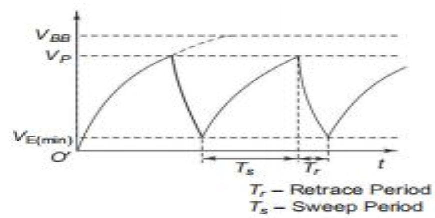


Fig. 7.9 Sawtooth output waveform

The emitter voltage VE reaches the minimum value rapidly and the UJT goes OFF. The capacitor recharges and the cycle repeats. To improve sweep linearity, two separate voltage supplies are used, a low voltage supply for UJT and a high voltage supply for the RT CT circuit. RT is used for continuous control of frequency within a range and CT is varied or changed in steps for range changing. They are sometimes called as timing resistor and timing capacitor respectively. The sync pulse enables the sweep frequency to be exactly equal to the input signal frequency, so that the signal is locked on the screen and does not drift.

OSCILLOSCOPE MEASUREMENT TECHNIQUES

Voltage Measurements Voltage is the amount of electric potential, expressed in volts, between two points in a circuit. Usually one of these points is ground (zero volts) but not always. Voltages can also be measured from peak-to-peak – from the maximum point of a signal to its minimum point. You must be careful to specify which voltage you mean.

Time and Frequency Measurements You can make time measurements using the horizontal scale of the oscilloscope. Time measurements include measuring the period and pulse width of pulses. Frequency is the reciprocal of the period, so once you know the period, the frequency is one divided by the period. Like voltage measurements, time measurements are more accurate when you adjust the portion of the signal to be measured to cover a large area of the screen.

Pulse Width and Rise Time Measurements In many applications, the details of a pulse's shape are important. Pulses can become distorted and cause a digital circuit to malfunction, and the timing of pulses in a pulse train is often significant. Standard pulse measurements are pulse width and pulse rise time. Rise time is the amount of time a pulse takes to go from a low to high voltage. By convention, the rise time is measured from 10% to 90% of the full voltage of the pulse. This eliminates any irregularities at the pulse's transition corners. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. By convention, the pulse width is measured at 50% of full voltage.

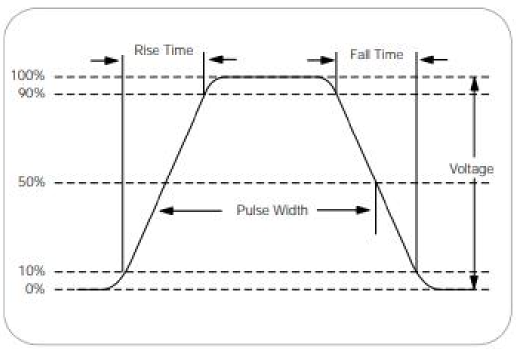


Figure 69. Rise time and pulse width measurement points.

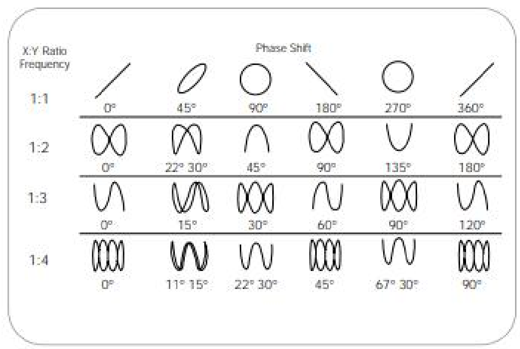


Figure 70. Lissajous patterns.

Phase Shift Measurements One method for measuring phase shift – the difference in timing between two otherwise identical periodic signals – is to use XY mode. This measurement technique involves inputting one signal into the vertical system as usual and then another signal into the horizontal system – called an XY measurement because both the X and Y axis are tracing voltages. The waveform that results from this arrangement is called a Lissajous pattern (named for French physicist Jules Antoine Lissajous and pronounced LEE–sa–zhoo). From the shape of the Lissajous pattern, you can tell the phase difference between the two signals. You can also tell their frequency ratio. Figure 70 shows Lissajous patterns for various frequency ratios and phase shift

SPECIAL OSCILLOSCOPES

1. *SAMPLING OSCILLOSCOPE*

An ordinary oscilloscope has a B.W. of 10 MHz. The HF performance can be improved by means of sampling the input waveform and reconstructing its shape from the sample, i.e. the signal to be observed is sampled and after a few cycles the sampling point is advanced and another sample is taken. The shape of the waveform is reconstructed by joining the sample levels together. The sampling frequency may be as low as 1/10th of the input signal frequency (if the input signal frequency is 100 MHz, the bandwidth of the CRO vertical amplifier can be as low as 10 MHz). As many as 1000 samples are used to reconstruct the original waveform.

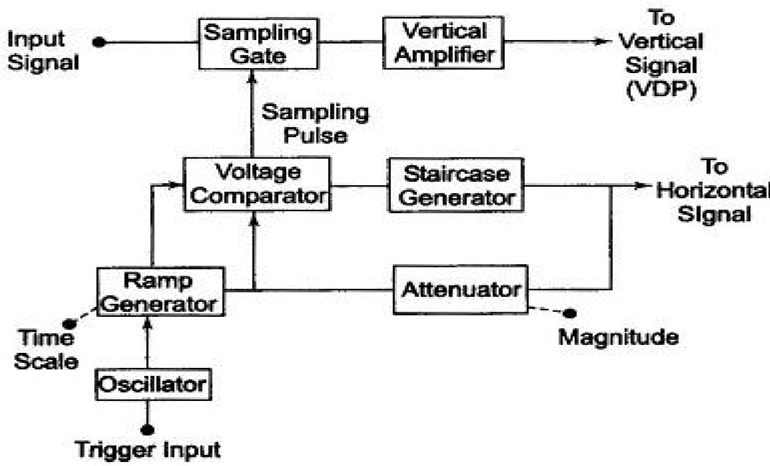


Fig. 7.24 Sampling Oscilloscope

Figure 7.24 shows a block diagram of a sampling oscilloscope. The input waveform is applied to the sampling gate. The input waveform is sampled whenever a sampling pulse opens the sampling gate. The sampling must be synchronised with the input signal frequency. The signal is delayed in the vertical amplifier, allowing the horizontal sweep to be initiated by the input signal. The waveforms are shown in Fig. 7.25.

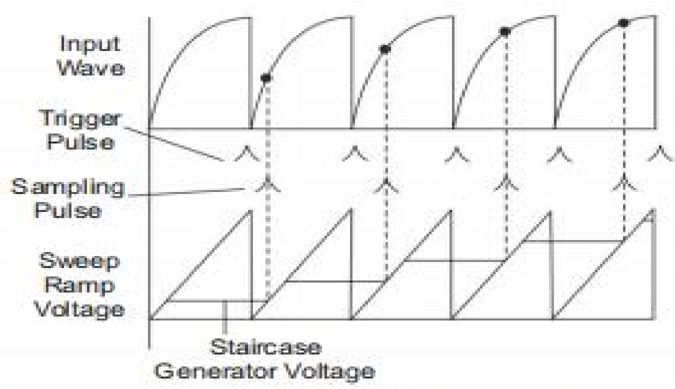


Fig. 7.25 Various waveforms at each block of a sampling oscilloscope

At the beginning of each sampling cycle, the trigger pulse activates an oscillator and a linear ramp voltage is generated. This ramp voltage is applied to a voltage comparator which compares the ramp voltage to a staircase generator. When the two voltages are equal in amplitude, the staircase advances one step and a sampling pulse is generated, which opens the sampling gate for a sample of input voltage. The resolution of the final image depends upon the size of the steps of the staircase generator. The smaller the size of the steps the larger the number of samples and higher the resolution of the image.

2. ***STORAGE OSCILLOSCOPE***

Storage targets can be distinguished from standard phosphor targets by their ability to retain a waveform pattern for a long time, independent of phosphor peristence. Two storage techniques are used in oscilloscope CRTs, mesh storage and phosphor storage.

A mesh-storage CRT uses a dielectric material deposited on a storage mesh as the storage target. This mesh is placed between the deflection plates and the standard phosphor target in the CRT. The writing beam, which is the focussed electron beam of the standard CRT, charges the dieletric material positively where hit. The storage target is then bombarded with low velocity electrons from a flood gun and the positively charged areas of the storage target allow these electrons to pass through to the standard phosphor target and thereby reproduce the stored image on the screen. Thus the mesh storage has both a storage target and a phosphor display target. The phosphor storage CRT uses a thin layer of phosphor to serve both as the storage and the display element.

Mesh Storage It is used to display Very Low Frequencies (VLF) signals and finds many applications in mechanical and biomedical fields. The conventional scope has a display with a phosphor peristence ranging from a few micro seconds to a few seconds. The persistence can be increased to a few hours from a few seconds.

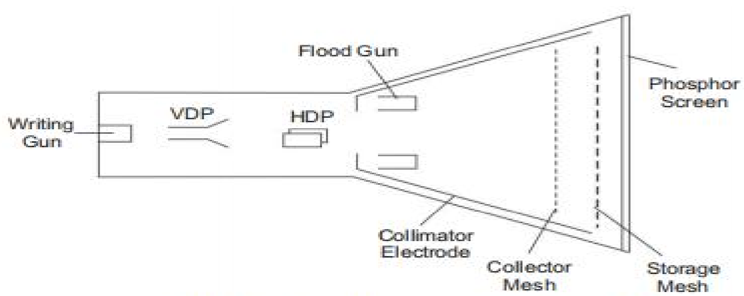


Fig. 7.26 Basic elements of storage mesh CRT

A mesh storage CRT, shown in Fig. 7.26, contains a dielectric material deposited on a storage mesh, a collector mesh, flood guns and a collimator, in addition to all the elements of a standard CRT. The storage target, a thin deposition of a dielectric material such as Magnesium Fluoride on the storage mesh, makes use of a property known as secondary emission.

The writing gun etches a positively charged pattern on the storage mesh or target by knocking off secondary emission electrons. Because of the excellent insulating property of the Magnesium Fluoride coating, this positively charged pattern remains exactly in the position where it is deposited. In order to make a pattern visible, a special electron gun, called the flood gun, is switched on (even after many hours).

The electron paths are adjusted by the collimator electrode, which constitutes a low voltage electrostatic lens system (to focus the electron beam), as shown in Fig. 7.27. Most of the electrons are stopped and collected by the collector mesh. Only electrons near the stored positive charge are pulled to the storage target with sufficient force to hit the phosphor screen.

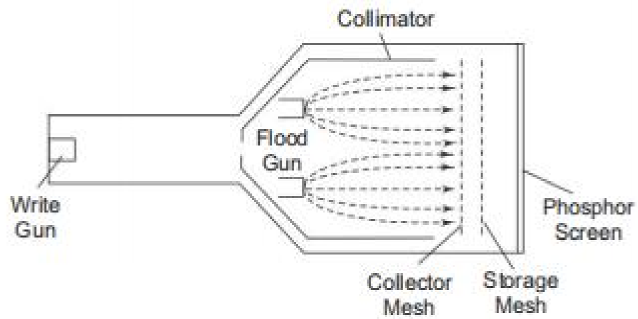


Fig. 7.27 Storage mesh CRT

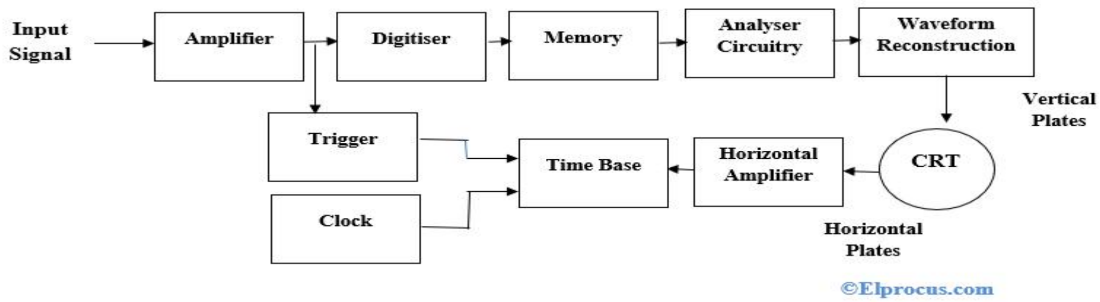
The CRT will now display the signal and it will remain visible as long as the flood guns operate. To erase the pattern on the storage mesh, a negative voltage is applied to neutralise the stored positive charge. Since the storage mesh makes use of secondary emission, between the first and second crossover more electrons are emitted than are absorbed by the material, and hence a net positive charge results. Below the first crossover a net negative charge results, since the impinging electrons do not have sufficient energy to force an equal number to be emitted. In order to store a trace, assume that the storage surface is uniformly charged and write gun (beam emission gun) will hit the storage target.

Those areas of the storage surface hit by the deflecting beam lose electrons, which are collected by the collector mesh. Hence, the write beam deflection pattern is traced on the storage surface as a positive charge pattern. Since the insulation of the dielectric material is high enough to prevent any loss of charge for a considerable length of time, the pattern is stored. To view, the stored trace, a flood gun is used when the write gun i

3. ***DIGITAL STORAGE OSCILLOSCOPE***

The digital storage oscilloscope is defined as the oscilloscope which stores and analysis the signal digitally, i.e. in the form of 1 or 0 preferably storing them as analogue signals.

The digital oscilloscope takes an input signal, store them and then display it on the screen. The digital oscilloscope has advanced features of storage, triggering and measurement. Also, it displays the signal visually as well as numerically. Working Principle of Digital Storage Oscilloscope The digital oscilloscope digitises and stores the input signal. This can be done by the use of CRT (Cathode ray tube) and digital memory. The block diagram of the basic digital oscilloscope is shown in the figure below. The digitisation can be done by taking the sample input signals at periodic waveforms.



The maximum frequency of the signal which is measured by the digital oscilloscope depends on the two factors.

Theses factors are

1. Sampling rate

2. Nature of converter.

Sampling Rate – For safe analysis of input signal the sampling theory is used. The sampling theory states that the sampling rate of the signal must be twice as fast as the highest frequency of the input signal. The sampling rate means analogue to digital converter has a high fast conversion rate.

Converter – The converter uses the expensive flash whose resolution decreases with the increases of a sampling rate. Because of the sampling rate, the bandwidth and resolution of the oscilloscope are limited.

The need of the analogue to digital signal converters can also be overcome by using the shift register. The input signal is sampled and stored in the shift register. From the shift register, the signal is slowly read out and stored in the digital form. This method reduces the cost of the converter and operates up to 100 megasample per second.

X–Y RECORDER

In most research fields, it is often convenient to plot the instantaneous relationship between two variables [Y = f(x)], rather than to plot each variable separately as a function of time. In such cases, the X–Y recorder is used, in which one variable is plotted against another variable. In an analog X–Y recorder, the writing head is deflected in either the x-direction or the y-direction on a fixed graph chart paper. The graph paper used is generally squared shaped, and is held fixed by electrostatic attraction or by vacuum.

The writing head is controlled by a servo feedback system or by a self balancing potentiometer. The writing head consist of one or two pens, depending on the application. In practice, one emf is plotted as a function of another emf in an X–Y recorder. In some cases, the X–Y recorder is also used to plot one physical quantity (displacement, force, strain, pressure, etc.) as a function of another physical quantity, by using an appropriate transducer, which produces an output (EMF) proportional to the physical quantity.

The motion of the recording pen in both the axis is driven by servo-system, with reference to a stationary chart paper. The movement in x and y directions is obtained through a sliding pen and moving arm arrangement.

A typical block diagram of an X–Y recorder is illustrated in Fig. 12.9.

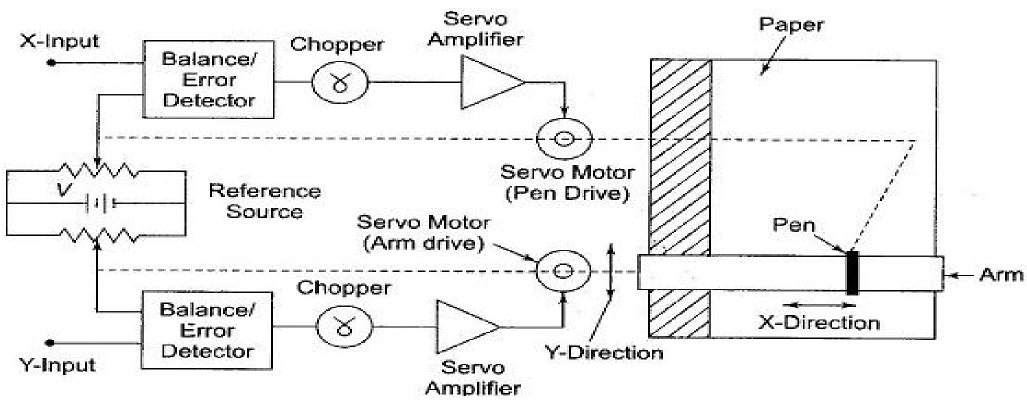


Fig. 12.9 Basic X–Y recorder

Referring to Fig. 12.9, each of the input signals is attenuated in the range of 0–5 mV, so that it can work in the dynamic range of the recorder. The balancing circuit then compares the attenuated signal to a fixed internal reference voltage. The output of the balancing circuit is a dc error signal produced by the difference between the attenuated signal and the reference voltage.

This dc error signal is then converted into an ac signal with the help of a chopper circuit. This ac signal is not sufficient to drive the pen/arm drive motor, hence, it is amplified by an ac amplifier. This amplified signal (error signal) is then applied to actuate the servo motor so that the pen/arm mechanism moves in an appropriate direction in order to reduce the error, thereby bringing the system to balance. Hence as the input signal being recorded varies, the pen/arm tries to hold the system in balance, producing a record on the paper.

MAGNETIC RECORDERS

The major advantage of using a magnetic tape recorder is that once the data is recorded, it can be replayed an almost indefinite number of times. The recording period may vary from a few minutes to several days. Speed translation of the data captured can be provided, i.e. fast data can be slowed down and slow data speeded up by using different record and reproduce speeds. The recorders described earlier have a poor high frequency response. Magnetic tape recorder, on the other hand, have a good response to high frequency, i.e. they can be used to record high frequency signals. Hence, magnetic tape recorders are widely used in instrumentation systems.

A magnetic tape recorder consists of the following basic components.

1. Recording Head

2. Magnetic Head

3. Reproducing Head

4. Tape transport mechanism

5. Conditioning devices

Magnetic Recording The basic elements of a simple magnetic recording system are illustrated in Fig. 12.10(a).

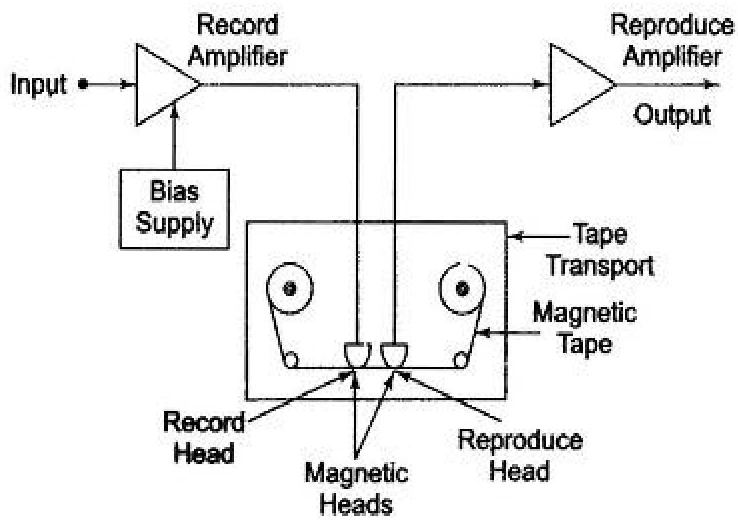


Fig. 12.10(a) ■ Elementary Magnetic Tape Recorder

The magnetic tape is made of a thin sheet of tough, dimensionally stable plastic, one side of which is coated with a magnetic material. Some form of finely powdered iron oxide is usually cemented on the plastic tape with a suitable binder. As the tape is transferred from one reel, it passes across a magnetising head that impresses a residual magnetic pattern upon it in response to an amplified input signal.

The methods employed in recording data on to the magnetic tape include direct recording, frequency modulation (FM) and pulse code modulation (PCM). Modulation of the current in the recording head by the signal to be recorded linearly modulates the magnetic flux in the recording gap. As the tape moves under the recording head, the magnetic particles retain a state of permanent magnetisation proportional to the flux in the gap. The input signal is thus converted to a spatial variation of the magnetisation of the particles on the tape. The reproduce head detects these changes as changes in the reluctance of its magnetic circuit which induce a voltage in its winding. This voltage is proportional to the rate of change of flux. The reproduce head amplifier integrates the signal to provide a fl at frequency characteristics.

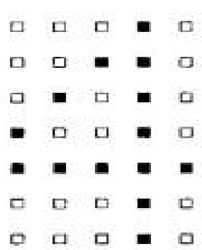
Since the reproduce head generates a signal which is proportional to the rate of change of flux, the direct recording method cannot be used down to dc. The lower limit is around 100 Hz and the upper limit for direct recording, around 2 MHz. The upper frequency limit occurs when the induced variation in magnetisation varies over a distance smaller than the gap in the reproduce head. The signal on an exposed tape can be retrieved and played out at any time by pulling the tape across the magnetic head, in which a voltage is induced.

DOT MATRIX DISPLAY

Excellent alphanumeric characters can be displayed by using dot matrix LEDs with an LED at each dot location. Commonly used dot matrices for the display of prominent characters are 5 × 7, 5 × 8, and 7 × 9, of which 5 × 7 shown in Fig. 2.20 (a), is very popular due to economic considerations. The two wiring patterns of dotmatrix displays are as follows.

1. Common anode or common cathode connection (uneconomical).

2. X – Y array connection (economical and can be extended vertically or horizontally using a minimum number of wires, Fig. 2.20 (b)



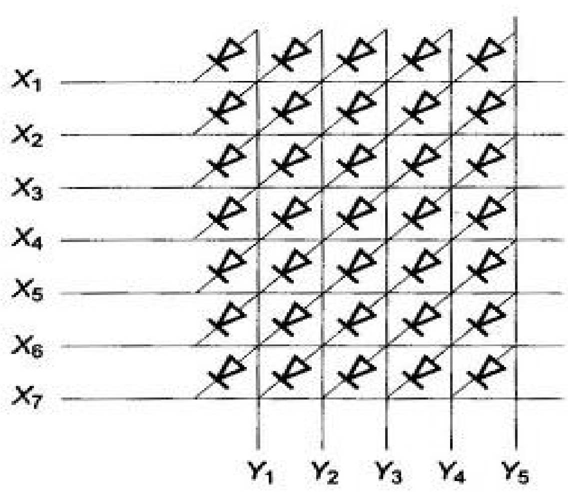


Fig. 2.20 (a) 5 x 7 Dot Matrix Character Using LED
(b) Wiring Pattern for 5 x 7 LED Character

A typical 3 digit alphanumeric character display system using 5 × 7 dot matrix LEDs is shown in Fig. 2.21.

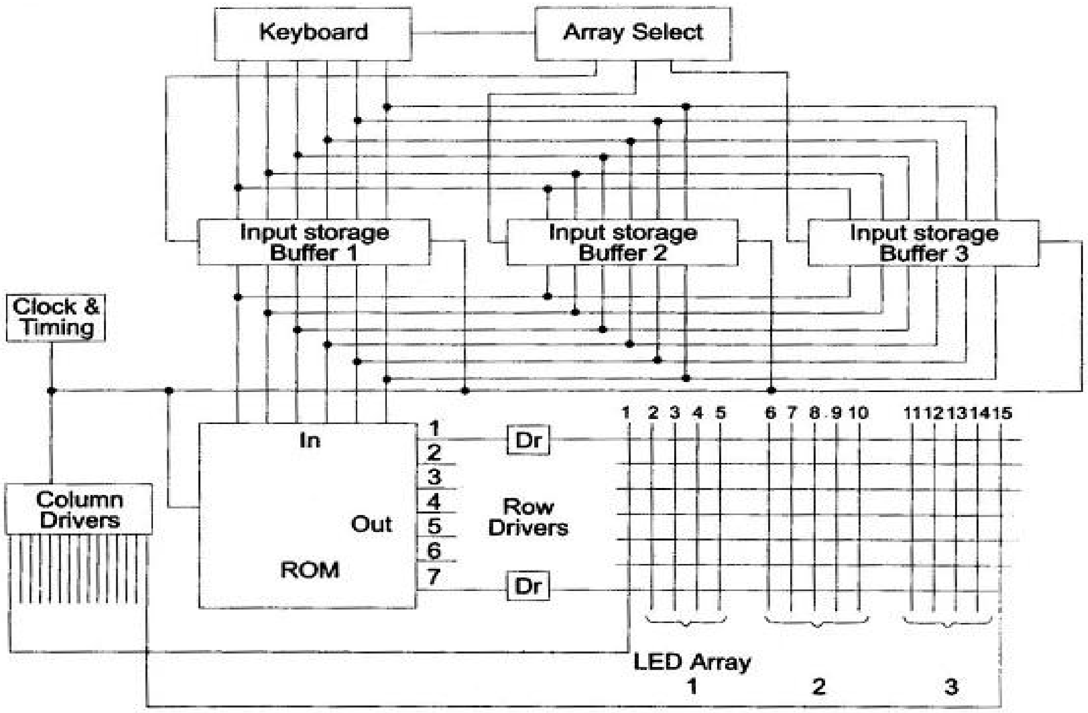


Fig. 2.21 A 3 Digit Alphanumeric Display System Using 5 x 7 Characters