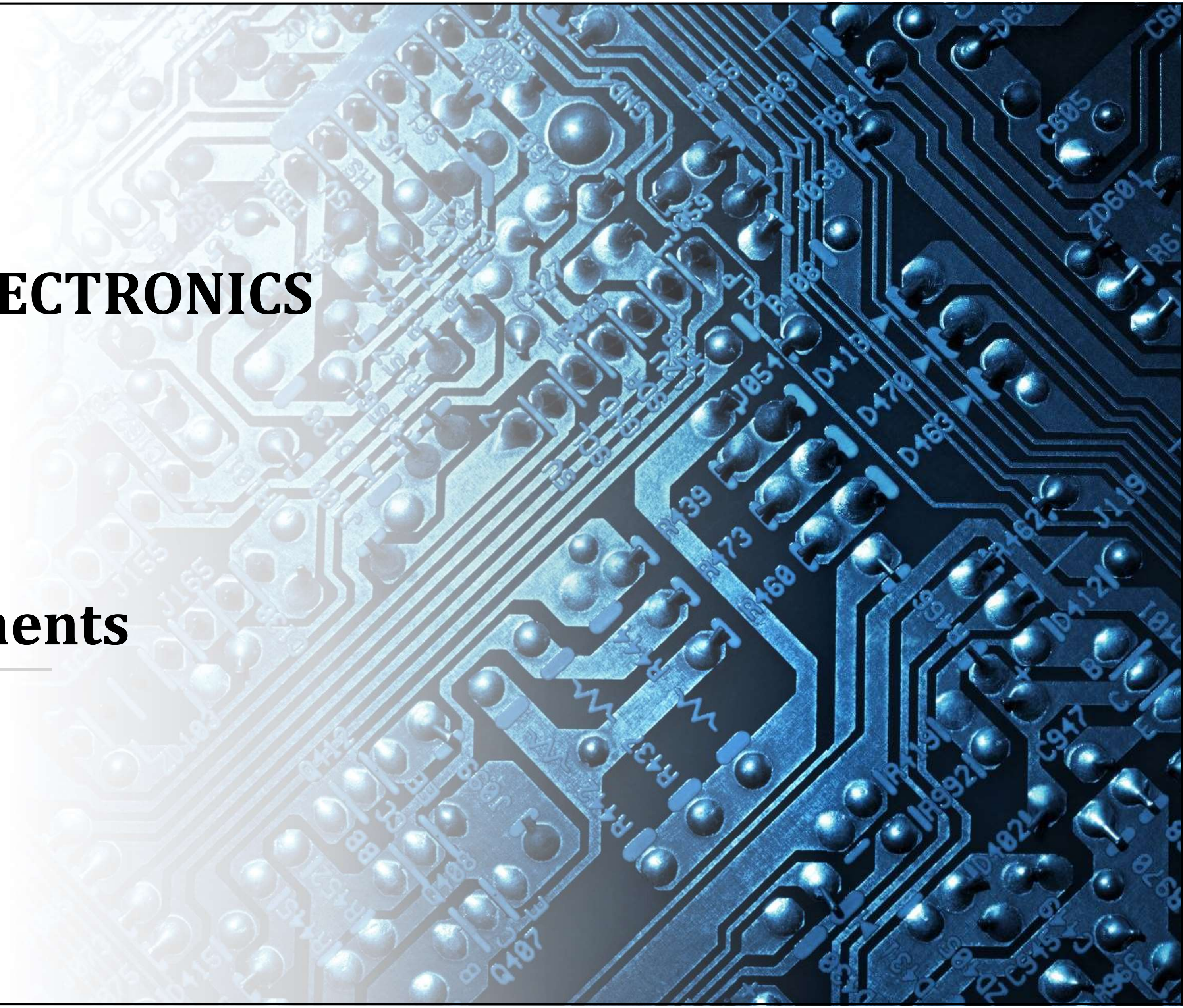
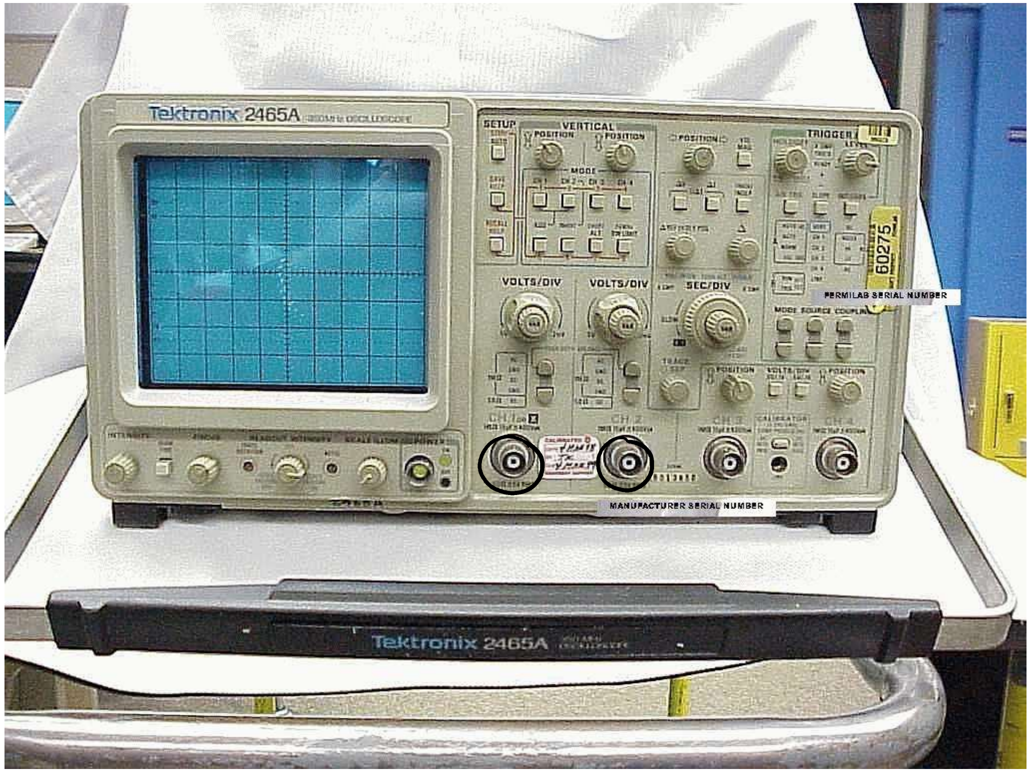
104010 : BASIC ELECTRONICS ENGINEERING

UNIT IV
Electronic Instruments

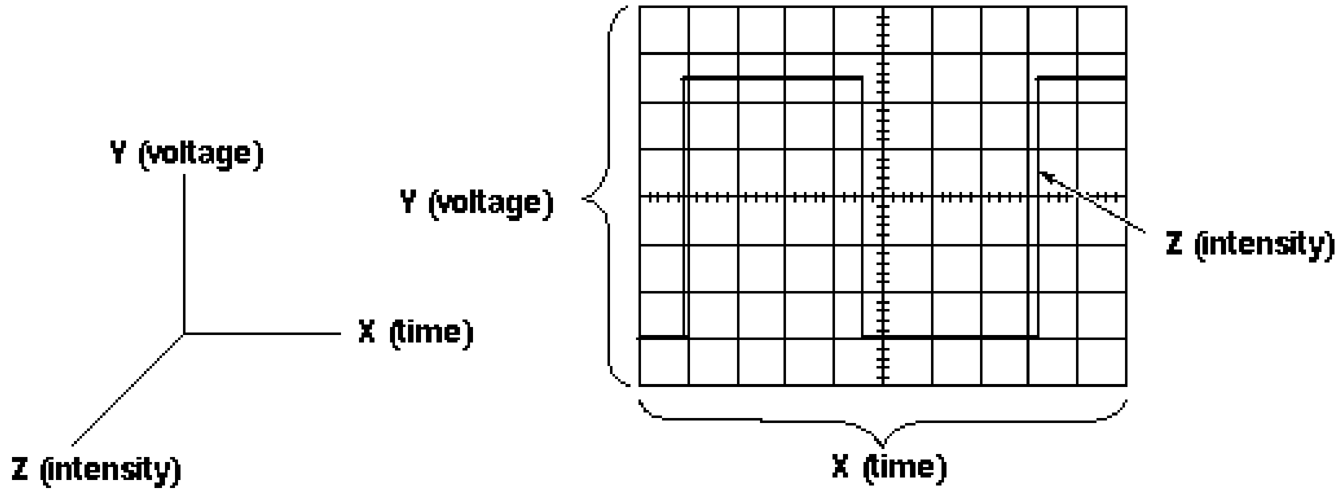


Oscilloscope



Introduction

- A graph-displaying device of electrical signal
  - X axis: Time
  - Y axis: Voltage
  - Z axis: Intensity or brightness



Oscilloscope

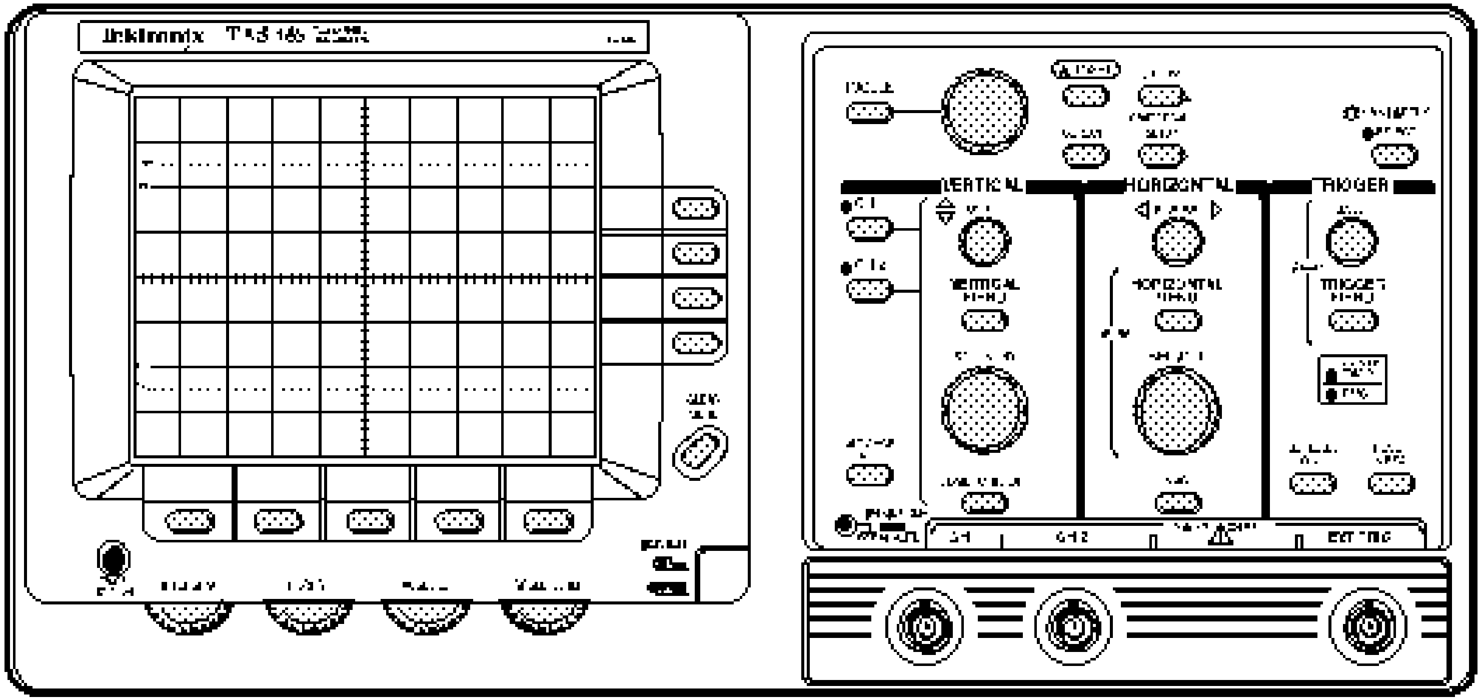
- The oscilloscope is basically a graph-displaying device – it draws a graph of an electrical signal.
- In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage, and the horizontal (X) axis represents time.
- The intensity or brightness of the display is sometimes called the Z axis.

Introduction

- Information given by oscilloscopes
  - Time and voltage
  - Frequency and phase
  - DC and AC components
  - Spectral analysis
  - Rise and fall time
  - Mathematical analysis

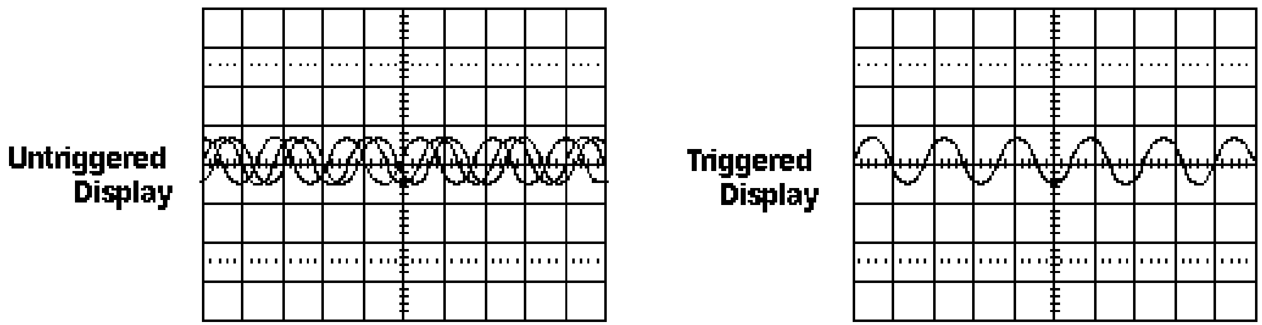
Control panel of an oscilloscope

- Vertical Section
- Horizontal Section
- Trigger Section

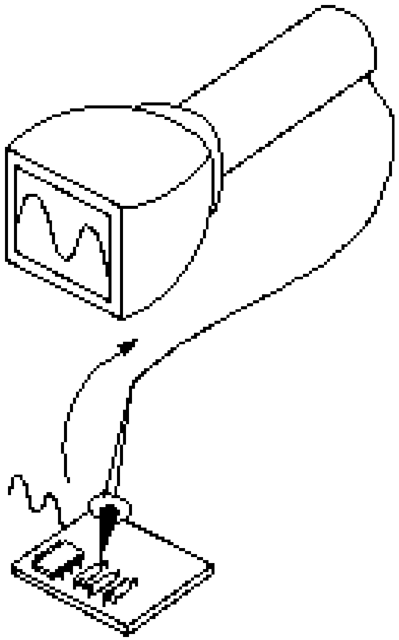


Basic Settings

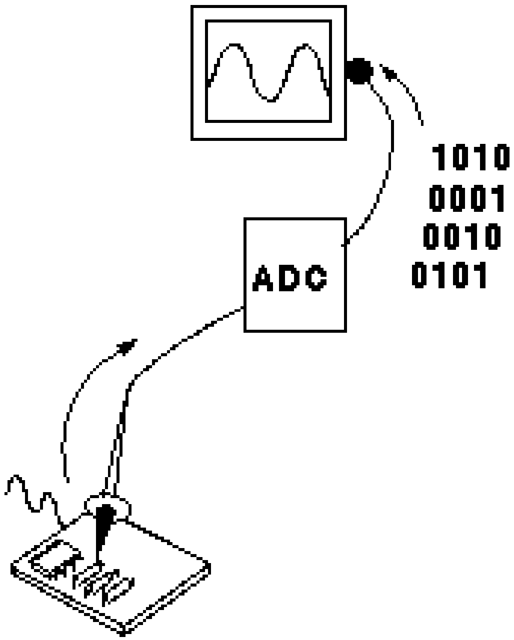
- Vertical system
  - attenuation or amplification of signal (volts/div)
- Horizontal system
  - The Time base (sec/div)
- Trigger system
  - To stabilize a repeating signal and to trigger on a single event



Analog and Digital Oscilloscope



Analog Oscilloscopes
Trace Signals

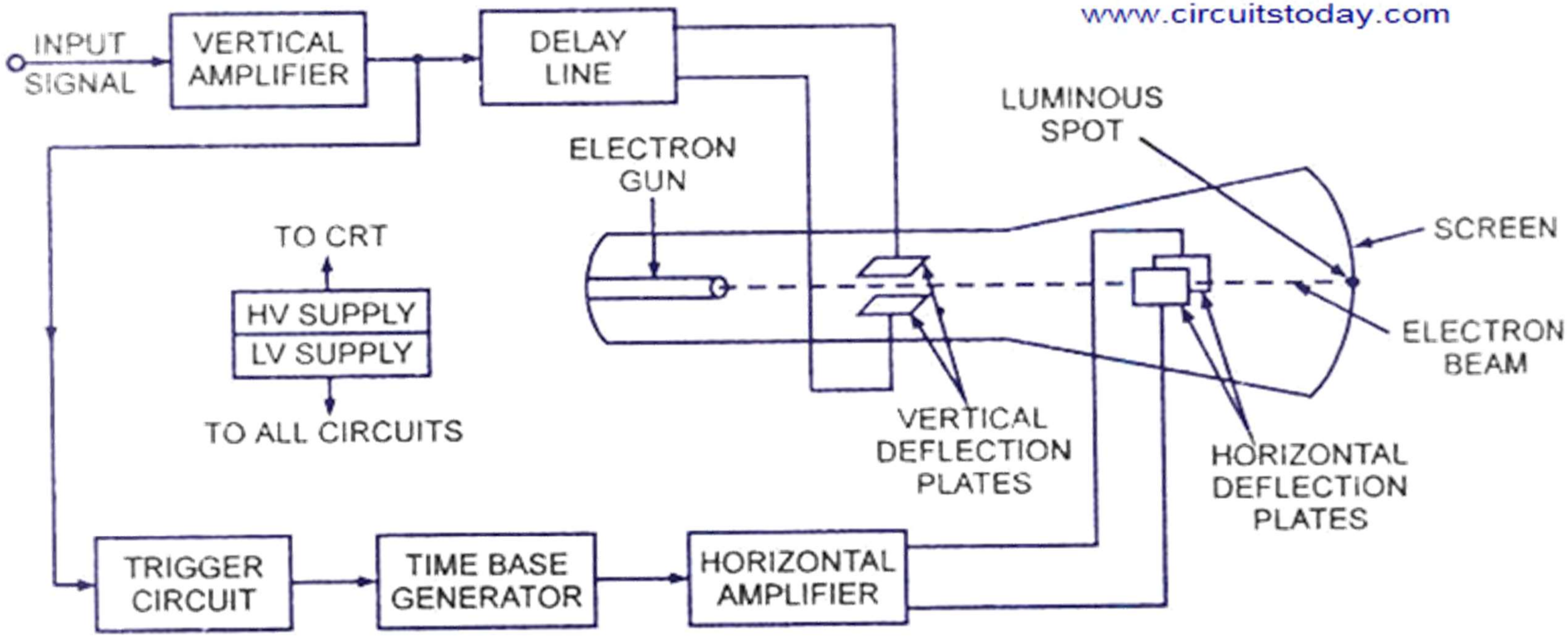


Digital Oscilloscopes Sample Signals
and Construct Displays

Cathode Ray Oscilloscope (CRO)

- The ***cathode ray oscilloscope*** is an extremely useful and versatile laboratory instrument used for studying wave shapes of alternating currents and voltages as well as for measurement of voltage, current, power and frequency, in fact, almost any quantity that involves amplitude and waveform.
- It allows the user to see the amplitude of electrical signals as a function of time on the screen. It is widely used for trouble shooting radio and TV receivers as well as laboratory work involving research and design.
- It can also be employed for studying the wave shape of a signal with respect to amplitude distortion and deviation from the normal.
- In true sense the cathode ray oscilloscope has been one of the most important tools in the design and development of modern electronic circuits.

Block Diagram of CRO



Block Diagram of a General Purpose CRO

Block Diagram Explanation

- The instrument employs a **cathode ray tube** (CRT), which is the heart of the oscilloscope. It generates the electron beam, accelerates the beam to a high velocity, deflects the beam to create the image, and contains a phosphor screen where the electron beam eventually becomes visible.
- For accomplishing these tasks various electrical signals and voltages are required, which are provided by the power supply circuit of the oscilloscope.
- Low voltage supply is required for the heater of the electron gun for generation of electron beam and high voltage, of the order of few thousand volts, is required for cathode ray tube to accelerate the beam. Normal voltage supply, say a few hundred volts, is required for other control circuits of the oscilloscope.

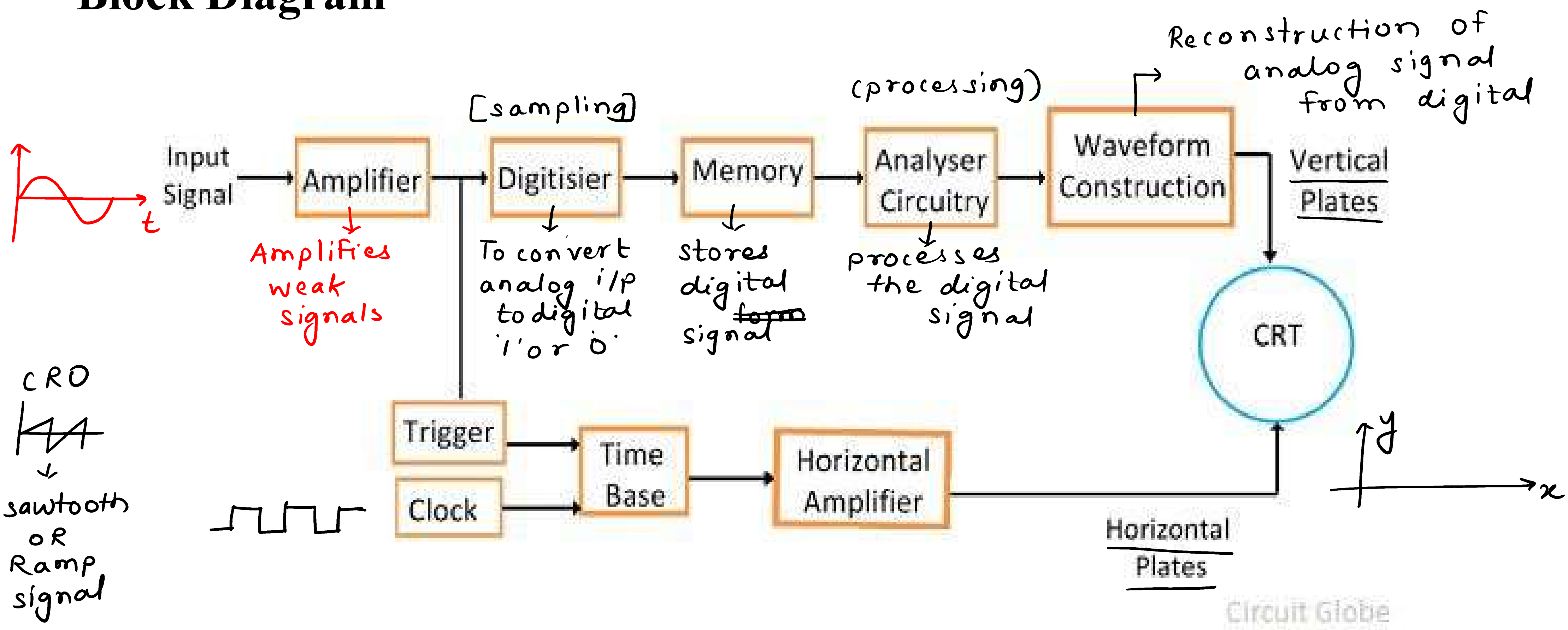
Block Diagram Explanation

- Horizontal and vertical deflection plates are fitted between electron gun and screen to deflect the beam according to input signal. Electron beam strikes the screen and creates a visible spot.
- This spot is deflected on the screen in horizontal direction (X-axis) with constant time dependent rate. This is accomplished by a time base circuit provided in the oscilloscope.
- The signal to be viewed is supplied to the vertical deflection plates through the vertical amplifier, which raises the potential of the input signal to a level that will provide usable deflection of the electron beam.
- Now electron beam deflects in two directions, horizontal on X-axis and vertical on Y-axis. A triggering circuit is provided for synchronizing two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.

Digital Storage Oscilloscope

- The **digital storage oscilloscope** is defined as the oscilloscope which **stores and analyzes the signal digitally**, i.e., in the form of 1 or 0. 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.
- The digital oscilloscope digitizes and stores the input signal. This can be done using **CRT** (Cathode Ray Tube) and **digital memory**. The block diagram of the basic digital oscilloscope is shown in the figure below. The digitization can be done by taking the sample input signals at periodic waveforms.

Block Diagram



Block Diagram Explanation

$F_s \geq 2F_m$

F_s : sampling freq ; $F_s = 1/T_s$; T_s = sampling Interval

F_m: Maximum freq in i/p signal

- Digitizing occurs by taking a sample of the input waveform at periodic intervals. In order to ensure that no information is lost, sampling theory states that the sampling rate must be at least twice as fast as the highest frequency in the input signal. If this is not done then aliasing will result, as shown in the figure below .

Information Loss

↳ overlapping/distortion

Nyquist Sampling Thm,

$\boxed{F_s \geq 2F_m}$

$F < 2F_m$ ↓ Aliasing

- This requirement for a high sampling rate means that the digitizer, which is an analog to digital converter, must have a fast conversion rate. This usually requires expensive flash analog to digital converters, whose resolution decreases as the sampling rate is increased. For this reason, that the bandwidth and resolution of a **digital storage oscilloscope (DSO)** is usually limited by its **analog to digital converter**.

High sampling rates

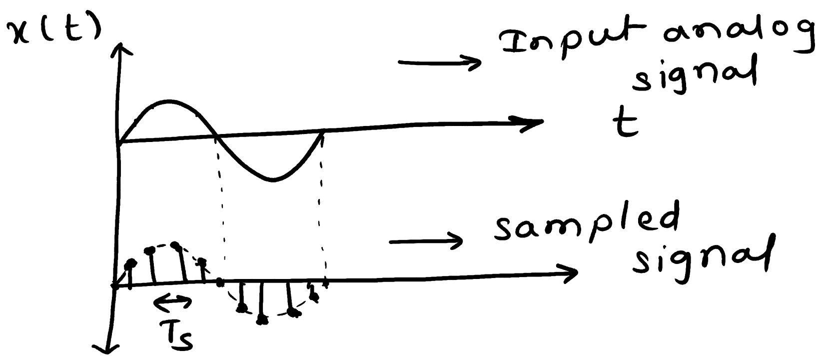
Ex. 1) $F_m = 3kHz$
$F_s = 8kHz$

BW = 100kHz
F_m = 50kHz

ii) $F_m = 100Hz$
$F_s \geq 200Hz$

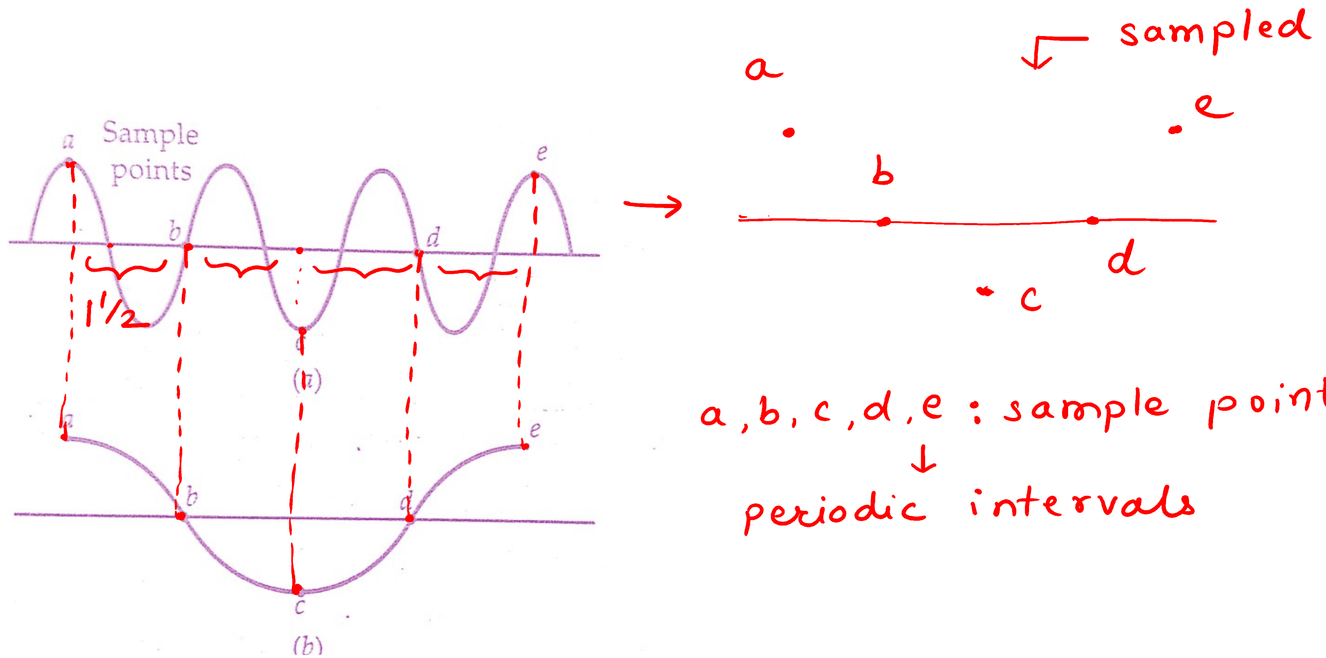
Analog store: Allows to read the waveform at slower rate

- One method of overcoming the need for a high-performance converter is to use an analog store. The input signals are sampled, and these are stored in an analog shift register. They can then be read out at a much slower rate to the **analog to digital converter**, and the results stored in a digital store.



$T_s = \frac{1}{F_s}$ = sampling interval

$F_s \geq 2 F_m$



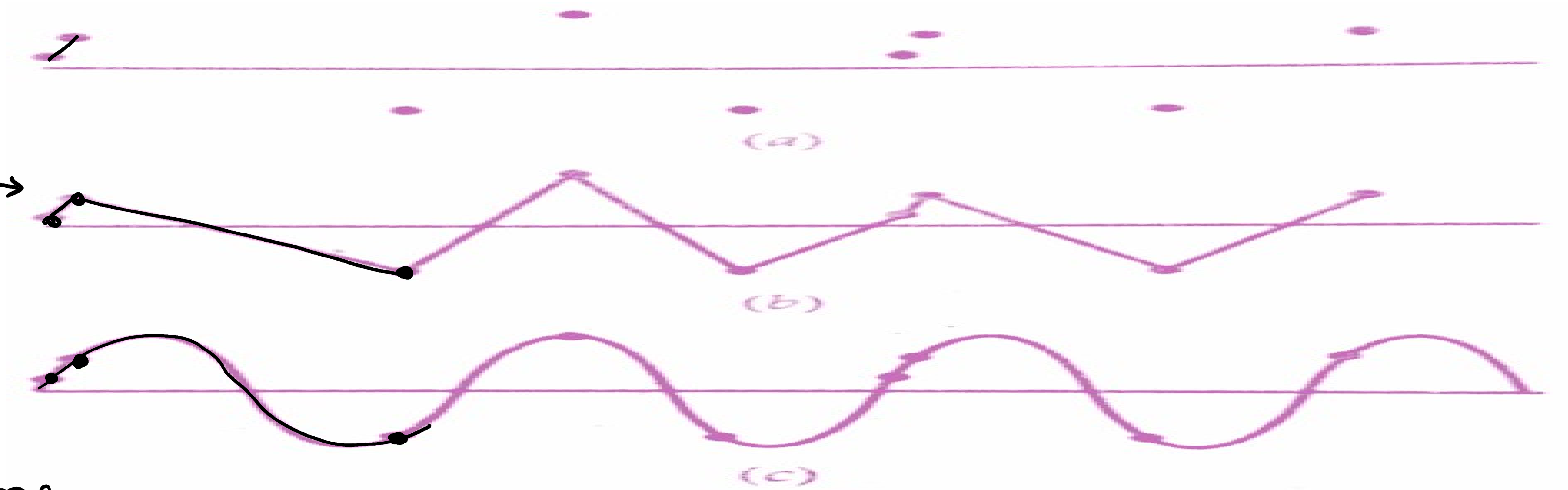
a, b, c, d, e : sample points
↓
periodic intervals

Waveform Reconstruction of Digital Storage Oscilloscope(DSO):

- Although the input signal may be sampled at greater than twice the highest signal frequency, aliasing can still result when the output is present as a series of dots, corresponding to the sampled values. This is illustrated in the figure (a) below, where the user's mind connects the dots which are physically closest to each other, rather than those which are closest on the time scale.
- In the illustration of the figure (a), it is difficult to visualize the final waveform. And **digital storage oscilloscopes** generally have the facility to interpolate between the dots, if required by the user. Two techniques are used,
  - ***Linear interpolation*** → St. line is used to connect the samples
  - ***Sinusoidal interpolation*** → sinusoidal curve to connect the samples

- In linear interpolation, shown in the figure(b) a straight line is used to connect the dots together. This works well on a pulsed or square waveform, but not on a sinusoidal wave, the figure(c) shows that sinusoidal interpolation gives a much better fit for sine waves, although it is not suitable for pulse or square waves.

← sampled waveform

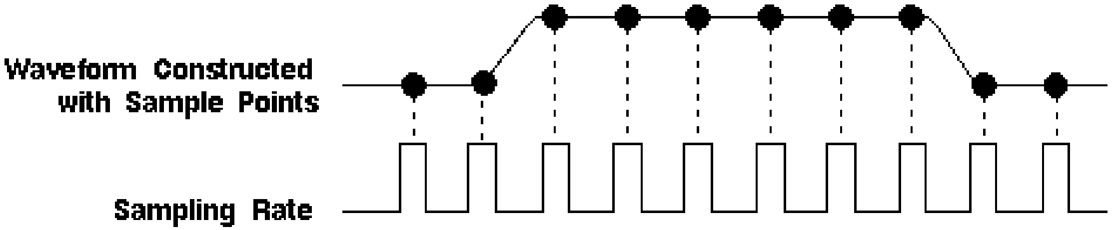


i> Linear →
↓
Triangular or square

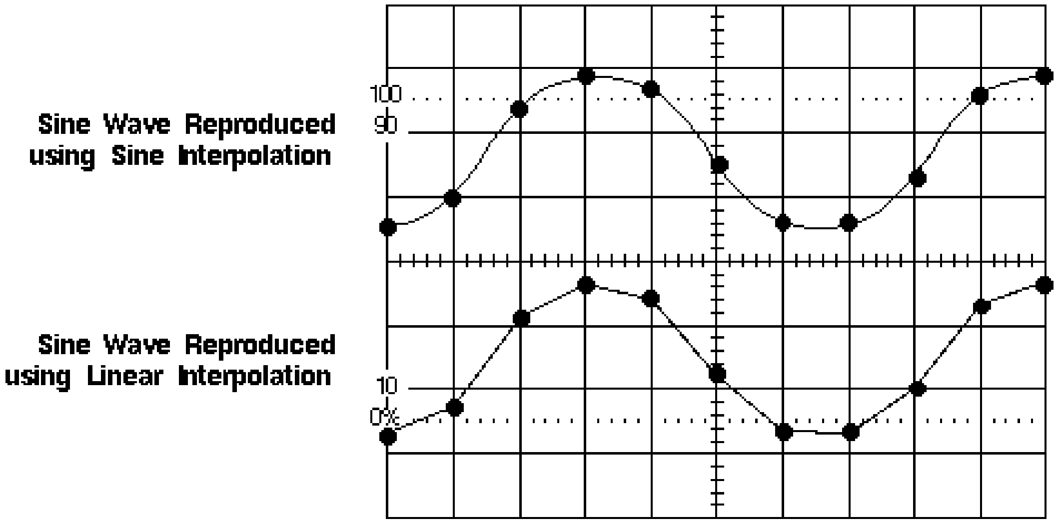
ii> sinusoidal
↓
sine waveforms

Sampling and Interpolation

- **Sampling**

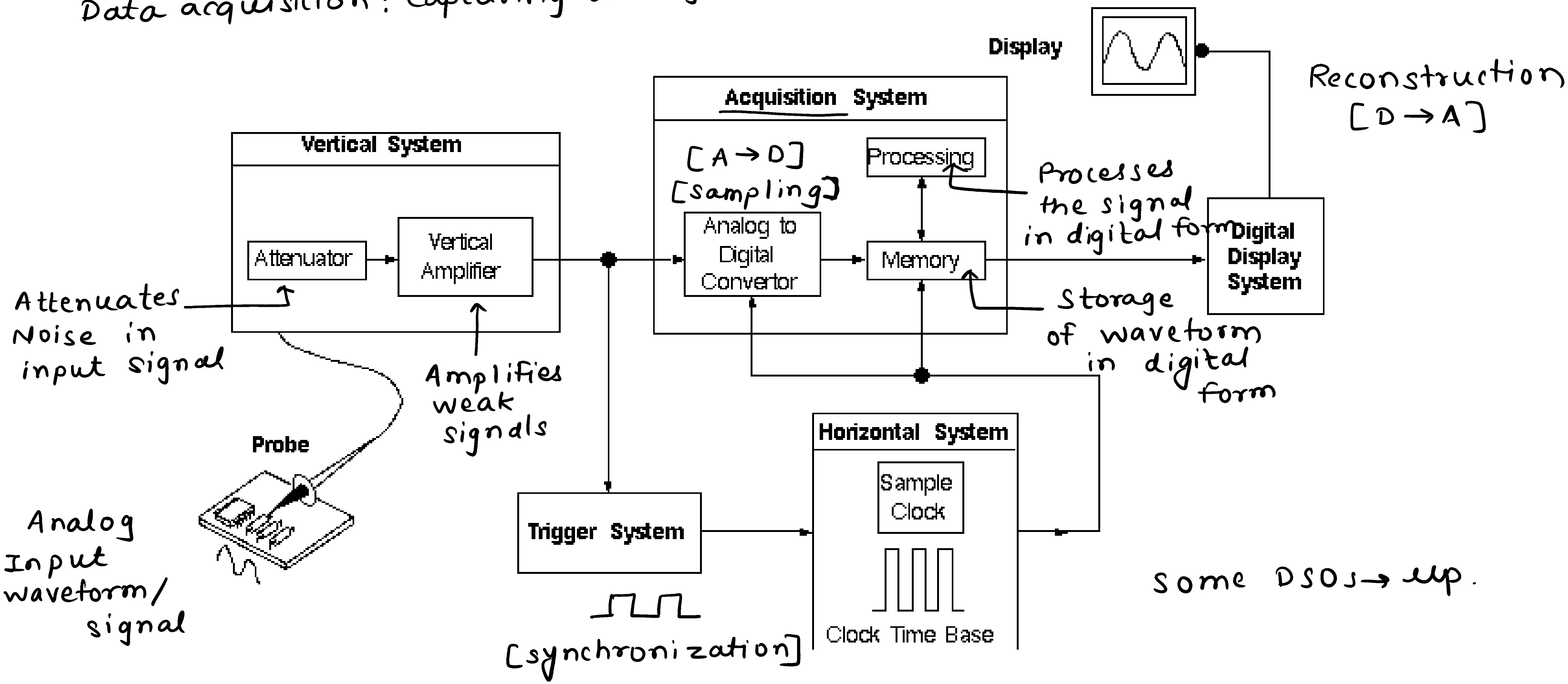


- **Interpolation**



Digital Storage Oscilloscope

Data acquisition : capturing of signal/waveform



some DSOs → up.

Digital Storage Oscilloscope

- The analog-to-digital converter (ADC) in the acquisition system **samples the signal** at discrete points in time and converts the signal's voltage at these points to digital values called *sample points.*

[sample points should be at periodic intervals]

Record length = 5

- The sample points from the ADC are stored in memory as *waveform points.* {a, b, c, d, e}
- Together, the waveform points make up one waveform *record. The* number of waveform points used to make a waveform record is called the *record length*. ***The trigger system determines** the start and stop* points of the record. The display receives these record points after being **stored in memory**.
- Depending on the capabilities of your oscilloscope, additional processing of the sample points may take place, enhancing the display.

Digital Storage Oscilloscope

- A conventional digital oscilloscope is known as a digital storage oscilloscope (DSO). Its display typically relies on **a raster-type screen** rather than the luminous phosphor found in an older analog oscilloscope.
- Digital storage oscilloscopes (DSOs) **allow you to capture and view events that may happen only once – known as transients**. Because the waveform information exists in digital form as a series of stored binary values, **it can be analyzed, archived, printed, and otherwise processed, within the oscilloscope itself or by an external computer**.
- The waveform need not be continuous; **it can be displayed even when the signal disappears.** Unlike analog oscilloscopes, digital storage oscilloscopes provide permanent signal storage and extensive waveform processing. However, DSOs typically have no real-time intensity grading; therefore, they cannot express varying levels of intensity in the live signal.

Advantage of Digital Scope

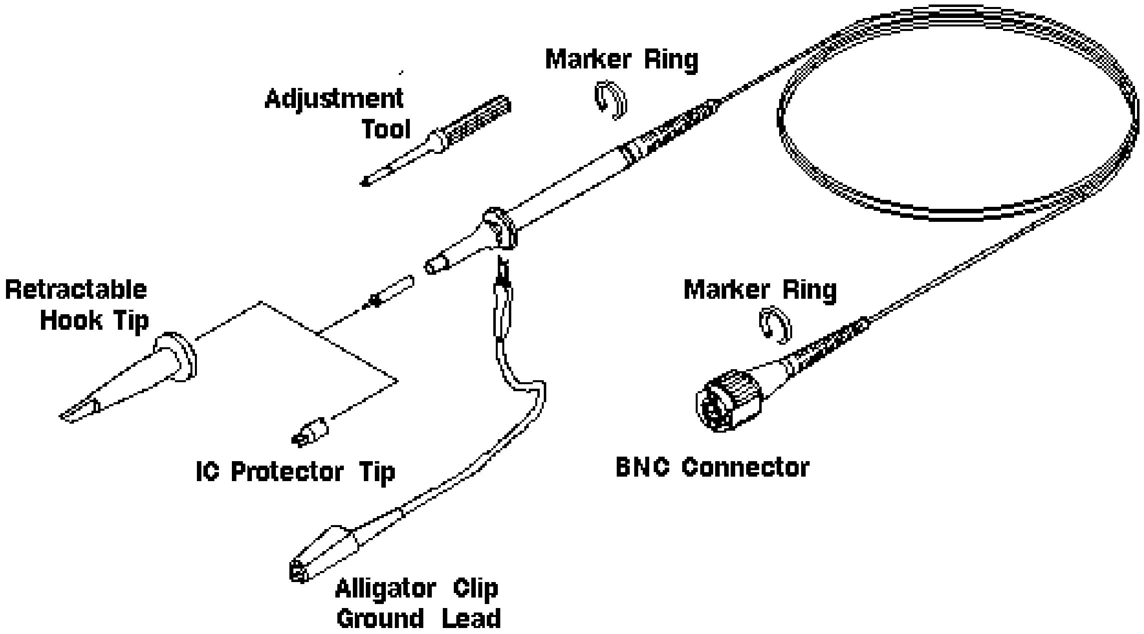
- Easy to use.
- Recoding
- Triggering
- Data reuse
- Connectivity

Digital Storage Oscilloscope (DSO)	Conventional Storage Oscilloscope (Analog Storage Oscilloscope (ASO))
1. It can store the given signal indefinitely as long as the small amount of power is supplied to the memory.	1. In this oscilloscope heavy amount-of power is to be supplied to the storage CRT.
2. It always collects the data and stops when triggered. [sampling starts after trigger]	2. It collects the data only after triggering.
3. It employs normal CRT, hence the cost of the tube is much cheaper than the storage tube used in ASO.	3. The cost of the tube is costlier than the storage tube used in DSO.
4. It can produce bright image even for high frequency signals.	4. It cannot produce bright image for high frequency signals.
5. In this oscilloscope, time base is generated, by a crystal clock.	5. In this oscilloscope, time base is generated by a ramp circuit.
6. It has higher resolution than ASO.	6. It has lower resolution than DSO.
7. It has less operating speed than ASO.	7. It has high operating speed than DSO.
8. Because of aliasing effect the useful storage bandwidth is limited. ↳ Due to sampling	8. It doesn't have aliasing effect. ↳ No sampling

Probes Components → Passive → Active

Connectors -
1) BNC *
2) SMA

- High quality connector
- High impedance (10MΩ)
- 50Ω for high frequency measurement



Passive Probe

1x Attenuation
10x Attenuation
100x Attenuation

- 10 × attenuation → Voltage Divider Network
  - Good for low circuit loading
  - Suitable to high frequency signal
  - Difficult to measure less than 10mV signals
- 1 × attenuation
  - Good for small signals
  - Introducing more interference

Active Probe

↳ Active components → Resistance + FETs

- Signal conditioning ⇒ oscilloscope
- Require power source
- Good for high-speed digital signals over 100 MHz clock frequency

Power Scope PX8000

Measures power in signal

Pout / Pin

- **With its combination of oscilloscope and power analyzer**, that enables users to measure power, efficiency, transient responses and many parameters that cannot be measured by available instruments.
- The oscilloscope are not designed to measure power.
- While, for instance, a power computation out of the measurement of voltage and current, does not take in account the phase displacement between both parameter under reactive loads, the PX8000 provides calibrated power measurements even with this kind of load.
- The **PX8000** is the world's first precision **power** scope, bringing oscilloscope-style time-based measurement to the world of **power** measurement. It can capture voltage and current waveforms precisely, opening applications and solutions for a huge variety of emerging **power** measurement problems.

Power Scope PX8000

- A complex mix of *renewable and conventional energies in the grid, electric and hybrid vehicles, aggravated standby power consumption regulations and faster-switching semiconductors with all the consequences for harmonic distortion* - these are just some examples out of the complex problem definition designers in the field of power electronics have to deal with today. In such an environment, exact measurement of all power-related parameters in an electronic circuit becomes an important requirement in many designs.

Difference between DSO and DPO

- A DSO is typically a real-time sampling oscilloscope. Real-time sampling simply means that the scope can capture signals in a single acquisition utilizing a high-sample-rate analog-to-digital converter (ADC). In other words, a DSO doesn't utilize repetitive acquisitions to "build-up" sufficient samples to represent the signal under test (equivalent-time sampling).
- A DPO adds one additional element that allows it to better represent the signal's third dimension. The first two obvious dimensions are voltage and time. The third and less obvious dimension is frequency-of-occurrence, which is represented by trace intensity on a scope's display.
- Basically, by counting the number of hits (digital samples) in particular XY regions of a bitmap—sometimes called buckets—pixel intensity could be digitally modified to represent trace-intensity modulation of phosphor. This is the genesis of the term digital phosphor oscilloscope (DPO).

References:

- “Electronic Instrumentation” by H.S. Kalsi, 3rd Edition, Tata McGraw Hill.
- “Electronic Instrumentation and Measurement” by William D. Cooper, Albert D. Helfrick , Prentice Hall PTR.
- Web Resources

Thank you!