Study Notes on Error Analysis & Oscilloscope

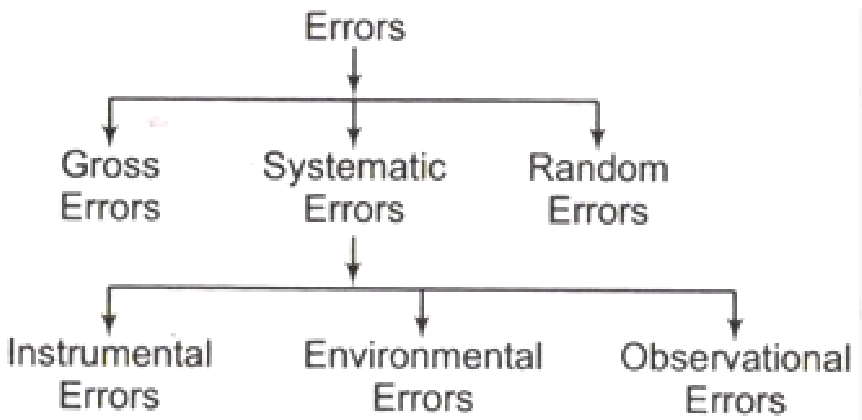
Error analysis is a process used to identify and quantify the sources of error or uncertainty in a measurement or experimental data. It involves examining various factors that can contribute to discrepancies between the measured values and the true values or expected results. When it comes to using an oscilloscope, error analysis can be applied to understand and minimize the sources of error in the measurements taken with the oscilloscope.

Here, you will find the study notes on Error Analysis & Oscilloscope which will cover the topics such as Errors and Statistical Analysis, Classification of Errors, Gross Errors, Instrumental Errors, Environmental Errors, Absolute Errors/Limiting Errors/Static Errors, Percentage Error, Combination of Quantities With Limiting Errors, The Cathode Ray Oscilloscope, Component of C.R.O, Deflection of Electron Beam, Deflection Sensitivity, Deflection Factor, Velocity of Electron Beam, Electrostatic Deflection, Frequency limit of CRO & Rising Time of Vertical Amplifier.

Errors Analysis

Errors: It is defined as the deviation of the true value from the desired value.

Classification of Errors



Errors classification

Gross Errors

- Mistake by observer
- Reading and recording error

- Calculation mistake

Systematic Errors

These errors occur due to shortcomings of the instruments such as defective or worn parts or aging or effects of the environment on the instrument. Systematic errors are classified as

Instrumental Errors

These errors arises due to following reasons

- Due to the inherent defect in the instrument.
- Due to mishandling or misuse of the instrument.
- Due to loading effects.

Environmental Errors

These errors occur due to changes in the environmental parameters such as temperature, humidity, pressure etc.

Observational Errors

The most common errors are the parallax error introduced in reading a meter scale and the error of estimation.

Absolute Errors/Limiting Errors/Static Errors

It is the difference between measured value and a true value of a quantity.

$\delta A = A_m - A_T$

where, A_m = Measured value or actual value

A_T = True value or nominal value

Relative Static Errors

It is the ratio of absolute static error (δA) to the true value (A_T) of the quantity under measurement.

$$\varepsilon_r = \frac{A_m - A_T}{A_T} = \frac{\delta A}{A_T}$$

Static Correction

$\delta C = A_T - A_m = -\delta A$

Percentage Error

The relative error may be quoted as a fraction *e.g.*, 5 parts in 1000 or may be expressed as a percentage.

$$\%\varepsilon_r = \frac{A_m - A_T}{A_T} \times 100 = \frac{\delta A}{A_T} \times 100$$

Shortcut

$$\%\varepsilon_r \text{ at } x = \frac{\text{full scale}}{x} \times (\varepsilon_r, \text{full scale})$$

Combination of Quantities With Limiting Errors

The following cases will be considered

Case 1 Sum of Quantities

Let $A = A_1 + A_2 + A_3 + \ldots + A_n$

$$\frac{\delta A}{A} = \pm\left(\frac{\delta A_1}{A_1} \cdot \frac{A_1}{A} + \frac{\delta A_2}{A_2} \cdot \frac{A_2}{A} + \ldots\ldots\right)$$

Where, δA_1, δA_2... = relative increment in quantity A_1, A_2.....

$\frac{\delta A_1}{A_1}, \frac{\delta A_2}{A_2} \ldots\ldots =$ relative limiting error in quantity A_1, A_2.......

$\frac{\delta A}{A} =$ relative limiting error in A

Case 2 Difference of Quantities

Let
$$A = A_1 - A_2$$
$$\frac{\delta A}{A} = \pm\left(\frac{\delta A_1}{A_1}\cdot\frac{A_1}{A} - \frac{\delta A_2}{A_2}\cdot\frac{A_2}{A}\right)$$

Case 3 Multiplication or Quotient of More than Two Quantities

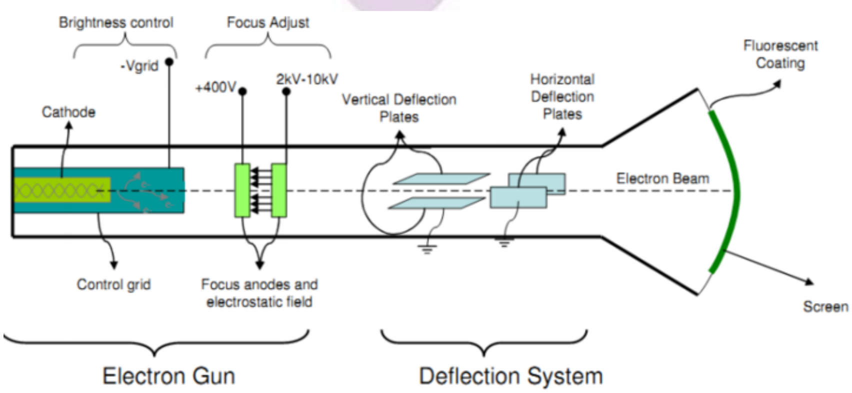
$$A = A_1 A_2 A_3 \ or \ A = \frac{A_1}{A_2 A_3} \ or \ A = \frac{1}{A_1 A_2 A_3}$$
$$\frac{\delta A}{A} = \pm\left(\frac{\delta A_1}{A_1} + \frac{\delta A_2}{A_2} + \frac{\delta A_3}{A_3}\right)$$

Case 4 Composite Errors

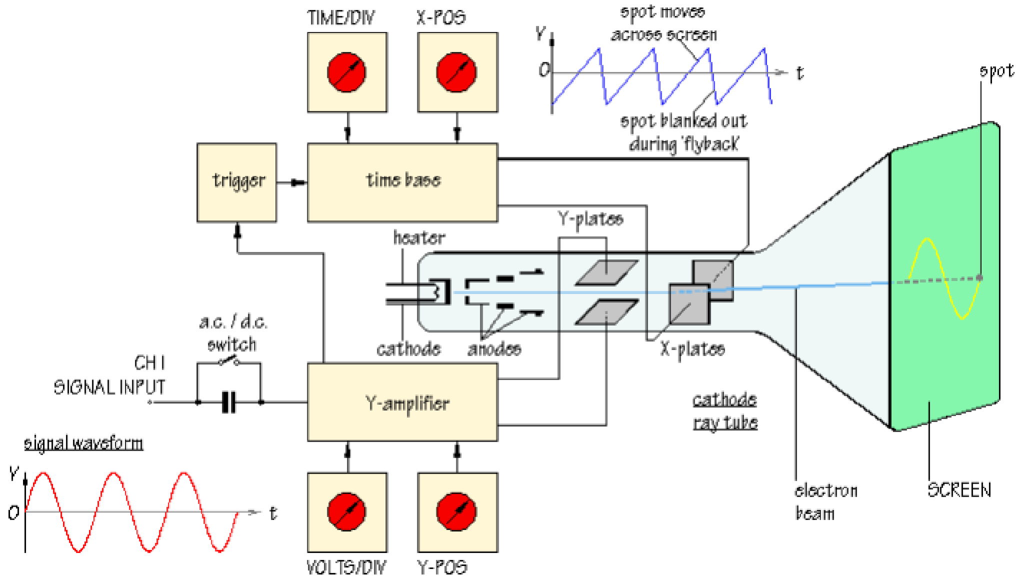
$$A = A_1^n \, . \, A_2^m ; \ \frac{\delta A}{A} = \pm\left(n\frac{\delta A_1}{A_1} + m\frac{\delta A_2}{A_2}\right)$$

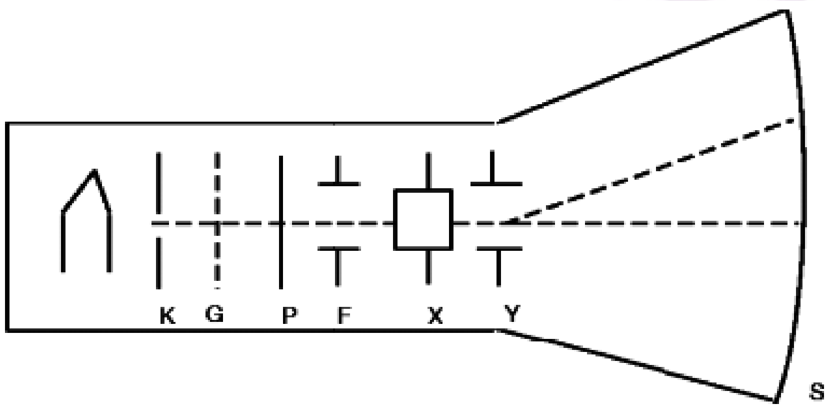
Case/Function		Propagated Error
1)	$z = ax \pm b$	$\Delta z = a\Delta x$
2)	$z = x \pm y$	$\Delta z = \left[(\Delta x)^2 + (\Delta y)^2\right]^{1/2}$
3)	$z = cxy$	$\frac{\Delta z}{z} = \left[\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2\right]^{1/2}$
4)	$z = c\frac{y}{x}$	$\frac{\Delta z}{z} = \left[\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2\right]^{1/2}$
5)	$z = cx^a$	$\frac{\Delta z}{z} = a\frac{\Delta x}{x}$
6)	$z = cx^a y^b$	$\frac{\Delta z}{z} = \left[\left(a\frac{\Delta x}{x}\right)^2 + \left(b\frac{\Delta y}{y}\right)^2\right]^{1/2}$
7)	$z = \sin x$	$\frac{\Delta z}{z} = \Delta x \cot x$
8)	$z = \cos x$	$\frac{\Delta z}{z} = \Delta x \tan x$
9)	$z = \tan x$	$\frac{\Delta z}{z} = \frac{\Delta x}{\sin x \cos x}$

The Cathode Ray Oscilloscope



The **main part** of the C.R.O. is a **highly evacuated glass tube** housing parts which generate a beam of electrons, accelerates them, shapes them into a narrow beam, and provides external connections to the sets of plates described m above for changing the direction of the beam.





Component of C.R.O

- **K,** an indirectly heated cathode which provides a source of electrons for the beam by "boiling" them out of the cathode.
- **P,** the anode (or plate) which is circular with a small central hole. The potential of P creates an electric field which accelerates the electrons, some of which emerge from the hole as a fine beam. This beam lies along the central axis of the tube.
- **G,** the grid. Controlling the potential of the grid controls the number of electrons for the beam, and hence the intensity of the spot on the screen where the beam hits.
- **F,** the focusing cylinder. This aids in concentrating the electron beam into a thin straight line much as a lens operates in optics.

- **X, Y,** deflection plate pairs. The X plates are used for deflecting the beam left to right (the x-direction) by means of the “ramp” voltage.The Y plates are used for deflection of the beam in the vertical direction. Voltages on the X and Y sets of plates determine where the beam will strike the screen and cause a spot of light.
- **S,** the screen. This is coated on the inside with a material which fluoresces with green light (usually) where the electrons are striking.

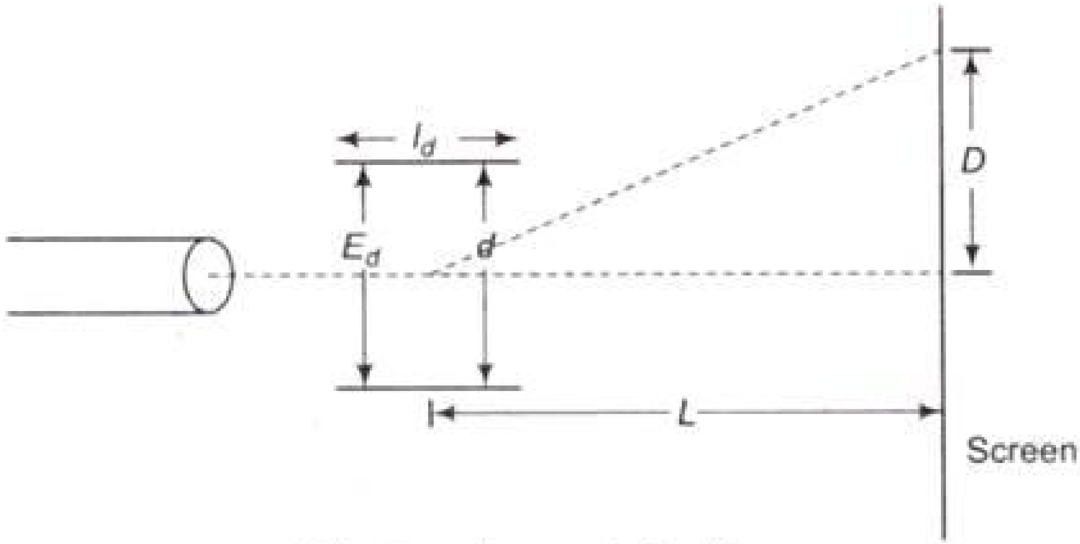
As well as this tube, there are **several electronic circuits required to operate the tube**, all within the C.R.O. along with the tube explained below

- A power supply, operated from the **110 volts 60 cycle per second** electrical “mains”. This supply provides all the voltages required for the different circuits within the C.R.O. for operation of the tube.
- A **“sawtooth”, or “ramp” signal generator** which makes the spot move left to right on the screen. External controls for this circuit allow variation of the sweep width, and the frequency of the sweep signal. Because of the persistence of our vision, this sweep is often fast enough that what we see on the screen is a continuous horizontal line.
- **Amplifiers** for the internally generated ramp signal, and for the “unknown” signal which we hook up to the C.R.O. for the purpose of displaying it.
- **Shift devices** which allow us to **control the mean position of the beam; up or down, or left to right.**
- The **synchronizer** circuit. This circuit allows us to **synchronize the “unknown” signal with the ramp signal** such that the **resulting display is a nice clear signal like a snapshot** of the unknown voltage vs. time.

CRO (Cathode Ray Oscilloscope) and Q-meter

CRO is a device which provides accurate time and amplitude of voltage signals over a wide range of frequencies.

Deflection of Electron Beam



Electron beam deflection

Deflection

$$D = \frac{L\, I_d E_d}{2dE_a} metre$$

Where, L = distance between screen and the center of deflecting plates (m)

l_d = length of deflecting plates (m)

E_d = potential between deflecting plates (V)

d = distance between deflecting plates (m)

E_a = voltage of pre-accelerating anode (V)

Deflection Sensitivity

$$S = \frac{D}{E_d} = \frac{LI_d}{2dE_a}\ m / V$$

Deflection Factor

$$G = \frac{1}{S} = \frac{2dE_a}{LI_d}\ V / m$$

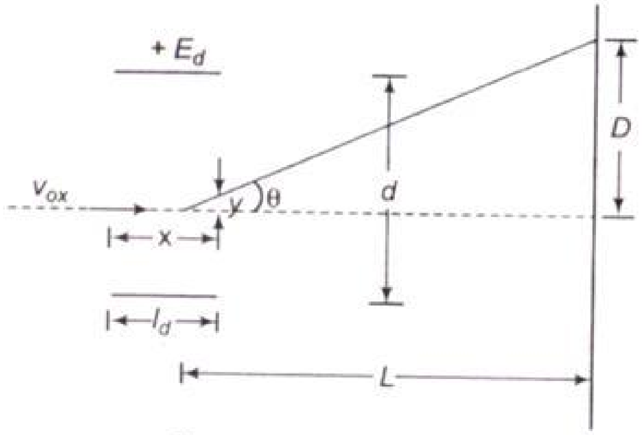
Velocity of Electron Beam

$v = \sqrt{\frac{2dE_a}{m}}$ in m/s

Where, *e* = charge of electron = 16 × 10^{-19} C

m = mass of electron = 9.1 × 10^{-31} kg

Electrostatic Deflection



Electrostatic deflection

$$y = \frac{1}{2}\frac{eEy}{mV_{ox}^2}x^2$$

Where, *y* = displacement in y-direction (m)

e = charge of an electron (C)

m = mass of electron (kg)

x = displacement in X-direction (m)

E_y = electric field intensity in y-direction (V/m)

V_{ox} = velocity of electron when entering in the fields of deflecting plates (m/s)

Frequency limit of CRO

$$f_c = \frac{v_{ox}}{4I_d}$$

Where, V_{ox} = velocity of the electron beam in X-direction before it enters in deflecting plates

l_d = length of vertical deflection plates

Rising Time of Vertical Amplifier

$$t_r = \frac{0.35}{BW}$$

Where, BW = Bandwidth of oscilloscope (CRO)

Thanks!

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