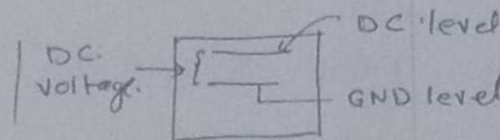
Applications of C.R.O

(1) Measurement of Voltage, Frequency, and time period.

In order to view any waveform, input signal is fed to Y plate of C.R.O.

Measurement of AC/DC level of Input signal: select AC or DC ~~switch~~ mode, depending upon the nature of the signal. Adjust Volts/DIV and Time/DIV knobs for optimal signal setting

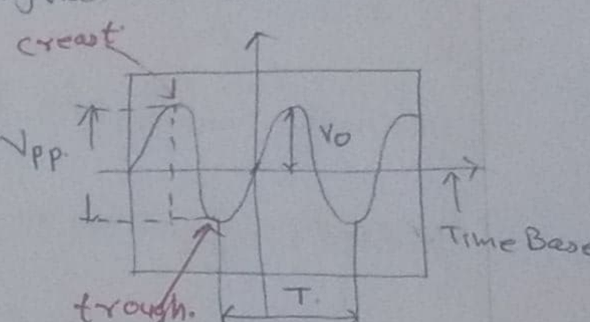
DC-level measurement: Keep the switch at GND mode. Note the position of reference level and then at DC mode [reference level shift]. Measure the vertical distance between the ~~initial~~ initial and final position of reference level.



The difference will give you the DC voltage and is given by the relation.

DC Voltage = Vertical distance (divisions) x Volts/divi (value)

AC. Measurement: The AC signal is shown in the diagram below.



Apply the input signal to the Y-plate, adjust volts/div, and time/div. for optimal display.

V_{pp} (Voltage peak to peak),

Measure the distance between crest and trough of the waveform. Then use the relation to find out

$$V_{pp} = \text{Vertical distance (divisions)} \times V/\text{division}.$$

$$V_0 = \frac{1}{2} V_{pp}. \qquad V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{V_{pp}}{2\sqrt{2}}$$

Time Period (T): Measure the distance/divisions between crest and crest or trough and trough. use the relation

$$T = \text{Horizontal distance/divisions} \times \text{Time/div}.$$

$$f = \frac{1}{T}.$$

Phase Measurement:

Let e_x and e_y be the signals applied to x and Y plates of C.R.O.

$$e_x = E_1 \sin(\omega t + \theta_1) \quad — ①$$

$$e_y = E_2 \sin(\omega t + \theta_2) \quad — ②$$

From ①

$$\frac{e_x}{E_1} = \sin(\omega t + \theta_1) = \sin\omega t \cos\theta_1 + \cos\omega t \sin\theta_1 \quad — ③$$

From (2)

$$\frac{e_y}{E_2} = \sin(\omega t + \theta_2) = \sin\omega t \cos\theta_2 + \cos\omega t \sin\theta_2 \quad — ④$$

Multiply (3) by $\cos\theta_2$ and (4) by $\cos\theta_1$ and subtract them.

$$\frac{e_x}{E_1}\cos\theta_2 = \sin\omega t \cos\theta_1 \cos\theta_2 + \cos\omega t \sin\theta_1 \cos\theta_2$$

$$\frac{e_y}{E_1}\cos\theta_1 = \sin\omega t \cos\theta_2 \cos\theta_1 + \cos\omega t \sin\theta_2 \cos\theta_1$$

$$\frac{e_x}{E_1}\cos\theta_2 - \frac{e_x}{E_2}\cos\theta_1 = \cos\omega t\left[\sin\theta_1\cos\theta_2 - \sin\theta_2\cos\theta_1\right] \quad — ⑤$$

Similarly multiply Eq(3) by $\sin\theta_2$ and (4) by $\sin\theta_1$ & subtract them.

$$\frac{e_x}{E_1}\sin\theta_2 - \frac{e_x}{E_2}\sin\theta_1 = \sin\omega t\left[\cos\theta_1 \sin\theta_2 - \cos\theta_2 \sin\theta_1\right] \quad — ⑥$$

squaring (5) and (6) and then add.

L.H.S

$$\frac{e_x^2}{E_1^2}\cos^2\theta_2 + \frac{e_x^2}{E_2^2}\cos^2\theta_1 - \frac{2 e_x e_y \cos\theta_2 \cos\theta_1}{E_1 E_2} + \frac{e_x^2}{E_1^2}\sin^2\theta_2 + \frac{e_x^2}{E_2^2}\sin^2\theta_1$$

$$- \frac{2 e_x^2 e_y \sin\theta_2 \sin\theta_1}{E_1 E_2}$$

$$\frac{e_x^2}{E_1^2}\left[\sin^2\theta_2 + \cos^2\theta_2\right] + \frac{e_x^2}{E_2^2}\left[\cos^2\theta_1 + \sin^2\theta_1\right] — 2$$

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$$\left(\frac{e_x}{E_1}\cos\theta_2 - \frac{e_y}{E_2}\cos\theta_1\right) = \cos\omega t\left[\sin\theta_1\cos\theta_2 - \sin\theta_2\cos\theta_1\right] \quad (5)$$

similarly multiply (3) by $\sin\theta_2$ and eq (4) by $\sin\theta_1$ and subtract them.

$$\left(\frac{e_x}{E_1}\sin\theta_2 - \frac{e_y}{E_2}\sin\theta_1\right) = \sin\omega t\left[\cos\theta_1\sin\theta_2 - \cos\theta_2\sin\theta_1\right] \quad 6$$

Squaring and adding Eq. (5) and Eq (6),

consider L.H.S.

$$\frac{e_x^2}{E_1^2}\cos^2\theta_2 + \frac{e_y^2}{E_2^2}\cos^2\theta_1 - \frac{2e_xe_y}{E_1E_2}\cos\theta_1\cos\theta_2 + \frac{e_x^2}{E_1^2}\sin^2\theta_2$$

$$+\frac{e_y^2}{E_2^2}\sin^2\theta_1 - \frac{2e_xe_y}{E_1E_2}\sin\theta_1\sin\theta_2.$$

$$\frac{e_x^2}{E_1}\left[\cos^2\theta_2 + \sin^2\theta_2\right] + \frac{e_y^2}{E_2^2}\left[\cos^2\theta_1 + \sin^2\theta_1\right] - \frac{2e_xe_y}{E_1E_2}\left[\cos\theta_1\cos\theta_2 - \sin\theta_1\sin\theta_2\right]$$

$$= \frac{e_x^2}{E_1} + \frac{e_y^2}{E_2^2} - \frac{2e_xe_y}{E_1E_2}\cos(\theta_1 - \theta_2) \quad (7).$$

Squaring R.H.S of eq (5).

$$\cos^2\omega t\left[\sin^2\theta_1\cos^2\theta_2 + \sin^2\theta_2\cos^2\theta_1 - 2\sin\theta_1\cos\theta_2\sin\theta_2\cos\theta_1.\right.$$

Squaring RHS of Eq (6).

$$\sin^2\omega t\left[\cos^2\theta_1\sin^2\theta_2 + \cos^2\theta_2\sin^2\theta_1 - 2\cos\theta_1\sin\theta_2\cos\theta_2\sin\theta_1\right.$$

Adding these two equations.

$$= \left[\sin^2\omega t + \cos^2\omega t\right]\left[\sin^2\theta_1\cos^2\theta_2 + \cos^2\theta_1\sin^2\theta_2\right]$$

$$- \left[\sin^2\omega t + \cos^2\omega t\right]\left[2\sin\theta_1\cos\theta_2\sin\theta_2\cos\theta_1\right]$$

$$= \left[\sin^2\theta_1\cos^2\theta_2 + \cos^2\theta_1\sin^2\theta_2 - 2\sin\theta_1\cos\theta_2\sin\theta_2\cos\theta_1\right]$$

$$= \left[\sin\theta_1\cos\theta_2 - \cos\theta_1\sin\theta_2\right]^2 \quad (8)$$

$$= \sin^2(\theta_1 - \theta_2) \quad (9).$$

From 7 and 9.

$$\frac{e_x^2}{E_1^2} + \frac{e_y^2}{E_2^2} - \frac{2 e_x e_y}{E_1 E_2} \cos(\theta_1 - \theta_2) = \sin^2(\theta_1 - \theta_2) \quad \text{—} (10)$$

Let $\theta_1 - \theta_2 = \delta$. Eq (10) can be rewritten as.

$$\frac{e_x^2}{E_1^2} + \frac{e_y^2}{E_2^2} - \frac{2 e_x e_y}{E_1 E_2} \cos\delta = \sin^2\delta \quad \text{—} (11).$$

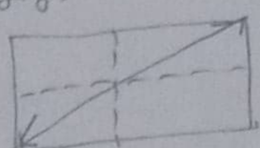
If $\delta = 0$. from (11) $\sin^2\delta = 0$, $\cos\delta = 1$.

$$\frac{e_x^2}{E_1^2} + \frac{e_y^2}{E_2} - \frac{2 e_x e_y}{E_1 E_2} = 0. \longrightarrow \left(\frac{e_x}{E_1} - \frac{e_y}{E_2}\right)^2 = 0.$$

$$\frac{e_x}{E_1} = \frac{e_y}{E_2}.$$

$E_y = e_x\left(\frac{E_2}{E_1}\right)$ — (12). This is the equation of st. lines with intercept is zero, slope is positive. ($y = mx \pm c$.), and is shown in fig.

$\delta = 0$

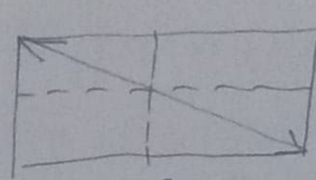


(ii) If $\delta = \pi$ then from Eq (11)

$$\frac{e_x^2}{E_1^2} + \frac{e_y^2}{E_2^2} + \frac{2 e_x e_y}{E_1 E_2} = 0. \longrightarrow \left(\frac{e_x}{E_1} + \frac{e_y}{E_2}\right)^2 = 0$$

$$\frac{e_x}{E_1} + \frac{e_y}{E_2} = 0.$$

$E_y = -e_x\left(\frac{E_2}{E_1}\right)$ — (13) This is equation of st. with intercept zero, but with -ve slope, and is shown in figure.



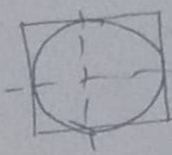
$\delta = \pi$.

If $\delta = \left(\frac{\pi}{2}\right)$. from Eq (11).

$$\frac{e_x^2}{E_1^2} + \frac{e_y^2}{E_2^2} = 1 \quad \text{—} \ (14).$$

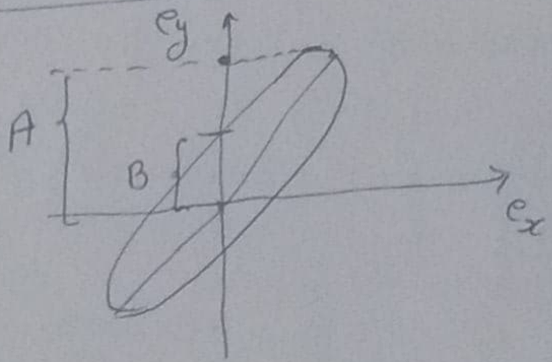
$$e_x^2 + e_y^2 = E_1^2 E_2^2 \quad \text{—} \ (15)$$

If $E_1 = E_2$. Then Eq (15), represents equation of circle, and is shown in figure.



If $E_1 \neq E_2$, then equation 14, represents equation of ellipse.

consider the figure shown below.



e_y Max $= A$.

e_y Min $= B$

at $x = 0$, $e_y = B$,

sub in Eq.(11)

$$\frac{e_y^2}{E_2^2} = \sin^2\delta$$

$$e_y^2 = E_2^2 \sin^2\delta.$$

$e_y = E_2 \sin\delta$ but $E_y = B$.

$B = E_2 \sin\delta$. For Maxima $e_y = A$.

$B = A \sin\delta$.

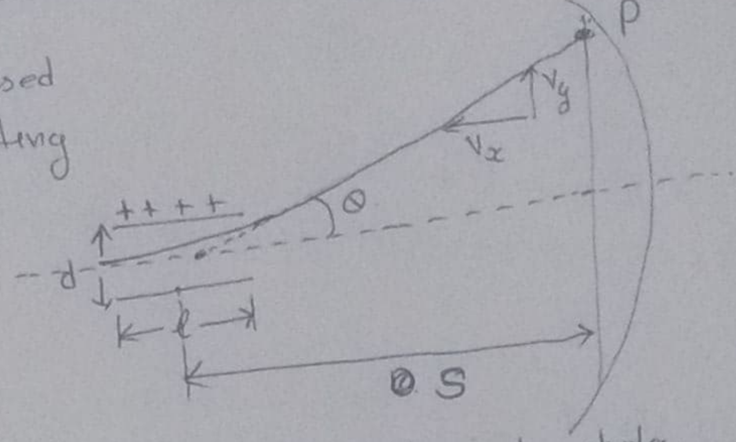
$$\delta = \sin^{-1}\left(\frac{B}{A}\right). \quad \text{—} \ (16)$$

This Equation gives the phase difference between two signals.

Deflection Sensitivity.

Let charge of electron is e, and mass m.

the electron is passed through the deflecting plate of length l and distance between the plate is d.



The path of electron within the plate is parabola, after that it follows st. line and hits the screen at P. Distance between the center of plate and screen is D.

Deflection sensitivity: It is defined as the vertical deflection of beam on the screen per unit deflecting voltage.

Let u be the initial velocity, time taken by e to pass through the deflecting plates.

$t = \frac{l}{u}$ — ①, Electron will experience the acceleration along y-direction and it given by.

$a_y = \frac{F}{m} = \frac{eE}{m} = \frac{e}{m}\left[\frac{V}{d}\right]$ — (2) where V is the potential applied across the plate. E-is the electric field intensity.

Velocity along y-axis after time t. — (3).

$V_y = 0 + a_y t = \frac{e}{m}\frac{V}{d}\times\left[\frac{l}{u}\right]$

$\tan\theta = \frac{y}{S} = \frac{V_y}{V_x} = \frac{e}{m}\frac{V}{d}\left(\frac{l}{u}\right)/u =$

$y \cancel{\tan\theta} = \frac{elVS}{mdu^2}$ — 4

Let V_a is the accelerating voltage and V_d is deflecting voltage then

$u^2 = \frac{2eV_a}{m}$ — ⑤ sub in 4

$u = \sqrt{\frac{2eV_d}{m}}$

$y = \frac{elV_dS}{m/d\left[2e\frac{V_a}{m}\right]} = \frac{lSV_d}{2dV_a}$

$y \propto V_d$ — ⑥

D sensitivity $= \frac{y}{V_d} = \frac{lS}{2dV_d}$ mm/V