سارة جبار

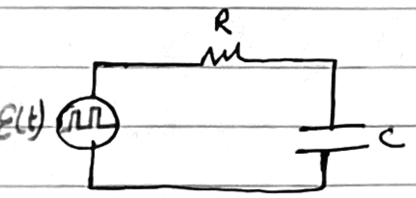
Experiment 6

Capacitors and Inductors

(A) RC circuits : A circuit that contains a resistor and capacitor connected in series and powered by power supply but in our experiment by signal generator

(1) Charging capacitor

During the positive half period of the squre wave

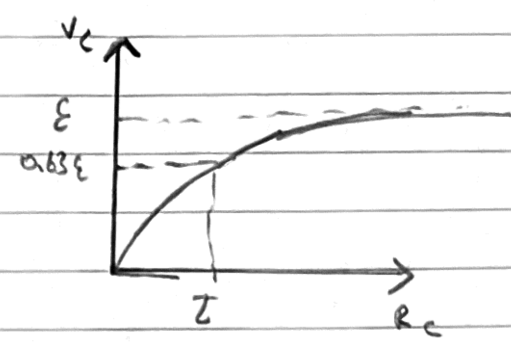


The voltage across the capacitor

$$V_c = \frac{Q}{C}$$

$$Q = \varepsilon C(1 - e^{-t/RC})$$

$$\Rightarrow V_c = \varepsilon(1 - e^{-t/RC})$$



- at $t = 0 \longrightarrow V_c = \varepsilon(1 - e^{0}) = 0$
- at $t = \infty \rightarrow V_c = \varepsilon(1 - e^{-\infty}) = \varepsilon$
- at $t = \tau = RC \rightarrow V_c = \varepsilon(1 - e^{-\frac{RC}{RC}}) = 0.63\,\varepsilon$

τ : time constant is a measure of how fast the voltage across the capacitor rises or how fast the charging is

* time constant : the time needed for the potential difference on capacitors to reach 0.63 of the max voltage ε

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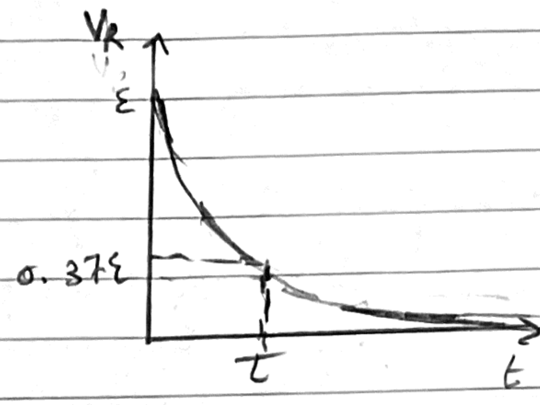
The voltage across the resistor

$V_R = IR \quad , \quad I = \frac{dQ}{dt} \quad , \quad Q = C\varepsilon(1 - e^{-t/RC})$

$V_R = \frac{dQ}{dt} R$

$= \cancel{C}\varepsilon \frac{1}{R\cancel{C}} e^{-t/RC} R$

$V_R = \varepsilon e^{-t/RC}$



- at $t = 0 \rightarrow V_R = \varepsilon e^{0} = \varepsilon$
- at $t = \infty \rightarrow V_R = \varepsilon e^{-\infty} = 0$
- at $t = RC \rightarrow V_R = \varepsilon e^{-1} = 0.37\varepsilon$

(A) Discharging a capacitor

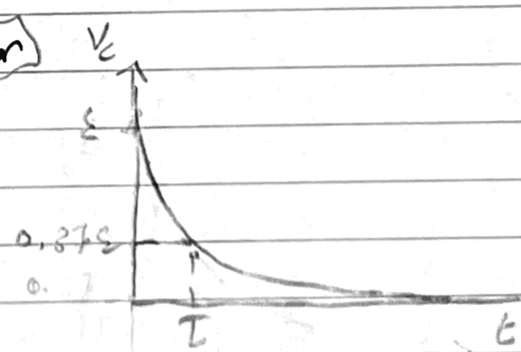
(During the negative half period of the squre wave)

$Q(t) = C\varepsilon e^{-t/RC}$

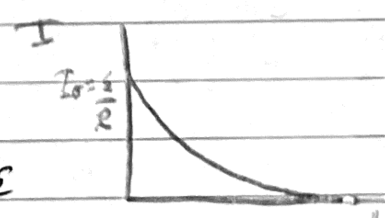
The voltage across the capacitor

$V_c = \frac{Q}{C} = \frac{C\varepsilon e^{-t/RC}}{C}$

$\Rightarrow V_c = \varepsilon e^{-t/RC}$

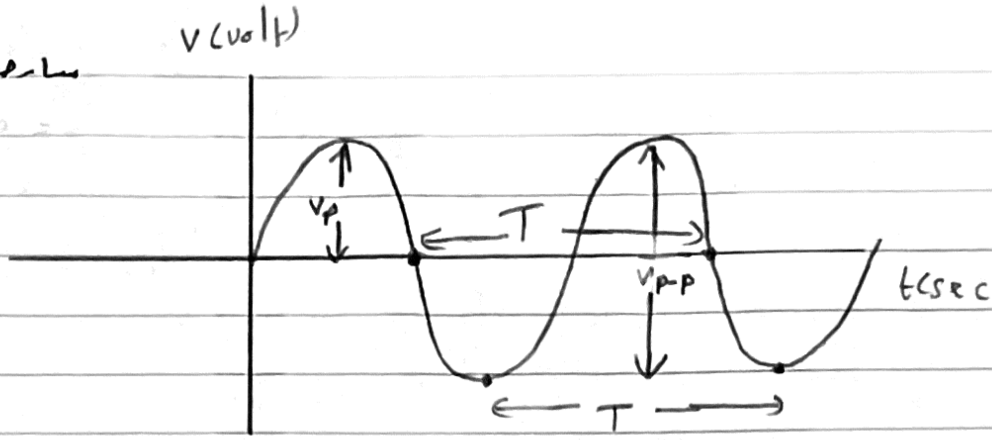


- at $t = 0 \rightarrow V_c = \varepsilon e^{0} = \varepsilon$
- at $t = \infty \rightarrow V_c = \varepsilon e^{-\infty} = 0$
- at $t = RC = \tau \Rightarrow V_c = \varepsilon e^{-1} = 0.37\varepsilon$



τ: a measure of how fast the voltage across capacitor decreases

τ: the time needed for potential difference on capacitor to reach 0.37 of the max voltage

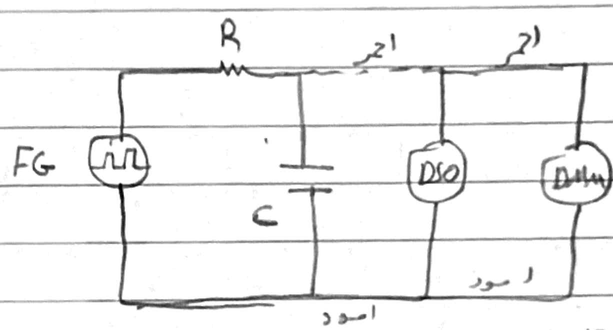


$$f = \frac{1}{T} \quad (\text{unit}: Hz)$$

$$V_{p-p} = 2\sqrt{2}\, V_{rms}$$

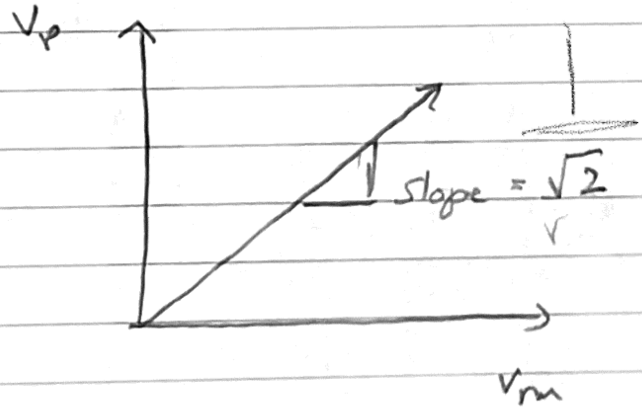
$$V_{rms} = \frac{1}{2\sqrt{2}} V_{p-p}$$

$$V_{rms} = \frac{1}{\sqrt{2}} V_p$$



قراءة DSO هي V_p او V_{p-p}

قراءة DMM هي V_{rms}



V_{rms} : هي قيمة الجهد التي تكون عندها كمية الطاقة المحدودة عندما يجري DC voltage هي نفس كمية الطاقة المحدودة عندما يجري AC voltage

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The voltage across the Resistors

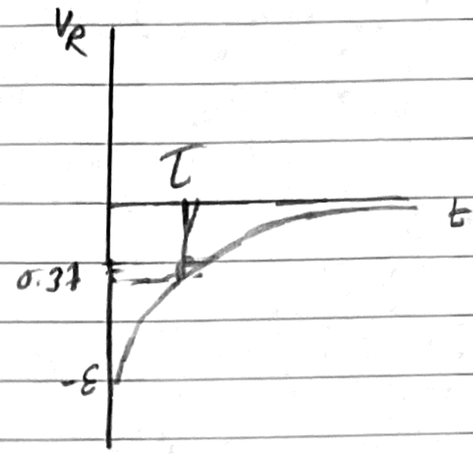
$V_R = IR$, $I = \frac{dQ}{dt}$, $Q = C\varepsilon e^{-t/RC}$ disg

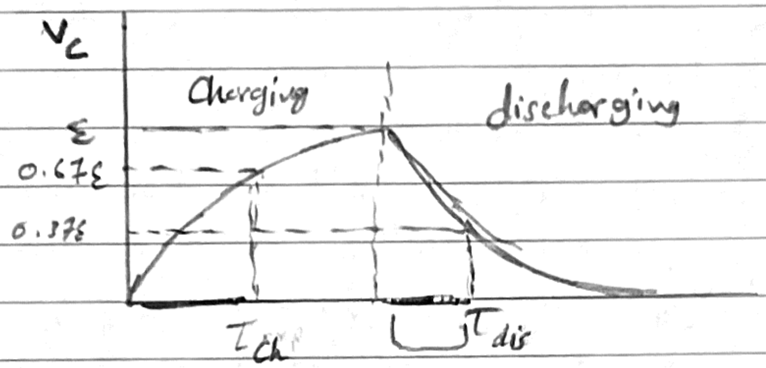
$V_R = \frac{dQ}{dt} R$

$V_R = \frac{-1}{RC} C\varepsilon e^{-t/RC} R$, $I = \frac{dQ}{dt} = -\frac{\varepsilon}{R} e^{-t/RC}$

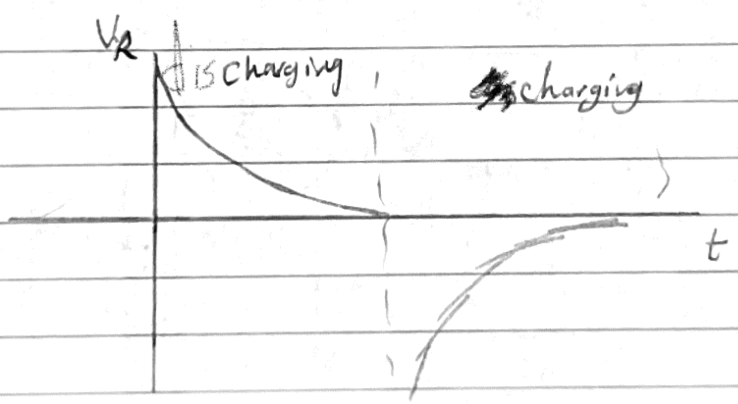
$V_R = -\varepsilon e^{-t/RC}$

- at $t=0 = -\varepsilon e^{0} = -\varepsilon$
- at $t=\infty = -\varepsilon e^{-\infty} = 0$
- at $t = RC = -\varepsilon e^{-1} = 0.37\varepsilon$





$\tau_{exp} = \frac{\tau_{ch} + \tau_{dis}}{2}$, $\tau_{theo} = RC$



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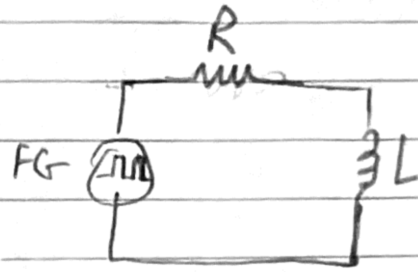
(B) **RL Circuit:** A circuit that contains an inductor connected in series with a resistance and powered by a power supply but in our experiment by a signal generator

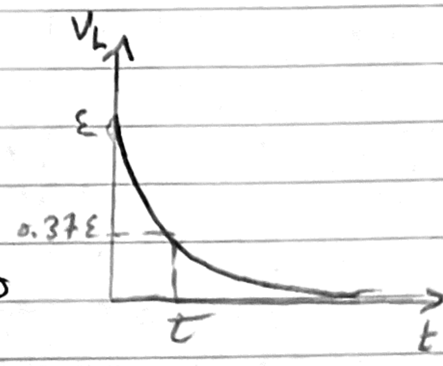
$$I(t) = \frac{\mathcal{E}}{R}\left(1 - e^{-Rt/L}\right)$$



The voltage across the inductor L

$$V_L = L\frac{dI}{dt} = \cancel{L}\,\frac{\mathcal{E}}{\cancel{R}}\,\frac{\cancel{R}}{\cancel{L}}\,e^{-Rt/L}$$

$$\Rightarrow \quad V_L = \mathcal{E}e^{-Rt/L}$$



- at $t = 0 \longrightarrow V_L = \mathcal{E}e^{0} = \mathcal{E}$
- at $t = \infty \longrightarrow V_L = \mathcal{E}e^{-\infty} = 0$
- at $t = \tau = \frac{L}{R} \longrightarrow V_L = \mathcal{E}e^{-1} = 0.37\,\mathcal{E}$

τ: a measure of how fast the current rises in the circuit

The voltage across the resistor R

$$V_R = IR = \frac{\mathcal{E}}{\cancel{R}}\left(1 - e^{-Rt/L}\right)\cancel{R}$$

$$V_R = \mathcal{E}\left(1 - e^{-Rt/L}\right)$$

- at $t = 0 \longrightarrow V_R = \mathcal{E}(1 - e^{0}) = 0$

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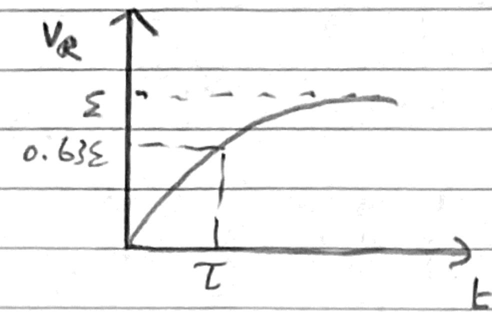
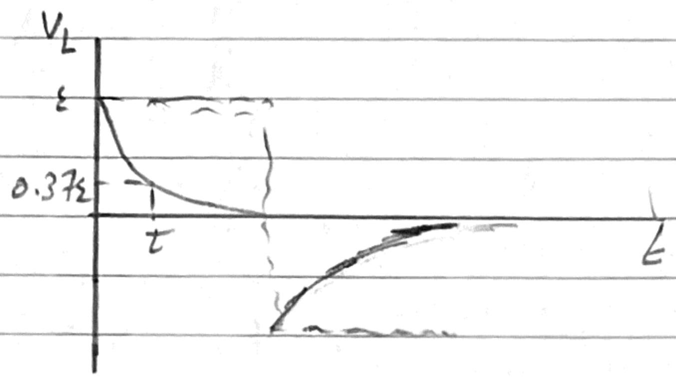
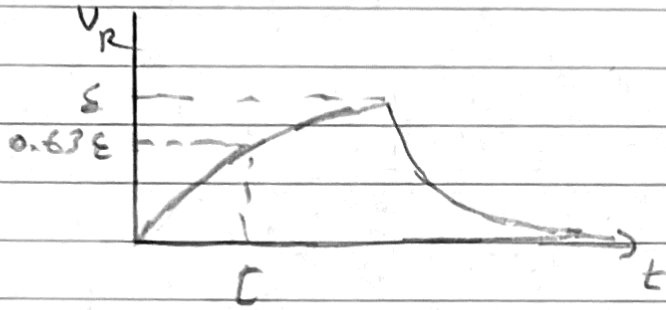
- at $t = \infty \rightarrow V_R = \varepsilon(1 - e^{-\infty}) = \varepsilon$

- at $t = \frac{L}{R} \rightarrow V_R = \varepsilon(1 - e^{-1}) = 0.63\,\varepsilon$







$$\tau_{exp} = \frac{\tau_{\text{th for } L} + \tau_{\text{dis for } L}}{2}$$

$$\tau_{theo} = L/R$$

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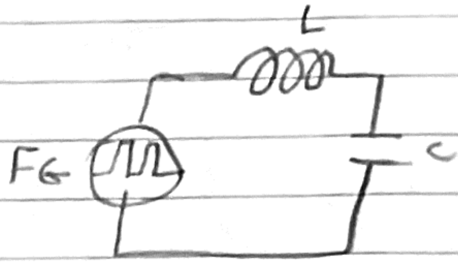
(c) LC circuit (LC tank or LC-osillator)



$$\mathcal{E} = L\frac{d^2Q}{dt^2} + \frac{Q}{C}$$

$$\Rightarrow Q(t) = Q_0 \cos(\omega t + \phi)$$

$$V_c = \frac{Q}{c} = \frac{Q_0}{c} \cos(\omega t + \phi)$$

$\Rightarrow V_c = V_0 \cos(\omega t + \phi)$ simple harmonic oscillator

$\omega = \frac{1}{\sqrt{LC}}$ natural angular frequncy

$$X_L = \omega L = 2\pi f L$$

$$X_c = \frac{1}{\omega c} = \frac{1}{2\pi f c}$$

$\Rightarrow$ at resonance

$$X_L = X_c$$

$$\omega L = \frac{1}{\omega c}$$

$$2\pi f L = \frac{1}{2\pi f C}$$

$$f^2 = \frac{1}{4\pi^2 LC}$$

$$\Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$$