ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تلخيص
دوائر كهربائية 2

للطالب المبدع
محمود مجدلاني

إرادة - ثقة - تغيير

Chapter 11

* We have 3 different ways to calculate RMS values

1) $Y_{rms} = \sqrt{\frac{1}{T}\int_0^T y^2(t)\,dt}$

2) $Y_{rms} = \sqrt{(Y_{rms_1})^2 + (Y_{rms_2})^2 + \dots}$ ← Different frequency

3) Same frequency → add with phaser

من مسميات ال Power avg

1) avarage power
2) active
3) Real power
4) consumed
5) dissipated // generated

* Power calculation

* $P(t) = V(t)\; i(t)$

$V(t) = V_m \cos(\omega t + \theta)$

$i(t) = I_m \cos(\omega t + \phi)$

$$P(t) = \underbrace{P_{avg}}_{} + \frac{V_m I_m}{2}\cos(2\omega t + \theta + \phi)$$

$\frac{V_m I_m}{2}\cos(\theta - \phi)$ $\quad$ $V_{rms} I_{rms} \cos(\theta - \phi)$

* $V_{rms} = \frac{V_m}{\sqrt{2}}$ $\quad$ * $I_{rms} = \frac{I_m}{\sqrt{2}}$

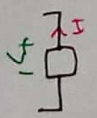
Apperant power

$P_{app} = S = \frac{V_m I_m}{2} = V_{rms} I_{rms}$ $\quad$ ($\underline{VA}$)

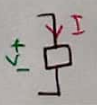
Power factor

$P_f = \cos(\theta - \phi)$ $\quad$ (ليس له وحدة)

Note



$P_g = VI$, $P_d = -VI$



$P_g = -VI$, $P_d = VI$

Chapter 11

$$\theta_z = \theta - \phi$$

- $+$
  - * load → Inductive
  - * I lags V
    - ↳ lagging power factor
- $-$
  - * capacitive load
  - * I Leads V
    - ↳ Leading power factor
- 0
  - * pure resistive
  - * I in phas V
    - ↳ $\theta = \phi$

$$0 \leq P_f = \cos(\theta - \phi) \leq 1$$

1 — for pure (R)

$\cos(\theta - \phi) = 1$

$\boxed{\theta = \phi}$

$P_{avg} = \frac{V_m I_m}{2} * \cancel{\cos(0)}$

$\therefore P_{avg} = \frac{V_m I_m}{2} = P_{app}$

$P_{avg} = P_{app}$:

- $V_{rms} I_{rms}$
- $I_{rms}^2 R$
- $\frac{V_{rms}^2}{R}$

$\boxed{\cancel{\frac{1}{2}}}$ لل rms ما بحط

- $\frac{V_m I_m}{2}$
- $\frac{I_m^2 R}{2}$
- $\frac{V_m^2}{2R}$

$\boxed{\frac{1}{2}}$ لل phase بحط

0 — for pure reactance

$\cos(\theta - \phi) = 0$

$\boxed{\theta - \phi = \pm 90}$

- $-$ capacitive
- $+$ inductive

$* \ P_{avg\,(C,L)} = 0$

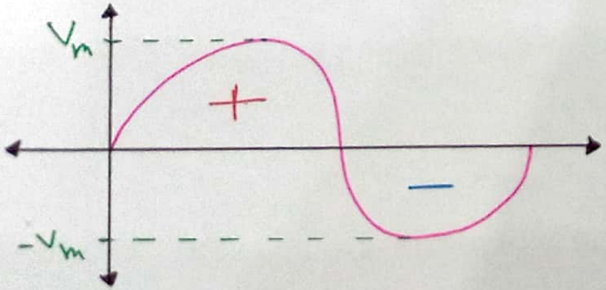
Chapter 11

* AC Power

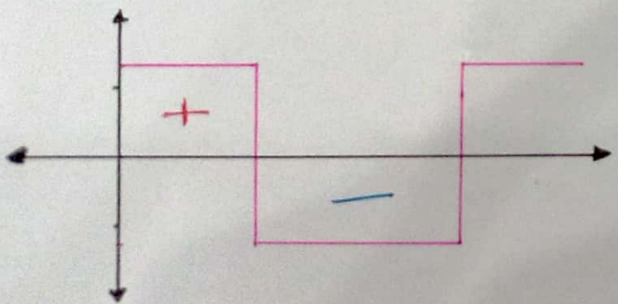
* Avarage value for any periodic function:-

$$Y_{avg} = \frac{1}{T}\int_0^T y(t)\cdot dt$$

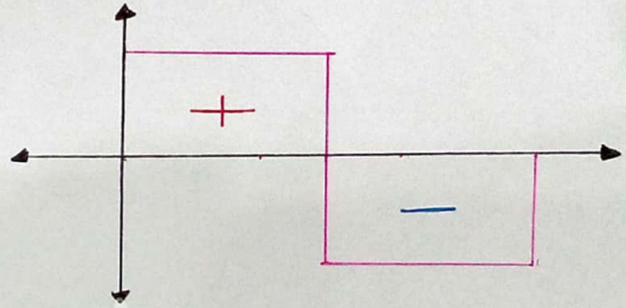
→ half symetry function (Y_{avg} = صفر)



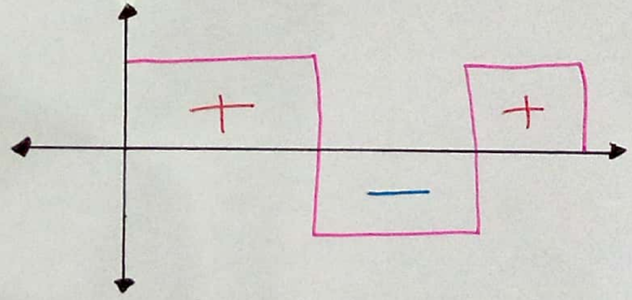
Y_{avg} = صفر



$Y_{avg} \neq$ صفر



Y_{avg} = صفر



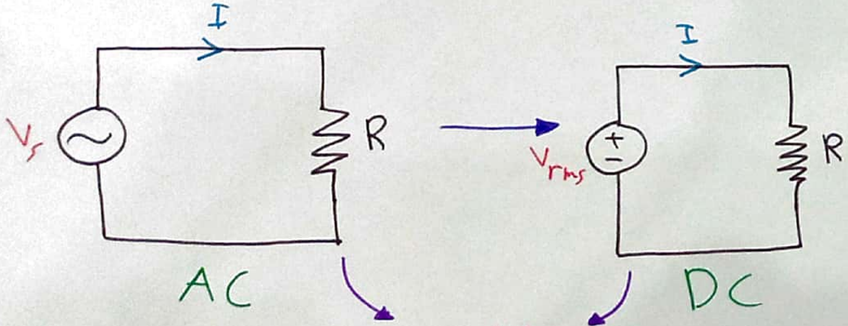
$Y_{avg} \neq$ صفر

sin / cos = صفر ← (avg) ال *

* RMS

↳ Root Mean square Value

$$Y_{Rms} = Y_{eff} = \sqrt{\frac{1}{T}\int_0^T y^2(t)\cdot dt}$$



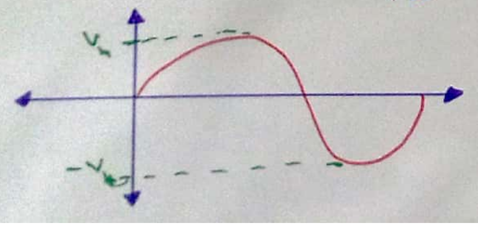
بيعطوني نفس

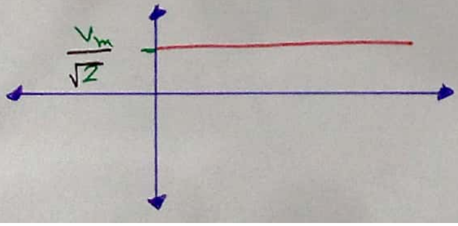
ال power

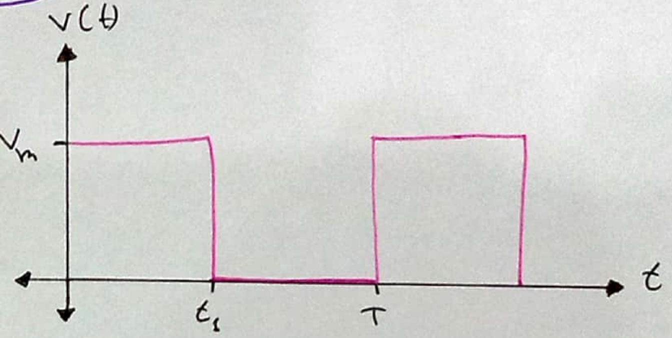
* $V(t) = V_m \cos(\omega t + \theta)$

→ $V_{avg} = 0$

→ $V_{rms} = V_{eff} = \frac{V_m}{\sqrt{2}}$

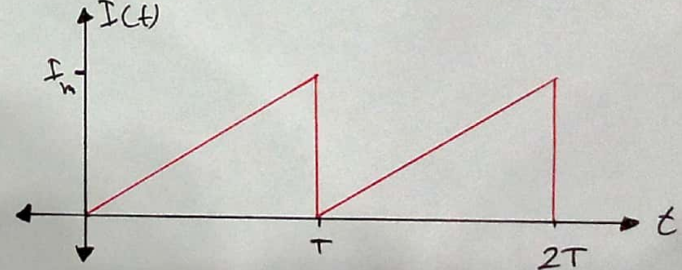






* $V_{avg} = \frac{V_m \cdot t_1}{T}$

* $V_{rms} = V_m \sqrt{\frac{t_1}{T}}$



* $I(t) = \frac{I_m\, t}{T}$

* $I_{rms} = \frac{I_m}{\sqrt{3}}$

Chapter 11

Complex Power (S)

$$S \to \begin{cases} V_{rms} I_{rms} \cos(\theta-\phi) + (V_{rms} I_{rms} \sin(\theta-\phi))\, j \\ P_{avg} + Q\, j \\ V_{rms} I^{*}_{rms} \to \dfrac{V_m I^{*}_m}{2} \\ P_{app} \angle \theta-\phi \end{cases}$$

- $P_{avg} = P_{app} \cos(\theta-\phi)$
- $Q = P_{app} \sin(\theta-\phi)$
- $P_{app} = \sqrt{(P_{avg})^2 + (Q)^2} \to |S| = P_{app}$
- $\theta - \phi = \tan^{-1}\left(\dfrac{Q}{P_{avg}}\right)$

* S → complex power → VA

* Q → Reaktive power → VAR

* P_{avg} → Avarage power → W

* for pure R

◆ $\theta = \phi$ — In phase

- $P_f = 1$
- $P_{avg_R} = V_{rms} I_{rms}$
- $Q_R = 0$
- $S_R = P_{avg} = P_{app}$

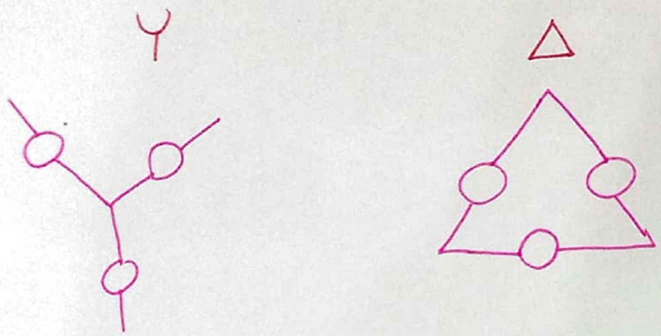
* for pure Reactive

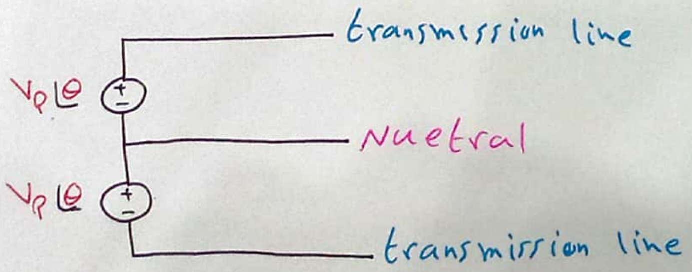
◆ $\theta - \phi = \pm 90$ ($\oplus$ L, $\ominus$ C)

- $P_f = 0$
- $P_{avg_{L,C}} = 0$
- $Q_L = V_{rms} I_{rms}$
- $Q_C = -V_{rms} I_{rms}$
- $S_L = (V_{rms} I_{rms})\, j$
- $S_C = -(V_{rms} I_{rms})\, j$

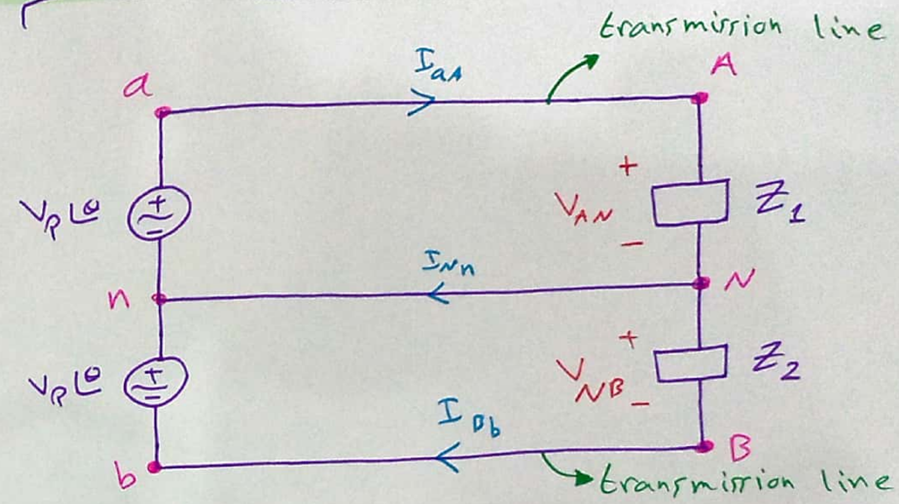
$S = P_{app} \angle \cos^{-1}(P_f)$

Poly Phase





Single Phase in 3 wires



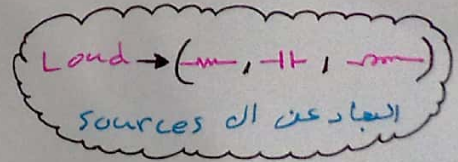
$$V_{AN} = V_{an} = V_P\angle\theta$$

$$I_{aA} = \frac{V_{an}}{Z_1} = \frac{V_{AN}}{Z_1} = \frac{V_P\angle\theta}{Z_1}$$

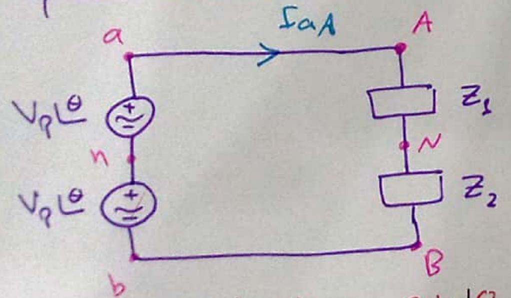
$$V_{NB} = V_{nb} = V_P\angle\theta$$

$$I_{Bb} = \frac{V_{nb}}{Z_2} = \frac{V_{nb}}{Z_2} = \frac{V_P\angle\theta}{Z_2}$$

$$I_{nN} = I_{Bb} - I_{aA}$$



balanced (symmetry) system

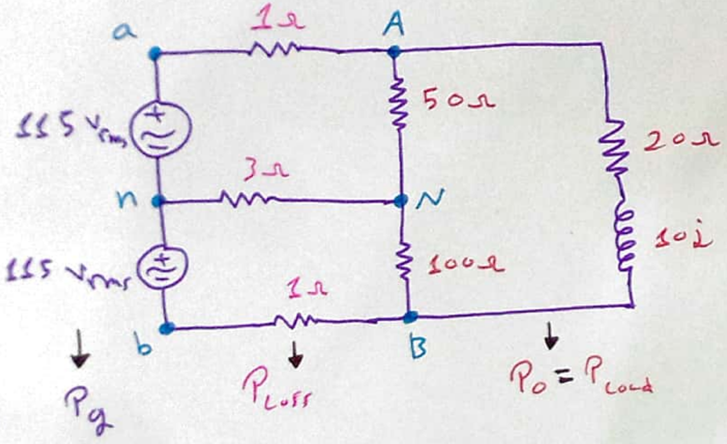


$$I_{aA} = \frac{2V_P\angle\theta}{2Z} = \frac{V_P\angle\theta}{Z}$$

* $Z_1 = Z_2$

- $I_{aA} = I_{Bb}$
- $I_{nN} = 0$

Chapter 12



$\rightarrow P_g = P_{in} = P_{Loss} + P_o$

* Note:

$\boxed{\text{generating Power}}$ come from sources (ϕ , ϕ)

$\boxed{\text{loss Power}}$ come from Resistance (—w—)

effeciency:

$$\eta = \frac{P_o}{P_i} * 100\%$$

* If $P_{Loss} = 0 \rightarrow P_o = P_i \rightarrow \eta = 100\%$

* Phase voltage:

Between Line — nuetral

* line voltage:

Between two lines

⊕ seq: -120

⊖ seq: $+120$

هذول فقط بجمعهم دال (t ot)

- $S_t = S_1 + S_2 + \ldots = P_{app_1} \angle \theta - \phi + P_{app_2} \angle \theta - \phi + \ldots$
- $Q_t = Q_1 + Q_2 + \ldots$
- $P_{avg_t} = P_{avg_1} + P_{avg_2} + \ldots$

* Note:

$P_g \rightarrow$ ϕ ϕ $\rightarrow P_{in}$

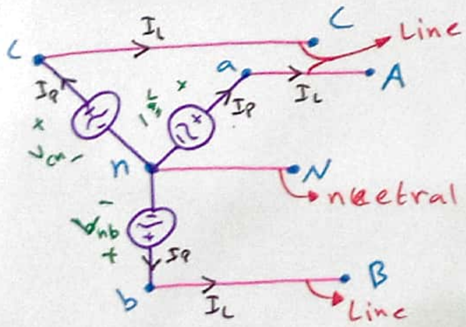
$P_{Loss} \rightarrow$ —w— (R_w)

$P_o \rightarrow$ Load $\rightarrow P_{Load}$

Chapter 12

Three Phase

Y - connective



$I_P = I_L$

$V_L = \sqrt{3}\, V_P \angle\theta$

line lage
phase by 30°
for ⊖ seq

* $|V_{an}| = |V_{bn}| = |V_{cn}| = V_P$

✓ $V_{an} + V_{bn} + V_{cn} = 0$

◆ $V_L > V_P$

Phase voltage

$V_{an} = V_P \angle 0$ +120

$V_{bn} = V_P \angle 120$ +120

$V_{cn} = V_P \angle 240$

⊖ seq

Line voltage

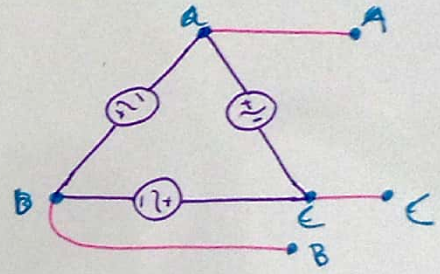
-30

$V_{ab} = \sqrt{3}\, V_P \angle -30$ +120

$V_{bc} = \sqrt{3}\, V_P \angle 90$ +120

$V_{ac} = \sqrt{3}\, V_P \angle 210$

Δ - connective



$I_L = \sqrt{3}\, I_P \angle\phi$

$V_P = V_L$

line lag
phase by
for ⊕ seq

* $|I_{bc}| = |I_{ab}| = |I_{ac}| = I_P$

✓ $I_{bc} + I_{ab} + I_{ac} = 0$

◆ $I_L > I_P$

Phase current

$I_{ab} = I_P \angle 0$ -120

$I_{ac} = I_P \angle -120$ -120

$I_{bc} = I_P \angle -240$

Line current

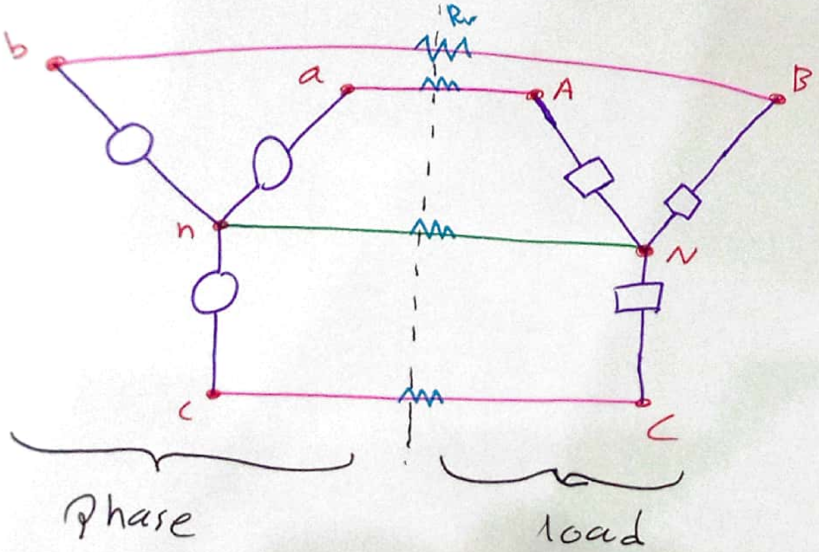
-30

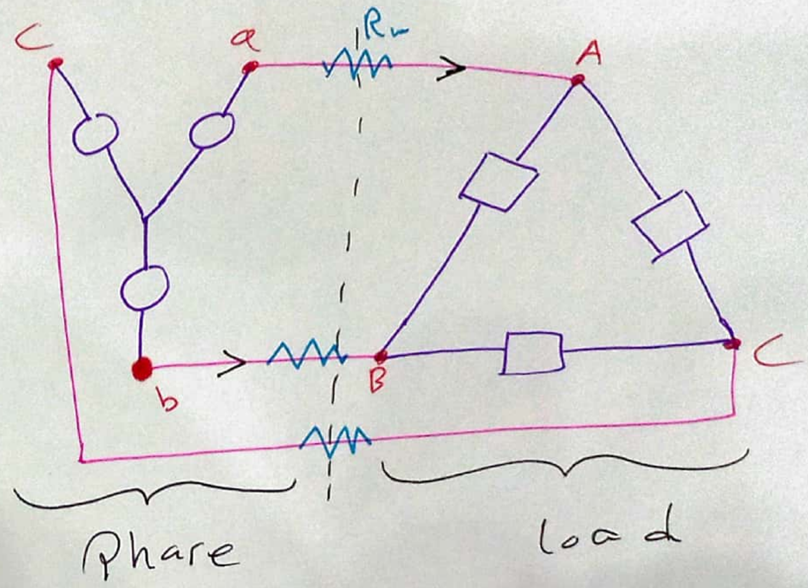
$I_{aA} = \sqrt{3}\, I_P \angle -30$ -120

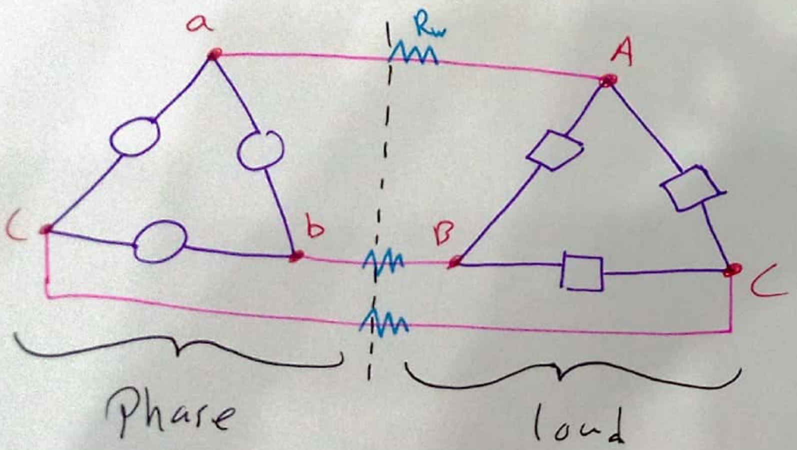
$I_{bB} = \sqrt{3}\, I_P \angle -150$ -120

$I_{cC} = \sqrt{3}\, I_P \angle -270$

⊕ seq



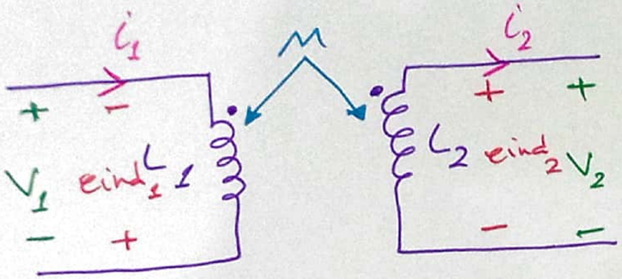




دائماً العناصر من (Phase) الى (load)

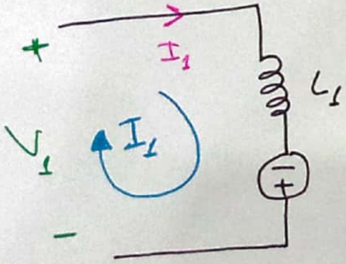
Chapter 13

Coupling circuit

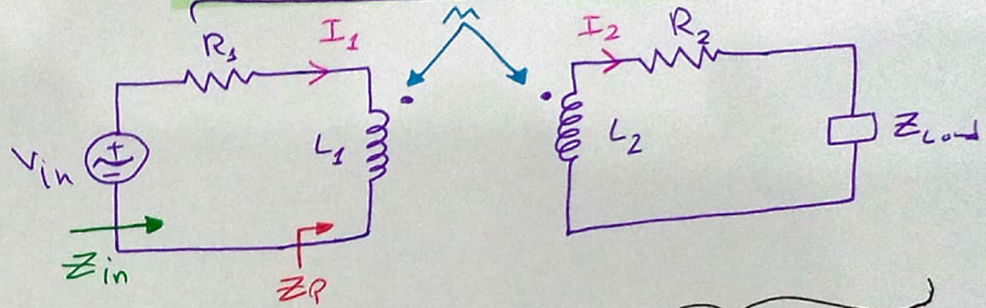


$$V_1(t) = L_1 \frac{di_1}{dt} - M \frac{di_2}{dt}$$

$$V_1 = jwL I_1 - jwM I_2$$



Linear Transformer



Primary side (source)

secondery (load)

$$* \; Z_{in} = \frac{V_{in}}{I_1} = Z_P + \frac{w^2 M^2}{Z_S}$$

impedence equ

impedence equ

Stored energy in coupling cct

$$W_L(t) = \frac{1}{2} L_1 i_1^2(t) + \frac{1}{2} L_2 i_2^2(t) \pm M \, i_1(t) \, i_2(t) \geq 0$$

$\hookrightarrow$ $M = k \sqrt{L_1 L_2}$ → coupling coefficiant

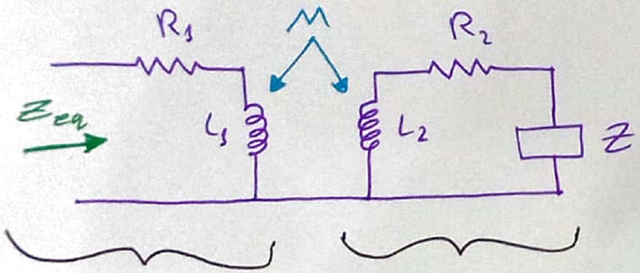
$\hookrightarrow$ $0 \leq k = \frac{M}{\sqrt{L_1 L_2}} \leq 1$

$M = 0$ ↳ No copling

tightly Copled

Chapter 13

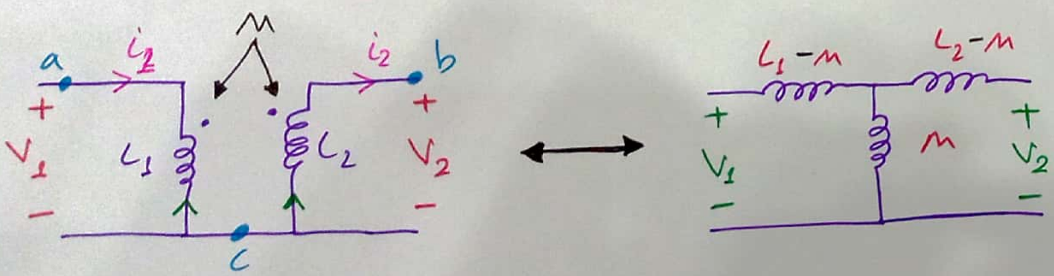
Linear Tranformer

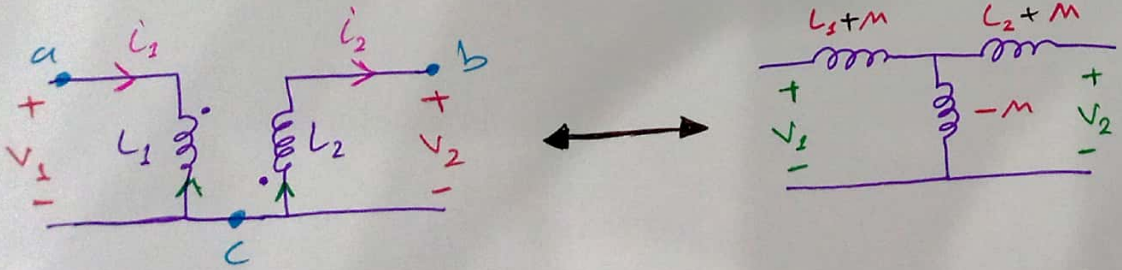


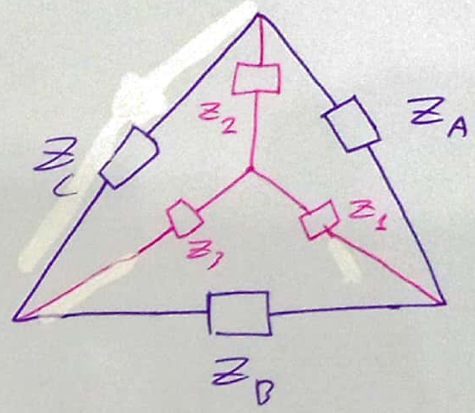
Primary

Secondary

$$\rightarrow Z_{eq} = Z_P + \frac{\omega^2 M^2}{Z_s} = R_1 + j\omega L_1 + \frac{\omega^2 M^2}{R_2 + Z + j\omega L_2}$$







Y − Δ

$$Z_A = \frac{Z_1 Z_2 + Z_1 Z_3 + Z_2 Z_3}{Z_3}$$

Δ − Y

$$Z_1 = \frac{Z_A Z_B}{Z_A + Z_B + Z_C}$$

$$* \; Z_\Delta = 3 Z_Y$$

Chapter 15

Analysis S Domain

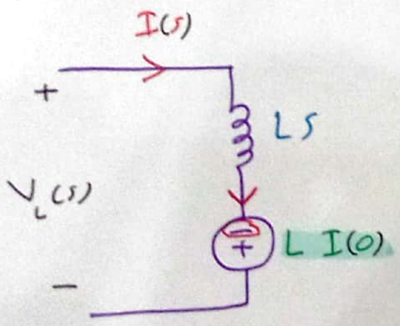
* $s = j\omega$
* $Z_L = sL$
* $Z_C = \frac{1}{sC}$

for R

$V(s) = R\,I(s)$

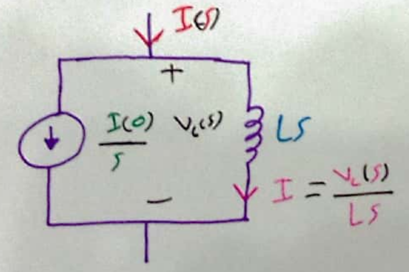
for L

Voltage Model



$V_L(s) = Ls\,I(s) - L\,I(0)$

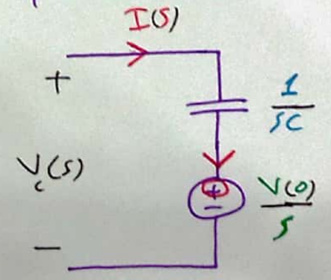
Current Model



$I(s) = \frac{V_L(s)}{Ls} + \frac{I(0)}{s}$

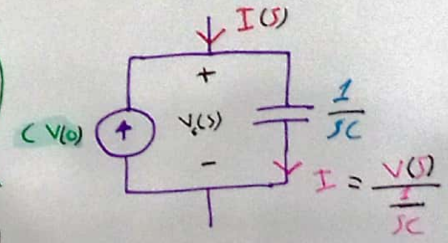
for C

Voltage model



$V(s) = \frac{I(s)}{Cs} + \frac{V(0)}{s}$

Current Model



$I_C(s) = Cs\,V(s) - C\,V(0)$

لما بدي اطلع ال $V_C(0), I_L(0)$

بخلي ال $L \rightarrow s.c$

$C \rightarrow o.c$

وبشيل ال sources

Chapter 16

Transfere function

Ratio between two quenbities $H(s)$

voltage gain: $H(s) = \dfrac{V_o(s)}{V_{in}(s)}$

$H(s) = \dfrac{V_o(s)}{I_{in}(s)}$

current gain: $H(s) = \dfrac{I_o(s)}{I_{in}(s)}$

$H(s) = \dfrac{I_o(s)}{V_{in}(s)}$

H(s) has Zero → أصفار البسط

at $s = s_o \Rightarrow$ If $H(s_o) = 0$

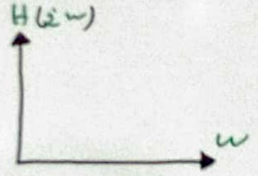
H(s) has Pole → أقطاب المقام

at $s = s_o \Rightarrow$ If $H(s_o) = \infty$

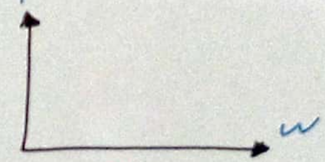
Bode Plote

a → cut of frequency, critical frequency, 3dB frequency

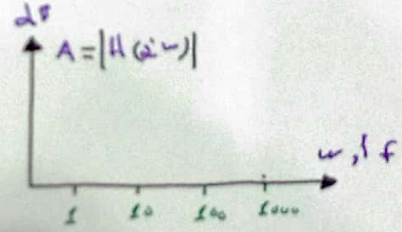
$H(j\omega) = A \angle \phi$

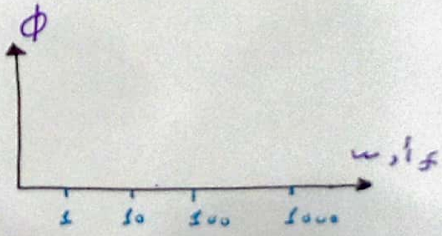


magnitude Bode plote



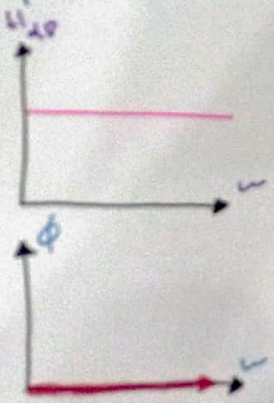
Phase Bode plote



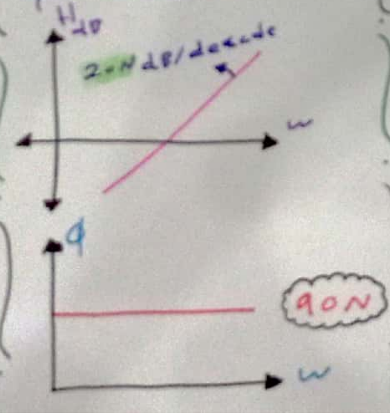


$H_{dB} = 20 \log |H(j\omega)|$

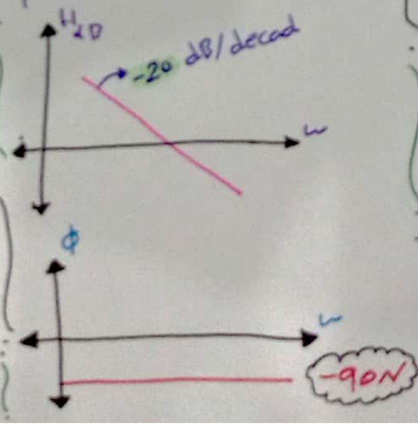
$H(s) = k$



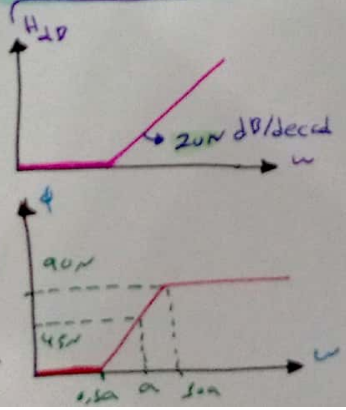
$H(s) = s^N$



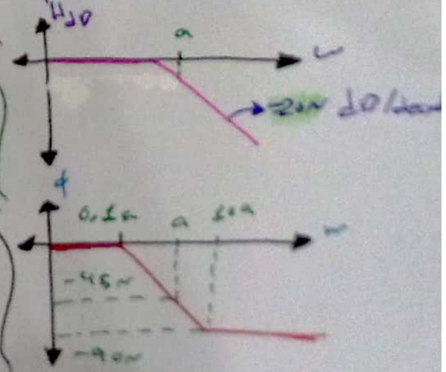
$H(s) = \dfrac{1}{s^N}$



$H(s) = \left(1 + \dfrac{s}{a}\right)^N$



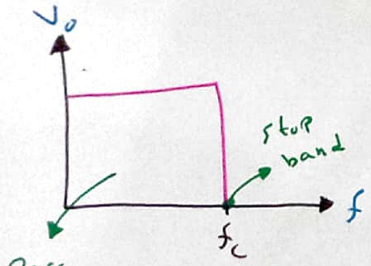
$H(s) = \left(1 + \dfrac{s}{a}\right)^{-N}$



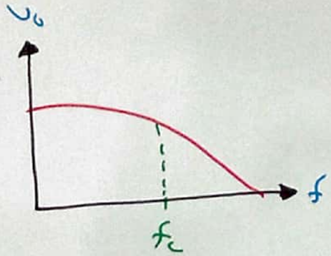
Filters

Types of filters acording of frequency band

Low Pass filter (LPF)

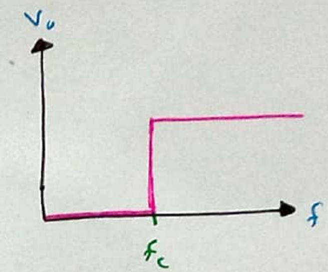


Ideal

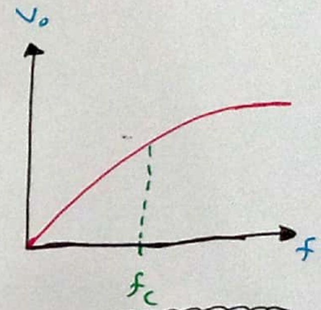


practical

High Pass filter (HPF)

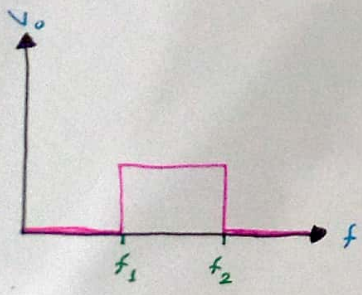


Ideal

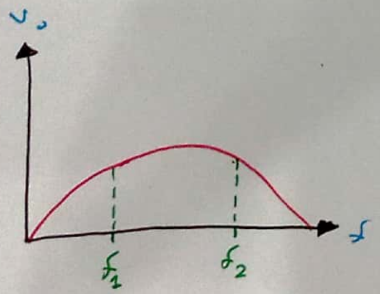


practical

Band Pass filter (BPF)

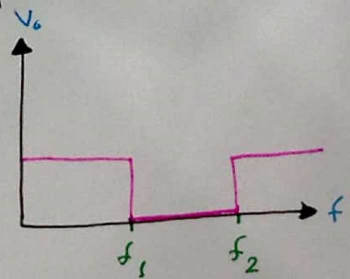


Ideal

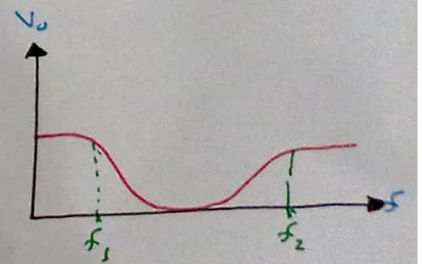


practical

Band stop filter (BSF)



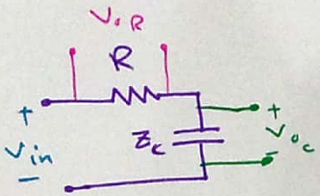
Ideal



practical

RC circuit

$$V_o = \frac{Z_C}{Z_C + R} * V_{in}$$



$$\frac{V_o}{V_{in}} = H(s) = \frac{1}{1 + j\omega CR}$$

Zc

$\omega = 0 \Rightarrow V_{oC} = V_{in}$

$\omega = \infty \Rightarrow V_{oC} = 0$

R

$\omega = 0 \Rightarrow V_{oR} = 0$

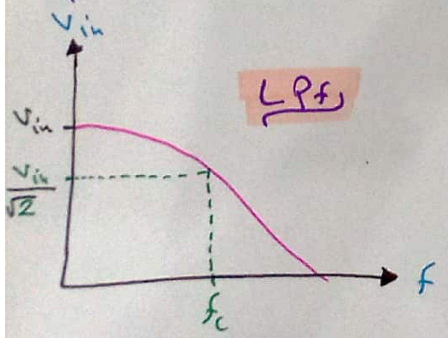
$\omega = \infty \Rightarrow V_{oR} = V_{in}$

$$\omega_c = \frac{1}{RC}$$

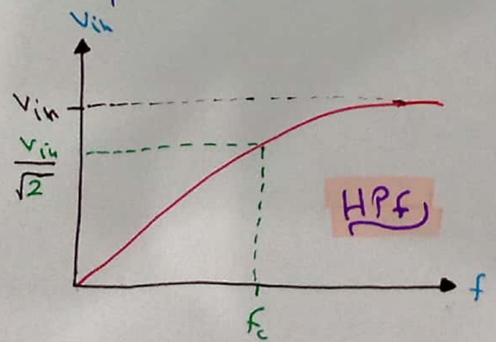
$$f_c = \frac{1}{2\pi RC}$$

$$V_o = \frac{1}{\sqrt{2}} V_{in}$$

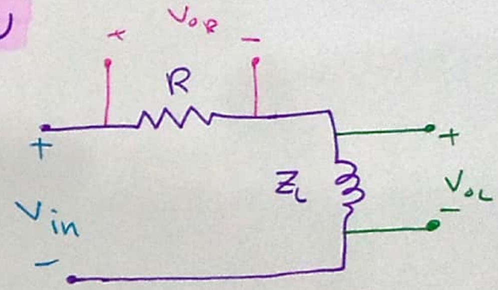
for C



for R



RL circuit



$\omega = 0 \Rightarrow V_{oL} = 0$

$\omega = \infty \Rightarrow V_{oL} = V_{in}$

$\omega = 0 \Rightarrow V_{oR} = V_{in}$

$\omega = \infty \Rightarrow V_{oR} = 0$

$$\omega_c = \frac{R}{L}$$

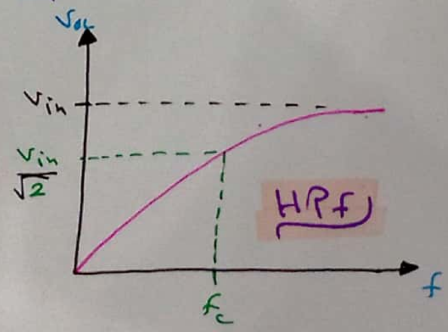
$$f_c = \frac{R}{2\pi L}$$

$$V_o = \frac{1}{\sqrt{2}} V_{in}$$

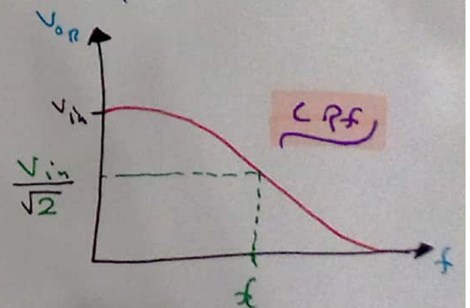
$\infty \rightarrow$ O.C

$0 \rightarrow$ S.C

for L



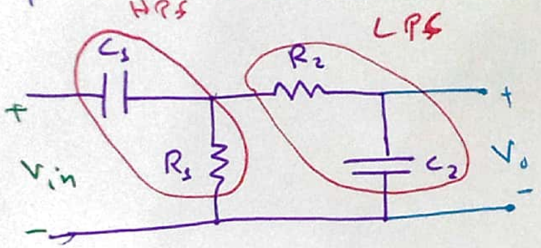
for R

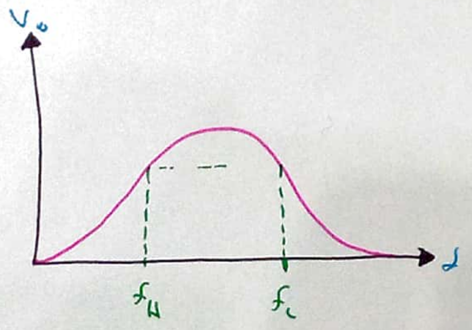


$\tau \begin{cases} \frac{L}{R} \\ RC \end{cases}$

$f_o \rightarrow$ ثابتة وين ما اخذناها بالسيركت

Band pass filter

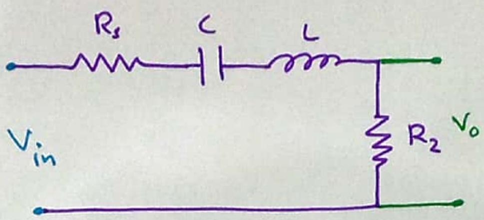


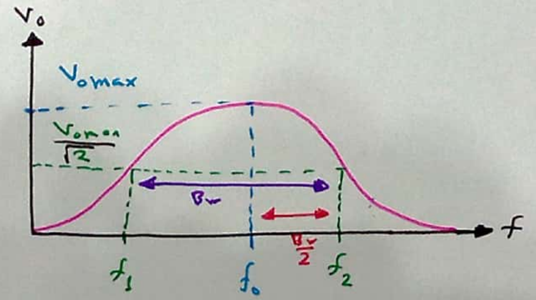


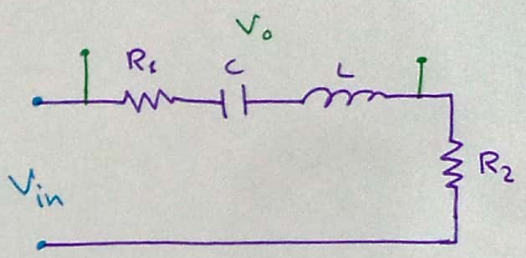
$$f_L = \frac{1}{2\pi R_2 C_2}$$

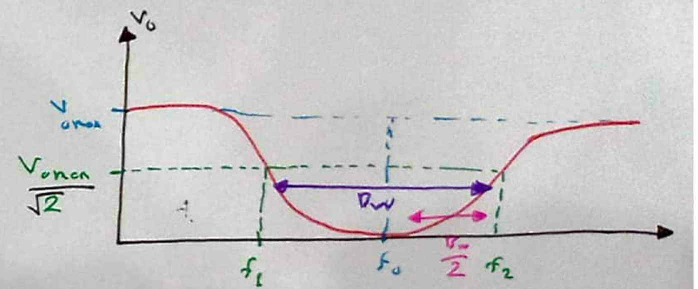
$$f_H = \frac{1}{2\pi R_1 C_1}$$

Series RLC









$$\begin{cases} f_1 = f_o - \frac{B_w}{2} \\ f_2 = f_o + \frac{B_w}{2} \end{cases}$$

$$\begin{cases} B_w = \frac{R}{L} \text{ (rad/s)} \rightarrow B_w = \frac{\omega_o}{Q} \\ B_w = \frac{R}{2\pi L} \text{ (Hz)} \rightarrow B_w = \frac{f_o}{Q} \end{cases}$$

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$\hookrightarrow V_o = V_{omax} = \frac{R_2}{R_1 + R_2} \cdot V_{in}$

V.d

$\hookrightarrow V_o = \frac{1}{\sqrt{2}} V_{omax}$

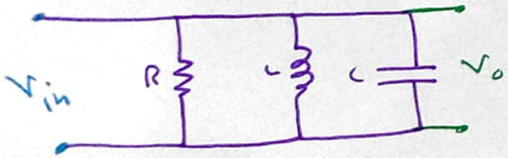
Series and Parallel RLC

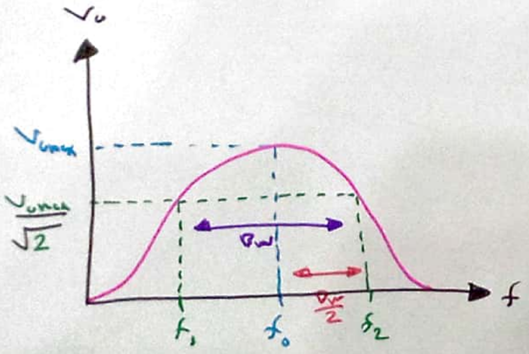
$\hookrightarrow$ Resonant circuit

* Quality factor

$$Q = \frac{X_L}{R_{eq}} = \frac{\omega_o L}{R_{eq}}$$

Parallel RLC





$$\left.\begin{cases} f_1 = f_o - \frac{B_w}{2} \\ f_2 = f_o + \frac{B_w}{2} \end{cases}\right\} V_o = \frac{1}{\sqrt{2}} V_{omax}$$

* $f_o = \frac{1}{2\pi\sqrt{LC}}$
* $w_o = \frac{1}{\sqrt{LC}}$

بالحسب فك
الدارة
فاحفظوا ثابتين

$$B_w = \frac{1}{RC} = \frac{w_o}{Q} \quad (rad/s)$$

$$B_w = \frac{1}{2\pi RC} = \frac{f_o}{Q} \quad (Hz)$$

* **Quality factor**

$$Q = w_o RC$$

Chapter 14

Complex frequency

$$s = \sigma + \omega j$$

- $s \rightarrow$ complex frequency $\rightarrow s^{-1}$
- $\sigma \rightarrow$ neper frequency $\rightarrow$ neper/s
- $\omega \rightarrow$ Angular frequency $\rightarrow$ rad/s

♦ $\omega = 2\pi f$

♦ $f = \frac{1}{T}$ $(s^{-1} \equiv Hz)$

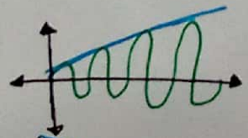
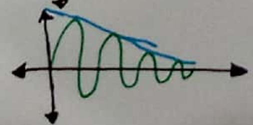
❖ $f(t) = k\, e^{st}$ — k: constant, s: complex frequency $= k \angle \phi$

1) $s = 0$

$\hookrightarrow f(t) = k$ (constant)(DC source)

2) $s = \sigma$

$\hookrightarrow f(t) = k\, e^{\sigma t}$ (exponential)

- $+\sigma \rightarrow$ Inc exp $\rightarrow$ 
- $-\sigma \rightarrow$ Dec exp $\rightarrow$ 

3) $s = \omega j$

$\hookrightarrow f(t) = k(\cos \omega t + \sin \omega t\, j)$ (sinusoidal)

4) $s = \sigma + \omega j$ (Damped sinousoidal)

$\hookrightarrow f(t) = k\, e^{\sigma t}(\cos \omega t + \sin \omega t\, j)$

* Note

♦ $e^{10j} \rightarrow \phi_{phase} = 10$

♦ $e^{10t} \rightarrow \sigma = 10$

♦ $e^{j10t} \rightarrow \omega = 10$

♦ $e^{10} \rightarrow$ constant

$$V(t) = e^{\sigma t} \cos(\omega t + \theta)$$

$\hookrightarrow s = \sigma \pm \omega j$

Chapter 14

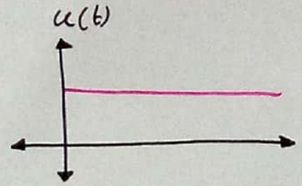
Laplace Transform

Time Domain	Frequency Domain
$A\,u(t)$	$\frac{A}{S}$
$A\,u(t-t_0)$	$\frac{A\,e^{-s\,t_0}}{S}$
$A\,e^{-at}\,u(t)$	$\frac{A}{S+a}$
$A\,t\,u(t)$	$\frac{A}{S^2}$
$A\,t\,e^{-at}\,u(t)$	$\frac{A}{(S+a)^2}$
$u(t)\sin(wt)$	$\frac{w}{S^2+w^2}$
$u(t)\cos(wt)$	$\frac{S}{S^2+w^2}$
$A\,\delta(t)$	A
$A\,\delta(t-t_0)$	$A\,e^{-st_0}$

→ $\mathcal{L}\,\frac{df}{dt} = s\,f(s) - f(0)$

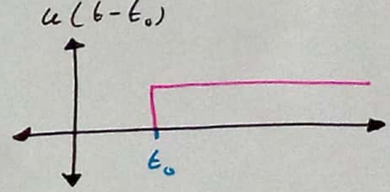
→ $\mathcal{L}\,\frac{d^2f}{dt^2} = s^2 f(s) - s\,f(0) - f'(0)$

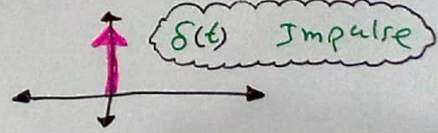
u(t) unit step function



$$u(t) = \begin{cases} 1, & t \geq 0 \\ 0, & t < 0 \end{cases}$$

$$u(t) = \begin{cases} 1, & t \geq t_0 \\ 0, & t < t_0 \end{cases}$$





* Note

$N \geq D$ → long division

$N < D$ → partial fraction

$\frac{N}{D}$

Initial value

♦ $f(0) = \lim_{t \to 0} f(t)$

♦ $F(0) = \lim_{s \to \infty} s\,F(s)$

Final value

♦ $f(\infty) = \lim_{t \to \infty} f(t)$

♦ $F(\infty) = \lim_{s \to 0} s\,F(s)$