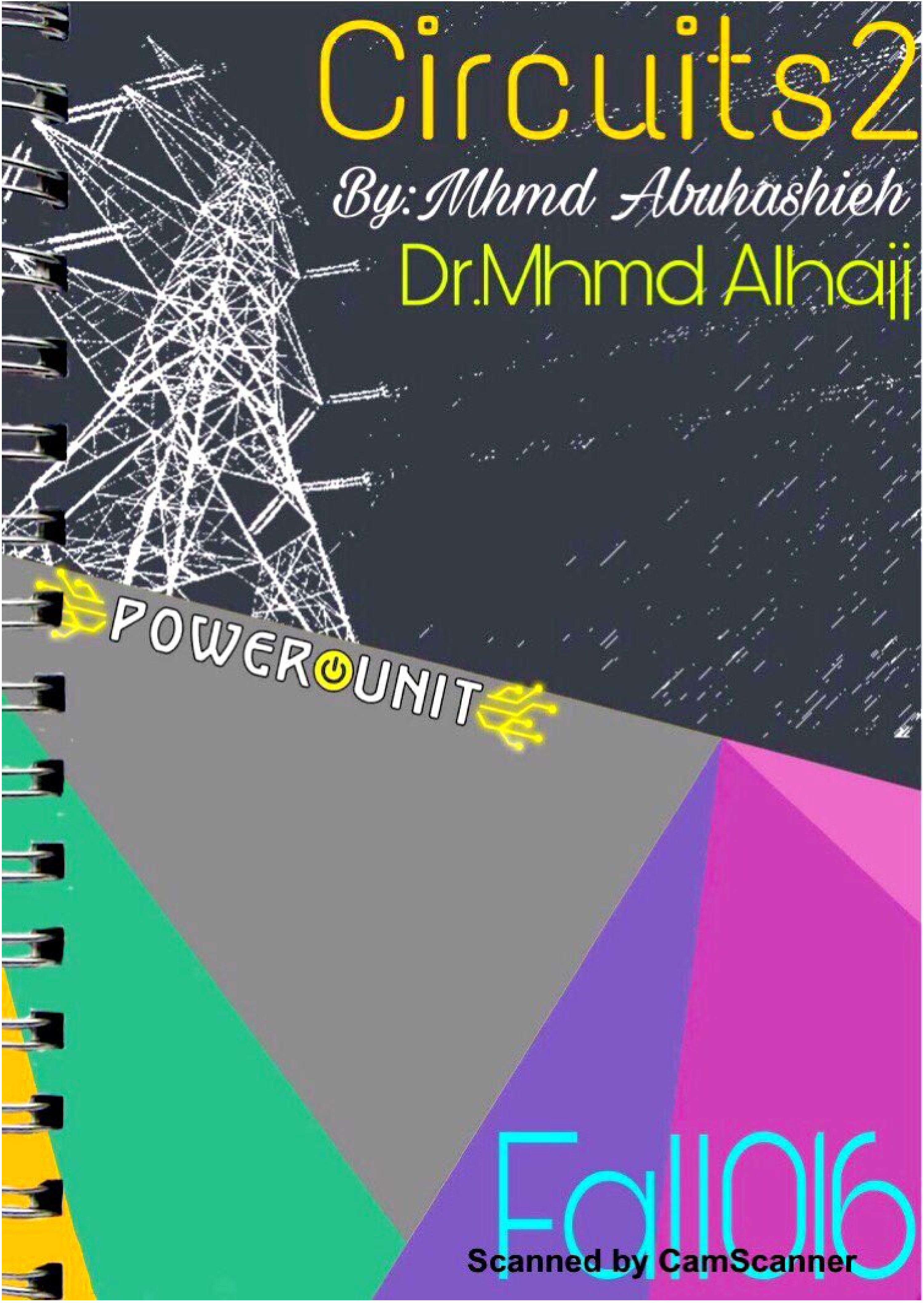

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Electrical Circuits II
* Summary *

※ CHAPTER (10):

* for the capacitor:

$$i_c(t) = C\frac{\partial v_c(t)}{\partial t}$$

$$v_c(t) = \frac{1}{C}\int_0^t i_c(t')dt' + v_c(0^-)$$

* the current leads the voltage.

* for the inductor:

$$v_L(t) = L\frac{\partial i_L(t)}{\partial t}$$

$$i_L(t) = \frac{1}{L}\int_0^t v_L(t')dt' + i_L(0^-)$$

* the voltage leads the current.

* Converting from phasor to time domain:
  * the amplitude must be positive and peak value.
* Converting from time domain to phasor:
  1. Amplitude must be (+ve).
  2. it must be a cosine function.

※ CHAPTER (11):

* instantaneous power:

$$P(t) = v(t)\cdot i(t)$$

$$P(t) = \frac{V_m I_m}{2}\left[\cos(2\omega t+\theta_v+\theta_I) + \cos(\theta_v-\theta_I)\right]$$

* Average Power:

$$P = \frac{1}{T}\int_0^T P(t)dt$$

* just the resistance has an average power.

$$P_{avg} = \frac{V_m I_m}{2} \text{ (in R)}$$

$$P_{avg} = \text{Zero (in L \& C)}$$

$$P_{avg} = \frac{V_m I_m}{2}\cos(\theta_v-\theta_I) \text{ (in any element)}$$

$$P_{avg\,(R)} = \frac{1}{2}V_m I_m = \frac{V_m^2}{2R} = \frac{1}{2}I_m^2 R$$

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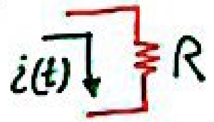
*** Maximum Power Transfer:**

happens when: $Z_{th} = Z_L^*$

if power is maximaized: $P_{avg}\Big|_{load} = \dfrac{V_{th}^2}{8R}$

*** for multiple signals & multiple frequancies:**

$i(t) = I_{m_1}\sin\omega_1 t + I_{m_2}\cos\omega_2 t + I_{m_3}\sin\omega_3 t + \cdots\cdots$

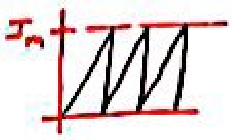


$$P_{avg} = \frac{1}{2}I_{m_1}^2 R + \frac{1}{2}I_{m_2}^2 R + \frac{1}{2}I_{m_3}^2 R + \cdots$$

$$P_{avg} = \frac{V_{m_1}^2}{2R} + \frac{V_{m_2}^2}{2R} + \frac{V_{m_3}^2}{2R} + \cdots\cdots$$

*** RMS:**

$$\boxed{V_{eff} = V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt}} \Rightarrow \text{in general.}$$



$$\boxed{I_{rms} = \frac{I_m}{\sqrt{3}}} \Rightarrow \text{for ST waveform.}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} \Rightarrow \text{for a sinusoidal Signal.}$$

$\Rightarrow$ for a resistor:

$$P_{avg} = V_{rms} I_{rms} = V_{rms}^2/R = I_{rms}^2 R$$

if there is multiple frequancies:

$$P_{avg} = \left(I_{rms_1}^2 + I_{rms_2}^2 + I_{rms_3}^2 + \cdots\right)R$$

*** Power factor:**

$$pf = \cos(\theta_v - \theta_I)$$

→ Leading if $\theta_v - \theta_I \Rightarrow (-ve)$.

→ Lagging if $\theta_v - \theta_I \Rightarrow (+ve)$.

- equal 1: for resistance.
- equal zero: for pure inductance or capacitance.

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*** Complex Power: (Assume RMS values)**

$$\boxed{\begin{aligned} S &= V I^* = \frac{V^2}{Z^*} = I^2 Z \\ |S| &= |V|\,|I| \\ P &= |V|\,|I| \cos(\theta_V - \theta_I) \\ Q &= |V|\,|I| \sin(\theta_V - \theta_I) \end{aligned}}$$

- S ⟹ Complex Power (VA)
- $|S|$ ⟹ Apparent Power (VA)
- P ⟹ Real/Average Power (W)
- Q ⟹ Reactive Power (VAR)

*** Adding capacitor to a cKt to give us new pf:**

we find P from the old pf since it will be always constant then find Q_1 Then Q_2 from $Q_2 = P * \tan(\cos^{-1}(pf_{new}))$

$\Rightarrow Q_c = Q_2 - Q_1 \quad \Rightarrow \quad C = \dfrac{|Q_c|}{|V_{rms}|^2 \omega}$

*** RMS value for multiple signals:**

$$V_{rms} = \sqrt{(V_{rms_1})^2 + (V_{rms_2})^2 + \cdots}$$

※ CHAPTER (12):

*** in Balanced systems:**

if the load is Δ-connected:

$$\boxed{\begin{aligned} V_{LL} &= V_{phase} \\ I_L &= \sqrt{3}\, I_p \angle -30^\circ \end{aligned}} \quad \text{---(1)}$$

if the load is Y-connected:

$$\boxed{\begin{aligned} V_{LL} &= \sqrt{3}\, V_{LN} \angle +30^\circ \\ I_L &= I_p \end{aligned}} \quad \text{---(2)}$$

$$Z_\Delta = 3 Z_Y \quad \text{---(3)}$$

*** Always in Balanced-systems:** convert to Y-Y and use the single phase cKt ⟹ will be the easiest way to solve.

*** In UnBalanced systems:** DON'T use the relations in Box (1) & (2) & (3)

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* Always the unbalanced system: ⇒ unbalanced in the load
(source is always balanced)
↳ $V_{ab} = \sqrt{3}\, V_{an} \angle{+30^\circ}$ (use it always)

* in Balanced system:

if there is a line (with or without impedance) ⇒ connected with n & N
⇒ we don't care to it, it has NO effect.

$I_a + I_b + I_c = 0$ ⇒ always in balanced-system.

* in Unbalanced system: (Three Cases)

1. if just only a line (without impedance) connected to n & N
⇒ $\boxed{I_a + I_b + I_c = I_{Nn}}$ & $\boxed{V_n = V_N = 0}$

2. if it is line (with impedance) ⇒ $\boxed{\begin{array}{l} I_a + I_b + I_c = I_{Nn} \\ V_n = 0 \quad V_N \neq 0 \end{array}}$
⇒ $V_N = Z_{line} * I_{Nn}$

3. if No line between n & N ⇒ $\boxed{V_N \neq 0, \; I_a + I_b + I_c = 0}$

* Power in 3phase system:

$P_\Delta = P_Y = 3 V_P I_P \cos(\theta_v - \theta_i)$	$S_\Delta = S_Y = 3 V_P I_P^*$
$Q_\Delta = Q_Y = 3 V_P I_P \sin(\theta_v - \theta_i)$	$\lvert S_\Delta \rvert = \lvert S_Y \rvert = \sqrt{3}\, \lvert V_L \rvert \lvert I_L \rvert$

* Losses in the 3phase system:
→ $S_{losses} = S_{source} - S_{load}$.
→ $S_{losses} = 3 \lvert I_L \rvert^2 Z_{T.L}$

* Wattmeter mesurments:

⇒ Determine the voltage (V) & the current (I) that measured by this wattmeter then: $P = \lvert V \rvert \lvert I \rvert \cos(\theta_v - \theta_i)$

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* if 3-Wattmeters used: $P_{Total} = P_1 + P_2 + P_3$

* In Two-Wattmeters method:

$P_T = P_1 + P_2$ $\quad$ $Q_T = \sqrt{3}(P_2 - P_1)$ $\quad$ $S_T = P_T + jQ_T$

$\boxed{pf = \cos\theta}$ $\rightarrow$ $\boxed{\theta = \tan^{-1}\left(\frac{\sqrt{3}(P_2 - P_1)}{P_1 + P_2}\right)}$

※ CHAPTER (13):

※ Linear Transformer:

⇒ Virtual source: we put it between the dot & the coil

* Choosing the polarities:

if the current enter the dot ⇒ take it (+ve) for the other dot.
if " " leaves " " ⇒ take it (-ve) " " " ".

* Energy stored:

$$W = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 \pm M I_1 I_2$$

(−) if one current leaves & the other enters.

(+) if both currents leaving or entering the dots.

* Coupling Coefficient: $\boxed{K = \frac{M}{\sqrt{L_1 L_2}}}$

* For linear transformer with current entering in primary & leaving in secondary:

$\boxed{Z_{11} = R_1 + j\omega L_1}$ + any other impedances in primary.

$\boxed{Z_{22} = R_2 + j\omega L_2 + Z_L}$ + any other impedances in secondary.

$$Z_{in} = Z_{11} + \frac{(\omega M)^2}{Z_{22}}$$

$$\text{Reflected Impedance} = \frac{(\omega M)^2}{Z_{22}}$$

⟶

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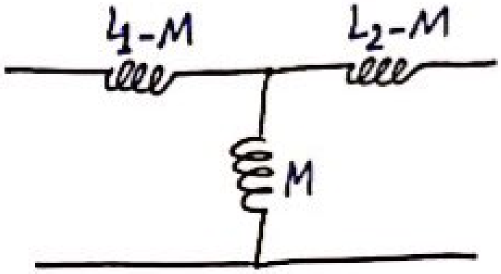
⇒ you can find I_1 & I_2 easly from:

$\boxed{I_1 = V_1/Z_{in}}$ for I_2: ⇒ $I_2 = \frac{j\omega M}{Z_{22}} I_1$

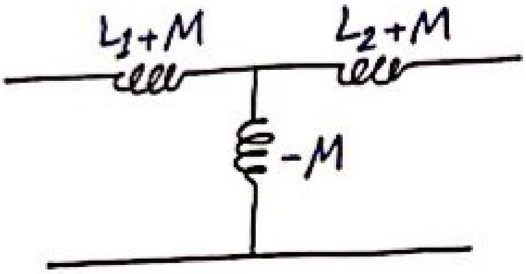
if both currents entering the dot here you have to multiply I_2 by (−1) if you use this way.

* T-equivalent ckt:

(Both currents entering or leaving)

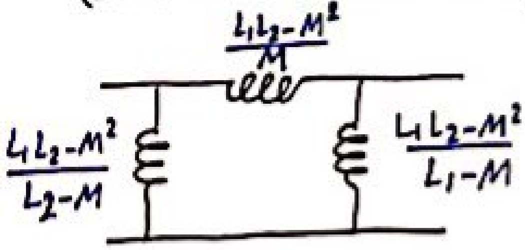


(one current enter and the other leave.)

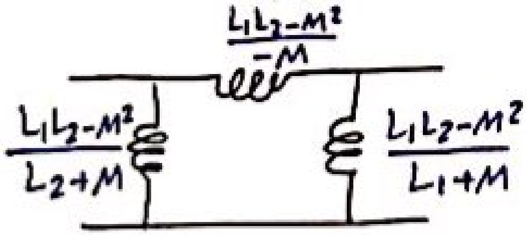


* π-equivalent ckt:

(Both currents enter or leave)



(one current enter & other leave)



*We use T & π just if there is a connection between the primary & the secondary

* Ideal Transformer:

$$\boxed{a \text{ or } n = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_2}{I_1}}$$

→ for currents: if the currents entering or leaving the dots together (−ve) n otherwise (+ve) n

always n (+ve) for $\frac{N_2}{N_1}$

→ for voltages: if V_1, V_2 both (+ve) or both (−ve) ⇒ (+ve) n otherwise (−ve) n.

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*** Complex power:**

$$\boxed{S_{primary} = S_{secondary} = V_1 I_1^* = V_2 I_2^*}$$

*** Reflection:**

⇒ To reflect with respect to primary:
- Z/n^2
- $V/\underline{n}$
- $I * \underline{n}$

⇒ To reflect with respect to secondary:
- $Z * n^2$
- $V * \underline{n}$
- $I/\underline{n}$

Be aware for the sign.

* we just do the reflection if there is NO connection between primary & secondary. Otherwise, use mesh & nodal.

※ CHAPTER (14):

*** Common Relations for series & Parallel Resonance:**

$$\beta = \frac{\omega_0}{Q_0} \qquad f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$\omega_0 = \sqrt{\omega_1 \omega_2}$$

$$\omega_{1,2} = \omega_0\left[\sqrt{1+\left(\frac{1}{2Q_0}\right)^2} \mp \frac{1}{2Q_0}\right]$$

* Approximate:

$$\omega_{1,2} = \omega_0 \mp \frac{1}{2}\beta$$

$$\omega_0 = \frac{1}{2}(\omega_1 + \omega_2)$$

$$N = \frac{\omega - \omega_0}{\frac{1}{2}\beta}$$

*** Series Resonance:**

$$Q_0 = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}$$

$$|V_L(\omega_0)| = |V_C(\omega_0)| = VQ_0$$

$$Z = R + j\omega L + \frac{1}{j\omega C}$$

$$Z_{app} = R(1+jN)$$

Y (max) (min)

I : V (max) | (max)

Z (min) (max)

*** Parallel Resonance:**

$$Q_0 = \omega_0 RC = \frac{R}{\omega_0 L}$$

$$|I_L(\omega_0)| = |I_C(\omega_0)| = I Q_0$$

$$Y = \frac{1}{R} + j\omega C + \frac{1}{j\omega L}$$

$$Y_{app} = \frac{1}{R}(1+jN)$$

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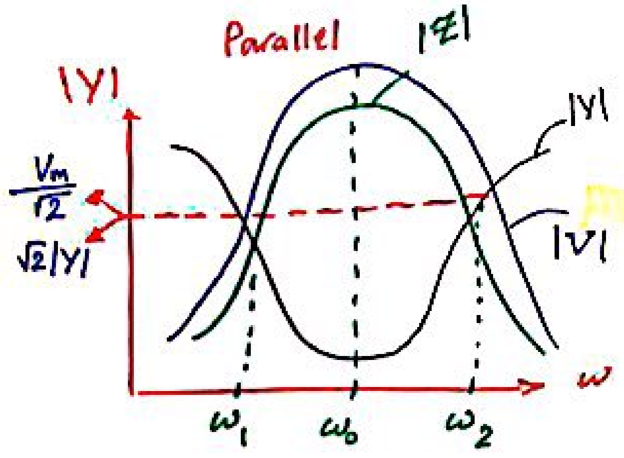

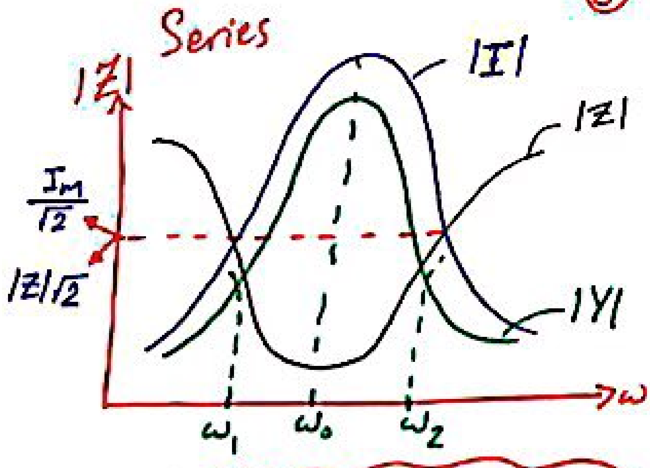

*** if you find $P(\omega_0)$ then $P(\omega_1) = P(\omega_2) = \frac{1}{2} P(\omega_0)$

* Other Resonance Forms:

KEY: To find ω_0 just choose what is easy to deal with Z or Y then find the equivelant & put the imaginary part $= 0$

* Transfer function: $\frac{\text{output}}{\text{input}}$.

* Filters:

* Low pass filter: RC ckt $\Rightarrow$ output on C. $\rightarrow$ $\omega_c = \frac{1}{RC}$
RL ckt $\Rightarrow$ output on R. $\rightarrow$ $\omega_c = \frac{R}{L}$
other ckt $\Rightarrow$ make $|H_v(\omega_c)| = \frac{1}{\sqrt{2}}$
Then find ω_c.

* High pass filter: RL ckt $\Rightarrow$ output on L. $\rightarrow$ $\omega_c = \frac{R}{L}$
RC ckt $\Rightarrow$ output on R. $\rightarrow$ $\omega_c = \frac{1}{RC}$
other ckt $\Rightarrow$ put $|H_v(\omega_c)| = \frac{1}{\sqrt{2}}$
Then find ω_c

* Band pass filter: RLC ckt $\Rightarrow$ output on R. $\Rightarrow$ ω_0 & ω_1 & ω_2 as in resonance.

* Band stop filter: RLC ckt $\Rightarrow$ output on (L&C) $\Rightarrow$ ω_0 & ω_1 & ω_2 as in resonance.

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* Bode Plot:

⇒ standard form:

$$H(\omega) = \frac{K\,(j\omega)^{\pm 1}\left[1 + \frac{j\omega}{z_1}\right]}{\left[1 + \frac{j\omega}{P_1}\right]}$$

could be zero or pole.

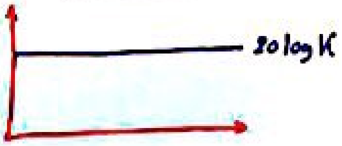
zero @ z_1

Constant.

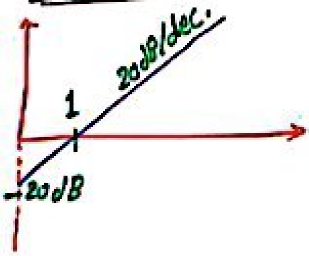
Pole @ P_1

⇒ Drawing $H_v(\omega)$:

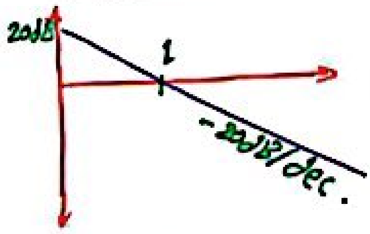
$\underline{20 \log K}$



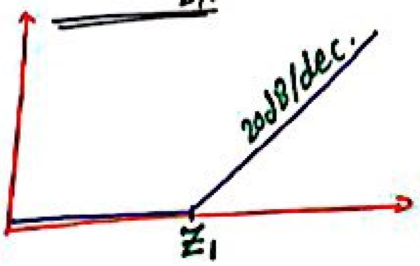
$\underline{20 \log |j\omega|}$



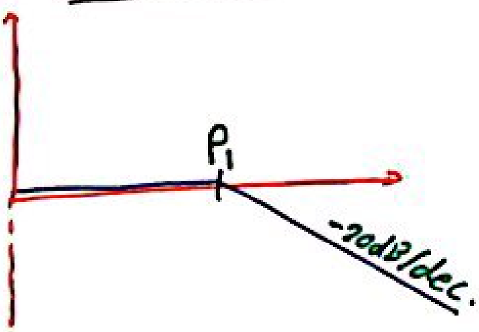
$\underline{-20 \log |j\omega|}$



$\underline{20 \log \left|1 + \frac{j\omega}{z_1}\right|}$



$\underline{-20 \log \left|1 + \frac{j\omega}{P_1}\right|}$

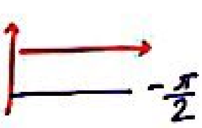


⇒ Drawing $\angle H_v(\omega)$:

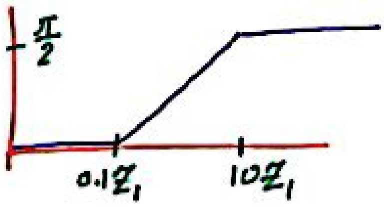
constant

$20 \log |j\omega|$

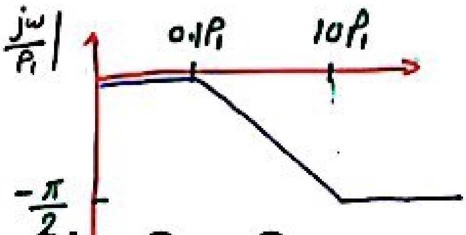
$-20 \log |j\omega|$



$20 \log \left|1 + \frac{j\omega}{z_1}\right|$



$-20 \log \left|1 + \frac{j\omega}{P_1}\right|$



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※ CHAPTER (19):

* Z-parameters:

* $I_2 = 0$:

$$Z_{11} = \frac{V_1}{I_1}$$

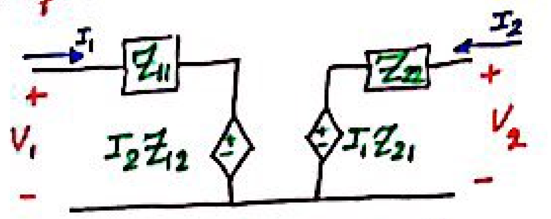
$$Z_{21} = \frac{V_2}{I_1}$$

* $I_1 = 0$:

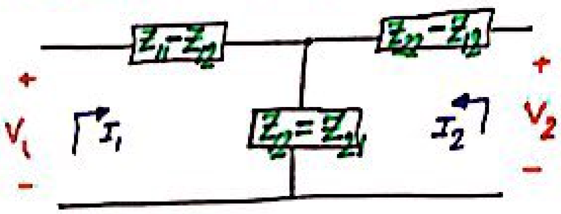
$$Z_{22} = \frac{V_2}{I_2}$$

$$Z_{12} = \frac{V_1}{I_2}$$

* equivalent ckt for 2-port network:



* Special case: (reciprocal)



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* Y-parameters:

* $V_2 = 0$:

$$Y_{11} = \frac{I_1}{V_1}$$

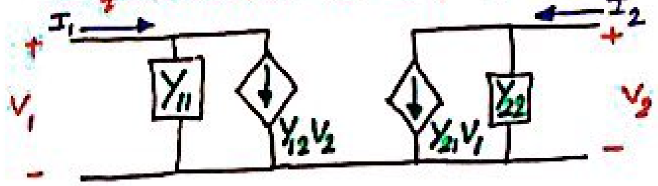
$$Y_{21} = \frac{I_2}{V_1}$$

* $V_1 = 0$:

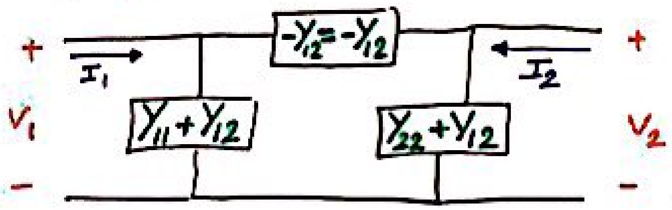
$$Y_{12} = \frac{I_1}{V_2}$$

$$Y_{22} = \frac{I_2}{V_2}$$

* equivalent ckt for 2-port network:



* special case: (reciprocal)



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* Z_{in} & Z_{out}:

$$Z_{in} = \frac{V_1}{I_1}$$

$$Z_{out} = Z_{22} - \frac{Z_{12} Z_{21}}{Z_{11} + Z_g}$$

GOOD LUCK

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