RANGKAIAN LISTRIK II

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OUTLINE

- Frekuensi Kompleks
- Respon Frekuensi
- Resonansi

REFERENSI

- Fundamentals Of Electric Circuits by Alexander Charles K., Sadiku Matthew O. N.
- Engineering Circuit Analysis by Hayt

1.

FREKUENSI KOMPLEKS

FREKUENSI KOMPLEKS

- Frekuensi kompleks = fungsi sinusoidal + konstanta peredam

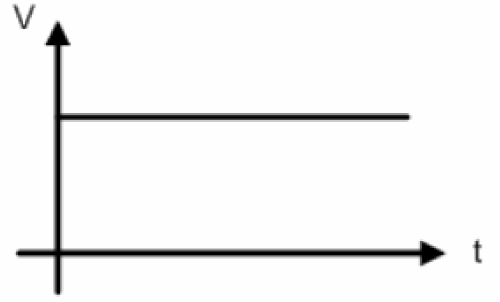
- Fungsi sinusoidal → $V_m \cos(\omega t + \theta)$

- Konstanta peredam → $e^{-\sigma t}$

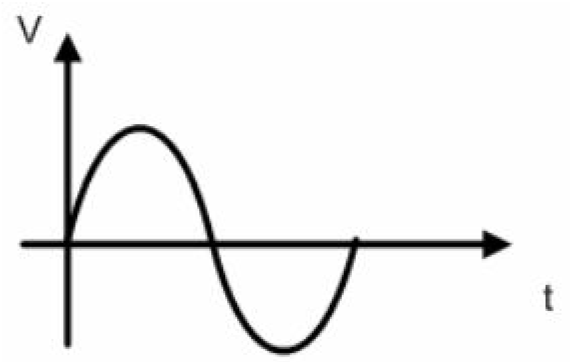
- σ → faktor peredam/ frekuensi Neper dengan satuan Np/s yang nilainya (-)/0

FREKUENSI KOMPLEKS

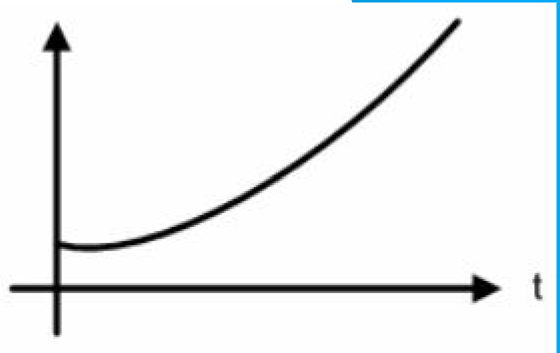
Fungsi sinusoidal dengan berbagai konstanta peredam dapat digambarkan dalam bentuk kurva.



v(t) = Vm
σ = 0
ω = 0



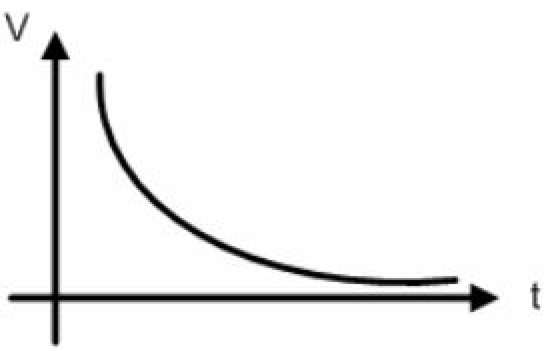
v(t) = $V_m \cos(\omega t + \theta)$
σ = 0



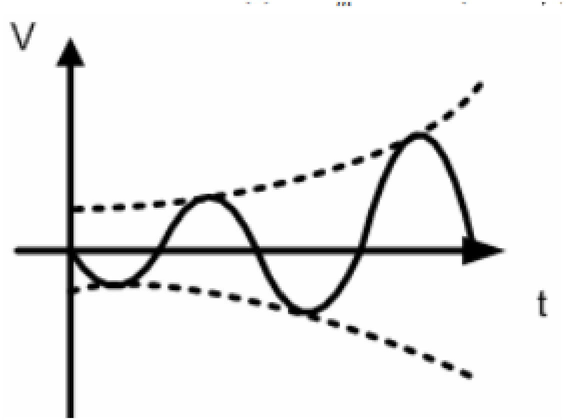
v(t) = Vm $e^{\sigma t}$
σ > 0
ω = 0

FREKUENSI KOMPLEKS

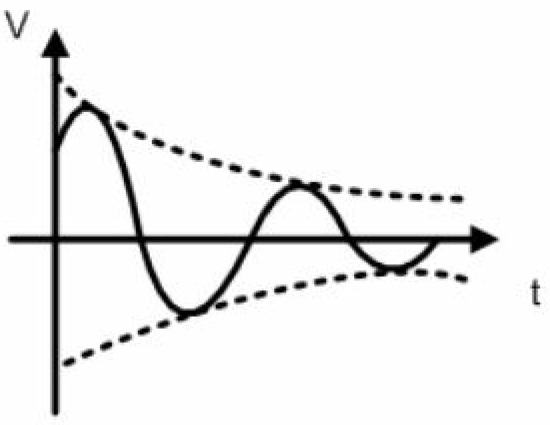
Fungsi sinusoidal dengan berbagai konstanta peredam dapat digambarkan dalam bentuk kurva.



$v(t) = V_m\, e^{-\sigma t}$
$\sigma < 0$
$\omega = 0$



$v(t) = V_m\, e^{\sigma t} \cos(\omega t + \theta)$
$\sigma > 0$



$v(t) = V_m\, e^{\sigma t} \cos(\omega t + \theta)$
$\sigma < 0$

FREKUENSI KOMPLEKS

Fasor sinyal AC

- $v(t) = V_m \cos(\omega t + \theta)$
- $V = Re\left[V_m\, e^{j(\omega t + \varphi)}\right]$
- $V = Re\left[V_m\, e^{j\varphi} e^{j\omega t}\right]$
- $V\,(j\omega) = V_m\, e^{j\varphi}$
- $V\,(j\omega) = V_m \angle \varphi$

Fasor sinyal frekuensi komples

- $v(t) = V_m e^{\sigma t} \cos(\omega t + \theta)$
- $V = Re\left[V_m e^{\sigma t} e^{j(\omega t + \varphi)}\right]$
- $V = Re\left[V_m\, e^{j\varphi} e^{(\sigma + j\omega)t}\right]$ → s = σ + jω
- $V = Re\left[V_m\, e^{j\varphi} e^{st}\right]$
- $V\,(s) = V_m\, e^{j\varphi}$
- $V\,(j\omega) = V_m \angle \varphi$

FREKUENSI KOMPLEKS

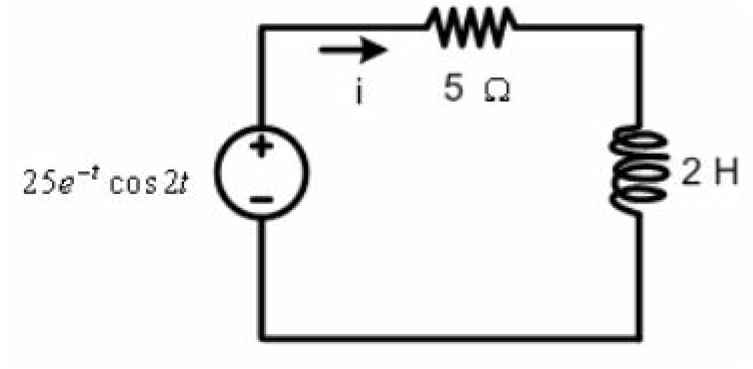
Impedansi dalam frekuensi kompleks

- $V(s) = \frac{Z(s)}{I(s)}$
- $Z_R\,(s) = R$ $\qquad Y_R\,(s) = \frac{1}{R} = G$
- $Z_L\,(s) = sL$ $\qquad Y_L\,(s) = \frac{1}{sL}$
- $Z_C\,(s) = \frac{1}{sC}$ $\qquad Y_C\,(s) = sC$

FREKUENSI KOMPLEKS

Contoh

Tentukan nilai i



$$s = -1 + j2$$
$$Z_R(s) = 5$$
$$Z_L(s) = sL = 2s$$
$$Z_T(s) = 5 + 2s$$
$$V = 25e^{-t}\cos 2t = 25\angle 0^o$$
$$i(s) = \frac{V(s)}{Z_T(s)} = \frac{25\angle 0^o}{5+2s} = \frac{25\angle 0^o}{5+2(-1+j2)} = 5\angle -53{,}1^o$$
$$i(t) = 5e^{-t}\cos(2t - 53{,}1^o)A$$

2.

RESPON FREKUENSI

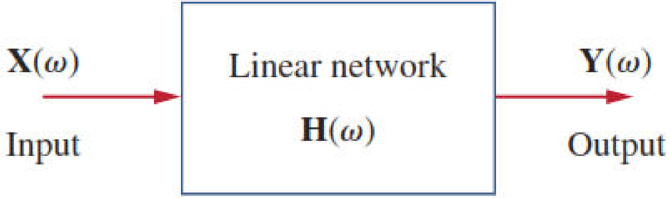
RESPON FREKUENSI

- Jika sebuah sumber sinusoidal dengan amplitudo konstan dan frekuensi yang berubah – ubah, akan di dapatkan **respon frekuensi**.
- **Respon frekuensi** dari rangkaian adalah perubahan sifat rangkaian akibat perubahan frekuensi sinyal
- Alat yang digunakan untuk menemukan respon frekuensi dari rangkaian adalah **Transfer Function** → $\mathbf{H}(\omega)$
- Respon frekuensi akan digambarkan sebagai **kurva** $\mathbf{H}(\omega)$ vs ω dimana nilai ω dari $0 - \infty$.

RESPON FREKUENSI

- Transfer Function adalah rasio perbandingan dari **output** dan **input** sistem, yang bergantung pada frekuensi

- $\mathbf{H}(\omega) = \frac{\mathbf{Y}(\omega)}{\mathbf{X}(\omega)}$



- Dalam rangkaian listrik, input dan output yang akan dicari adalah tegangan dan arus, sehingga kemungkinan dari transfer function ialah:

- $\mathbf{H}(\omega) = \text{voltage gain} = \frac{\mathbf{V_o}(\omega)}{\mathbf{V_i}(\omega)}$ $\quad\quad$ $\mathbf{H}(\omega) = \text{transfer impedance} = \frac{\mathbf{V_o}(\omega)}{\mathbf{I_i}(\omega)}$

- $\mathbf{H}(\omega) = \text{current gain} = \frac{\mathbf{I_o}(\omega)}{\mathbf{I_i}(\omega)}$ $\quad\quad$ $\mathbf{H}(\omega) = \text{transfer admittance} = \frac{\mathbf{I_o}(\omega)}{\mathbf{V_i}(\omega)}$

RESPON FREKUENSI

- $\mathbf{H}(\omega) = \mathrm{H}(\omega)\angle\theta \longrightarrow$ Sudut Fasa

  $\downarrow$ Magnitude

- Transfer Function dapat di rumuskan sebagai perbandingan numerator polynomial dan denominator polynomial

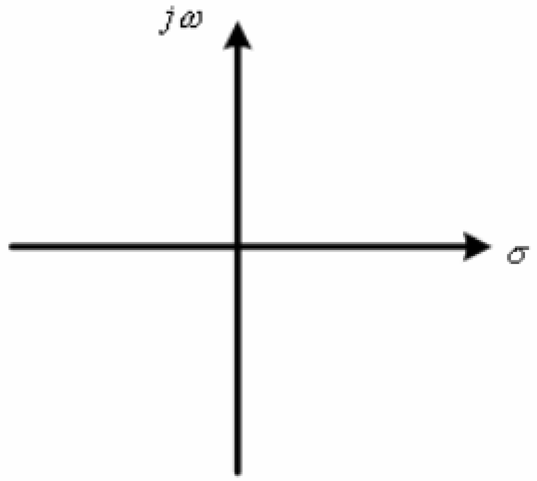
- $\mathbf{H}(\omega) = \dfrac{\mathbf{N}(\omega)}{\mathbf{D}(\omega)}$ $$H(s) = \frac{b_m(s-Z_1)(s-Z_2)........(s-Z_m)}{a_n(s-P_1)(s-P_2)........(s-P_n)}$$

- **Zero**, akar dari numerator (Z_1, Z_2,…, Z_m) yang membuat transfer function menjadi nol

- **Pole**, akar dari denominator (P_1, P_2,…, P_m) yang membuat fungsi menjadi tak hingga

RESPON FREKUENSI

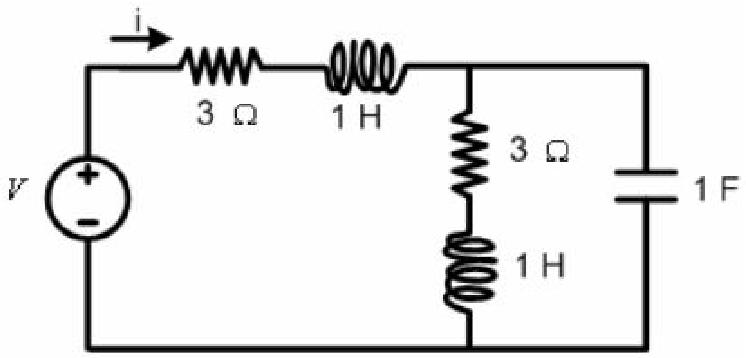
- Diagram bode pada S-plane
- Dapat menentukan kestabilan sistem, dimana kestabilan BIBO (Bounded Input Bounded Output) terletak di sebelah kiri pole – polenya.
- Jenis kestabilan:
  - Absolutely : ada di sebelah kiri jω axis
  - Conditionally : tidak ada yang di sebelah kanan pole tetapi pada jω axis untuk orde > 1
  - Unstable : ada di sebelah kanan jω axis

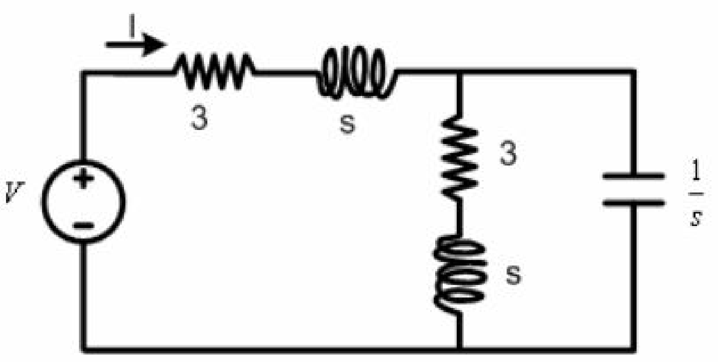


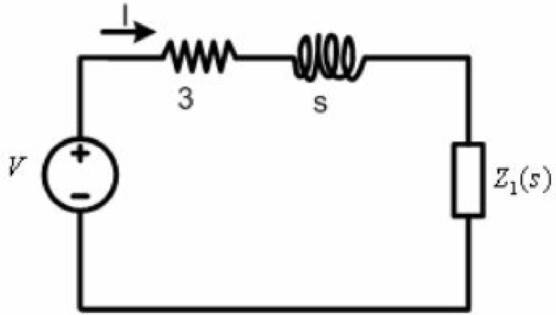
RESPON FREKUENSI

Contoh soal

- Tentukan fungsi transfer I terhadap V







$$Z_1(s) = \frac{3+s}{s^2+3s+1}$$

$$H(s) = \frac{I(s)}{V(s)} = \frac{1}{3+s+\dfrac{3+s}{s^2+3s+1}}$$

$$H(s) = \frac{s^2+3s+1}{s^3+6s^2+11s+6}$$

$$H(s) = \frac{s^2+3s+1}{(s+2)(s+3)(s+1)}$$

RESPON FREKUENSI

Contoh soal

- Tentukan output tegangan jika diberikan fungsi transfer sebagai berikut

$$H(s) = \frac{4(s+5)}{s^2+4s+5}$$

dimana input $V_i(s) = 2\angle 0^o$ dan s = -2+j3

Jawaban :

$$V_o(s) = H(s).V_i(s) = \frac{4(s+5)}{s^2+4s+5}.2\angle 0^o = \frac{4(-2+j3+5)}{(-2+j3)^2+4(-2+j3)+5}.2\angle 0^o = -3(1+j)$$

$$V_o(s) = 3\sqrt{2}\angle -135^o$$

$$V_o(t) = 3\sqrt{2}e^{-t}\cos(3t-135^o)$$

RESPON FREKUENSI

Rangkaian RL

- Fungsi transfer dalam domain s

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{R}{R + sL} = \frac{1}{1 + {sL}/{R}}$$

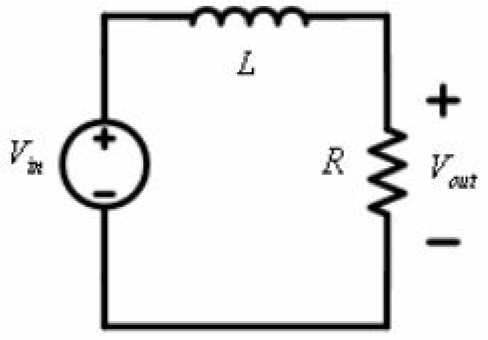
- Jika s = jω, fungsi transfernya menjadi

$$H(j\omega) = \frac{1}{1 + {j\omega L}/{R}}$$

- Respon frekuensi menjadi

$$|H(j\omega)| = \frac{1}{\sqrt{1 + \left({\omega L}/{R}\right)^2}}$$

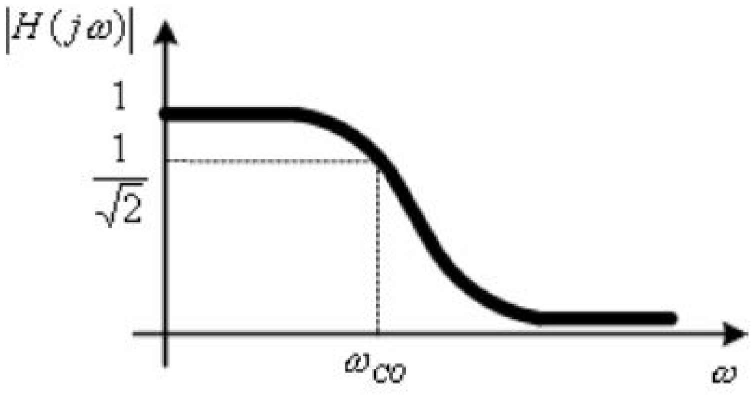
$$\angle H(j\omega) = -\tan^{-1}\left(\frac{\omega L}{R}\right)$$



RESPON FREKUENSI

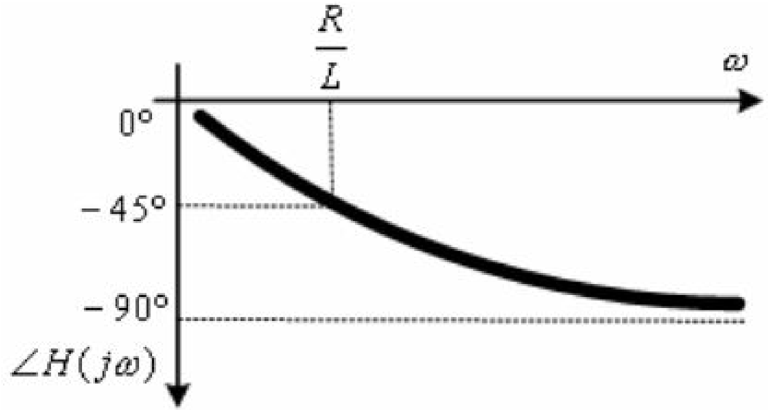
Respon Frekuensi Magnitudo

- $\omega = 0 \rightarrow |\mathrm{H}(\omega)| = 1$
- $\omega = \infty \rightarrow |\mathrm{H}(\omega)| = 0$
- $\omega = \frac{R}{L} \rightarrow |\mathrm{H}(\omega)| = \frac{\mathbf{1}}{\sqrt{\mathbf{2}}}$



Respon Frekuensi Fasa

- $\omega = 0 \rightarrow \angle\mathrm{H}(\omega) = 0°$
- $\omega = \infty \rightarrow \angle\mathrm{H}(\omega) = -90°$
- $\omega = \frac{R}{L} \rightarrow \angle\mathrm{H}(\omega) = -45°$



RESPON FREKUENSI

Rangkaian RL

- Fungsi transfer dalam domain s

$$H(s)=\frac{V_{out}(s)}{V_{in}(s)}=\frac{sL}{sL+R}=\frac{1}{1+R/sL}$$

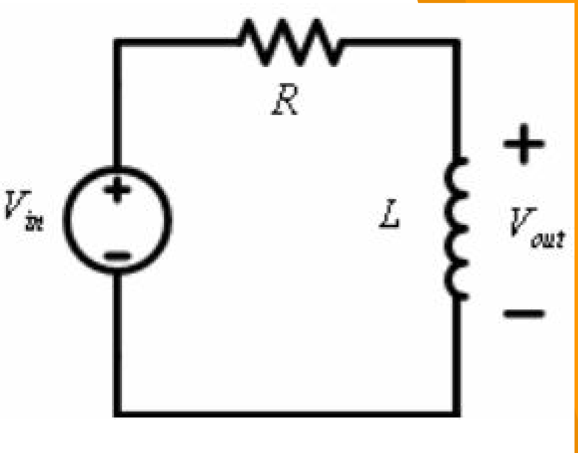
- Jika s = jω, fungsi transfernya menjadi

$$H(j\omega)=\frac{1}{1+R/j\omega L}=\frac{1}{1-jR/\omega L}$$

- Respon frekuensi menjadi

$$|H(j\omega)|=\frac{1}{\sqrt{1+\left(R/\omega L\right)^2}}$$

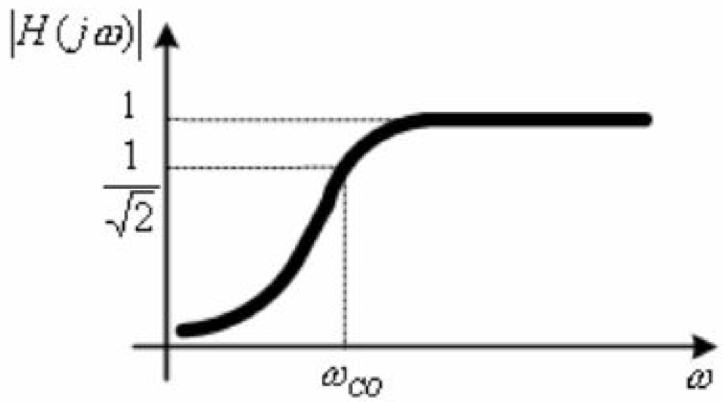
$$\angle H(j\omega)=-\tan^{-1}\left(-\frac{R}{\omega L}\right)$$



RESPON FREKUENSI

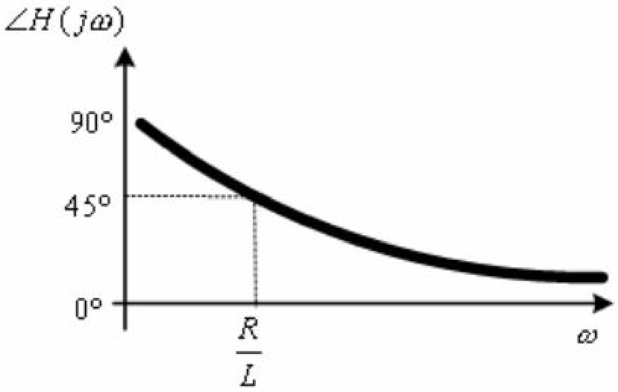
Respon Frekuensi Magnitudo

- $\omega = 0 \rightarrow |\mathrm{H}(\omega)| = 0$
- $\omega = \infty \rightarrow |\mathrm{H}(\omega)| = 1$
- $\omega = \frac{R}{L} \rightarrow |\mathrm{H}(\omega)| = \frac{\mathbf{1}}{\sqrt{\mathbf{2}}}$



Respon Frekuensi Fasa

- $\omega = 0 \rightarrow \angle\mathrm{H}(\omega) = 90°$
- $\omega = \infty \rightarrow \angle\mathrm{H}(\omega) = 0°$
- $\omega = \frac{R}{L} \rightarrow \angle\mathrm{H}(\omega) = 45°$



RESPON FREKUENSI

Rangkaian RC

- Fungsi transfer dalam domain s

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{1/sC}{1/sC + R} = \frac{1}{1 + sCR}$$

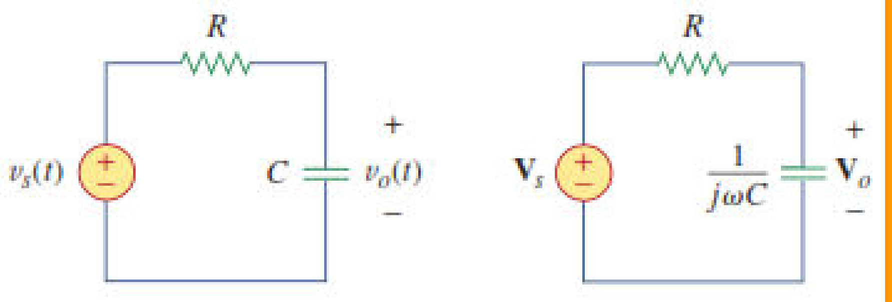
- Jika s = jω, fungsi transfernya menjadi

$$H(j\omega) = \frac{1}{1 + j\omega CR}$$

- Respon frekuensi menjadi

$$|H(j\omega)| = \frac{1}{\sqrt{1 + (\omega CR)^2}}$$

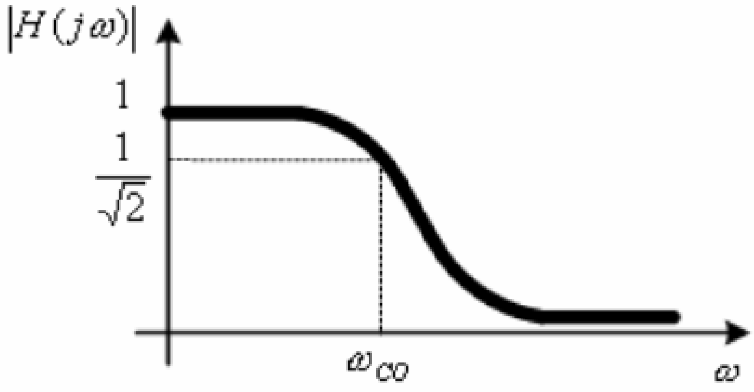
$$\angle H(j\omega) = -\tan^{-1}(\omega CR)$$



RESPON FREKUENSI

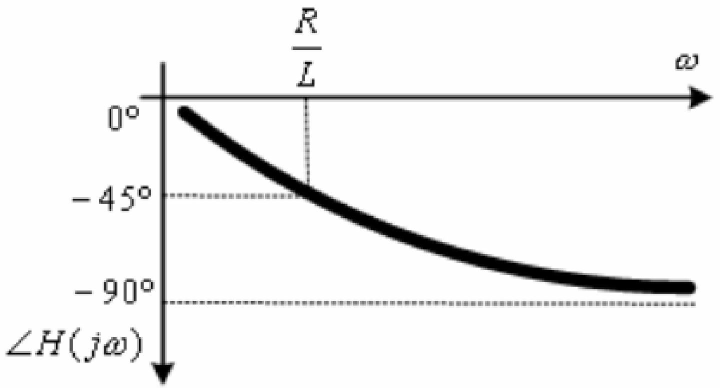
Respon Frekuensi Magnitudo

- $\omega = 0 \rightarrow |\mathrm{H}(\omega)| = 1$
- $\omega = \infty \rightarrow |\mathrm{H}(\omega)| = 0$
- $\omega = \frac{1}{CR} \rightarrow |\mathrm{H}(\omega)| = \frac{\mathbf{1}}{\sqrt{\mathbf{2}}}$



Respon Frekuensi Fasa

- $\omega = 0 \rightarrow \angle\mathrm{H}(\omega) = 0°$
- $\omega = \infty \rightarrow \angle\mathrm{H}(\omega) = -90°$
- $\omega = \frac{1}{CR} \rightarrow \angle\mathrm{H}(\omega) = -45°$



3.

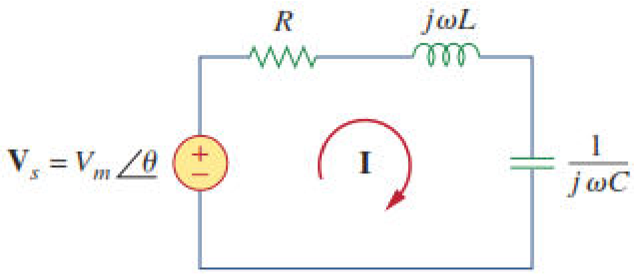
RESONANSI

RESONANSI

- Resonansi adalah keadaan dimana nilai magnitude dari reaktansi kapasitif dan induktif sama sehingga impedansi rangkaian hanya berupa resistif murni

- Rangkaian resonansi dibuat untuk membentuk filter, karena Transfer function dari rangkaian dapat memilih frekuensi

- Resonansi dapat dibentuk dari rangkaian seri ataupun paralel



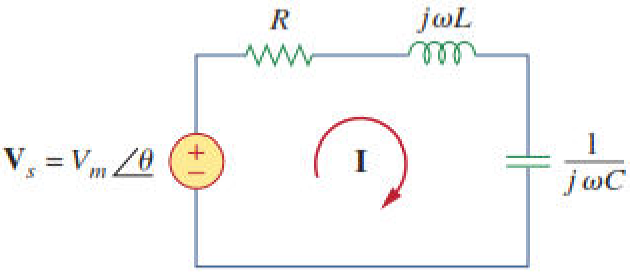
- Transfer function

$$\mathbf{Z} = \mathbf{H}(\omega) = \frac{\mathbf{V}_s}{\mathbf{I}} = R + j\omega L + \frac{1}{j\omega C}$$

- Total impedansi rangkaian

$$\mathbf{Z} = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

RESONANSI



- Keadaan resonansi akan tercapai jika total reaktansi indukstif dan kapasitif adalah nol

$$\mathrm{Im}(\mathbf{Z}) = \omega L - \frac{1}{\omega C} = 0$$

- Nilai ω yang dapat memenuhi kondisi di atas di sebut frekuensi resonansi (ω_0)

$$\omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \boxed{\omega_0 = \frac{1}{\sqrt{LC}} \text{ rad/s}}$$

- $\omega_0 = 2 \times \pi \times f_0$

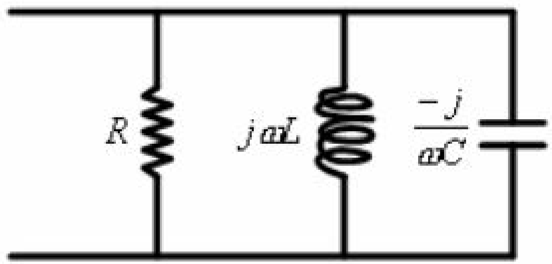
$$f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}$$

- Impedansi menjadi resistif murni, sehingga LC seri akan menjadi SC dan seluruh tegangan melewati R

- Vs dan I berada satu fasa, pf menjadi unity

- H(ω) = Z(ω) -> minimum

RESONANSI



Admitansi total :

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{R} + \frac{1}{j\omega L} + \frac{1}{-j/\omega C} = \frac{1}{R} - \frac{j}{\omega L} + j\omega C$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)$$

saat resonansi :

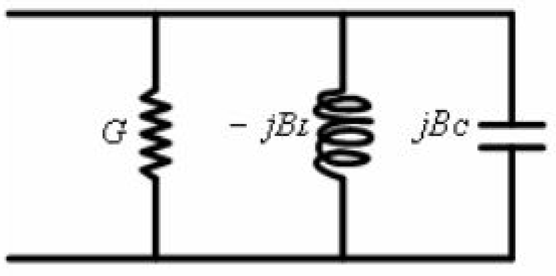
$$\omega C - \frac{1}{\omega L} = 0 \rightarrow \omega C = \frac{1}{\omega L}$$

$$\omega^2 = \frac{1}{LC}$$

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

Pada saat resonansi impedansi **Z** maksimum, sehingga arusnya minimum.

RESONANSI



$$Y = G + jB_C - jB_L$$

$$Y = G + j(\omega C - \frac{1}{\omega L})$$

saat resonansi :

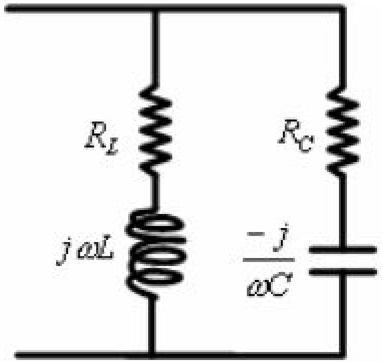
$$\omega C - \frac{1}{\omega L} = 0 \rightarrow \omega C = \frac{1}{\omega L}$$

$$\omega^2 = \frac{1}{LC}$$

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

RESONANSI

Resonansi Paralel 2 Cabang



$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{R_L + j\omega L} + \frac{1}{R_C - \dfrac{j}{\omega C}}$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{R_L + j\omega L}\left(\frac{R_L - j\omega L}{R_L - j\omega L}\right) + \frac{1}{R_C - \dfrac{j}{\omega C}}\left(\frac{R_C + \dfrac{j}{\omega C}}{R_C + \dfrac{j}{\omega C}}\right)$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{R_L - j\omega L}{R_L^{\;2} + (\omega L)^2} + \frac{R_C + \dfrac{j}{\omega C}}{R_C^{\;2} + \left(\dfrac{1}{\omega C}\right)^2}$$

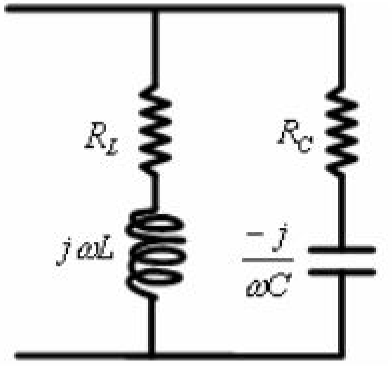
$$\frac{1}{\mathbf{Z}_{tot}} = \frac{R_L}{R_L^{\;2} + (\omega L)^2} + \frac{R_C}{R_C^{\;2} + \left(\dfrac{1}{\omega C}\right)^2} + j\left(\frac{\dfrac{1}{\omega C}}{R_C^{\;2} + \left(\dfrac{1}{\omega C}\right)^2} - \frac{\omega L}{R_L^{\;2} + (\omega L)^2}\right)$$

saat resonansi:

$$\frac{\dfrac{1}{\omega C}}{R_C^{\;2} + \left(\dfrac{1}{\omega C}\right)^2} - \frac{\omega L}{R_L^{\;2} + (\omega L)^2} = 0$$

RESONANSI

Resonansi Paralel 2 Cabang



$$\frac{\frac{1}{\omega C}}{R_C^{\,2} + \left(\frac{1}{\omega C}\right)^2} = \frac{\omega L}{R_L^{\,2} + (\omega L)^2}$$

$$R_L^{\,2} + (\omega L)^2 = \omega^2 LC\left(R_C^{\,2} + \left(\frac{1}{\omega C}\right)^2\right)$$

$$R_L^{\,2} + \omega^2 L^2 = \omega^2 LCR_C^{\,2} + \frac{L}{C}$$

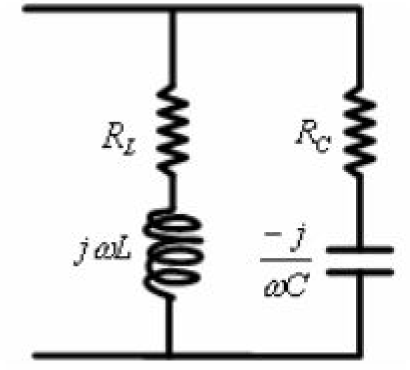
$$\omega^2 LCR_C^{\,2} - \omega^2 L^2 = R_L^{\,2} - \frac{L}{C}$$

$$\omega^2 LC\left(R_C^{\,2} - \frac{L}{C}\right) = R_L^{\,2} - \frac{L}{C}$$

$$f_o = \frac{1}{2\pi\sqrt{LC}}\sqrt{\frac{R_L^{\,2} - \frac{L}{C}}{R_C^{\,2} - \frac{L}{C}}}$$

RESONANSI

Resonansi Paralel 2 Cabang

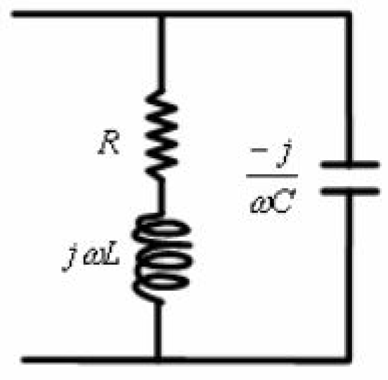


Perlu diingat bahwa : $\sqrt{\dfrac{R_L{}^2 - \dfrac{L}{C}}{R_C{}^2 - \dfrac{L}{C}}}$ harus positif real sehingga syarat :

$R_l{}^2 > \dfrac{L}{C}$ dan $R_C{}^2 > \dfrac{L}{C}$ atau $R_L{}^2 < \dfrac{L}{C}$ dan $R_C{}^2 < \dfrac{L}{C}$

Ketika nilai $R_L{}^2 = R_C{}^2 = \dfrac{L}{C}$, maka rangkaian beresonansi untuk semua frekuensi.

RESONANSI



$$\mathbf{Z}_1 = R + j\omega L$$

$$\mathbf{Z}_2 = \frac{1}{j\omega C}$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2} = \frac{1}{R + j\omega L} + \frac{1}{\frac{1}{j\omega C}} = \frac{1}{R + j\omega L} + j\omega C$$

$$\frac{1}{\mathbf{Z}_{tot}} = j\omega C + \frac{1}{R + j\omega L}\left(\frac{R - j\omega L}{R - j\omega L}\right)$$

$$\frac{1}{\mathbf{Z}_{tot}} = j\omega C + \frac{R - j\omega L}{R^2 + \omega^2 L^2}$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{R}{R^2 + \omega^2 L^2} + j\left(\omega C - \frac{\omega L}{R^2 + \omega^2 L^2}\right)$$

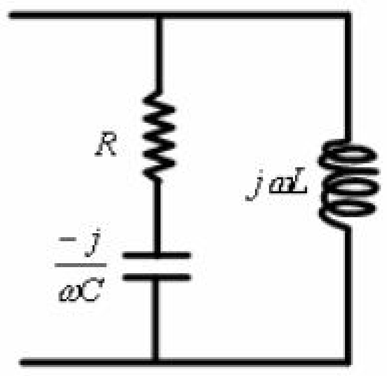
saat resonansi : $\omega_C = \dfrac{\omega_L}{R^2 + \omega^2 L^2}$, sehingga :

$$R^2 + \omega^2 L^2 = \frac{L}{C} \rightarrow \omega^2 L^2 = \frac{L}{C} - R^2 \rightarrow \omega^2 = \frac{1}{L^2}\left(\frac{L}{C} - R^2\right) = \frac{1}{LC} - \frac{R^2}{L^2} = \frac{1}{LC}\left(1 - \frac{R^2 C}{L^2}\right)$$

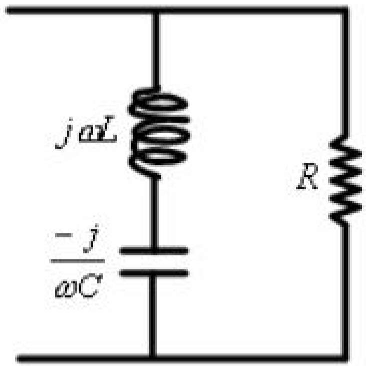
$$f_0 = \frac{1}{2\pi\sqrt{LC}}\sqrt{\left(1 - \frac{R^2 C}{L^2}\right)}$$

RESONANSI

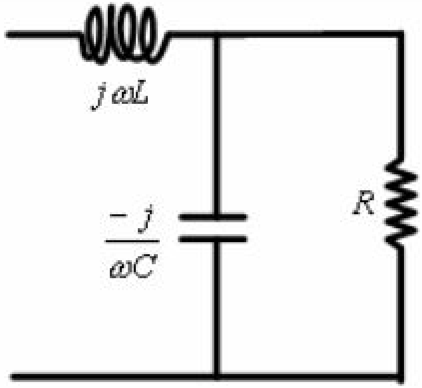
Resonansi Kombinasi 2



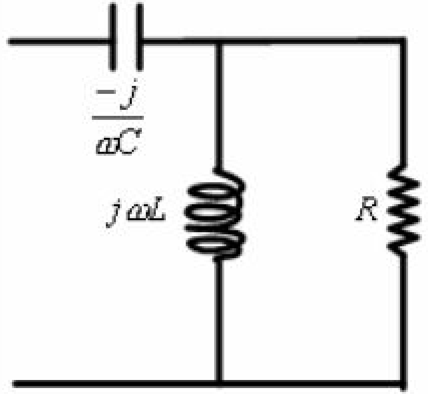
Resonansi Kombinasi 3



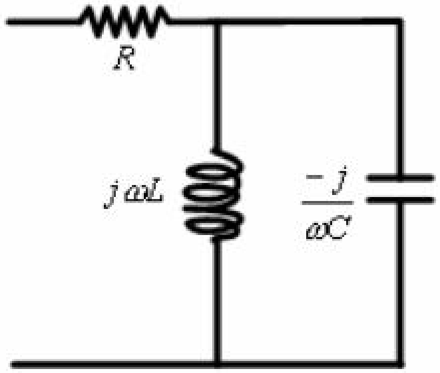
Resonansi Kombinasi 4



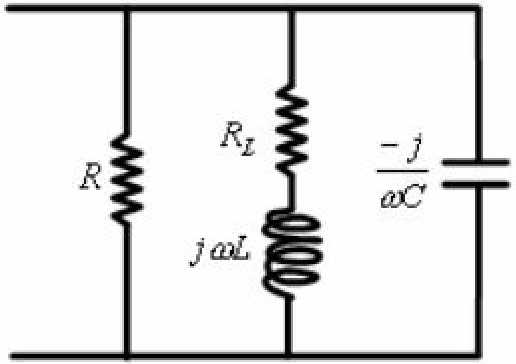
Resonansi Kombinasi 5



Resonansi Kombinasi 6



Resonansi Paralel 3 Cabang



RESONANSI

1. Suatu rangkaian seri RLC dengan $R = 50\Omega, L = 0{,}05H, C = 20\mu F$ terpasang pada $V = 100\angle 0^o$ dengan frekuensi variabel. Pada frekuensi berapa tegangan induktor mencapai maksimum ? Berapakah tegangan induktor tersebut ?

   Jawaban :

   Tegangan induktor maksimum jika arus maksimum, arus maksimum jika Z minimum, Z minimum terjadi saat resonansi.

   $$f_o = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0{,}05.20.10^{-6}}} = 159{,}1Hz$$

   $$Z_{resonansi} = R \rightarrow i_{maks} = \frac{V}{Z_{res}} = \frac{100\angle 0^o}{50} = 2\angle 0^o$$

   $$V_L = i_{maks}.X_L = i_{maks}.j\omega L = 2\angle 0^o.2\pi fL\angle 90^o = 2\angle 0^o.2\pi.159{,}1.0{,}05\angle 90^o = 100\angle 90^o$$

RESONANSI

Pada saat terjadi resonansi tegangan terpasang pada rangkaian seri RLC adalah $v = 70{,}7\sin(500t + 30^o)V$ menghasilkan arus sebesar $i = 2{,}83\sin(500t + 30^o)A$, jika $L = 0{,}5H$. Tentukan nilai R dan C !

Jawaban :

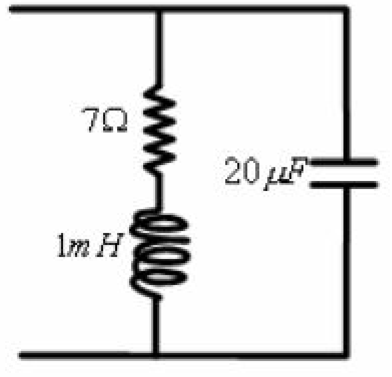
$$Z = \frac{V}{I} = \frac{70{,}7\angle 30^o}{2{,}83\angle 30^o} = 25 \rightarrow R = 25\Omega$$

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

$$C = \frac{1}{\omega^2 L} = \frac{1}{500^2.0{,}5} = 8\mu F$$

RESONANSI

3. Tentukan frekuensi resonansi pada gambat berikut :



Jawaban :

$$\frac{1}{\mathbf{Z}_{tot}} = j\omega C + \frac{1}{R + j\omega L}\left(\frac{R - j\omega L}{R - j\omega L}\right)$$

$$\frac{1}{\mathbf{Z}_{tot}} = j\omega C + \frac{R - j\omega L}{R^2 + \omega^2 L^2}$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{R}{R^2 + \omega^2 L^2} + j\left(\omega C - \frac{\omega L}{R^2 + \omega^2 L^2}\right)$$

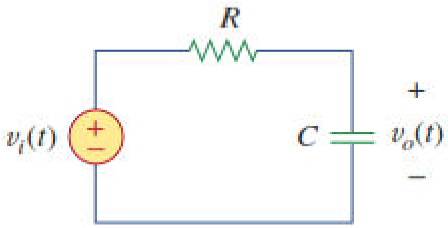
saat resonansi : $\omega_C = \dfrac{\omega_L}{R^2 + \omega^2 L^2}$, sehingga :

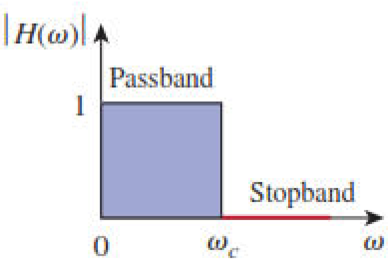
$$R^2 + \omega^2 L^2 = \frac{L}{C} \rightarrow \omega^2 L^2 = \frac{L}{C} - R^2 \rightarrow \omega^2 = \frac{1}{L^2}\left(\frac{L}{C} - R^2\right) = \frac{1}{LC} - \frac{R^2}{L^2} = \frac{1}{LC}\left(1 - \frac{R^2 C}{L^2}\right)$$

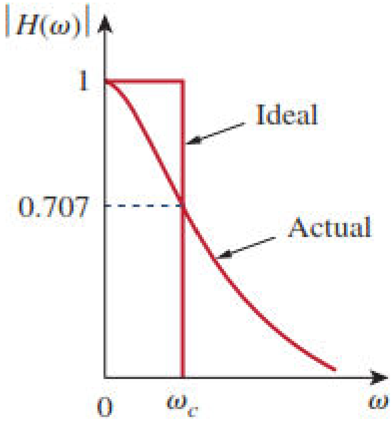
$$f_0 = \frac{1}{2\pi\sqrt{LC}}\sqrt{\left(1 - \frac{R^2 C}{L^2}\right)} = \frac{1}{2\pi\sqrt{10^{-3}.20.10^{-6}}}\sqrt{\left(1 - \frac{7^2.20.10^{-6}}{10^{-3}}\right)} = 159{,}2Hz$$

RESONANSI

Type of Filter	$H(0)$	$H(\infty)$	$H(\omega_c)$ or $H(\omega_0)$
Lowpass	1	0	$1/\sqrt{2}$
Highpass	0	1	$1/\sqrt{2}$
Bandpass	0	0	1
Bandstop	1	1	0







RESONANSI

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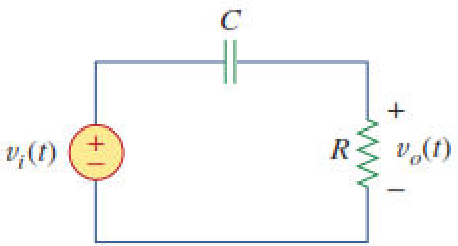

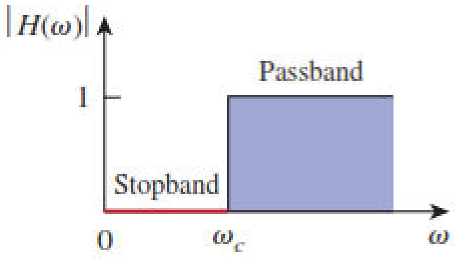

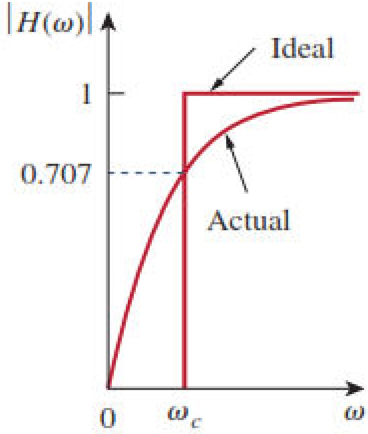

RESONANSI

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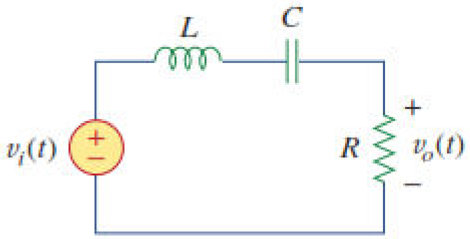

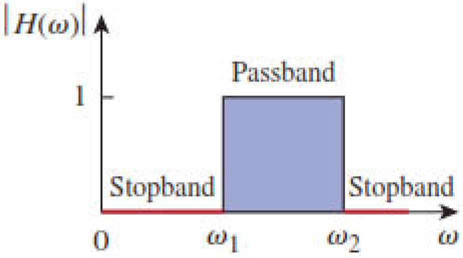

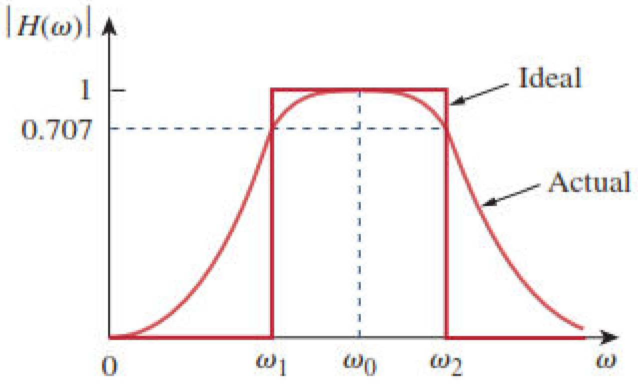

RESONANSI

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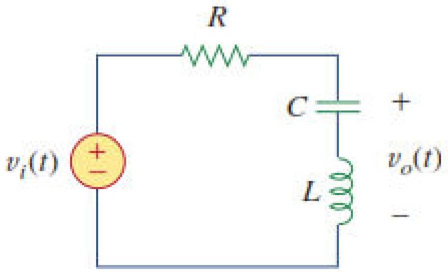

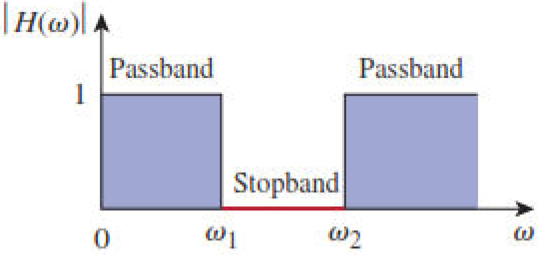

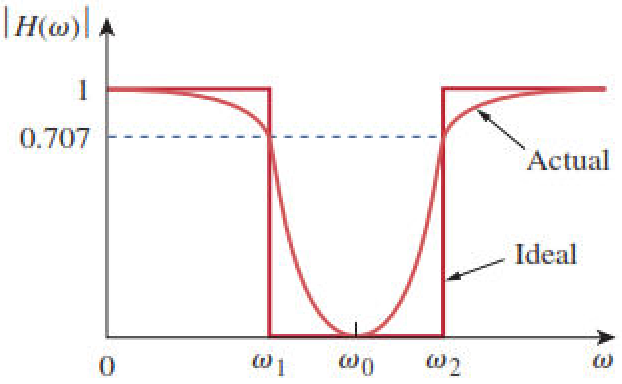

THANKS!

Any questions?