Pertemuan ke 12

RESPON FREKUENSI DAN RESONANSI

Respon frekuensi merupakan hubungan atau relasi frekuensi tak bebas pada kedua besaran magnitude dan phasa diantara input sinusoidal steady state dan output sinusoidal steady state.

Direpresentasikan sebagai perbandingan output respon $Y(j\omega)$terhapap input sinusoidal $X(j\omega)$ atau yang lebih dikenal dengan fungsi transfer dalam domain $j\omega$:

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

Dimana:

$$|H(j\omega)| = \frac{|Y(j\omega)|}{|X(j\omega)|}$$

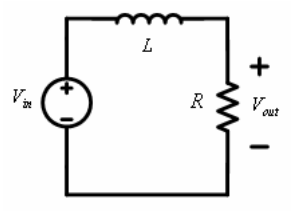
$$\angle H(j\omega) = \frac{\angle Y(j\omega)}{\angle X(j\omega)} = \angle Y(j\omega) - \angle X(j\omega)$$

Misalkan:

Input $V_{in}(t) = Acos(\omega_0 t + \theta) maka\ output\ V_{out}(t) = A|H(j\omega)|\cos\big(\omega_0 t + \theta + \angle H(j\omega)\big)$

1. Rangkaian RL

Jika komponen R sebagai output tegangan:



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, maka fungsi transfernya menjadi:

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

Sehingga respon frekuensi:

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

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

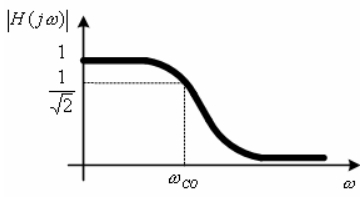
Gambar respon frekuensi magnitude:

Saat:

$$\omega = 0 \Rightarrow |H(j\omega)| = 1$$

$$\omega = \infty \Rightarrow |H(j\omega)| = 0$$

$$\omega = \frac{R}{L} \Rightarrow |H(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow frekuensi\ cut\ off$$



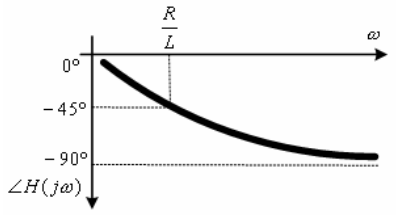
Gambar respon frekuensi phasa:

Saat:

$$\omega = 0 \Rightarrow \angle H(j\omega) = 0^0$$

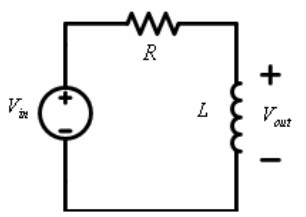
$$\omega = \infty \Rightarrow \angle H(j\omega) = -90^0$$

$$\omega = \frac{R}{L} \Rightarrow \angle H(j\omega) = -45^0 \Rightarrow frekuensi\ cut\ off$$



Rangkaian RL diatas sebagai low pass filter (LPF)

Jika komponen L sebagai output:



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, maka fungsi transfernya menjadi:

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

Sehingga respon frekuensi:

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

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

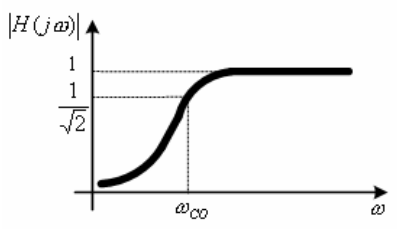
Gambar respon frekuensi magnitude:

Saat:

$$\omega = 0 \Rightarrow |H(j\omega)| = 0$$

$$\omega = \infty \Rightarrow |H(j\omega)| = 1$$

$$\omega = \frac{R}{L} \Rightarrow |H(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow frekuensi\ cut\ off$$



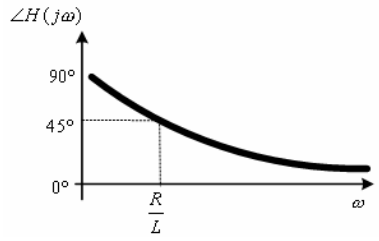
Gambar respon frekuensi phasa:

Saat:

$$\omega = 0 \Rightarrow \angle H(j\omega) = 90^0$$

$$\omega = \infty \Rightarrow \angle H(j\omega) = 0^0$$

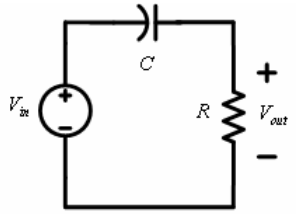
$$\omega = \frac{R}{L} \Rightarrow \angle H(j\omega) = 45^0 \Rightarrow frekuensi\ cut\ off$$



Rangkaian RL diatas sebagai high pass filter (HPF)

2. Rangkaian RC

Jika komponen R sebagai output tegangan:



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

Jika s = jω, maka fungsi transfernya menjadi:

$$H(j\omega) = \frac{1}{1 + {}^{1}/_{j\omega CR}} = \frac{1}{1 - {}^{j}/_{\omega sC}}$$

Sehingga respon frekuensi:

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

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

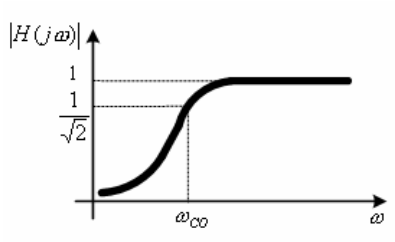
Gambar respon frekuensi magnitude:

Saat:

$$\omega = 0 \Rightarrow |H(j\omega)| = 0$$

$$\omega = \infty \Rightarrow |H(j\omega)| = 1$$

$$\omega = \frac{1}{CR} \Rightarrow |H(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow frekuensi\ cut\ off$$



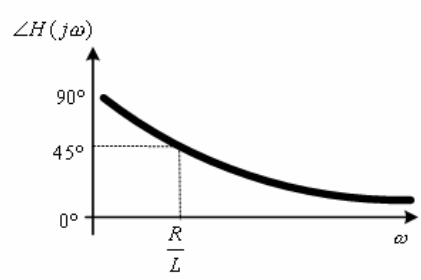
Gambar respon frekuensi phasa:

Saat:

$$\omega = 0 \Rightarrow \angle H(j\omega) = 90^0$$

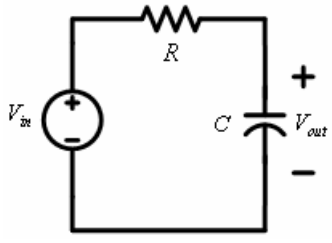
$$\omega = \infty \Rightarrow \angle H(j\omega) = 0^0$$

$$\omega = \frac{1}{CR} \Rightarrow \angle H(j\omega) = 45^0 \Rightarrow frekuensi\ cut\ off$$



Rangkaian RC diatas sebagai high pass filter (HPF).

Jika komponen C sebagai output:



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, maka fungsi transfernya menjadi:

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

Sehingga respon frekuensi:

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

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

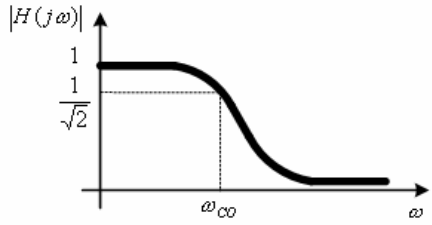
Gambar respon frekuensi magnitude:

Saat:

$$\omega = 0 \Rightarrow |H(j\omega)| = 1$$

$$\omega = \infty \Rightarrow |H(j\omega)| = 0$$

$$\omega = \frac{1}{CR} \Rightarrow |H(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow frekuensi\ cut\ off$$



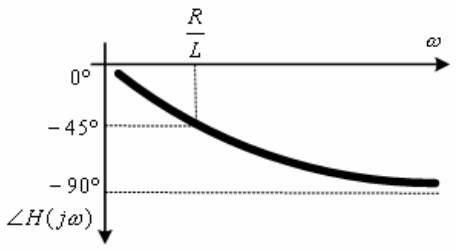
Gambar respon frekuensi phasa:

Saat:

$$\omega = 0 \Rightarrow \angle H(j\omega) = 0^0$$

$$\omega = \infty \Rightarrow \angle H(j\omega) = 90^0$$

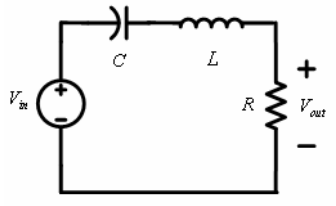
$$\omega = \frac{1}{CR} \Rightarrow \angle H(j\omega) = -45^0 \Rightarrow frekuensi\ cut\ off$$



Rangkaian RC diatas sebagai low pass filter (LPF)

3. Rangkaian RLC

Jika komponen R sebagai output tegangan:



Fungsi transfer dalam domain s:

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

Jika s = jω, maka fungsi transfernya menjadi:

$$H(j\omega) = \frac{1}{1 + \frac{j\left(\omega L - {}^{1}/_{\omega C}\right)}{R}}$$

Sehingga respon frekuensi:

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

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

Gambar respon frekuensi magnitude:

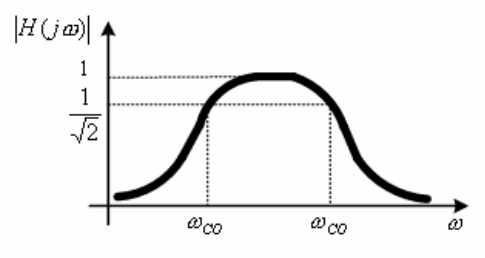
Saat:

$$\omega = 0 \Rightarrow |H(j\omega)| = 0$$

$$\omega = \infty \Rightarrow |H(j\omega)| = 0$$

$$\omega = \frac{1}{\sqrt{LC}} \Rightarrow |H(j\omega)| = 1$$

$$\omega = \frac{R \pm \sqrt{R^2 + {}^{4L}/_{C}}}{2L} \Rightarrow |H(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow frekuensi\ cut\ off$$



Gambar respon frekuensi phasa:

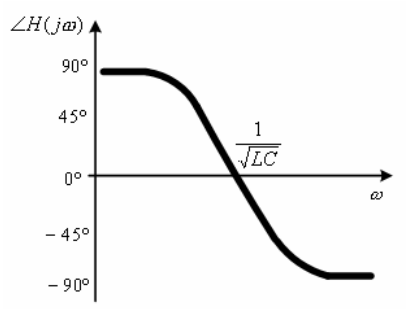
Saat:

$$\omega = 0 \Rightarrow \angle H(j\omega) = 90^0$$

$$\omega = \infty \Rightarrow \angle H(j\omega) = -90^0$$

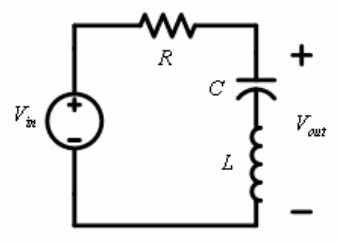
$$\omega = \frac{1}{\sqrt{LC}} \Rightarrow \angle H(j\omega) = 0^0$$

$$\omega = \frac{R \pm \sqrt{R^2 + {}^{4L}/_{C}}}{2L} \Rightarrow \angle H(j\omega) = \pm 45^0 \Rightarrow frekuensi\ cut\ off$$



Rangkaian RLC diatas sebgai band pass filter (BPF)

Jika komponen LC sebagai output tegangan:



Fungsi transfer dalam domain s:

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{sL + {}^{1}/_{sC}}{R + sL + {}^{1}/_{sC}} = \frac{1}{1 + {}^{R}/_{\left(sL + {}^{1}/_{sC}\right)}}$$

Jika s = jω, maka fungsi transfernya menjadi:

$$H(j\omega) = \frac{1}{1 + \frac{R}{j\left(\omega L - {}^{1}/_{\omega C}\right)}} = \frac{1}{\frac{jR}{\left(\omega L - {}^{1}/_{\omega C}\right)}}$$

Sehingga respon frekuensi:

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

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

Gambar respon frekuensi magnitude:

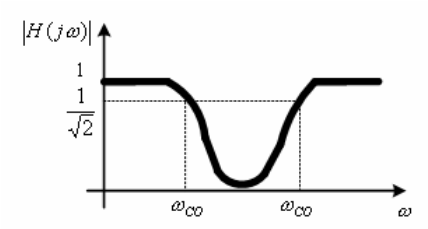
Saat:

$$\omega = 0 \Rightarrow |H(j\omega)| = 1$$

$$\omega = \infty \Rightarrow |H(j\omega)| = 1$$

$$\omega = \frac{1}{\sqrt{LC}} \Rightarrow |H(j\omega)| = 0$$

$$\omega = \frac{R \pm \sqrt{R^2 + {}^{4L}/_{C}}}{2L} \Rightarrow |H(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow frekuensi\ cut\ off$$



Gambar respon frekuensi phasa:

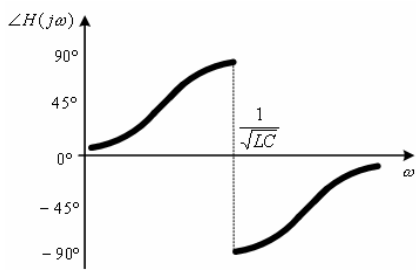
Saat:

$$\omega = 0 \Rightarrow \angle H(j\omega) = 0^0$$

$$\omega = \infty \Rightarrow \angle H(j\omega) = 0^0$$

$$\omega = \frac{1}{\sqrt{LC}} \Rightarrow \angle H(j\omega) = 90^0$$

$$\omega = \frac{R \pm \sqrt{R^2 + {}^{4L}/_{C}}}{2L} \Rightarrow \angle H(j\omega) = \pm 45^0 \Rightarrow frekuensi\ cut\ off$$



Rangkaian RLC diatas sebagai band stop filter (BSF)

Soal-soal:

1. Rangkaian seri RLC dengan L = 0,5 H mempunyai tegangan sesaat $v = 70{,}7\sin(500t + 30^0)\,V$ dan arus sesaat $i = 1{,}5\sin(500t)\,A$. Tentukan nilai R dan C. berapa frekuensi resonansinya?
2. Suatu rangkaian seri L = 25mH dan C = 75 µF mempunyai sudut phasa lagging 25^0 pada $\omega_0 = \frac{200rad}{s}$. Berapa frekuensi sudut pada saat sudut phasa leading 25^0 ?
3. Rangkaian seri RLC dengan R = 25 Ω dan L = 0,6 H akan menghasilkan arus leading sebesar 60^0 pada frekuensi 40Hz. Tentukan frekuensi rangkaian serinya!

Lembar Jawaban: