BAB XIII
OSILATOR

Tujuan instruksional :
- *Memahami konsep umpan balik positif dan prinsip kerja osilator gelombang sinusoidal*
- *Mengenal jenis-jenis osilator gelombang sinusoidal yang populer*
- *Dapat menentukan nilai komponen penentu osilasi dan frekuensi osilasi*

Osilator adalah rangkaian yang menghasilkan bentuk gelombang periodik yang spesifik, misalnya gelombang kotak, segitiga, gigi gergaji, atau sinusoidal.

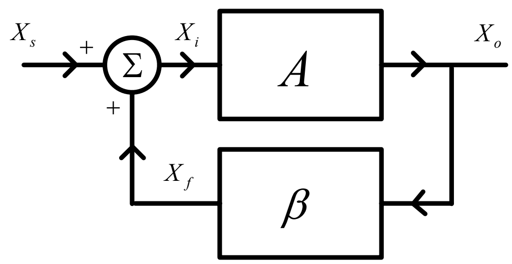
Osilator sebenarnya merupakan rangkaian yang mengubah sinyal DC menjadi sinyal ac.

Ada 2 kelompok osilator berdasarkan metode operasinya :

1. Osilator balikan → daya keluaran dikembalikan ke masukan (rangkaian LC), contoh penerima radio dan TV.
2. Osilator relaksasi → merespon piranti elektronik dimana akan bekerja pada selang waktu tertentu kemudian mati untuk periode waktu tertentu lainnya (pemuatan dan pengosongan RC, RL), contoh generator seeeping horizontal dan vertikal pada penerima TV.

13.1 Rangkaian Dasar Osilator

Rangkaian penguat dengan umpan balik positif dan sebuah rangkaian penentu frekuensi.



Gambar 13.1 Rangkaian dasar osilator

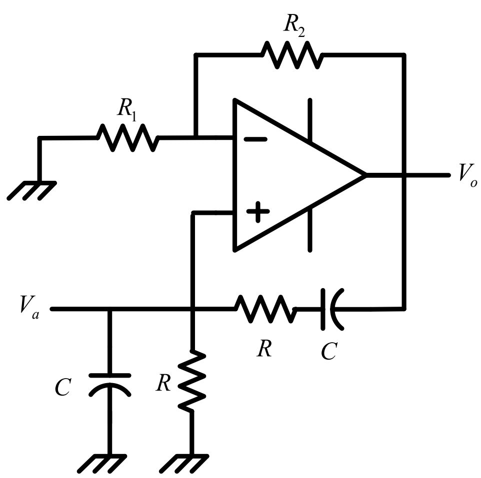
$$X_i = X_s + X_f$$
$$X_o = AX_i$$
$$X_f = \beta X_o$$
$$X_i = X_s + X_f \Rightarrow \frac{X_o}{A} = X_s + \beta X_o \Rightarrow X_o\left(\frac{1}{A} - \beta\right) = X_s$$
$$\frac{X_o}{X_s} = \frac{A}{1 - A\beta}$$

Syarat terjadinya osilasi (kriteria Barkusen) :

1. Penguatan loop tertutup → $|A\beta| \geq 1$
2. Pergeseran phasa → $\angle A\beta = 0$ atau $2\pi n$, dengan n = bilangan bulat.

13.2 Rangkaian Osilator Op-Amp RC

13.2.1 Osilator Jembatan Wien



Gambar 13.2 Jembatan Wien

$$A = \frac{V_o}{V_a} = 1 + \frac{R_2}{R_1}$$

$$\beta = \frac{V_a}{V_o} = \frac{Z_p}{Z_p + Z_s}$$

$$Z_p = \frac{R \, {}^{1}\!/_{sC}}{R + {}^{1}\!/_{sC}} = \frac{R}{1 + sCR}$$

$$Z_s = R + \frac{1}{sC} = \frac{1 + sCR}{sC}$$

$$A\beta(s) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{Z_p}{Z_p + Z_s}\right) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{\frac{R}{1 + sCR}}{\frac{R}{1 + sCR} + \frac{1 + sCR}{sC}}\right)$$

$$A\beta(s) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{sCR}{(sCR)^2 + 3sCR + 1}\right) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{3 + sCR + {}^{1}\!/_{sCR}}\right)$$

Jika $s = j\omega$, maka :

$$A\beta(j\omega) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{3 + j\omega CR + {}^{1}\!/_{j\omega CR}}\right) == \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{3 + j\left(\omega CR - {}^{1}\!/_{\omega CR}\right)}\right)$$

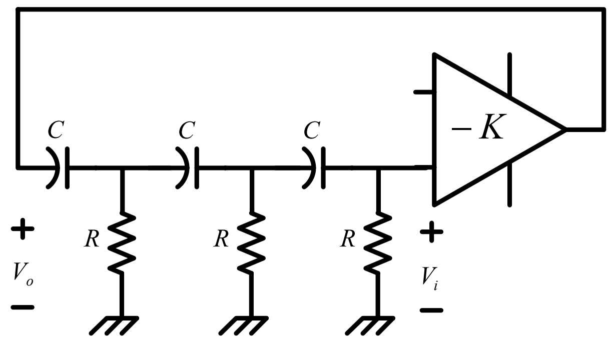
Syarat osilasi berdasarkan kriteria Barkusen :

1. $\angle A\beta = 0 \Rightarrow \omega CR - {}^{1}\!/_{\omega CR} = 0 \Rightarrow \omega_o = {}^{1}\!/_{CR}$

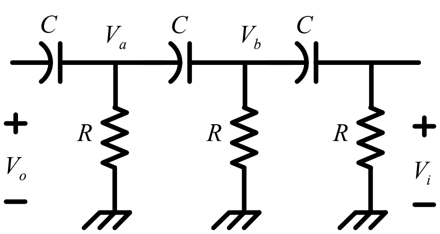
2. $|A\beta| \geq 1 \Rightarrow \left|\frac{1 + {}^{R_2}\!/_{R_1}}{3}\right| \geq 1 \Rightarrow \left|\frac{R_2}{R_1}\right| \geq 2$

13.2.2 Osilator Penggeser Phasa

Rangkaian akan berosilasi pada frekuensi dimana pergeseran phasa jaringan RC $\phi = 180^o$ sedangkan totalphasa satu loop 0^o atau 360^o (dikalikan penguat Op-Amp –k).



Gambar 13.3 Penggeser phasa



$$\frac{V_i}{V_b} = \frac{R}{R + 1/sC} = \frac{1}{1 + 1/sCR} = \frac{1}{1+\alpha} \Rightarrow \alpha = 1/sCR$$

$$\frac{V_b}{V_a} = \frac{Z_b}{Z_b + 1/sC} \Rightarrow Z_b = \left(R + 1/sC\right) // R = \frac{R\left(1 + 1/sCR\right)}{2 + 1/sCR} = \frac{R(1+\alpha)}{2+\alpha}$$

$$\frac{V_b}{V_a} = \frac{\frac{R(1+\alpha)}{2+\alpha}}{\frac{R(1+\alpha)}{2+\alpha} + 1/sC} = \frac{\frac{R(1+\alpha)}{2+\alpha}}{R\left[\frac{(1+\alpha)}{2+\alpha} + 1/sCR\right]} = \frac{\frac{R(1+\alpha)}{2+\alpha}}{R\left[\frac{(1+\alpha)}{2+\alpha} + \alpha\right]} = \frac{(1+\alpha)}{\alpha^2 + 3\alpha + 1}$$

$$\frac{V_a}{V_o} = \frac{Z_a}{Z_a + 1/sC} \Rightarrow Z_a = R\left[\frac{(1+\alpha)}{2+\alpha} + \alpha\right] // R = \frac{R\left(\alpha^2 + 3\alpha + 1\right)}{\alpha^2 + 4\alpha + 3}$$

$$\frac{V_a}{V_o} = \frac{\frac{R\left(\alpha^2 + 3\alpha + 1\right)}{\alpha^2 + 4\alpha + 3}}{\frac{R\left(\alpha^2 + 3\alpha + 1\right)}{\alpha^2 + 4\alpha + 3} + 1/sC} = \frac{\frac{R\left(\alpha^2 + 3\alpha + 1\right)}{\alpha^2 + 4\alpha + 3}}{R\left[\frac{\left(\alpha^2 + 3\alpha + 1\right)}{\alpha^2 + 4\alpha + 3} + 1/sCR\right]} = \frac{\left(\alpha^2 + 3\alpha + 1\right)}{\alpha^3 + 5\alpha^2 + 6\alpha + 1}$$

$$A = \frac{V_o}{V_i} = -k$$

$$\beta = \frac{V_i}{V_o} = \frac{V_i}{V_b}\frac{V_b}{V_a}\frac{V_a}{V_o} = \frac{1}{(1+\alpha)}\frac{(1+\alpha)}{\left(\alpha^2 + 3\alpha + 1\right)}\frac{\left(\alpha^2 + 3\alpha + 1\right)}{\left(\alpha^3 + 5\alpha^2 + 6\alpha + 1\right)} = \frac{1}{\alpha^3 + 5\alpha^2 + 6\alpha + 1}$$

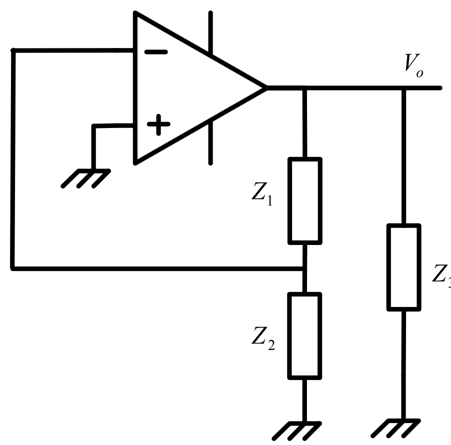
$$s = j\omega \Rightarrow \alpha = \frac{1}{j\omega CR} = \frac{-j}{\omega CR}$$

$$A\beta = -k\,\frac{1}{\alpha^3 + 5\alpha^2 + 6\alpha + 1}$$

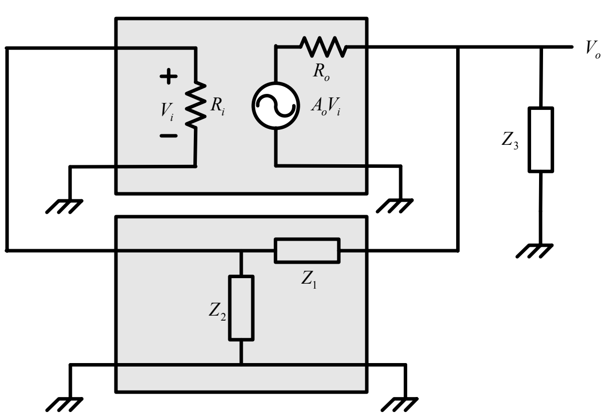
$$\alpha^3 + 6\alpha = 0 \Rightarrow j\left(1/\omega CR\right)^3 - \left(6\,j/\omega CR\right) = 0 \Rightarrow \omega_o = \frac{1}{CR\sqrt{6}}$$

$$\beta = \frac{1}{\alpha^3 + 5\alpha^2 + 6\alpha + 1} = \frac{1}{5\alpha^2 + 1} = \frac{1}{5\left(\frac{-j}{\omega_o CR}\right)^2 + 1} = \frac{1}{5\left(\frac{-j}{\frac{1}{CR\sqrt{6}}CR}\right)^2 + 1} = -\frac{1}{29}$$

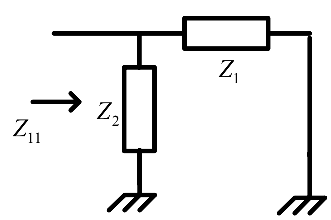
13.3 Bentuk Umum Osilator LC



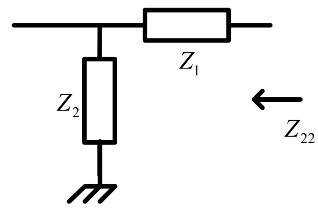
Gambar 13.4 Osilator LC



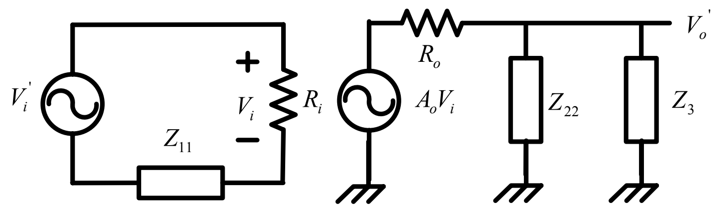
Topologi umpan balik seri tegangan :



$$Z_{11} = Z_1 // Z_2 = \frac{Z_1 Z_2}{Z_1 + Z_2}$$



$$Z_{22} = Z_1 + Z_2$$



$$V_o^{'} = \frac{Z_{22} // Z_3}{Z_{22} // Z_3 + R_o} A_o V_i = \frac{Z_{22} // Z_3}{Z_{22} // Z_3 + R_o} A_o \frac{R_i}{R_i + Z_{11}} V_i^{'}$$

$$A = \frac{V_o^{'}}{V_i^{'}} = \frac{Z_{22} // Z_3}{Z_{22} // Z_3 + R_o} A_o \frac{R_i}{R_i + Z_{11}} = \frac{\frac{(Z_1 + Z_2)Z_3}{Z_1 + Z_2 + Z_3}}{\frac{(Z_1 + Z_2)Z_3}{Z_1 + Z_2 + Z_3} + R_o} A_o \frac{R_i}{R_i + \frac{Z_1 Z_2}{Z_1 + Z_2}}$$

$$A = A_o R_i \frac{(Z_1 + Z_2)Z_3}{(Z_1 + Z_2)Z_3 + R_o(Z_1 + Z_2 + Z_3)} \frac{(Z_1 + Z_2)}{Z_1 Z_2 + R_i(Z_1 + Z_2)}$$

$$\beta = \frac{V_f}{V_o^{'}} = \frac{Z_2}{Z_2 + Z_1}$$

$$-A\beta = -\frac{A_o R_i Z_2 Z_3}{(Z_1 + Z_2)Z_3 + R_o(Z_1 + Z_2 + Z_3)} \frac{(Z_1 + Z_2)}{Z_1 Z_2 + R_i(Z_1 + Z_2)}$$

Jika $R_i = \infty$, maka :

$$-A\beta = -\frac{A_o Z_2 Z_3}{(Z_1 + Z_2)Z_3 + R_o(Z_1 + Z_2 + Z_3)}$$

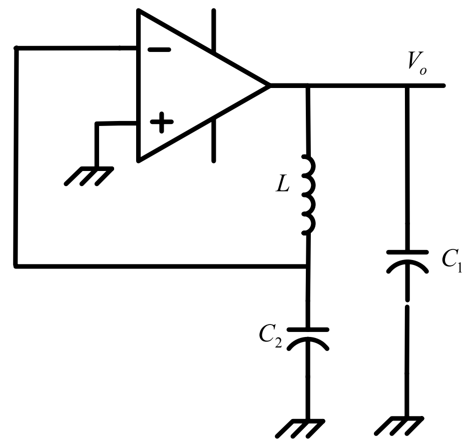
Dengan Z_1, Z_2, Z_3 reaktif, maka : $Z_1 = jX_1, Z_2 = jX_2, Z_3 = jX_3$

$$-A\beta = -\frac{A_o jX_2 jX_3}{(jX_1 + jX_2)jX_3 + R_o(jX_1 + jX_2 + jX_3)}$$

$$-A\beta = \frac{A_o X_2 X_3}{-(X_1 + X_2)X_3 + jR_o(X_1 + X_2 + X_3)}$$

dimana $jR_o\left(X_1 + X_2 + X_3\right) = 0$ dan $\left|A\beta\right| = \left|\dfrac{A_o X_2}{\left(X_1 + X_2\right)}\right|$

13.3.1 Osilator Collpits

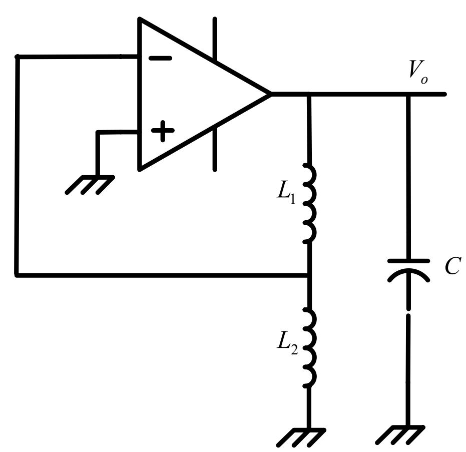


Gambar 13.5 Osilator Collpits

$$Z_1 + Z_2 + Z_3 = 0 \Rightarrow j\omega_o L + \frac{1}{j\omega_o C_1} + \frac{1}{j\omega_o C_2} = 0 \Rightarrow j\left(\omega_o L - \frac{1}{\omega_o C_1} - \frac{1}{\omega_o C_2}\right) = 0$$

$$\omega_o L = \frac{1}{\omega_o C_1} + \frac{1}{\omega_o C_2} \Rightarrow \omega_o{}^2 L = \frac{C_1 + C_2}{C_1 C_2} \Rightarrow \omega_o = \frac{1}{\sqrt{L\dfrac{C_1 C_2}{C_1 + C_2}}}$$

13.3.2 Osilator Hartley

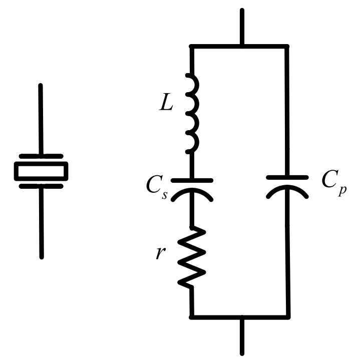


Gambar 13.6 Osilator Hartley

$$Z_1 + Z_2 + Z_3 = 0 \Rightarrow j\omega_o L_1 + j\omega_o L_2 + \frac{1}{j\omega_o C} = 0 \Rightarrow j\left(\omega_o L_1 + \omega_o L_2 - \frac{1}{\omega_o C}\right) = 0$$

$$\omega_o (L_1 + L_2) = \frac{1}{\omega_o C} \Rightarrow \omega_o = \frac{1}{\sqrt{(L_1 + L_2)C}}$$

13.4 Osilator Kristal



Gambar 13.7 Osilator kristal

Dengan mengabaikan r, maka :

$$Z_{tot} = \frac{1}{1/Z_{tot}} = \frac{1}{1/(sL + 1/sC_s) + sC_p} = \frac{1}{\dfrac{sC_s}{s^2 LC_s + 1} + sC_p} = \frac{s^2 LC_s + 1}{sC_s + s^3 LC_s C_p + sC_p}$$

$$Z_{tot} = \frac{s^2 LC_s + 1}{s^3 LC_s C_p + s(C_s + C_p)} = \frac{LC_s\left(s^2 + 1/LC_s\right)}{sLC_s C_p\left(s^2 + (C_s + C_p)/LC_s C_p\right)}$$

$$Z_{tot} = \frac{1}{sC_p} \frac{s^2 + 1/LC_s}{s^2 + (C_s + C_p)/LC_s C_p}$$

Resonansi seri :

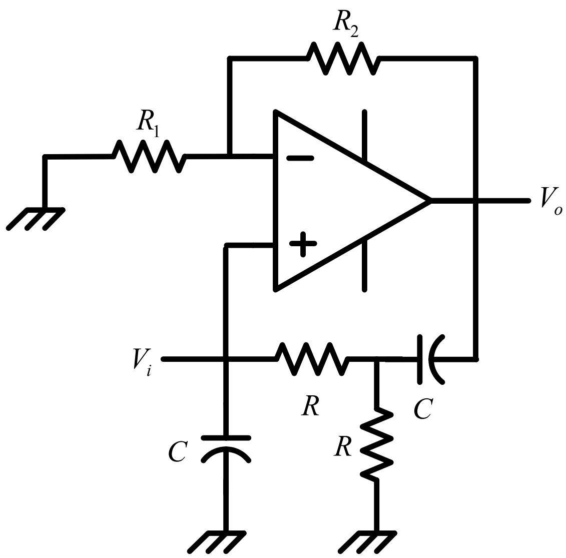
$$\omega_s = \frac{1}{\sqrt{LC_s}}$$

Resonansi paralel :

$$\omega_p = \frac{1}{\sqrt{L\dfrac{C_s C_p}{C_s + C_p}}}$$

Latihan soal :

1. Tentukan kriteria dari osilator berikut :



Jawaban :

$$A = \frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}$$

$$\beta = \frac{V_i}{V_o} = \frac{\dfrac{R\left(R + \frac{1}{sC}\right)}{R + R + \frac{1}{sC}}}{\dfrac{R\left(R + \frac{1}{sC}\right)}{R + R + \frac{1}{sC}} + \dfrac{1}{sC}} \frac{1}{1 + sCR} = \frac{sCR}{(sCR)^2 + 3sCR + 1}$$

$$A\beta = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{sCR + 3 + \frac{1}{sCR}}\right)$$

$$A\beta(j\omega) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{3 + j\left(\omega CR - \frac{1}{\omega CR}\right)}\right)$$

$$\omega CR - \frac{1}{\omega CR} = 0$$

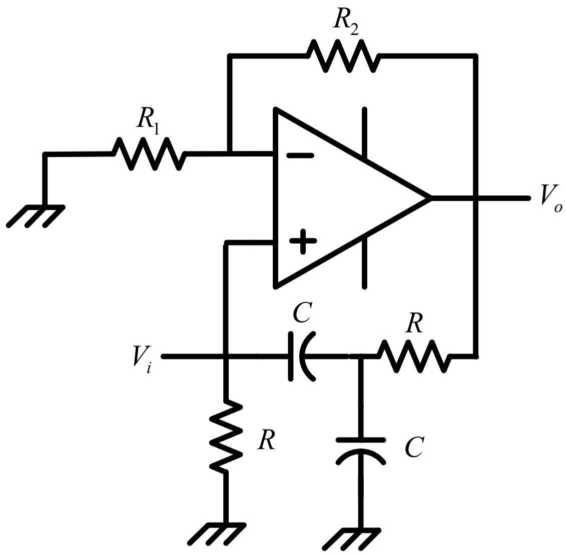
$$\omega_o = \frac{1}{CR}$$

$$|A\beta| \geq 1$$

$$\frac{1+\dfrac{R_2}{R_1}}{3} \geq 1$$

$$\frac{R_2}{R_1} \geq 2$$

2. Tentukan kriteria dari osilator berikut :



Jawaban :

$$A = \frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}$$

$$\beta = \frac{V_i}{V_o} = \frac{\dfrac{\frac{1}{sC}\left(R + \frac{1}{sC}\right)}{\frac{1}{sC} + R + \frac{1}{sC}}}{\dfrac{\frac{1}{sC}\left(R + \frac{1}{sC}\right)}{\frac{1}{sC} + R + \frac{1}{sC}} + R} \frac{sCR}{1 + sCR} = \frac{sCR}{(sCR)^2 + 3sCR + 1}$$

$$A\beta = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{sCR + 3 + \frac{1}{sCR}}\right)$$

$$A\beta(j\omega) = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{3 + j\left(\omega CR - \frac{1}{\omega CR}\right)}\right)$$

$$\omega CR - \frac{1}{\omega CR} = 0$$

$$\omega_o = \frac{1}{CR}$$

$$\left|A\beta\right| \geq 1$$

$$\frac{1 + \frac{R_2}{R_1}}{3} \geq 1$$

$$\frac{R_2}{R_1} \geq 2$$