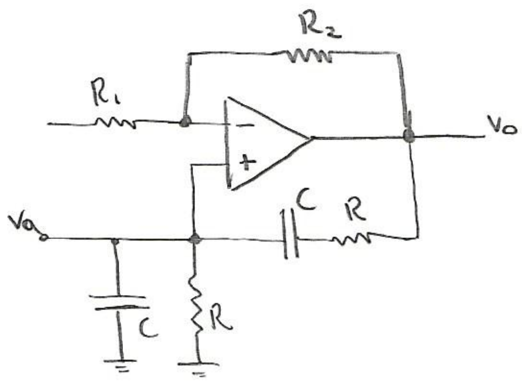
Sedra - 5th Edition - Ingles

13.9 Ponte de Wien



$$\frac{V_a(s)}{V_o(s)} = \frac{\frac{1}{sC /\!/ R}}{\frac{1}{sC /\!/ R} + \frac{1}{sC} + R} = \frac{\frac{\frac{R}{sC}}{\frac{1}{sC}+R}}{\frac{\frac{R}{sC}}{\frac{1}{sC}+R} + \frac{1}{sC} + R}$$

$$\frac{V_a(s)}{V_o(s)} = \frac{\frac{R}{sC}}{\frac{R}{sC} + \left(\frac{1}{sC}+R\right)^2} \times \frac{s^2C^2}{s^2C^2} = \frac{sCR}{sCR + (1+sCR)^2} = \frac{s\frac{1}{RC}}{s^2 + s\frac{3}{RC} + \frac{1}{R^2C^2}}$$

A função $\frac{V_a}{V_o}$ possui zeros para $s = 0$ e para $s = \infty$

Isso caracteriza Bandpass.

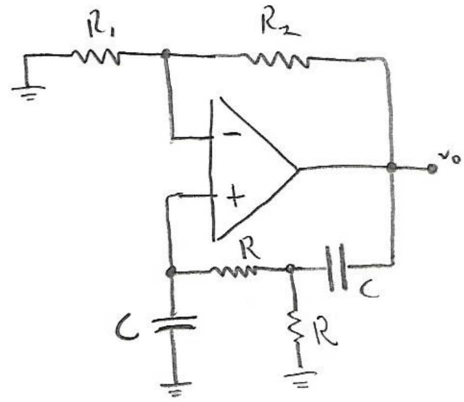
$$\omega_o^2 = \frac{1}{R^2C^2} \rightarrow \omega_o = \frac{1}{RC} \qquad \frac{\omega_o}{Q} = \frac{3}{RC} \rightarrow Q = \frac{1}{3}$$

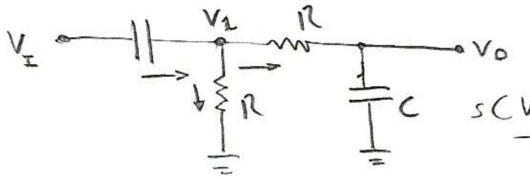
O ganho para a frequencia central é:

$$s = j\omega_o = \frac{j}{RC}$$

$$\therefore \left.\frac{V_a}{V_o}\right|_{s=\frac{j}{RC}} = \frac{\frac{1}{RC}\cdot\frac{j}{RC}}{-\cancel{\frac{1}{R^2C^2}} + \frac{3}{RC}\left(\frac{j}{RC}\right) + \cancel{\frac{1}{R^2C^2}}} = \frac{1}{3}$$

13.13 Encontrar $L(s)$, $L(j\omega)$, freq. para zero loop phase e $\frac{R_2}{R_1}$





$sCV_o = i$

$$\frac{V_1 - V_o}{R} = sCV_o \rightarrow V_1 = v_o(1 + sCR)$$

No ponto V_1, temos as correntes:

$$\frac{V_1}{R} + sC(V_1 - V_I) + sCV_o = 0$$

$$v_o(1 + sCR) + sCR(V_o + V_o sCR) - sCRV_I + sCRV_o = 0$$

$$V_o(1 + sCR + sCR + s^2C^2R^2 + sCR) = sCRV_I$$

Assim, $$\frac{V_o}{V_I} = \frac{sCR}{s^2C^2R^2 + 3sCR + 1} = \frac{1}{3 + sCR + \frac{1}{sCR}}, \quad s = j\omega$$

$$G(j\omega) = \frac{1}{3 + j\omega CR + \frac{1}{j\omega CR}} = \frac{1}{3 + j\left(\omega CR - \frac{1}{\omega CR}\right)}$$

Zero phase ocorre para $\omega CR = \frac{1}{\omega CR} \rightarrow \boxed{\omega = \frac{1}{CR}}$

$$\left|G\left(\omega = \frac{1}{RC}\right)\right| = \frac{1}{3 + j\underbrace{\left(\frac{CR}{CR} - \frac{CR}{CR}\right)}_{0}} = \frac{1}{3}$$

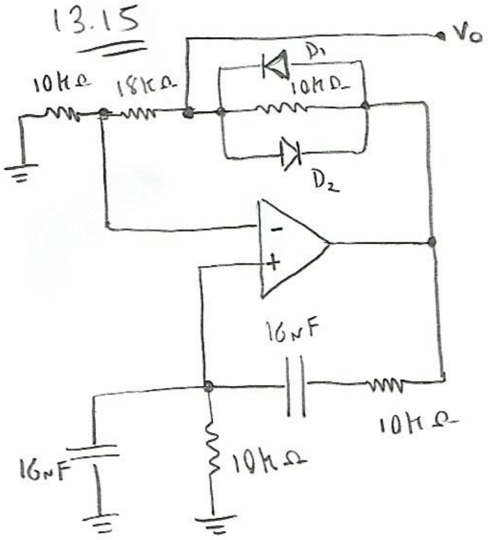
Para que oscile, $1 + \frac{R_2}{R_1} \geq 3 \rightarrow \frac{R_2}{R_1} \geq 2$

Considerando agora $\frac{R_2}{R_1}$ na função de transferência,

$$L(s) = 1 + \frac{R_2}{R_1} \cdot G(s)$$

Assim, $$L(s) = \frac{1 + \frac{R_2}{R_1}}{3 + sCR + \frac{1}{sCR}} \qquad L(j\omega) = \frac{1 + \frac{R_2}{R_1}}{3 + j\left(\omega CR - \frac{1}{\omega CR}\right)}$$

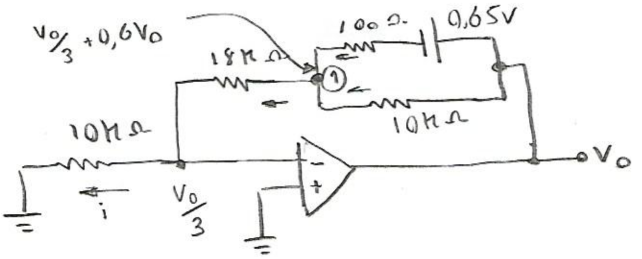
13.15



Cada diodo considerado como uma bateria de 0,65V em serie com uma resistencia de 100 Ω.

Encontrar tensão pico-a-pico da saída senoidal

Fazendo a analise para um dos ciclos, temos:



$i = \frac{V_o}{30k}$

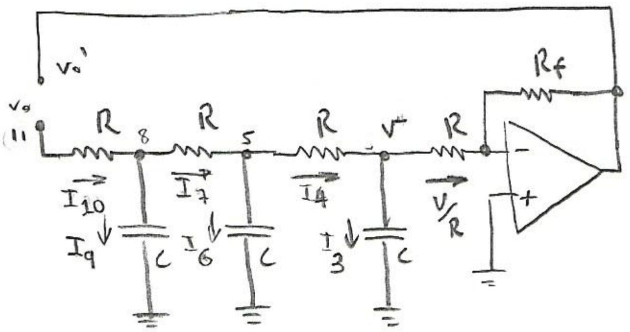
Soma das correntes no nó 1:

$$\frac{V_o}{30k} = \frac{V_o - \frac{V_o}{3} - 0{,}6V_o}{10k} + \frac{V_o - 0{,}65 - \frac{V_o}{3} - 0{,}6V_o}{100}$$

$$\frac{V_o}{30} = 0{,}00666\,V_o + 0{,}666\,V_o - 0{,}65 \rightarrow V_o = 10{,}156V \rightarrow \text{pico}$$

$$V_{pp} = 2 \times V_p = 2 \times 10{,}156 = 20{,}3\,V$$

13.18



$I_3 = sCV$

$I_4 = I_3 + \frac{V}{R} = sCV + \frac{V}{R}$

Tensão em 5:

$V_5 = V + sCV \cdot R + \frac{V}{R} \cdot R = 2V + sCRV$

$I_6 = sC V_5 = 2sCV + s^2C^2RV$

$I_7 = I_6 + I_4 = 3sCV + s^2C^2RV + \frac{V}{R}$

Tensão em 8:

$V_8 = V_5 + I_7 \cdot R = 2V + sCRV + 3sCRV + s^2C^2R^2V + V$

$V_8 = 3V + 4sCRV + s^2C^2R^2V$

$I_9 = V_8 \cdot sC = 3sCV + 4s^2C^2RV + s^3C^3R^2V$

$I_{10} = I_9 + I_7 = 6sCV + 5s^2C^2RV + s^3C^3R^2V + \frac{V}{R}$

Tensão no ponto 11:

$V_o = V_8 + I_{10} \cdot R = 4V + 10sCVR + 6s^2C^2R^2V + s^3C^3R^3V$

$$L(s) = -\frac{V_o'}{V_o} = \frac{V\frac{R_f}{R}}{V(s^3C^3R^3 + 6s^2C^2R^2 + 10sCR + 4)} = \frac{\frac{R_f}{R}}{s^3C^3R^3 + 6s^2C^2R^2 + 10sCR + 4}$$

Sabendo que $s = j\omega \rightarrow L(j\omega) = \dfrac{\frac{R_f}{R}}{(4 - 6\omega^2C^2R^2) + j(10\omega CR + \omega^3R^3C^3)}$ → $L(j\omega)$ deve ser puramente real

$10\omega CR = \omega^3R^3C^3 \rightarrow \omega_0 = \frac{1}{RC} = \frac{1}{\sqrt{10}}$ → Dado $R = 10k\Omega$ e $f_0 = 10kHz$,

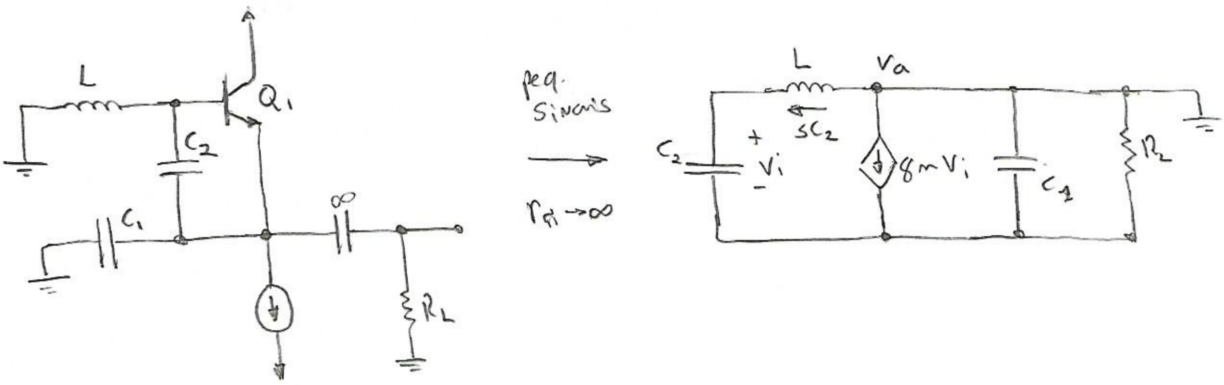
$C = \frac{\omega_0}{R \cdot 2\pi f_0} = 0{,}503\, nF$

$$|L(j\omega_0)| = \frac{R_f/R}{4 - 6\omega_0^2R^2C^2} = \frac{R_f/R}{4 - 6\frac{1}{10\cancel{R^2C^2}}\cancel{R^2C^2}} = \frac{R_f/R}{4 - 6/10} \geq 1$$

$\frac{R_f}{R} \geq 3{,}4 \rightarrow R_f \geq 34k\Omega$

13.21 Osciladores Colpitts

a)



$$V_a = \underbrace{\text{tensão sobre } C_2}_{\frac{1}{sC_2} \cdot sC_2 = 1} + \underbrace{\text{tensão sobre } L}_{sC_2 \cdot sL} \rightarrow V_a = 1 + s^2 C_2 L$$

$\hookrightarrow V_i$

Correntes no nó de $\underline{V_a}$: $\quad \Sigma I = 0$

$$g_m \cancel{V_i}^{1} + sC_2 + \frac{V_a}{\frac{1}{sC_1}} + \frac{V_a}{R} = g_m + sC_2 + sC_1(1 + s^2 C_2 L) + \frac{(1+s^2 C_2 L)}{R_L} = 0$$

$$g_m + \frac{1}{R_L} + s(C_1 + C_2) + \frac{s^2 C_2 L}{R_L} + s^3 C_1 C_2 L = 0$$

para $s = j\omega \rightarrow g_m + \frac{1}{R_L} - \frac{\omega^2 C_2 L}{R_L} + j\left((C_1+C_2)\omega - \omega^3 C_1 C_2 L\right) = 0$

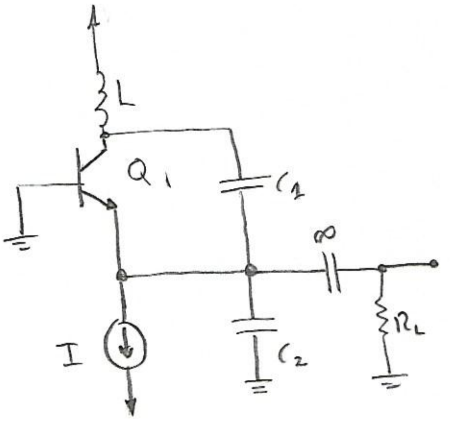
Parte imaginária = 0 $\rightarrow$ $C_1 + C_2 - \omega^2 C_1 C_2 L = 0 \rightarrow \omega = \sqrt{\frac{C_1 + C_2}{C_1 C_2 L}}$ $\rightarrow$ freq. de oscilação!

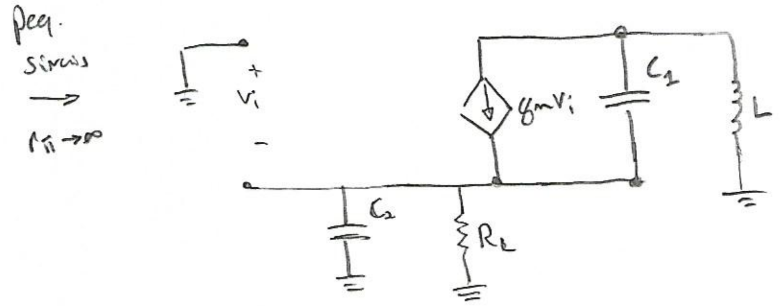
Parte real = 0 $\rightarrow$ $g_m + \frac{1}{R_L} - \frac{\omega^2 C_2 L}{R_L} \rightarrow g_m R_L = \omega^2 C_2 L - 1$

$$g_m R_L = \frac{C_1 + C_2}{C_1 \cancel{C_2 L}} \cancel{C_2 L} - 1 = \frac{C_1 + C_2}{C_1} - 1 = \frac{C_2}{C_1}$$ $\rightarrow$ limite de ganho

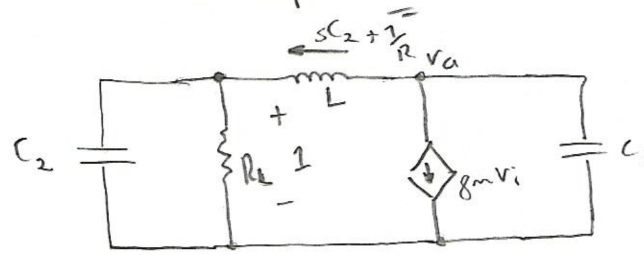
13.21

c)





Quebrando o loop em $\underline{V_i}$:



$$V_a = \left(sC_2 + \frac{1}{R_L}\right)sL + 1$$

Correntes no nó de $V_a = 0$ $\quad \Sigma I = 0$

$$g_m \cancel{V_i}^{1} + sC_2 + \frac{1}{R_L} + \frac{V_a}{\frac{1}{sC_1}} = g_m + \frac{1}{R_L} + sC_2 + sC_1\left[\left(sC_2 + \frac{1}{R_L}\right)sL + 1\right] = 0$$

$$g_m + \frac{1}{R_L} + sC_2 + s^3 C_1 C_2 L + \frac{s^2 C_1 L}{R_L} + sC_1 = 0$$

Eq. característica: $g_m + \frac{1}{R_L} + s(C_1 + C_2) + \frac{s^2 C_1 L}{R_L} + s^3 C_1 C_2 L = 0$

para $s = j\omega \rightarrow g_m + \frac{1}{R_L} - \frac{\omega^2 C_1 L}{R_L} + j\left[(C_1 + C_2)\omega - \omega^3 C_1 C_2 L\right] = 0$

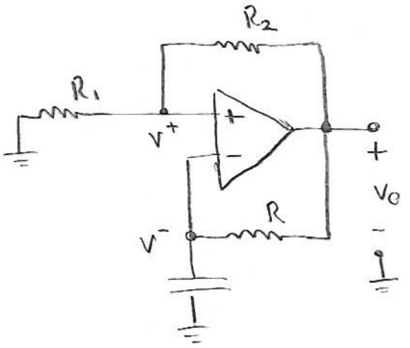
Parte imaginária $= 0$ $\quad C_1 + C_2 - \omega^2 C_1 C_2 L = 0 \rightarrow \omega = \sqrt{\frac{C_1 + C_2}{C_1 C_2 L}} \rightarrow$ freq. de oscilação

Parte real $= 0 \rightarrow g_m + \frac{1}{R_L} - \frac{\omega^2 C_1 L}{R_L} \rightarrow g_m R_L = \omega^2 C_1 L - 1$

$$g_m R_L = \frac{C_1 + C_2}{\cancel{C_1} C_2 \cancel{L}} \cdot \cancel{C_1}\cancel{L} - 1 = \frac{C_1 + \cancel{C_2}}{C_2} - \cancel{1} = \frac{C_1}{C_2} \rightarrow \text{Limite do ganho.}$$

13.30

Freq. de oscilação para o circuito abaixo:



$R_1 = 10k\Omega$

$R_2 = 16k\Omega$

$R = 62k\Omega$

$C = 10nF$

$$T = 2\tau \ln \frac{1+\beta}{1-\beta} \quad , \text{ onde } \beta = \frac{R_1}{R_1+R_2} = \frac{10}{26}$$

$$\tau = CR = 10\times10^{-9} \cdot 62\times10^{3} = 0{,}62 \text{ ms}$$

$$T = 2\times 0{,}62m \times \ln\left(\frac{1+10/26}{1-10/26}\right) = 1{,}0055 \text{ ms}$$

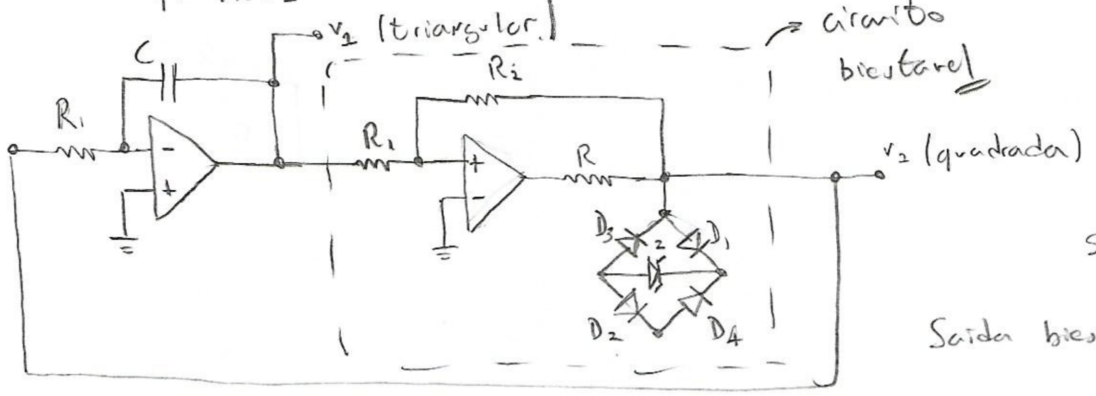
$$f = \frac{1}{T} = 994{,}48 \text{ Hz}$$

13.32

Ondas quadradas 10V pico-a-pico, ondas triangulares 10V pico-a-pico.

$f = 1kHz$ $\quad C = 0{,}01\mu F$ $\quad I_Z = 1mA$ (min)

$I_R = 0{,}2mA$ (max)



Saturação $\pm 13V$

Saída biestavel $\pm 5V$

$$V_Z = 5 - 2V_D = 5 - 2\cdot0{,}7 = 3{,}6V \quad , \quad R_1 = R_2 \rightarrow L_+ = -L_- = 5V$$

$$V_{TH} = -V_{TL} = 5V$$

$$I_R(max) = 0{,}2mA = \frac{5}{R_1+R_2} \rightarrow R_1 = R_2 = 25k\Omega$$

Maxima corrente do diodo: $1mA \rightarrow \dfrac{13-5}{R_2} = (0{,}2+1)\,mA \rightarrow R_2 = \dfrac{8}{1{,}2m} = 6{,}667k\Omega$

Inclinação $\rightarrow \dfrac{-L}{RC} = \dfrac{V_{TH}-V_{TL}}{T/2} \rightarrow \dfrac{5}{R\cdot 0{,}01\times10^{-6}} = \dfrac{10}{10^{-3}/2}$

$$R = 25k\Omega$$