Analog Electronics

HW #4.

(1) $\epsilon = \sqrt{10^{A_{max}/10} - 1} = \sqrt{10^{3/10} - 1} \simeq 1$

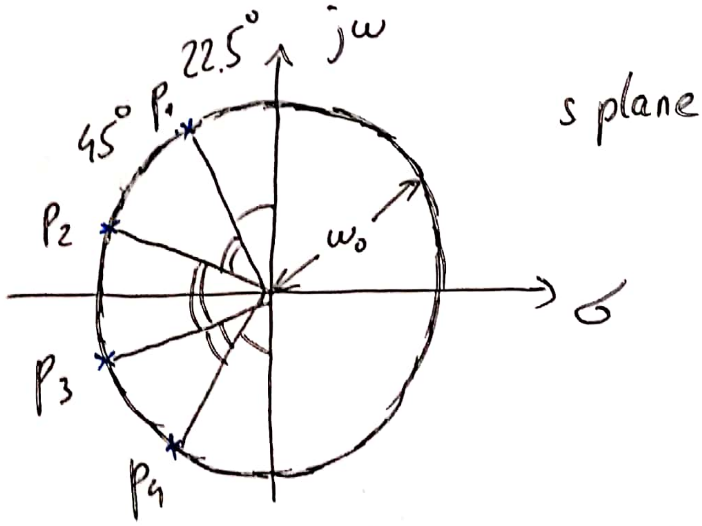
$$A(\omega = \omega_s)(dB) = 10 \log \left[1 + \epsilon^2 \left(\frac{\omega_s}{\omega_p} \right)^{2N} \right]$$

$$= 10 \log \left[1 + \left(\frac{16}{8} \right)^{2N} \right]$$

$$= 10 \log \left[1 + 4^N \right]$$

$A(\omega_s) \geq A_{min} = 24dB.$ $\begin{cases} N = 3 \rightarrow A(\omega_s) \simeq 18.13dB \\ N = 4 \rightarrow A(\omega_s) = 24.1dB \end{cases}$

$\Rightarrow$ Choose $N = 4$.



Poles have same frequency $\omega_0 = \omega_p (1/\epsilon)^{1/N}$

$$= 2\pi \times 8 \times 10^3 \times 1^{1/4}$$

$$\simeq 5 \times 10^4 \ rad/s$$

$P_{1,4} = \omega_0 (-\cos 67.5^\circ \pm j \sin 67.5^\circ) = \omega_0 (-0.38 \pm j\, 0.92)$

$P_{2,3} = \omega_0 (-\cos 22.5^\circ \pm j \sin 22.5^\circ) = \omega_0 (-0.92 \pm j\, 0.38)$

$$T(s) = \frac{K\omega_0^{\,N}}{(s-p_1)\dots(s-p_N)} = \frac{\omega_0^{\,4}}{(s^2+s0.76\omega_0+\omega_0^2)(s^2+s1.84\omega_0+\omega_0^2)}$$

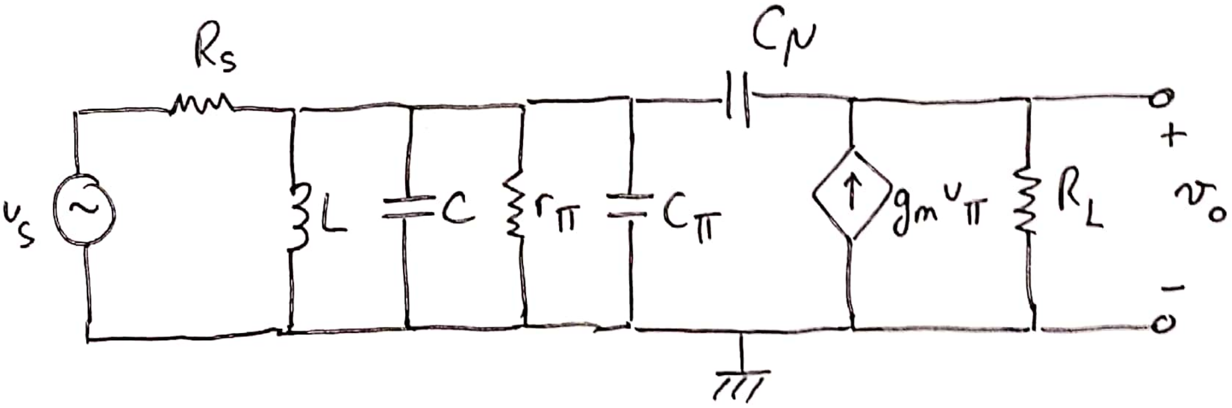
- Attenuation at $f_1 = 24\,kHz$

$$|T(j\omega_1)|\,(dB) = 20\log\left|\frac{1}{\sqrt{1+\epsilon^2\left(\frac{\omega_1}{\omega_p}\right)^{2N}}}\right|$$

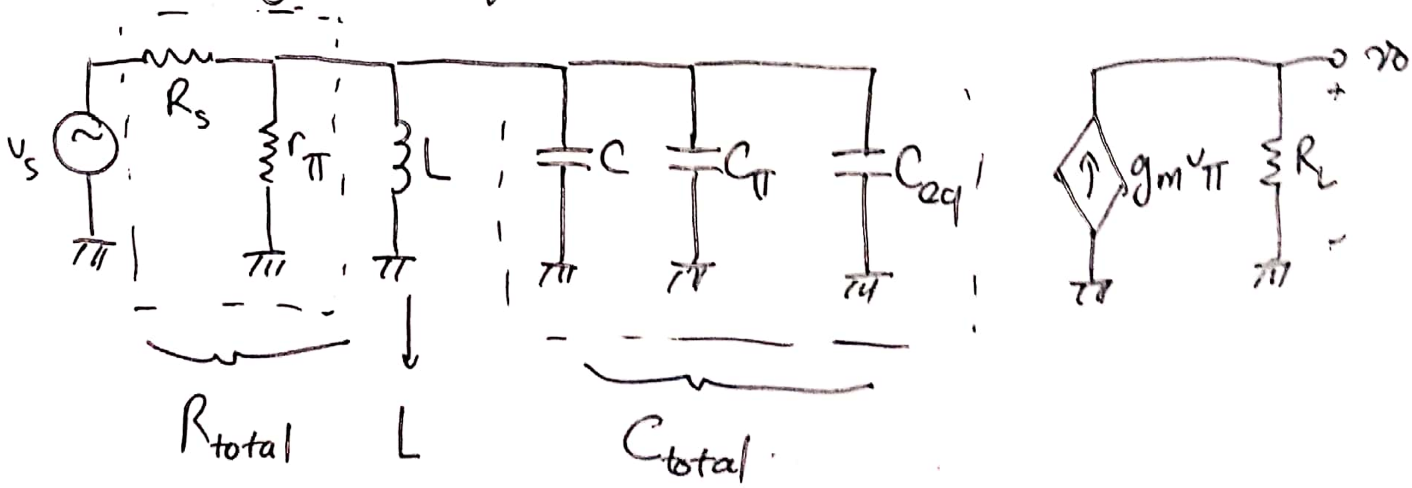
$$= 20\log\left|\frac{1}{\sqrt{1+3^8}}\right| \simeq -38\,dB$$

2

* AC equivalent circuit.



* Using Miller effect :



$$g_m = \frac{I_C}{V_T} = \frac{1^{mA}}{25^{mV}} = 0.04 \ (A/V)$$

$$C_{eq} = C_\mu (1 + g_m R_L) = 0.6^p (1 + 0.04 \times 4^k) = 96.6 \ (pF)$$

$$C_{total} = C_\pi + C + C_{eq} = 12^p + 100^p + 96.6^p = 208.6 \ (pF)$$

$$R_{total} = R_s // r_\pi = 8^k // 2.5^k \approx 1.9 \ (k\Omega)$$

$$, \text{with } r_\pi = \beta / g_m = 100 / 0.04 = 2.5 \ (k\Omega)$$

$$w_o = \frac{1}{\sqrt{LC_{total}}} = \frac{1}{\sqrt{1^\mu \times 208.6^p}} \approx 70 \times 10^6 \ (rad/s)$$

$$Q = w_o R_{total} C_{total} = 70 \times 10^6 \times 1.9^k \times 208.6^p \approx 27.74$$

$$\text{3-dB BW} = \frac{w_o}{Q} = \frac{70 \times 10^6}{27.74} \approx 2.52 \times 10^6 \ (rad/s)$$

$$A_M = \left| \frac{V_o}{V_s} \Big|_{w = w_o} \right| = \frac{r_\pi}{R_s + r_\pi} (g_m R_L)$$

$$= \frac{2.5^k}{8^k + 2.5^k} \, 0.04 \times 4^k \approx 38$$

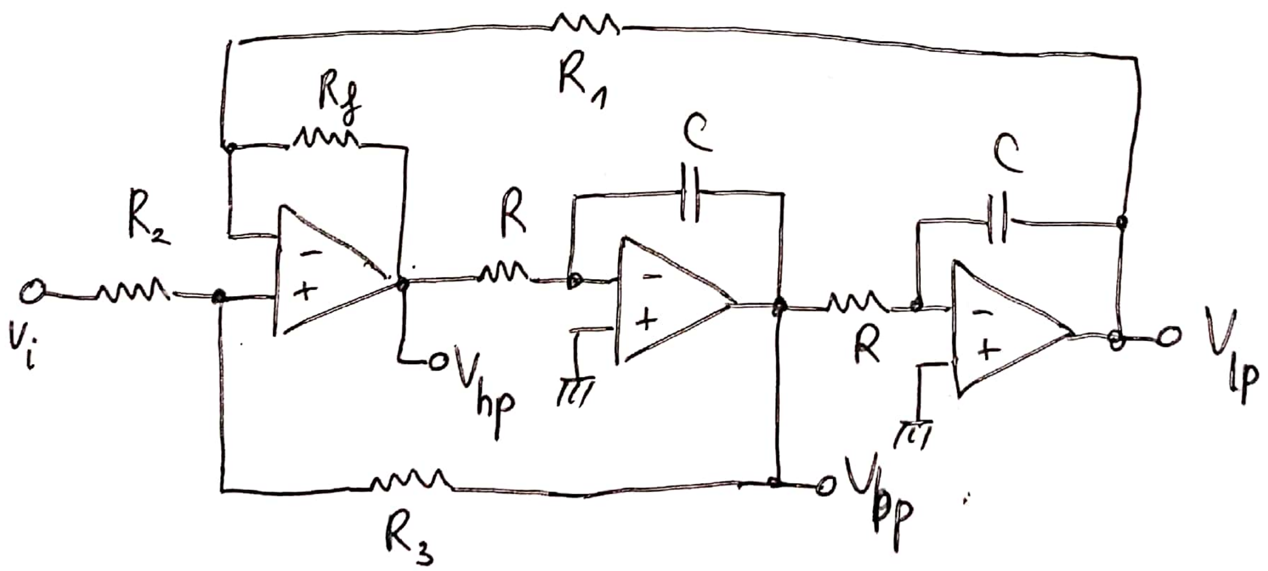
3 $f_o = \dfrac{1}{2\pi RC} \Rightarrow R = \dfrac{1}{2\pi f_o C} = \dfrac{1}{2\pi \times 10^4 \times 10^{-8}} \simeq 1.6\ (k\Omega)$

Let $R_f = R_1 = 1\ (k\Omega)$

$Q = \dfrac{\omega_o}{BW} = \dfrac{10^k}{500} = 20$

$\dfrac{R_3}{R_2} = 2Q - 1 = 39$. Let $R_2 = 2 (k\Omega) \Rightarrow R_3 = 78 (k\Omega)$

$K = 2 - \dfrac{1}{Q} = 1.95$



$R_f = R_1 = 1k\Omega$

$R_2 = 2k\Omega$

$R_3 = 39k\Omega$

$C = 10nF$