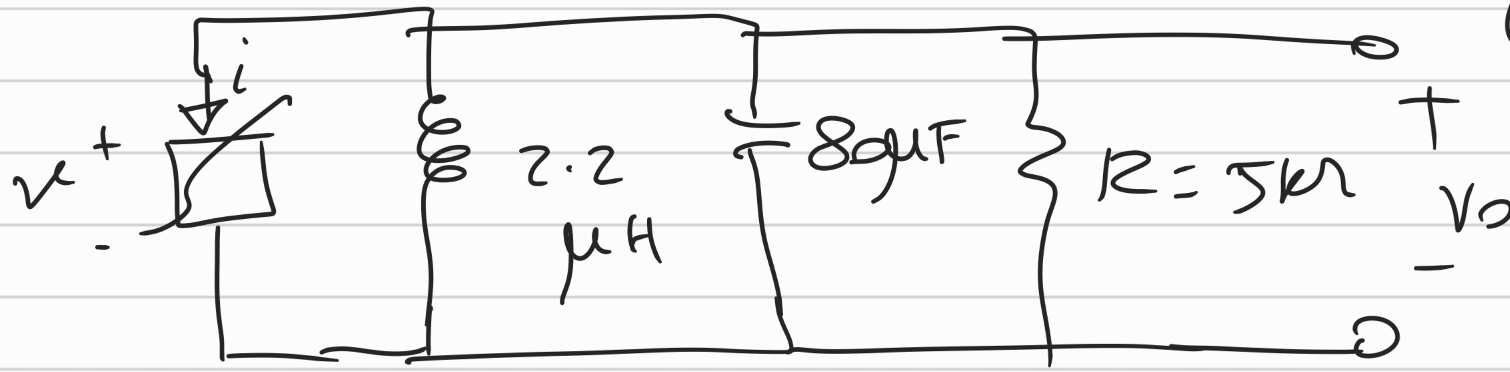
1)



$$i = -10^{-3} v + 2\times 10^{-4} v^2 + 3\times 10^{-5} v^3$$

هارمونی اصلی خروجی

$$v_o(t) = V_o \cos\omega_o t$$

$$i(t) = -10^{-3} V_o \cos\omega_o t + 2\times 10^{-4} V_o^2 \cos^2\omega_o t + 3\times 10^{-5} (V_o \cos\omega_o t)^3$$

$$i(t) = -10^{-3} V_o \cos\omega_o t + 2\times 10^{-4} V_o^2 \left(\frac{1+\cos 2\omega_o t}{2}\right) + 3\times 10^{-5} V_o^3 (\cos\omega_o t)\left(\frac{1+\cos 2\omega_o t}{2}\right)$$

مؤلفه هارمونی اصلی

$$i_1(t) = \left(-10^{-3} V_o + 3/2 \times 10^{-5} V_o^3\right) \cos\omega_o t$$

kcl:

$$V_o\left(\frac{1}{j\omega_o L} + j\omega_o C + G\right) + \left(-10^{-3} V_o + 3/2 \times 10^{-5} V_o^3\right) = 0$$

$$\underbrace{j\left(\omega_0 C - \frac{1}{\omega_0 L}\right)}_{0} + (G - 10^{-3}) + 1.5\times 10^{-5} V_0^2 = 0$$

$$\rightarrow \omega_0 = \frac{1}{\sqrt{LC}} = 75.187 \ \text{Mrad/sec}$$

$$f_0 \simeq 11.966 \ \text{MHz}$$

$$G - 10^{-3} + 1.5\times 10^{-5} V_0^2 = 0$$

$$\frac{1}{5000} - 10^{-3} + 1.5\times 10^{-5} V_0^2 = 0 \Rightarrow V_0^2 = 53.33$$

دامنه ولتاژ خروجی $V_0 = 7.30$ ولت

مؤلفه هارمونیک دوم خروجی چقدر است؟

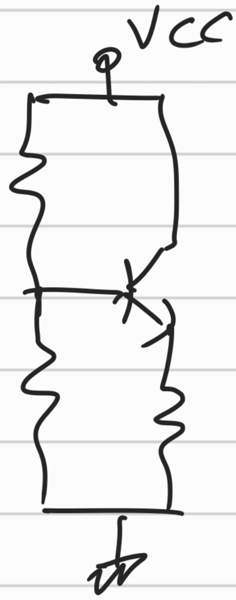
$$\left|\frac{V_n}{V_1}\right| = \frac{I_n}{I_1} \times \frac{n}{(n^2-1)\,Q_T}$$

$$\left|\frac{V_2}{V_1}\right| = \frac{(10^{-4}\times 7.3^2)}{(10^{-3}\times 7.3 - 1.5\times 10^{-5}\times 7.3^3)} \times \frac{2}{(4-1)\times 30.2}$$

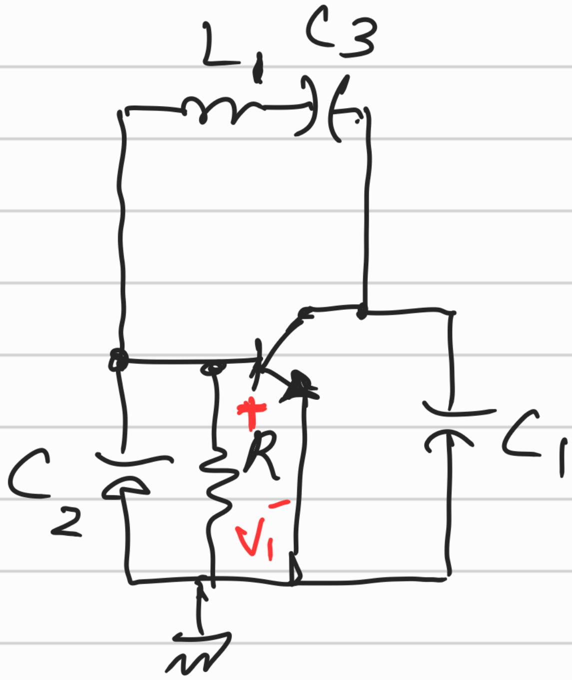
$$Q_T = \frac{R}{\omega_0 L} = 30.2$$

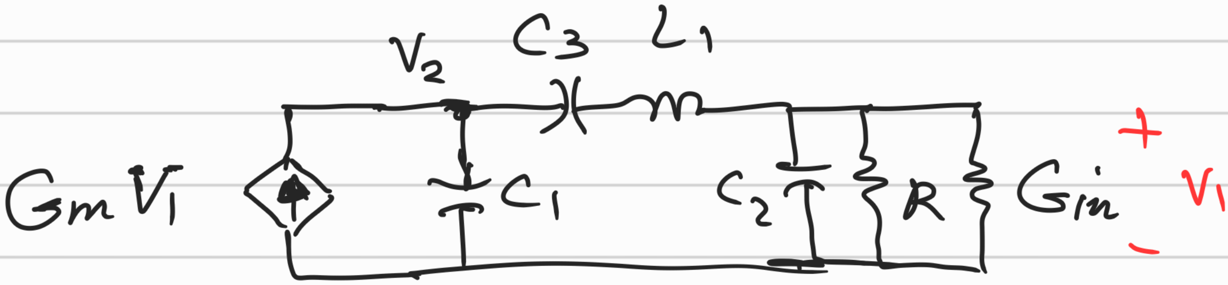
$$\left|\frac{V_2}{V_1}\right| = 0.018 \quad \text{با} \quad V_2 = 0.132 \ \text{Volt}$$

۲) مدار معادل DC



مدار معادل ac :





1

$$\begin{cases} G_m V_1 + V_2 (j\omega C_1) + (V_2 - V_1)\left(\dfrac{1}{\frac{1}{j\omega C_3} + j\omega L_1}\right) = 0 \\ (V_1 - V_2)\dfrac{1}{\frac{1}{j\omega C_3} + j\omega L_1} + V_1 (j\omega C_2 + G + G_{in}) = 0 \end{cases}$$

$$V_1\left(\frac{j\omega C_3}{1-\omega^2 C_3 L_1} + j\omega C_2 + G + G_{in}\right) = \frac{V_2 j\omega C_3}{1-\omega^2 C_3 L_1}$$

$$V_2 = \frac{V_1\left(j\omega C_3/_{1-\omega^2 C_3 L_1} + j\omega C_2 + G + G_{in}\right)}{j\omega C_3/_{1-\omega^2 C_3 L_1}}$$

$$V_2 = V_1\left(1 + \frac{C_2}{C_3}(1-\omega^2 C_3 L_1) + \frac{-j(G+G_{in})(1-\omega^2 C_3 L_1)}{\omega C_3}\right.$$

1

$$\left(G_m - \frac{j\omega C_3}{1-\omega^2 C_3 L_1}\right)V_1 + \left(j\omega C_1 + \frac{j\omega C_3}{1-\omega^2 C_3 L_1}\right)V_2 = 0$$

$$G_m - \frac{j\omega C_3}{1-\omega^2 C_3 L_1} + \left(j\omega C_1 + \frac{j\omega C_3}{1-\omega^2 C_3 L_1}\right)\left(1 + \frac{C_2}{C_3}\left(1-\omega^2 C_3 L_1\right) - j\,\frac{(G+G_{in})(1-\omega^2 C_3 L_1)}{\omega C_3}\right) = 0$$

$$G_m + \frac{C_1}{C_3}(G+G_{in})(1-\omega^2 C_3 L_1) + (G+G_{in}) + j\left(\omega C_1 + \omega C_2 + \frac{\omega C_1 C_2}{C_3}\left(1-\omega^2 C_3 L_1\right)\right) = 0$$

$$C_1 + C_2 + \frac{C_1 C_2}{C_3} - C_1 C_2 L_1 \omega^2 = 0$$

$$\omega_0 = \sqrt{\frac{C_1 + C_2 + \frac{C_1 C_2}{C_3}}{C_1 C_2 L_1}}$$

فرکانس نوسان

$$G_{in} = \frac{i_b}{v_{be}} = \frac{i_b}{i_c}\cdot\frac{i_c}{v_{be}} = \frac{1}{\beta}G_m$$

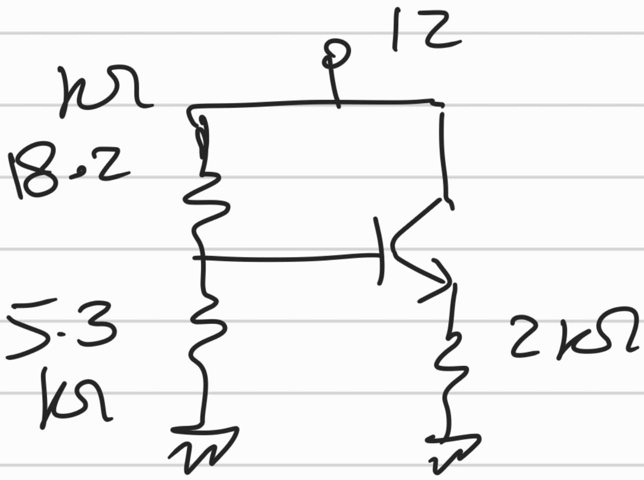
$$G_m + \frac{C_1}{C_3}(G + G_{in})(1 - \omega_0^2 C_3 L_1) + G + G_{in} = 0$$

$$G_m\left(1 + \frac{C_1}{C_3}\frac{1}{\beta}(1 - \omega_0^2 C_3 L_1) + \frac{1}{\beta}\right)$$

$$+ \frac{C_1}{C_3} G (1 - \omega_0^2 C_3 L_1) + G = 0$$

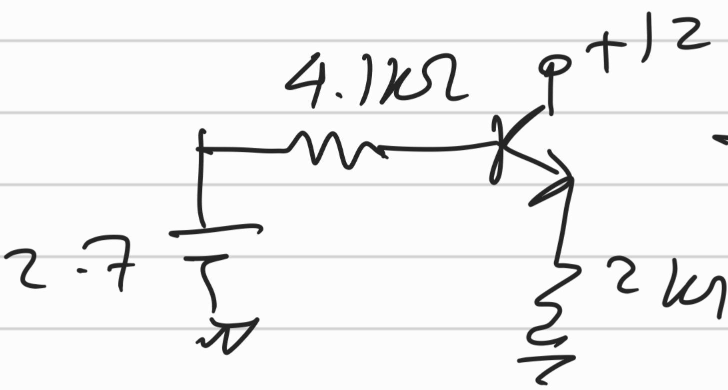
$$G_m = \frac{G\left(\frac{C_1}{C_3}(1 - \omega_0^2 C_3 L_1) + 1\right)}{\frac{C_1}{\beta C_3}(\omega_0^2 C_3 L_1 - 1) - \left(1 + \frac{1}{\beta}\right)}$$

سوال ۳) تحلیل DC



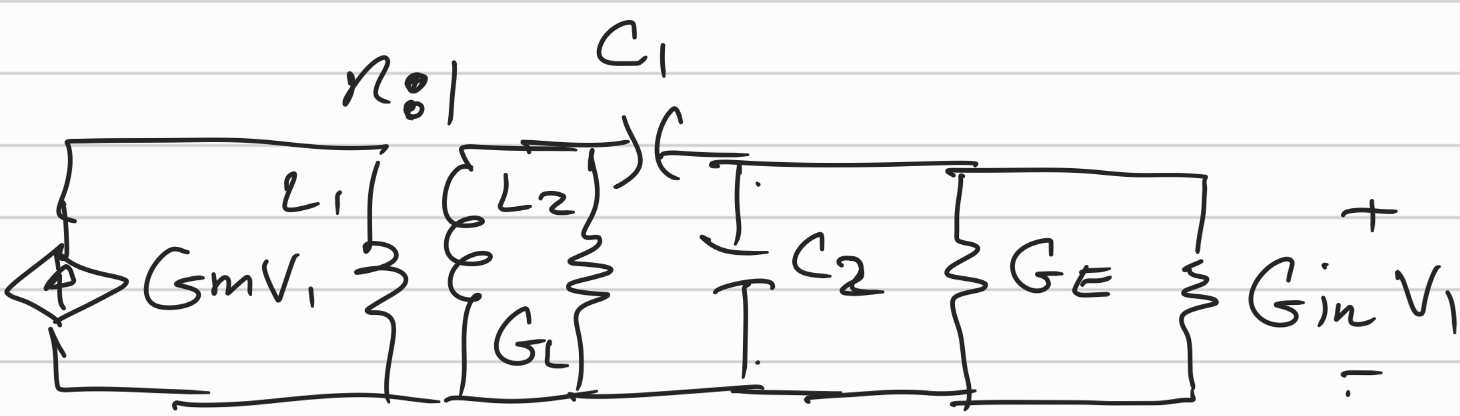
$\beta = \infty$

$\alpha = 1$

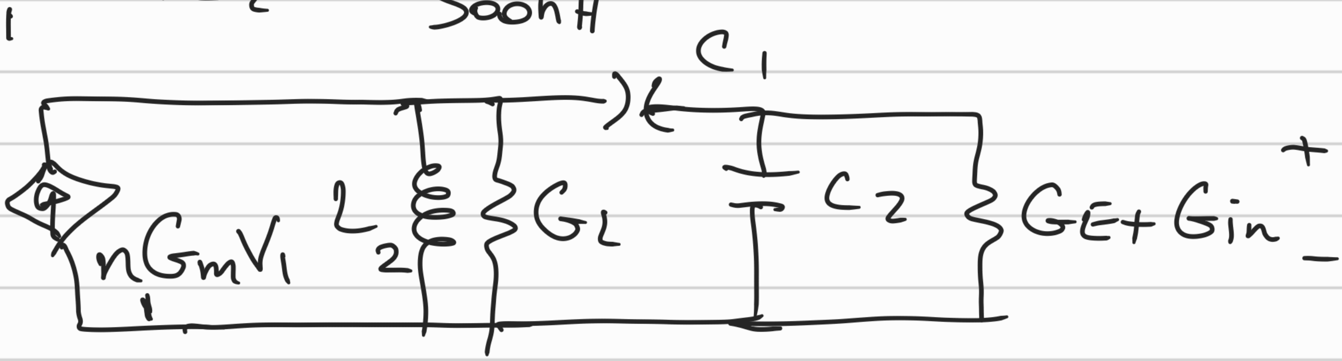


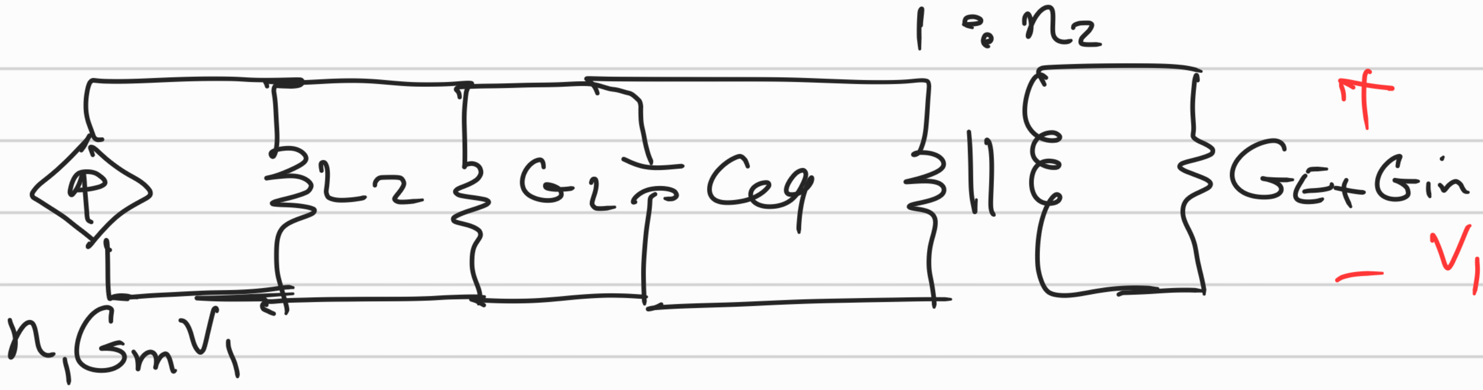
$$I_C = \alpha \frac{2.7 - 0.7}{\frac{4.1}{\beta+1} + 2}$$

$$I_C = 1mA$$



$$n = M/L_2 = \frac{200nH}{500nH} = 0.4$$





$$n_1 G_m V_1 = \frac{V_1}{n_2}\left(\frac{1}{j\omega L_2} + j\omega C_{eq} + G_L + n_2^2 (G_E + G_{in})\right)$$

$$\frac{n_2 n_1 G_m}{j\left(\omega C_{eq} - \frac{1}{\omega L_2}\right) + G_L + n_2^2 (G_E + G_{in})} = 1$$

شرط نوسان:

$$\omega C_{eq} - \frac{1}{\omega L_2} = 0 \rightarrow \omega_0 = \frac{1}{\sqrt{L_2 C_{eq}}}$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$\frac{n_2 n_1 G_m}{G_L + n_2^2 (G_E + G_{in})} = 1$$

$$G_{in} = \frac{i_e}{i_c} \cdot \frac{i_c}{v_{be}} = \frac{1}{\alpha} G_m$$

$$n_1 n_2 G_m = G_L + n_2^2 G_E + n_2^2 \frac{G_m}{\alpha}$$

$$G_m = \frac{G_L + n_2^2 G_E}{n_2 (n_1 - n_2/\alpha)}$$

$$n_1 = M/L_2$$

$$n_2 = \frac{C_1}{C_1 + C_2}$$

$$G_E = 1/R_E$$