Electronics II Exam-1 Solution 2023

(1)

$$R_{TH} = R_1 \| R_2 = 40 \| 5 = 4.44\ \text{k}\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{5}{5+40}\right)(10) = 1.111\ \text{V}$$

$$I_{BQ} = \frac{1.111 - 0.7}{4.44 + (121)(0.5)} = 0.00633\ \text{mA}$$

$$I_{CQ} = 0.760\ \text{mA}$$

$$r_\pi = \frac{(120)(0.026)}{0.760} = 4.11\ \text{k}\Omega$$

$$g_m = \frac{0.760}{0.026} = 29.23\ \text{mA/V}$$

$$r_0 = \infty$$

$$f_T = \frac{g_m}{2\pi\left(C_\pi + C_\mu\right)}$$

$$C_\pi + C_\mu = \frac{g_m}{2\pi f_T} = \frac{29.23 \times 10^{-3}}{2\pi\left(250 \times 10^6\right)}$$

$$C_\pi + C_\mu = 18.6\ \text{pF};\ C_\mu = 3\ \text{pF} \Rightarrow C_\pi = 15.6\ \text{pF}$$

$$C_M = C_\mu\left[1 + g_m\left(R_C \| R_L\right)\right]$$

$$C_M = 3\left[1 + (29.2)(5 \| 2.5)\right] \Rightarrow C_M = 149\ \text{pF}$$

For upper frequency:

$$\tau_H = R_{eq}\left(C_\pi + C_M\right)$$

$$R_{eq} = r_\pi \| R_1 \| R_2 \| R_S = 4.11 \| 40 \| 5 \| 0.5$$

$$R_{eq} = 0.405\ \text{k}\Omega$$

$$\tau_H = \left(0.405 \times 10^3\right)(15.6 + 149) \times 10^{-12}$$

$$= 6.67 \times 10^{-8}\ \text{s}$$

$$f_H = \frac{1}{2\pi\tau_H} \Rightarrow f_H = 2.39\ \text{MHz}$$

For lower frequency:

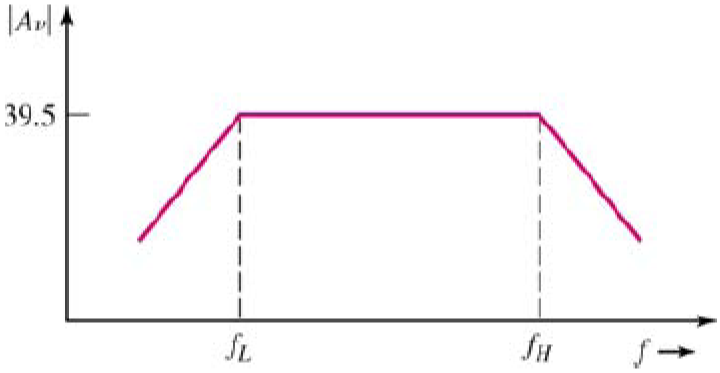
$$\tau_L = R_{eq} C_{C1}$$

$$R_{eq} = R_S + R_1 \| R_2 \| r_\pi = 0.5 + 40 \| 5 \| 4.11$$

$$R_{eq} = 2.64\ \text{k}\Omega$$

$$\tau_L = \left(2.64 \times 10^3\right)\left(4.7 \times 10^{-6}\right) = 1.24 \times 10^{-2}\ \text{s}$$

$$f_L = \frac{1}{2\pi\tau_L} \Rightarrow f_L = 12.8\ \text{Hz}$$



$$V_0 = -g_m V_\pi \left(R_C \| R_L\right)$$

$$V_\pi = \left(\frac{R_1 \| R_2 \| r_\pi}{R_1 \| R_2 \| r_\pi + R_S}\right) V_i$$

$$V_\pi = \left(\frac{2.135}{2.135 + 0.5}\right) V_i = 0.8102 V_i$$

$$|A_V| = (29.23)(0.8102)(5 \| 2.5)$$

$$\underline{|A_V| = 39.5}$$

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(2)

$$I_D = K_P \left(V_{SG} + V_{TP}\right)^2 = \frac{9 - V_{SG}}{R_S}$$

$$(2)(1.2)\left(V_{SG}^2 - 4V_{SG} + 4\right) = 9 - V_{SG}$$

$$2.4V_{SG}^2 - 8.6V_{SG} + 0.6 = 0$$

$$V_{SG} = \frac{8.6 \pm \sqrt{(8.6)^2 - 4(2.4)(0.6)}}{2(2.4)}$$

$$V_{SG} = 3.512 \text{ V}$$

$$g_m = 2K_P\left(V_{SG} + V_{TP}\right) = 2(2)(3.512 - 2)$$

$$g_m = 6.049 \; mA/V$$

$$I_D = (2)(3.512 - 2)^2 = 4.572 \text{ mA}$$

$$r_0 = \frac{1}{\lambda I_o} = \frac{1}{(0.01)(4.56)} \Rightarrow r_0 = 21.9 \text{ k}\Omega$$

$$C_M = C_{gdT}\left(1 + g_m\left(r_o \| R_D\right)\right)$$

$$C_M = (1)\left[1 + (6.04)(21.9 \| 1)\right] \Rightarrow \underline{C_M = 6.785 \text{ pF}}$$

$$\tau_H = (R_i \| R_G)(C_{gsT} + C_M)$$

$$\tau_H = (2\|100)\times 10^3 \times (10 + 6.78)\times 10^{-12}$$

$$\tau_H = 3.29\times 10^{-8}\ \text{s}$$

$$f_H = \frac{1}{2\pi\tau_H} \Rightarrow f_H = 4.84\ \text{MHz}$$

$$V_o = -g_m (r_o \| R_D)\cdot V_{gs}$$

$$V_{gs} = \left(\frac{R_G}{R_G + R_i}\right)\cdot V_i = \left(\frac{100}{102}\right)\cdot V_i$$

$$A_\upsilon = -(6.04)\left(\frac{100}{102}\right)(21.9\|1)$$

$$A_\upsilon = -5.67$$

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(3)

The dc analysis

$$I_{BQ} = \frac{10 - 0.7}{100 + (101)(10)} = 0.00838\ \text{mA}$$

$$I_{CQ} = 0.838\ \text{mA}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{(100)(0.026)}{0.838} = 3.10\ \text{k}\Omega$$

$$g_m = \frac{I_{CQ}}{V_T} = 32.22\ \text{mA/V}$$

For the input

$$\tau_{p\pi} = \left[\left(\frac{r_\pi}{1+\beta}\right)\Big\| R_E \| R_S\right] C_\pi = \left[\left(\frac{3.10}{101}\right)\Big\| 10\|1\right]\times 10^3 \times 24\times 10^{-12}$$

$$= 7.13\times 10^{-10}\ \text{s}$$

$$f_{H\pi} = \frac{1}{2\pi\tau_{p\pi}} = \frac{1}{2\pi(7.13\times 10^{-10})} \Rightarrow f_{H\pi} = 223\ \text{MHz}$$

For the output

$$\tau_{p\mu} = (R_C \| R_L) C_\mu = (10\|1)\times 10^3 \times 3\times 10^{-12}$$

$$= 2.73\times 10^{-9}\text{ s}$$

$$f_{H\mu} = \frac{1}{2\pi\tau_{p\mu}} = \frac{1}{2\pi(2.73\times 10^{-9})} \Rightarrow f_{H\mu} = 58.4\text{ MHz}$$

$$(A_\upsilon)_M = g_m(R_C\|R_L)\left[\frac{R_E\left\|\left(\frac{r_\pi}{1+\beta}\right)\right.}{R_E\left\|\left(\frac{r_\pi}{1+\beta}\right)\right.+R_S}\right]$$

$$= (32.22)(10\|1)\left[\frac{10\left\|\left(\frac{3.1}{101}\right)\right.}{10\left\|\left(\frac{3.1}{101}\right)\right.+1}\right] \Rightarrow (A_\upsilon)_M = 0.870$$