Electronics II Exam-1 Solution 2020

(1)

$$I_E = 0.5\text{ mA} \Rightarrow I_{CQ} = \left(\frac{100}{101}\right)(0.5) = 0.495\text{ mA}$$

$$g_m = \frac{0.495}{0.026} = 19.0\text{ mA/V}$$

$$r_\pi = \frac{(100)(0.026)}{0.495} = 5.25\text{ k}\Omega$$

a. Input: From Eq. (7.114(b))

$$\tau_{P\pi} = \left[\frac{r_\pi}{1+\beta}\Big\|R_E\|R_S\right]C_\pi$$

$$= \left[\frac{5.25}{101}\Big\|0.5\|0.05\right]\times 10^3 \times \left(10\times 10^{-12}\right)$$

$$= 2.43\times 10^{-10}\text{ s}$$

$$f_{H\pi} = \frac{1}{2\pi\tau_{P\pi}} \Rightarrow f_{H\pi} = 656\text{ MHz}$$

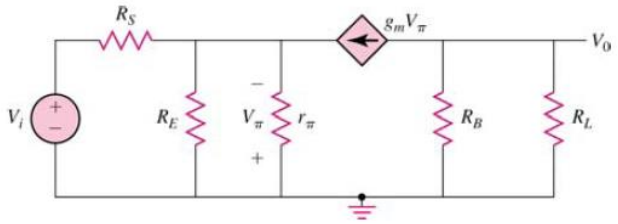
Output: From Eq. (7.115(b))

$$\tau_{P\mu} = \left(R_B\|R_L\right)C_\mu = (100\|1)\times 10^3 \times \left(10^{-12}\right)$$

$$= 9.90\times 10^{-10}\text{ s}$$

$$f_{H\mu} = \frac{1}{2\pi\tau_{P\mu}} \Rightarrow f_{H\mu} = 161\text{ MHz}$$

b.



$$V_o = -g_m V_\pi \left(R_B\|R_L\right)$$

$$g_m V_\pi + \frac{V_\pi}{r_\pi} + \frac{V_\pi}{R_E} + \frac{V_i - (-V_\pi)}{R_S} = 0$$

$$V_\pi\left[g_m + \frac{1}{r_\pi} + \frac{1}{R_E} + \frac{1}{R_S}\right] = -\frac{V_i}{R_S}$$

$$V_\pi\left[19 + \frac{1}{5.25} + \frac{1}{0.5} + \frac{1}{0.05}\right] = \frac{-V_i}{0.05}$$

$$V_\pi(41.19) = -V_i(20)$$

$$V_\pi = -(0.4856)V_i$$

$$\frac{V_o}{V_i} = -(19)(-0.4856)(100\|1)$$

$$A_\upsilon = 9.14$$

(2)

(a)

$$V_G = \left(\frac{R_2}{R_1+R_2}\right)V_{DD} = \left(\frac{166}{166+234}\right)(10)$$

$$= 4.15\text{ V}$$

$$I_D = \frac{V_G - V_{GS}}{R_S} = K_n\left(V_{GS} - V_{TN}\right)^2$$

$$4.15 - V_{GS} = (0.5)(0.5)\left(V_{GS}^2 - 4V_{GS} + 4\right)$$

$$0.25V_{GS}^2 - 3.15 = 0 \Rightarrow V_{GS} = 3.55\text{ V}$$

$$g_m = 2K_n\left(V_{GS} - V_{TN}\right) = 2(0.5)(3.55-2)$$

$$g_m = 1.55\ mA/V$$

$$R_0 = R_S\left\|\frac{1}{g_m} = 0.5\right\|\frac{1}{1.55} = 0.5\|0.645$$

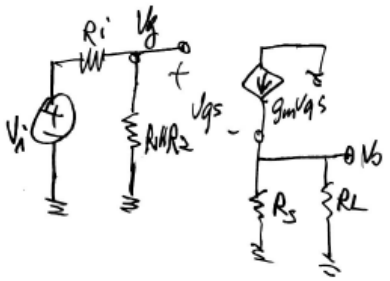
$$R_0 = 0.282\text{ k}\Omega$$

$$r = \left(R_0\|R_L\right)C_L \text{ and } f_H = \frac{1}{2\pi r}$$

$$\beta\omega \approx f_H = 5\text{ MHz} \Rightarrow r = \frac{1}{2\pi\left(5\times 10^6\right)} = 3.18\times 10^{-8}\text{ s}$$

$$C_L = \frac{r}{R_0\|R_L} = \frac{3.18\times 10^{-8}}{(0.282\|4)\times 10^3} \Rightarrow \underline{C_L = 121\text{ pF}}$$

(b)



$$V_g = \frac{R_1 \| R_2}{R_1 \| R_2 + R_i} \cdot V_i$$

$$V_g = V_{gs} + g_m (R_S \| R_L) V_{gs}$$
$$= [1 + g_m (R_S \| R_L)] \cdot V_{gs}$$

$$V_o = g_m (R_S \| R_L) V_{gs}$$
$$= g_m (R_S \| R_L) \frac{V_g}{1 + g_m (R_S \| R_L)}$$

$$\Rightarrow A_v = \frac{V_o}{V_i} = \frac{g_m (R_S \| R_L)}{1 + g_m (R_S \| R_L)} \cdot \frac{R_1 \| R_2}{R_1 \| R_2 + R_i}$$

$g_m = 1.55$ mA/V

$R_S \| R_L = \frac{2}{4.5} = 0.445$ KΩ

$R_1 \| R_2 = 97.11$ KΩ

$A_v = \frac{1.55 \times 0.445}{1 + 1.55 \times 0.445} \times \frac{97.11}{97.11 + 2} = 0.4$

---

(3)

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

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

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

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

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

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

$$r_0 = \infty$$

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

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

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

a.

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

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

For upper frequency:

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

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

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

$$\tau_H = (0.405 \times 10^3)(15.6 + 149) \times 10^{-12}$$
$$= 6.67 \times 10^{-8} \text{ s}$$

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

For lower frequency:

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

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

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

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

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