Electronics II Exam-1 Solution 2021

(1)

a.

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

$$9-V_{SG}=(0.5)(12)\left(V_{SG}^2-4V_{SG}+4\right)$$

$$6V_{SG}^2-23V_{SG}+15=0$$

$$V_{SG}=\frac{23\pm\sqrt{(23)^2-4(6)(15)}}{2(6)}\Rightarrow V_{SG}=3\text{ V}$$

$$g_m=2K_P\left(V_{SG}+V_{TP}\right)=2(0.5)(3-2)\Rightarrow g_m=1\text{ mA/V}$$

$$R_o=\frac{1}{g_m}\Big\|R_S=1\|12\Rightarrow \underline{R_o=0.923\text{ k}\Omega}$$

b. $\tau=\left(R_o+R_L\right)C_C$

$$f_L=\frac{1}{2\pi\tau}\Rightarrow\tau=\frac{1}{2\pi f_L}=\frac{1}{2\pi(20)}\Rightarrow\tau=7.96\text{ ms}$$

$$C_C=\frac{\tau}{R_o+R_L}=\frac{7.96\times10^{-3}}{(0.923+10)\times10^3}\Rightarrow C_C=0.729\ \ \mu\text{ F}$$

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(2)

(a)

$$R_{TH}=R_1\|R_2=33\|22=13.2\text{ k}\Omega$$

$$V_{TH}=\left(\frac{R_2}{R_1+R_2}\right)(5)=\left(\frac{22}{22+33}\right)(5)=2\text{ V}$$

$$I_{BQ}=\frac{2-0.7}{13.2+(121)(4)}=0.00261\text{ mA}$$

$$I_{CQ}=0.3138$$

$$r_\pi=\frac{(120)(0.026)}{0.3138}=9.94\text{ k}\Omega$$

$$g_m=\frac{0.3138}{0.026}=12.07\text{ mA/V}$$

$$r_0=\frac{100}{0.3138}=318\text{ k}\Omega$$

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

$$C_\pi + C_\mu = \frac{g_m}{2\pi f_T} = \frac{12.07\times10^{-3}}{2\pi\left(600\times10^{6}\right)}$$

$$C_\pi + C_\mu = 3.20\text{ pF};\ C_\mu = 1\text{ pF} \Rightarrow C_\pi = 2.20\text{ pF}$$

(b)

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

$$= (1)\left[1 + (12.07)\left(318\|4\|5\right)\right]$$

$$C_M = 27.6\text{ pF}$$

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

$$R_{eq} = R_1 \| R_2 \| R_S \| r_\pi = 33\|22\|2\|r_\pi$$

$$= 1.74\|9.94 \Rightarrow R_{eq} = 1.48\text{ k}\Omega$$

$$\tau = \left(1.48\times10^{3}\right)(2.20 + 27.6)\times10^{-12}$$

$$\tau = 4.41\times10^{-8}\text{ s}$$

$$f_H = \frac{1}{2\pi\tau} = \frac{1}{2\pi\left(4.41\times10^{-8}\right)} \Rightarrow f_H = 3.61\text{ MHz}$$

(c)

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

$$V_\pi = \frac{R_1 \| R_2 \| r_\pi}{R_1 \| R_2 \| r_\pi + R_S} \cdot V_i$$

$$R_1 \| R_2 \| r_\pi = 33\|22\|9.94 = 5.67\text{ k}\Omega$$

$$V_\pi = \frac{5.67}{5.67 + 2} \cdot V_i = (0.739)V_i$$

$$r_o \| R_C \| R_L = 318\|4\|5 = 2.18\text{ k}\Omega$$

$$A_\upsilon = -(12.07)(0.739)(2.18)$$

$$A_\upsilon = -19.7$$

(3)

(a)

$$V_{B1} = \left(\frac{R_3}{R_1 + R_2 + R_3}\right)(12) = \left(\frac{7.92}{58.8 + 33.3 + 7.92}\right)(12) = 0.9502 \text{ V}$$

Neglecting base currents

$$I_C = \frac{0.9502 - 0.7}{0.5} = 0.50 \text{ mA}$$

(b)

$$r_\pi = \frac{\beta V_T}{I_C} = \frac{(100)(0.026)}{0.5} = 5.2 \text{ K}$$

$$g_m = \frac{I_C}{V_T} = \frac{0.5}{0.026} = 19.23 \text{ mA/V}$$

From Eq (7.119(a)),

$$\tau_{p\pi} = \left(R_S \| R_{B1} \| r_\pi\right)\left(C_{\pi 1} + C_{M1}\right)$$

$$R_{B1} = R_2 \| R_3 = 33.3 \| 7.92 = 6.398 \text{ k}\Omega$$

$$C_{M1} = 2C_{\mu 1} = 6 \text{ pF}$$

Then

$$\tau_{p\pi} = \left(1 \| 6.398 \| 5.2\right) \times 10^3 \times (24 + 6) \times 10^{-12} \Rightarrow \tau_{p\pi} = 22.24 \text{ ns}$$

$$f_{H\pi} = \frac{1}{2\pi\tau_{p\pi}} = \frac{1}{2\pi\left(22.24 \times 10^{-9}\right)} \Rightarrow f_{H\pi} = 7.15 \text{ MHz}$$

From Eq (7.120(a)),

$$\tau_{p\mu} = \left(R_C \| R_L\right) C_{\mu 2} = \left(7.5 \| 2\right) \times 10^3 \times 3 \times 10^{-12} \Rightarrow \tau_{p\mu} = 4.737 \text{ ns}$$

$$f_{H\mu} = \frac{1}{2\pi\tau_{p\mu}} = \frac{1}{2\pi\left(4.737 \times 10^{-9}\right)} \Rightarrow f_{H\mu} = 33.6 \text{ MHz}$$

(c)

From Eq. (7.125),

$$\left|A_v\right|_M = g_{m2}\left(R_C \| R_L\right)\left[\frac{R_{B1} \| r_{\pi 1}}{R_{B1} \| r_{\pi 1} + R_S}\right] = (19.23)(7.5 \| 2)\left[\frac{6.40 \| 5.2}{6.40 \| 5.2 + 1}\right]$$

$$\left|A_v\right|_M = 22.5$$