Homework 9 Solutions

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Solution 7.17

a.

$$R_{TH} = R_1 \| R_2 = 10 \| 1.5 = 1.304 \text{ k}\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{1.5}{1.5 + 10}\right)(12) = 1.565 \text{ V}$$

$$I_{BQ} = \frac{1.565 - 0.7}{1.30 + (101)(0.1)} = 0.0759 \text{ mA}$$

$$I_{CQ} = 7.585 \text{ mA}$$

$$r_\pi = \frac{(100)(0.026)}{7.59} = 0.343 \text{ k}\Omega$$

$$g_m = \frac{7.59}{0.026} = 292 \text{ mA/V}$$

$$R_i = R_1 \| R_2 \| [r_\pi + (1 + \beta) R_E]$$

$$= 10 \| 1.5 \| [0.343 + (101)(0.1)]$$

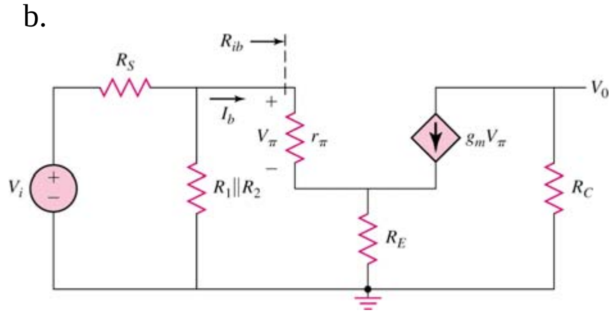
$$= 1.30 \| 10.44 \Rightarrow R_i = 1.159 \text{ k}\Omega$$

$$\tau = (R_S + R_i) C_C = (0.5 + 1.16) \times 10^3 \times (0.1 \times 10^{-6})$$

$$\tau = 1.659 \times 10^{-4} \text{ s}$$

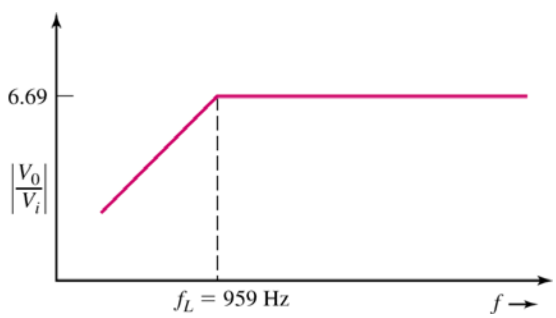
$$f_L = \frac{1}{2\pi\tau} = \frac{1}{2\pi(1.66 \times 10^{-4})} \Rightarrow f_L = 959 \text{ Hz}$$

b.



$$V_0 = -(\beta I_b) R_C$$
$$R_{1b} = r_\pi + (1+\beta) R_E$$
$$= 0.343 + (101)(0.1) = 10.44 \text{ k}\Omega$$
$$I_b = \left(\frac{R_1 \| R_2}{R_1 \| R_2 + R_{ib}}\right) I_i$$
$$= \left(\frac{1.30}{1.30 + 10.4}\right) I_i = (0.111) I_i$$
$$I_i = \frac{V_i}{R_S + R_1 \| R_2 \| R_{ib}}$$
$$= \frac{V_i}{0.5 + (1.3) \| (10.44)}$$
$$I_i = \frac{V_i}{1.659}$$
$$\left|\frac{V_0}{V_i}\right| = \frac{\beta R_C (0.111)}{1.659} \Rightarrow \left|\frac{V_0}{V_i}\right|_{\text{midband}} = \frac{(100)(1)(0.111)}{1.659} \Rightarrow \underline{\left|\frac{V_0}{V_i}\right|_{\text{midband}} = 6.69}$$

c.



Solution 7.21

(a) $R_{TH} = (0.1)(1+\beta)R_E = (0.1)(121)(4) = 48.4 \text{ k}\Omega$

$$I_{BQ} = \frac{I_{EQ}}{1+\beta} = \frac{1.5}{121} = 0.012397 \text{ mA}$$

$$V_{TH} = I_{BQ}R_{TH} + V_{BE}(on) + I_{EQ}R_E = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC}$$

so $\frac{1}{R_1}(48.4)(12) = (0.012397)(48.4) + 0.7 + (1.5)(4)$

which yields $R_1 = 79.6 \text{ k}\Omega$ and $R_2 = 124 \text{ k}\Omega$

(b) $I_{CQ} = \left(\frac{120}{121}\right)(1.5) = 1.488 \text{ mA}$

$$r_\pi = \frac{(120)(0.026)}{1.488} = 2.097 \text{ k}\Omega, \quad r_o = \frac{50}{1.488} = 33.6 \text{ k}\Omega$$

$$A_\upsilon = \frac{(1+\beta)(r_o \| R_E \| R_L)}{r_\pi + (1+\beta)(r_o \| R_E \| R_L)}$$

Now $r_o \| R_E \| R_L = 33.6 \| 4 \| 4 = 1.888 \text{ k}\Omega$

$$A_\upsilon = \frac{(121)(1.888)}{2.097 + (121)(1.888)} = 0.991$$

(c) $R_o = R_E \| r_o \| \frac{r_\pi}{1+\beta} = 4 \| 33.6 \| \frac{2.097}{121} \Rightarrow R_o = 17.25 \, \Omega$

(d) $f_L = \frac{1}{2\pi(R_o + R_L)C_{C2}} = \frac{1}{2\pi(17.25 + 4000)(2 \times 10^{-6})}$

$f_L = 19.8 \text{ Hz}$

Solution 7.23

(a) $$\frac{V_{gs}}{V_i}=\frac{-\left(\frac{1}{g_m}\left\|\frac{1}{sC_i}\right.\right)}{\left(\frac{1}{g_m}\left\|\frac{1}{sC_i}\right.\right)+R_S}$$

Now $$\left(\frac{1}{g_m}\left\|\frac{1}{sC_i}\right.\right)=\frac{\left(\frac{1}{g_m}\right)\left(\frac{1}{sC_i}\right)}{\frac{1}{g_m}+\frac{1}{sC_i}}=\frac{\frac{1}{g_m}}{1+s\left(\frac{1}{g_m}\right)C_i}$$

So $$\frac{V_{gs}}{V_i}=\frac{-\frac{1}{g_m}}{\frac{1}{g_m}+R_S\left(1+s\left(\frac{1}{g_m}\right)C_i\right)}=\left(\frac{-\frac{1}{g_m}}{\frac{1}{g_m}+R_S}\right)\cdot\frac{1}{\left[1+s\left(\frac{1}{g_m}\|R_S\right)C_i\right]}$$

We have

$$V_o=-g_mV_{gs}\left[\frac{R_D}{R_D+R_L+\frac{1}{sC_C}}\right]\cdot R_L=-g_mV_{gs}\left[\frac{R_DR_L(sC_C)}{1+s(R_D+R_L)C_C}\right]$$

$$V_o=-g_mV_{gs}\left(\frac{R_DR_L}{R_D+R_L}\right)\left[\frac{s(R_D+R_L)C_C}{1+s(R_D+R_L)C_C}\right]$$

Then $$T(s)=\frac{V_o(s)}{V_i(s)}=\frac{+g_m(R_D\|R_L)}{1+g_mR_S}\cdot\frac{1}{\left[1+s\left(\frac{1}{g_m}\|R_S\right)C_i\right]}\cdot\left[\frac{s(R_D+R_L)C_C}{1+s(R_D+R_L)C_C}\right]$$

(b) $\tau=\left(\frac{1}{g_m}\|R_S\right)C_i$

(c) $\tau=(R_D+R_L)C_C$

Solution 7.29

(a) $V^+ = V_{CEQ} + I_{EQ} R_E$

$3.3 = 1.8 + (0.25)R_E \Rightarrow R_E = 6\ \text{k}\Omega$

$I_{BQ} = \dfrac{0.25}{121} = 0.002066\ \text{mA}$

$V^+ = I_{BQ} R_B + V_{BE}(on) + I_{EQ} R_E$

$3.3 = (0.002066)(R_B) + 0.7 + (0.25)(6) \Rightarrow R_B = 532\ \text{k}\Omega$

(b) $I_{CQ} = \left(\dfrac{120}{121}\right)(0.25) = 0.2479\ \text{mA}, \quad r_\pi = \dfrac{(120)(0.026)}{0.2479} = 12.59\ \text{k}\Omega$

$R_{ib} = r_\pi + (1+\beta)R_E = 12.59 + (121)(6) = 738.6\ \text{k}\Omega$

$R_i = R_B \| R_{ib} = 532 \| 738.6 = 309.25\ \text{k}\Omega$

$\tau_S = \dfrac{1}{2\pi f_L} = \dfrac{1}{2\pi(20)} = 0.007958 = (R_S + R_i)C_C$

so $C_C = \dfrac{0.007958}{(0.1 + 309.25)\times 10^3} \Rightarrow C_C = 0.0257\ \mu\text{F}$

(c) For $R_S << R_B$,

$A_\upsilon \cong \dfrac{(1+\beta)R_E}{r_\pi + (1+\beta)R_E} = \dfrac{(121)(6)}{12.59 + (121)(6)} = 0.983$

Solution 7.39

$$V_G = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD} \quad = \left(\frac{166}{166+234}\right)(10)$$
$$= 4.15 \text{ V}$$

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

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

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

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

$$g_m = 1.55\ mA/V$$

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

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

$$\tau = \left(R_o \| R_L\right)C_L \quad \text{and} \quad f_H = \frac{1}{2\pi\tau}$$

$$\text{BW} \cong f_H = 5\ \text{MHz} \Rightarrow \tau = \frac{1}{2\pi\left(5\times10^6\right)} = 3.18\times10^{-8}\ \text{s}$$

$$C_L = \frac{\tau}{R_o \| R_L} = \frac{3.18\times10^{-8}}{(0.282\|4)\times10^3} \Rightarrow C_L = 121\,\text{pF}$$