Homework 7, Solutions

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Solution 6.13

(a) $R_{TH} = R_1 \| R_2 = 33 \| 50 = 19.88\ \text{k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{CC} = \left(\frac{50}{50+33}\right)(3.3) = 1.988\ \text{V}$$

$$V_{CC} = I_{BQ}(1+\beta)R_E + V_{EB}(on) + I_{BQ}R_{TH} + V_{TH}$$

Then $I_{BQ} = \dfrac{3.3 - 0.7 - 1.988}{19.88 + (101)(1)} = 0.005063\ \text{mA}$

$I_{CQ} = 0.506\ \text{mA};\quad I_{EQ} = 0.511\ \text{mA}$

$$V_{ECQ} = V_{CC} - I_{CQ}R_C - I_{EQ}R_E = 3.3 - (0.506)(2) - (0.511)(1)$$

$V_{ECQ} = 1.78\ \text{V}$

(b) $r_\pi = \dfrac{\beta V_T}{I_{CQ}} = \dfrac{(100)(0.026)}{0.506} = 5.14\ \text{k}\Omega$

$$A_\upsilon = \frac{-\beta R_C}{r_\pi + (1+\beta)R_E} = \frac{-(100)(2)}{5.14 + (101)(1)} = -1.884$$

(c) $R_1 = (1.05)(33) = 34.65\ \text{k}\Omega$

$R_2 = (0.95)(50) = 47.5\ \text{k}\Omega$

$R_{TH} = R_1 \| R_2 = 34.65 \| 47.5 = 20.03\ \text{k}\Omega$

$$V_{TH} = \left(\frac{47.5}{47.5 + 34.65}\right)(3.3) = 1.908\ \text{V}$$

$$I_{CQ} = (100)\left(\frac{3.3 - 0.7 - 1.908}{20.03 + (101)(1)}\right) = 0.5718\ \text{mA}$$

$$r_\pi = \frac{(100)(0.026)}{0.5718} = 4.547\ \text{k}\Omega$$

$$A_\upsilon = \frac{-(100)(2)}{4.547 + (101)(1)} = -1.895$$

Also $R_1 = (0.95)(33) = 31.35\ \text{k}\Omega$

$R_2 = (1.05)(50) = 52.5\ \text{k}\Omega$

$R_{TH} = 31.35 \| 52.5 = 19.63\ \text{k}\Omega$

$$V_{TH} = \left(\frac{52.5}{52.5 + 31.35}\right)(3.3) = 2.066\ \text{V}$$

$$I_{CQ} = (100)\left(\frac{3.3 - 0.7 - 2.066}{19.63 + (101)(1)}\right) = 0.4427\ \text{mA}$$

$$r_\pi = \frac{(100)(0.026)}{0.4427} = 5.873\ \text{k}\Omega$$

$$A_\upsilon = \frac{-(100)(2)}{5.873 + (101)(1)} = -1.871$$

So $1.871 \le |A_\upsilon| \le 1.895$

Solution 6.19

(a) (i) $I_{BQ} = \dfrac{5-0.7}{2.5+(81)(10)} = 0.005292\ \text{mA}, \quad \Rightarrow I_{CQ} = 0.4234\ \text{mA}$

$$g_m = \frac{0.4234}{0.026} = 16.28\ \text{mA/V}, \quad r_\pi = \frac{(80)(0.026)}{0.4234} = 4.91\ \text{k}\Omega$$

$$A_\upsilon = -g_m\left(R_C \| R_L\right)\left(\frac{r_\pi}{r_\pi + R_S}\right) = -(16.28)(5\|5)\left(\frac{4.91}{4.91+2.5}\right) = -26.97$$

$$i_o = \frac{\upsilon_o}{R_L} = \frac{A_\upsilon \upsilon_s}{R_L}$$

or $\quad G_f = \dfrac{i_o}{\upsilon_s} = \dfrac{-26.97}{5} = -5.39\ \text{mA/V}$

(ii) $\upsilon_o = -(26.97)\left(4\times10^{-3}\sin\omega t\right) = -0.108\sin\omega t \ \ (\text{V})$

$i_o = \left(-5.39\times10^{-3}\right)\left(4\times10^{-3}\sin\omega t\right) \Rightarrow -21.6\sin\omega t \ \ (\mu\,\text{A})$

(b) (i) $I_{CQ} = (120)\left(\dfrac{5-0.7}{2.5+(121)(10)}\right) = 0.4256\ \text{mA}$

$$g_m = \frac{0.4256}{0.026} = 16.37\ \text{mA/V}, \quad r_\pi = \frac{(120)(0.026)}{0.4256} = 7.33\ \text{k}\Omega$$

$$A_\upsilon = -(16.37)(5\|5)\left(\frac{7.33}{7.33+2.5}\right) = -30.5$$

$$G_f = \frac{-30.5}{5} = -6.1\ \text{mA/V}$$

(ii) $\upsilon_o = -(30.5)\left(4\times10^{-3}\sin\omega t\right) = -0.122\sin\omega t \ \ (\text{V})$

$i_o = -24.4\sin\omega t \ \ (\mu\,\text{A})$

Solution 6.35

$I_{EQ} = 0.8\,\text{mA}, \quad I_{CQ} = 0.790\ \text{mA}, \quad I_{BQ} = 0.009877\ \text{mA}$

$V_E = 0.7 + (0.009877)(20) = 0.898\ \text{V}$

$V_C = (0.79)(2.5) - 5 = -3.025\ \text{V}$

Then $V_{ECQ} = V_E - V_C = 3.923\ \text{V}$

$\Delta V_{EC} = \Delta I_C (R_C \| R_L) = \Delta I_C (2.5 \| 4) = \Delta I_C (1.538)$

For $\Delta I_C = 0.79 - 0.08 = 0.71\,\text{mA}$, then $\Delta V_{EC} = (0.71)(1.538) = 1.09\ \text{V}$

So, $\Delta I_C = 2(0.71) = 1.42\,\text{mA}$ peak-to-peak,

$$\Delta i_o = \left(\frac{2.5}{2.5+4}\right)\Delta I_C = 0.546\ \text{mA peak-to-peak}$$

Solution 6.45

a.

$$R_{TH} = R_1 \| R_2 = 10 \| 10 = 5\ \text{k}\Omega$$

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

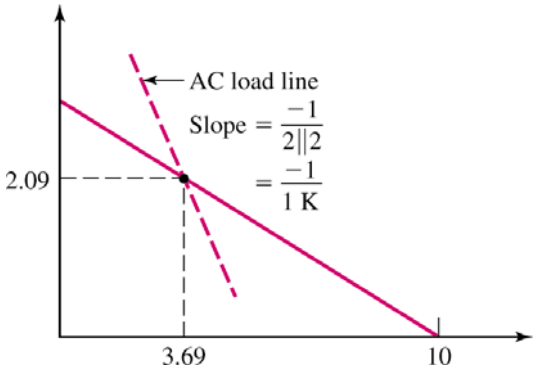
$$V_{TH} = I_{BQ} R_{TH} + V_{BE}(on) + (1+\beta) I_{BQ} R_E - 10$$

$$I_{BQ} = \frac{-5 - 0.7 - (-10)}{5 + (121)(2)} = 0.0174\ \text{mA}$$

$$I_{CQ} = 2.09\ \text{mA}, \quad I_{EQ} = 2.11\ \text{mA}$$

$$V_{CEQ} = 10 - (2.09)(1) - (2.11)(2) = 3.69\ \text{V}$$

b.



c.

$$r_\pi = \frac{(120)(0.026)}{2.09} = 1.49\ \text{k}\Omega$$

$$A_v = \frac{(1+\beta)(R_E \| R_L)}{r_\pi + (1+\beta)(R_E \| R_L)} \cdot \left(\frac{R_1 \| R_2 \| R_{ib}}{R_1 \| R_2 \| R_{ib} + R_S}\right)$$

$$R_{ib} = r_\pi + (1+\beta)(R_E \| R_L) = 1.49 + (121)(2 \| 2)$$

$$R_{ib} = 122.5\ k\Omega, \qquad R_1 \| R_2 \| R_{ib} = 5 \| 122.5 = 4.80\ k\Omega$$

$$A_v = \frac{(121)(2 \| 2)}{1.49 + (121)(2 \| 2)} \cdot \left(\frac{4.80}{4.80 + 5}\right) \Rightarrow \underline{A_v = 0.484}$$

d.

$$R_{ib} = r_\pi + (1+\beta)(R_E \| R_L)$$

$$R_{ib} = 1.49 + (121)(2 \| 2) \Rightarrow R_{ib} = 122\ \text{k}\Omega$$

$$R_o = R_E \left\| \left(\frac{r_\pi + R_1 \| R_2 \| R_S}{1+\beta}\right) = 2 \right\| \left(\frac{1.49 + 5 \| 5}{121}\right) \Rightarrow R_o = 32.4\,\Omega$$

Solution 6.51

$$R_{TH} = R_1 \| R_2 = 40 \| 60 = 24\,\text{k}\Omega$$

$$V_{TH} = \left(\frac{60}{60+40}\right)(10) = 6\,\text{V}$$

For $\beta = 75$, $I_{BQ} = \dfrac{6-0.7}{24+(76)(5)} = 0.0131\,\text{mA}$

$$I_{CQ} = 0.984\,\text{mA}$$

For $\beta = 150$, $I_{BQ} = \dfrac{6-0.7}{24+(151)(5)} = 0.00680\,\text{mA}$

$$I_{CQ} = 1.02\,\text{mA}$$

For $\beta = 75$, $r_\pi = \dfrac{(75)(0.026)}{0.984} = 1.98\,\text{k}\Omega$

For $\beta = 150$, $r_\pi = \dfrac{(150)(0.026)}{1.02} = 3.82\,\text{k}\Omega$

For $\beta = 75$, $R_{ib} = r_\pi + (1+\beta)(R_E \| R_L) = 65.3\,\text{k}\Omega$

For $\beta = 150$, $R_{ib} = 130\,\text{k}\Omega$

$$A_\upsilon = \frac{(1+\beta)(R_E \| R_L)}{r_\pi + (1+\beta)(R_E \| R_L)} \cdot \frac{R_1 \| R_2 \| R_{ib}}{R_1 \| R_2 \| R_{ib} + R_S}$$

For $\beta = 75$, $R_1 \| R_2 \| R_{ib} = 40 \| 60 \| 65.3 = 17.5\,\text{k}\Omega$

$$A_\upsilon = \frac{(76)(0.833)}{1.98+(76)(0.833)} \cdot \frac{17.5}{17.5+4} = 0.789$$

For $\beta = 150$, $R_1 \| R_2 \| R_{ib} = 40 \| 60 \| 130 = 20.3\,\text{k}\Omega$

$$A_\upsilon = \frac{(151)(0.833)}{3.82+(151)(0.833)} \cdot \frac{20.3}{20.3+4} = 0.811$$

So $0.789 \le A_v \le 0.811$

$$A_i = (1+\beta)\left(\frac{R_E}{R_E+R_L}\right)\left(\frac{R_{TH}}{R_{TH}+R_{ib}}\right)$$

$\beta = 75$

$$A_i = (76)\left(\frac{5}{5+1}\right)\left(\frac{24}{24+65.3}\right) \Rightarrow \underline{A_i = 17.0}$$

$\beta = 150$

$$A_i = (151)\left(\frac{5}{6}\right)\left(\frac{24}{24+130}\right) \Rightarrow \underline{A_i = 19.6}$$

$\underline{17.0 \le A_i \le 19.6}$