Homework 8 Solutions

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Solution 6.71

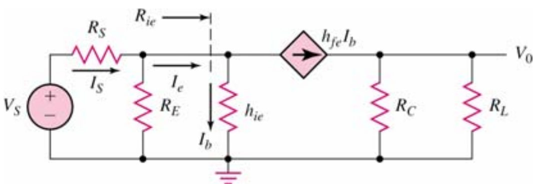
a.

$$I_{EQ} = \frac{20-0.7}{10} = 1.93 \text{ mA}$$

$$\underline{I_{CQ} = 1.91 \text{ mA}}$$

$$V_{ECQ} = V_{CC} + V_{EB}(\text{on}) - I_C R_C$$
$$= 25 + 0.7 - (1.91)(6.5) \Rightarrow \underline{V_{ECQ} = 13.3 \text{ V}}$$

b.



Neglect effect h_{oe}
Assume

$$2.45 \le h_{ie} \le 3.7 \text{ k}\Omega$$
$$80 \le h_{fe} \le 120$$
$$V_o = (h_{fe} I_b)(R_C \| R_L)$$
$$R_{ie} = \frac{h_{ie}}{1+h_{fe}}, \quad I_e = \left(\frac{R_E}{R_E + R_{ie}}\right) \cdot I_s$$
$$I_b = \left(\frac{I_e}{1+h_{fe}}\right), \quad I_s = \frac{V_s}{R_S + (R_E \| R_{ie})}$$
$$A_\upsilon = \left(\frac{h_{fe}}{1+h_{fe}}\right)(R_C \| R_L)\left(\frac{R_E}{R_E + R_{ie}}\right)\left(\frac{1}{R_S + R_E \| R_{ie}}\right)$$

High gain device: $h_{ie} = 3.7 \text{ k}\Omega,\ h_{fe} = 120$

$$R_{ie} = \frac{3.7}{121} = 0.0306 \text{ k}\Omega$$
$$R_E \| R_{ie} = 10 \| 0.0306 = 0.0305 \text{ k}\Omega$$
$$A_\upsilon = \left(\frac{120}{121}\right)(6.5 \| 5)\left(\frac{10}{10+0.0306}\right)\left(\frac{1}{1+0.0305}\right) \Rightarrow A_\upsilon = 2.711$$

Low gain device: $h_{ie} = 2.45 \text{ k}\Omega,\ h_{fe} = 80$

$$R_{ie} = \frac{2.45}{81} = 0.03025 \text{ k}\Omega$$
$$R_E \| R_{ie} = 10 \| 0.03025 = 0.0302 \text{ k}\Omega$$
$$A_\upsilon = \left(\frac{80}{81}\right)(6.5 \| 5)\left(\frac{10}{10+0.03025}\right)\left(\frac{1}{1+0.0302}\right) \Rightarrow A_\upsilon = 2.70$$

$\underline{2.70 \le A_v \le 2.71}$ So $A_\upsilon \cong$ constant c.

$$R_i = R_E \| R_{ie}$$

We found $\underline{0.0302 \le R_i \le 0.0305 \text{ k}\Omega}$

Neglecting h_{oe}, $\underline{R_o = R_C = 6.5 \text{ k}\Omega}$

Solution 6.73

(a) $g_{m1} = g_{m2} = \dfrac{1}{0.026} = 38.46 \text{ mA/V}$

$$r_{\pi 1} = \frac{(120)(0.026)}{1} = 3.12 \text{ k}\Omega, \quad r_{\pi 2} = \frac{(80)(0.026)}{1} = 2.08 \text{ k}\Omega$$

$$A_{\upsilon 1} = \frac{V_{o1}}{V_i} = \frac{(1+\beta_1)\left(R_E \middle\| \dfrac{r_{\pi 2}}{1+\beta_2}\right)}{r_{\pi 1} + (1+\beta_1)\left(R_E \middle\| \dfrac{r_{\pi 2}}{1+\beta_2}\right)}$$

We find $R_E \left\| \dfrac{r_{\pi 2}}{1+\beta_2} = 1 \right\| \dfrac{2.08}{81} = 0.02504 \text{ k}\Omega$

Then $A_{\upsilon 1} = \dfrac{(121)(0.02504)}{3.12 + (121)(0.02504)} = 0.4927$

(b) $A_{\upsilon 2} = \dfrac{V_{o2}}{V_{o1}} = g_{m2} R_C = (38.46)(4) = 153.8$

(c) $A_\upsilon = A_{\upsilon 1} \cdot A_{\upsilon 2} = (0.4927)(153.8) = 75.8$

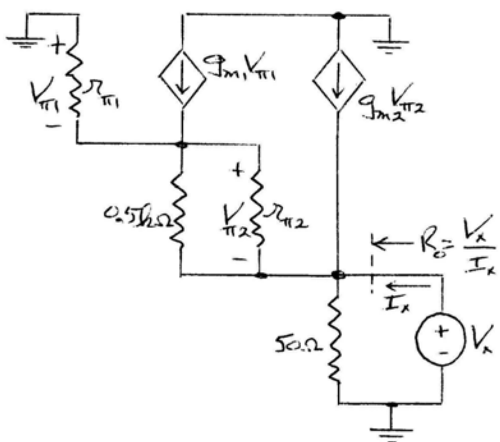
Solution 6.77

(a) $I_{R2} = \frac{5-2(0.7)}{0.050} = 72\,\text{mA}, \quad I_{R1} = \frac{0.7}{0.5} = 1.4\,\text{mA}$

$I_{E2} = 72 - 1.4 = 70.6\,\text{mA}, \quad I_{C2} = \left(\frac{80}{81}\right)(70.6) = 69.73\,\text{mA}, \quad I_{B2} = \frac{70.6}{81} = 0.8716\,\text{mA}$

$I_{E1} = 1.4 + 0.8716 = 2.2716\,\text{mA}, \quad I_{C1} = \left(\frac{120}{121}\right)(2.2716) = 2.253\,\text{mA}$

(b)



$$g_{m1} = \frac{2.253}{0.026} = 86.65\,\text{mA/V}, \quad g_{m2} = \frac{69.73}{0.026} = 2681.9\,\text{mA/V}$$

$$r_{\pi1} = \frac{(120)(0.026)}{2.253} = 1.385\,\text{k}\Omega\,, \quad r_{\pi2} = \frac{(80)(0.026)}{69.73} = 0.02983\,\text{k}\Omega$$

$$V_s = V_{\pi1} + V_{\pi2} + V_o$$

$$V_o = \left[\left(\frac{V_{\pi1}}{r_{\pi1}} + g_{m1}V_{\pi1}\right) + g_{m2}V_{\pi2}\right](0.05)$$

$$V_{\pi2} = \left(\frac{V_{\pi1}}{r_{\pi1}} + g_{m1}V_{\pi1}\right)(0.5\|r_{\pi2}) = V_{\pi1}\left(\frac{1}{1.385} + 86.65\right)(0.5\|0.02983) = V_{\pi1}(2.4595)$$

$$V_o = \left[V_{\pi1}\left(\frac{1}{1.385} + 86.65\right) + (2681.9)V_{\pi1}(2.4595)\right](0.05) = V_{\pi1}(334.175)$$

$$V_s = V_{\pi1} + V_{\pi2} + V_o = V_{\pi1} + V_{\pi1}(2.4595) + V_o$$

So $V_{\pi1} = (V_s - V_o)(0.28906)$

And $V_o = (334.175)(V_s - V_o)(0.28906) = 96.596(V_s - V_o)$

$$A_\upsilon = \frac{V_o}{V_s} = 0.990$$

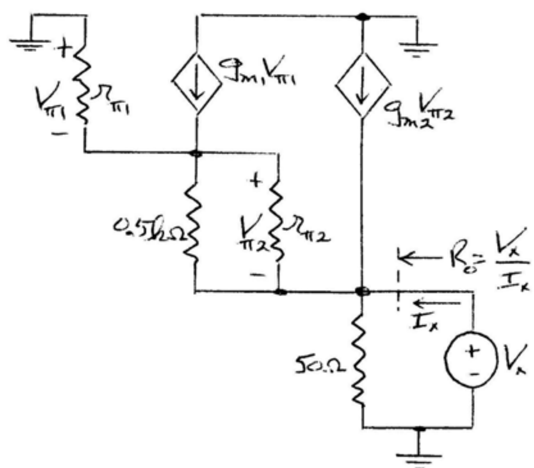
(c) For R_{ib}:

We have $V_o = (0.989754)V_s$

$$V_{\pi 1} = (V_s - V_o)(0.28906) = V_s(1 - 0.98975)(0.28906) = V_s(0.0029618)$$

$$R_{ib} = \frac{V_s}{I_s} = \frac{V_s}{\left(V_{\pi 1}/r_{\pi 1}\right)} = \frac{r_{\pi 1}}{0.0029618} \Rightarrow R_{ib} = 467.6\ \mathrm{k}\Omega$$

For R_o:



(1) $V_{\pi 1} + V_{\pi 2} + V_x = 0$

(2) $I_x + g_{m2}V_{\pi 2} + \left(\frac{V_{\pi 1}}{r_{\pi 1}} + g_{m1}V_{\pi 1}\right) = \frac{V_x}{0.05}$

We had $V_{\pi 2} = V_{\pi 1}(2.4595)$

(1) $V_{\pi 1} + V_{\pi 1}(2.4595) + V_x = 0 \Rightarrow V_{\pi 1} = -V_x(0.28906)$

(2) $I_x + g_{m2}V_{\pi 1}(2.4595) + V_{\pi 1}\left(\frac{1}{r_{\pi 1}} + g_{m1}\right) = \frac{V_x}{0.05}$

$$I_x + V_{\pi 1}\left[(2681.9)(2.4595) + \left(\frac{1}{1.385} + 86.65\right)\right] = \frac{V_x}{0.05}$$

$$I_x - V_x(0.28906)[6683.5] = \frac{V_x}{0.05}$$

$$R_o = \frac{V_x}{I_x} = 0.512\ \Omega$$

Problem 7.5

Consider the circuit shown in Figure P7.5. (a) What is the value of the voltage transfer function V_o/V_i at very low frequencies? (b) Determine the voltage transfer function at very high frequencies. (c) Derive the expression for the voltage transfer function $T(s)=V_o(s)/V_i(s)$. Put the expression in the form $T(s)=K(1+s\tau_A)/(1+s\tau_B)$. What are the values of K, τ_A, and τ_B?

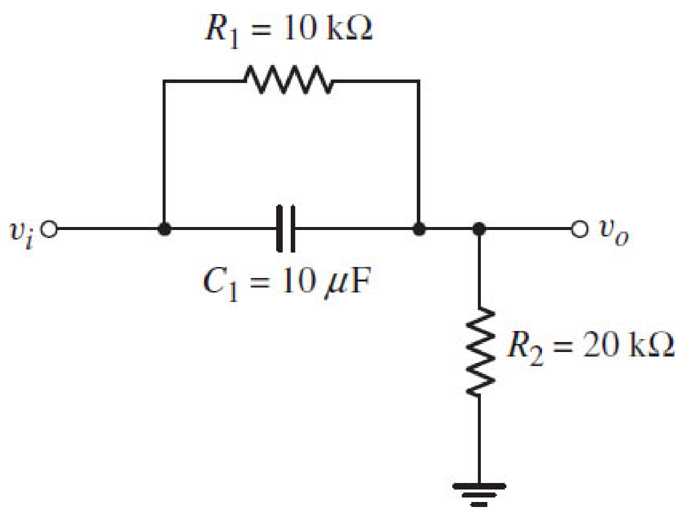


Figure P7.5

Problem 7.7

A voltage transfer function is given by $T(f) = 1/(1 + jf / f_T)^3$. (a) Show that the actual response at $f = f_T$ is approximately 9 dB below the maximum value. What is the phase angle at this frequency? (b) What is the slope of the magnitude plot for $f >> f_T$? What is the phase angle in this frequency range?