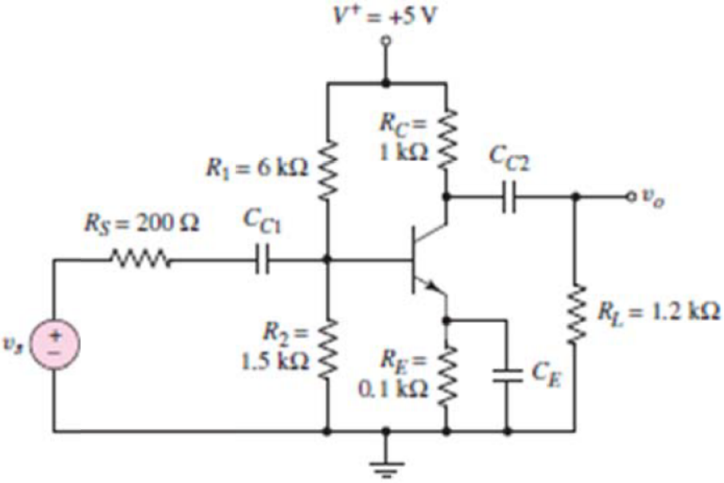
14. Refer to the BJT amplifier below. Determine the q-point values, small signal hybrid-π parameters and small signal voltage gain ($A_v = v_o/v_i$), if $\beta = 180$ and $r_o = \infty$.



a.

$$R_{TH} = R_1 \| R_2 = 6 \| 1.5 = 1.2\ \text{k}\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V^+ = \left(\frac{1.5}{1.5+6}\right)(5) = 1.0\ \text{V}$$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta) R_E} = \frac{1.0 - 0.7}{1.2 + (181)(0.1)} = 0.0155\ \text{mA}$$

$\underline{I_{CQ} = 2.80\ \text{mA}}$, $I_{EQ} = 2.81$

$$V_{CEQ} = V^+ - I_{CQ} R_C - I_{EQ} R_E$$

$$= 5 - (2.8)(1) - (2.81)(0.1) \Rightarrow \underline{V_{CEQ} = 1.92\ \text{V}}$$

b.

$$r_\pi = \frac{(180)(0.026)}{2.80} \Rightarrow \underline{r_\pi = 1.67\ \text{k}\Omega}$$

$$g_m = \frac{2.80}{0.026} \Rightarrow \underline{g_m = 108\ \text{mA/V}},\ r_0 = \text{`}$$

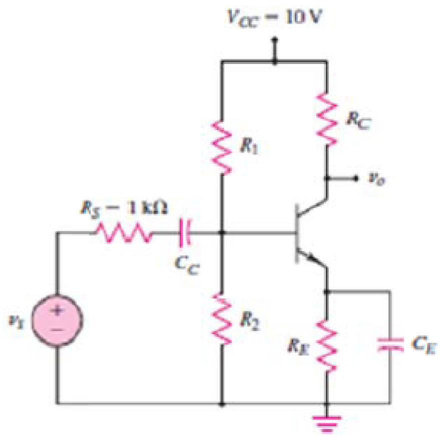
(c)

$$A_v = 2\, g_m \left(\frac{R_1 \| R_2 \| r_\pi}{R_1 \| R_2 \| r_\pi + R_S}\right)(R_C \| R_L)$$

$$R_1 \| R_2 \| r_\pi = 6 \| 1.5 \| 1.67 = 0.698\ kV$$

$A_v =$ [redacted] $(108)\left(\dfrac{0.698}{0.698+0.2}\right)(1 \| 1.2) \Rightarrow A_v =$ [redacted] 45.8

15. Design a single stage BJT amplifier for a microphone of 1kΩ series resistance. The microphone produces 10 mV (rms) and the required output voltage is 0.5V (rms). Calculate the component values that are used in the circuit while assuming suitable device parameters (eg. β).



Assume an npn transistor with $b = 100$ and $V_A = \infty$. Let $V_{CC} = 10\ V$.

$$|A_v| = \frac{0.5}{0.01} = 50$$

Bias at $I_{CQ} = 1\ mA$ and let $R_E = 1\ k\Omega$

For a bias stable circuit

$$R_{TH} = (0.1)(1+b)R_E = (0.1)(101)(1) = 10.1\ k\Omega$$

$$V_{TH} = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = \frac{1}{R_1}(10.1)(10) = \frac{101}{R_1}$$

$$I_{BQ} = \frac{1}{100} = 0.01\ mA$$

$$V_{TH} = I_{BQ}R_{TH} + V_{BE}(on) + (1+b)I_{BQ}R_E$$

$$\frac{101}{R_1} = (0.01)(10.1) + 0.7 + (101)(0.01)(1)$$

which yields $\underline{R_1 = 55.8\ k\Omega}$ and $\underline{R_2 = 12.3\ k\Omega}$

Now

$$r_\pi = \frac{(100)(0.026)}{1} = 2.6\ k\Omega$$

$$g_m = \frac{1}{0.026} = 38.46\ mA/V$$

$$V_o = -g_m V_\pi R_C$$

where $V_\pi = \left(\dfrac{R_1 \| R_2 \| r_\pi}{R_1 \| R_2 \| r_\pi + R_S} \right) \cdot V_s = \left(\dfrac{10.1 \| 2.6}{10.1 \| 2.6 + 1} \right) . V_s$

or $V_\pi = 0.674\ V_s$

Then $A_v = \dfrac{V_o}{V_s} = -(0.674)\, g_m R_C = -(0.674)(38.46) R_C = -50$

which yields $\underline{R_C = 1.93\ k\Omega}$

With this R_C, the dc bias is OK.

Finish Design, Set $R_C = 2$ K $\qquad R_E = 1$ K

$$R_1 = 56\ \text{K}$$

$$R_2 = 12\ \text{K}$$

$$R_{TH} = R_1 \| R_2 = 9.88\ \text{K}$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2} \right) V_{CC} = \left(\frac{12}{12 + 56} \right) (10) = 1.765\ \text{V}$$

$$I_{BQ} = \frac{1.765 - 0.7}{9.88 + (101)(1)} = 9.60\ \mu\text{A}$$

$$I_{CQ} = 0.9605\ \text{mA}$$

$$r_\pi = \frac{(100)(0.026)}{0.9605} = 2.707\ \text{K} \quad g_m = \frac{0.9605}{0.026} = 36.94$$

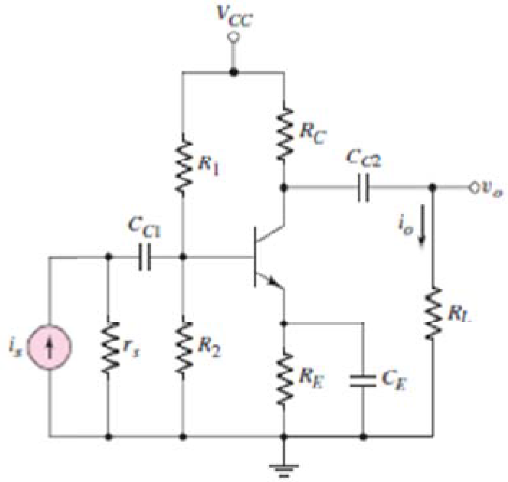
$$R_{TH} \| r_\pi = 2.125\ \text{K}$$

$$V_\pi = \left(\frac{R_{TH} \| r_\pi}{R_{TH} \| r_\pi + R_S} \right) V_s = \left(\frac{2.125}{2.125 + 1} \right) V_s = (0.680)\ V_s$$

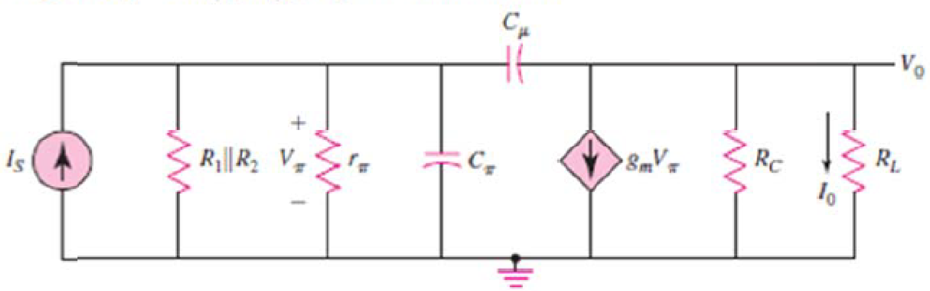
$$A_v = -(0.680)\, g_m R_C = -(0.680)(36.94)(2) = -50.2$$

This meets the design specifications.

16. Consider the circuit shown below. Let, $R_1//R_2=5k$, $r_s=\infty$, $R_C=R_L=1k\Omega$, $I_{cq}=5mA$, $\beta_o=200$, $V_A=\infty$, $C_\mu=5pF$ and $f_T=250$ MHz. Find the upper cut-off frequency for a small signal current gain.



High Freq. $\Rightarrow C_{C1}, C_{C2}, C_E \rightarrow$ short circuits



$$g_m = \frac{I_{CQ}}{V_T} = \frac{5}{0.026} = 192.3 \text{ mA/V}$$

$$f_T = \frac{g_m}{2\pi\left(C_\pi + C_\mu\right)} \Rightarrow 250\times10^6 = \frac{192\times10^{-3}}{2\pi\left(C_\pi + C_\mu\right)}$$

$$C_\pi + C_\mu = 122.4 \text{ pF} \Rightarrow C_\mu = 5 \text{ pF}, C_\pi = 117.4 \text{ pF}$$

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

$$= 5\left[1 + (192.3)(1\|1)\right] \Rightarrow C_M = 485.8 \text{ pF}$$

$$C_i = C_\pi + C_M = 117 + 485 = 603 \text{ pF}$$

$$r_\pi = \frac{(200)(0.026)}{5} = 1.04 \text{ k}\Omega$$

$$R_{eq} = R_1\|R_2\|r_\pi = 5\|1.04 = 0.861 \text{ k}\Omega$$

$$\tau = R_{eq}\cdot C_i = \left(0.861\times10^3\right)\left(603\times10^{-12}\right)$$

$$= 5.19\times10^{-7} \text{ s}$$

$$f = \frac{1}{2\pi\tau} = \frac{1}{2\pi\left(5.19\times10^{-7}\right)} \Rightarrow \underline{f = 307 \text{ kHz}}$$