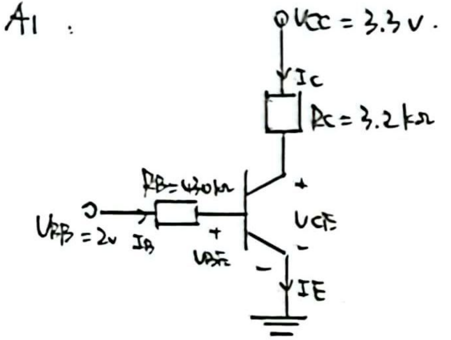
EEE 211 Assignment 1

Q1: $V_{BB} = 2V$, $V_{CC} = 3.3V$, $R_C = 3.2k\Omega$

$R_B = 430k\Omega$, $\beta = 150$, $V_{BE} = 0.7V$

Find base, collector and emitter currents and V_{CE}

A1:



Step 1: KVL around B-E loop.

$\Rightarrow V_{BB} = I_B \cdot R_B + V_{BE}$

Step 2: Assume transistor is biased in forward-active Mode and $I_E = (1+\beta) I_B$,

We can then write base current as

$$\Rightarrow I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{2-0.7}{430k} = 3.023\,\mu A$$

Step 3: Collector Current, $I_C = \beta \cancel{I_E}^{I_B} = 150 \times 3.023\mu = 0.453mA$

Step 4: Emitter Current, $I_E = (1+\beta) i_B = 151 \times 3.023\mu = 0.457mA$

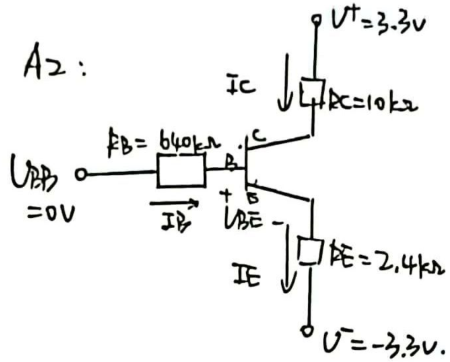
Step 5: CE voltage, KVL around CE Loop

$\Rightarrow V_{CE} = V_{CC} - I_C \cdot R_C = 3.3 - 0.453m \times 3.2k = 1.850V$

Step 6: Verification: $V_{CE} = 1.850V > 0.7V$ Verifies the forward-active mode assumption

Q2: Calculate the characteristics (I_C, V_{CE}) of a circuit including base and emitter currents, which consists of an emitter resistor. The circuit parameters are annotated in the figure and $\beta = 80$ and $V_{BE(on)} = 0.7V$

A2:



Step 1: KVL around B-E loop.

$\Rightarrow V_{BB} = I_B \cdot R_B + V_{BE(on)} + I_E \cdot R_E + V^-$

Step 2: Assume transistor is biased in forward-active Mode and $I_E = (1+\beta) I_B$,

We can then write base current as

$$\Rightarrow I_B = \frac{V_{BB} - V^- - V_{BE(on)}}{R_B + (1+\beta) R_E} = \frac{0-(-3.3)-0.7}{640k + (1+80)\cdot 2.4k} = \cancel{3.12}^{3.116}\,\mu A$$

Step 3: Collector Current, $I_C = \beta i_B = 80 \times 3.12\mu A = 0.249\,mA$

Step 4: Emitter Current, $I_E = (1+\beta) i_B = (1+80) \times 3.12\mu A = 0.252\,mA$

Step 5: CE Voltage, KVL around C-E loop

$\Rightarrow V_{CE} = V^+ - I_C \cdot R_C - I_E \cdot R_E - V^- = 3.3 - 0.249m \cdot 10k - 0.252 \cdot 2.4k + 3.$

$\Rightarrow V_{CE} = 3.505\,V$

Step 6: Verification: $V_{CE} = 3.505V > 0.7V$ verifies the forward-active assumpt

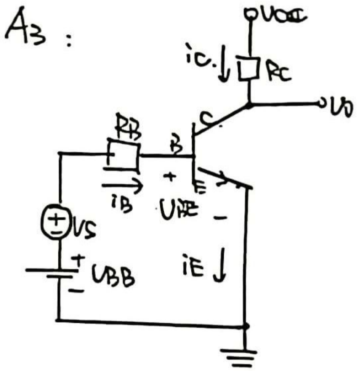
Q3 : For the circuit shown in Fig.3, assume $V_{CC} = 5V$, $V_{BB} = 1.025V$, $R_B = 100k\Omega$, $R_C = 6k\Omega$, $\beta = 150$, $V_{BE(on)} = 0.7V$, $V_A = 150V$

(a) Calculate the Q-point values (I_{CQ}, V_{CEQ}) using DC Analysis

(b) Determine the small signal hybrid-π parameters (r_π, g_m, r_o)

(c) Find the small signal voltage gain $A_v = V_o/V_s$

A3 :



(a) step1 : For the DC Analysis, we set $V_s = 0$.

step2 : KVL around B-E loop.

$V_{BB} = I_{BQ} \cdot R_B + V_{BE(on)} + 0$

step3 : Assume transistor is biased in forward-active mode and $I_{EQ} = (1+\beta) I_{BQ}$.

we can write base current (Q-point)

as $I_{BQ} = \dfrac{V_{BB} - V_{BE(on)}}{R_B} = \dfrac{1.025 - 0.7}{100k} \doteq 3.250\mu A$

step4 : Collector Current, $I_{CQ} = \beta I_{BQ}$

$I_{CQ} = 150 \times 3.250\mu = 0.488 \ mA$

step5 : Emitter Current, $I_{EQ} = (1+\beta) I_{BQ}$

$I_{EQ} = (150+1) \times 3.250\mu = 0.491 \ mA$

step6 : $V_{CEQ} = V_{CC} - I_{CQ} \cdot R_C = 5 - 0.488m \times 6k = 2.07V$

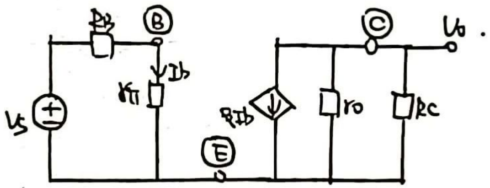
(b). $r_\pi = \dfrac{\beta V_T}{I_{CQ}} = \dfrac{150 \times 26m}{0.488m} = 8.0k\Omega$

$g_m = \dfrac{\beta}{r_\pi} = \dfrac{150}{8.0k} = 18.77 mA/V$

$r_o = \dfrac{V_A}{I_{CQ}} = \dfrac{150}{0.488m} = 307k\Omega$.

(c) Step1 : For the AC Analysis. We set DC sources to 0

step2 : Draw the Small-signal hybrid-π Equivalent Circuit.



Step3 : $V_s = I_b(R_B + r_\pi)$

Step4 : $V_o = -\beta I_b(r_o \| R_C)$

Step5 : $A_v = \dfrac{V_o}{V_s} = \dfrac{-\beta I_b(r_o\|R_C)}{I_b(R_B + r_\pi)}$

$= (-\beta) \dfrac{\frac{r_o \cdot R_C}{r_o + R_C}}{R_B + r_\pi}$

$= (-150) \cdot \dfrac{\frac{307k \cdot 6k}{307k + 6k}}{100k + 8k}$

$= -8.17$

Q4: For the Circuit shown in Fig.4, $R_E = 0.6k\Omega$, $R_C = 5.6k\Omega$, $\beta = 120$, $V_{BE(on)} = 0.7$, $R_1 = 250k\Omega$, $R_2 = 75k\Omega$.

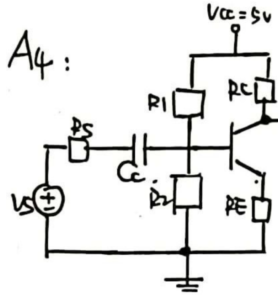
(a) Calculate Q-point values (I_{CQ}, V_{CEQ}) using DC Analysis.

(b) Determine the small signal hybrid-π parameters (r_π, g_m, r_o)

(c) Find the small signal voltage gain $A_v = V_o/V_s$, assuming $V_A = \infty$

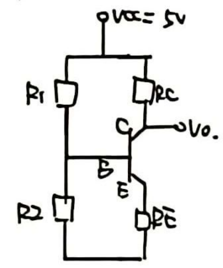
(d) Determine the Input resistance looking into the base of transistor

A4 :

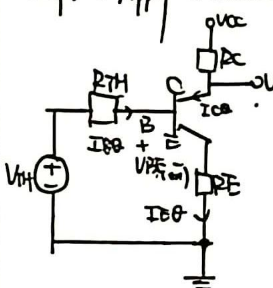


(a) Step1 : For DC Analysis, we set $V_s = 0$, Capacitor : open circuit

step2 : Draw the DC circuit.



step3 : Apply Thevenin Equivalent Circuit.



$V_{TH} = \dfrac{R_2}{R_1 + R_2} V_{CC}$

$= \dfrac{75k}{250k + 75k} \times 5$

$= 1.15V$

$R_{TH} = \dfrac{R_2 \times R_1}{R_2 + R_1}$

$= \dfrac{75k \times 250k}{\dots} = 58k\Omega$

step4 : KVL around BE loop

$\Rightarrow V_{TH} = R_{TH} \cdot I_{BQ} + V_{BE(on)} + I_{EQ} \cdot R_E$

step5 : Assume transistor is biased in forward-active mode and $I_{EQ} = (1+\beta) I_{BQ}$

we can write base current (Q-point)

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

$= \dfrac{1.15 - 0.7}{58k + (1+120) \times 0.6}$

$= 3.446 \ \mu A$

step6 : Collector Current, $I_{CQ} = \beta I_{BQ}$.

$\Rightarrow I_{CQ} = 120 \times 3.446 \mu A = 0.414 mA$

step7 : Emitter Current, $I_{EQ} = (1+\beta) I_{BQ}$

$\Rightarrow I_{EQ} = (120+1) \times 3.446\mu A = 0.417 \ mA$

Step8 : V_{CEQ}, KVL around CE loop

$\Rightarrow V_{CEQ} = V_{CC} - I_{CQ} \cdot R_C - I_{EQ} \cdot R_E$

$= 5 - 0.414m \cdot 5.6k - 0.417m \cdot 0.6k$

$= 2.431 \ V$

(b) Step 1 : parameters for AC

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{120\times 26m}{0.414m} = 7.5k\Omega.$$

$$g_m = \frac{\beta}{r_\pi} = \frac{120}{7.5k} = 15.92\,mA/V$$

$$r_o = \frac{V_A}{I_{CQ}} = \frac{\infty}{0.414m} = \infty$$

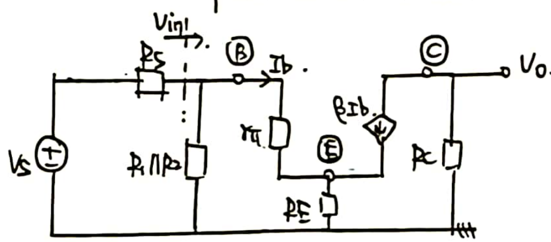
which means we can neglect Early Effect

(c) Step 1 : For the AC Analysis

we set DC sources to 0

Step 2 : Draw the small-signal hybrid-π Equivalent Circuit

(Capacitor is seen as Short Circuit)



Step 3 : $V_s = V_{in}\cdot\frac{(R_1\|R_2)+R_S}{R_1\|R_2}$

$V_{in} = I_b\cdot[r_\pi + (1+\beta)R_E]$

Step 4 : $V_o = -\beta I_b\cdot R_C.$

Step 5 : $A_v = \frac{V_o}{V_s} = \frac{-\beta I_b\cdot R_C}{I_b[r_\pi+(1+\beta)R_E]}\cdot\frac{(R_1\|R_2)}{(R_1\|R_2)+R_S}$

$$= \frac{-120\times 5.6k}{7.5k+(1+120)\times 0.6k}\cdot\frac{\frac{250k\times 75k}{250k+75k}}{\frac{250k\times75k}{250k+75k}+0.5k}$$

$$= -8.318$$

(d) Step 1 : $R_{in} = \frac{V_{in}}{I_{in}}.$

$$= \frac{I_b[r_\pi+(1+\beta)R_E]}{I_b}.$$

$$= r_\pi + (1+\beta)R_E$$

$$= 7.5k + (1+120)\times 0.6k$$

$$= 80.1\,k\Omega.$$

Q5: For the circuit shown as Fig.5, $V_{CC}=V_{EE}=3.3V$

$R_S = 500k\Omega$, $R_L = 6k\Omega$, $R_B = 100k\Omega$, $R_E = 12k\Omega$

$R_C = 12k\Omega$, $\beta = 120$, $V_{BE(on)} = 0.7V$, $V_A=\infty$

(a) Calculate Q-point values : I_{CQ}, V_{CEQ}

(b) Determine small signal hybrid-π parameters (r_π, g_m, r_o)

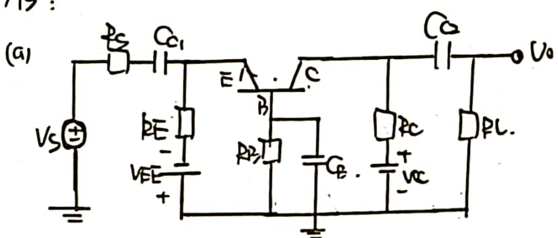
(c) Find $A_v = V_o/V_s$

(d) Find the small signal current gain $A_i = i_o/i_i$

(e) Determine the input resistance R_i and output resistance R_o.

A5:

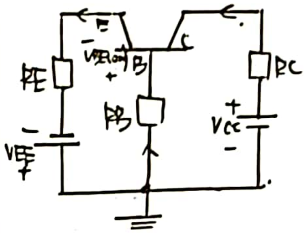
(a)



Step 1 : For DC Analysis

we set $\begin{cases} V_S = 0 \\ \text{Capacitors - open circuit.}\end{cases}$

Step 2 : Draw the DC Circuit.



Step 3 : KVL around B-E loop.

$\Rightarrow V_{EE} = R_B\cdot I_{BQ} + V_{BE(on)} + I_{EQ}\cdot R_E$

Step 4 : Assume transistor is biased in forward-active mode and

$I_{EQ} = (1+\beta)\cdot I_{BQ}$

we can write Base current (Q-point)

$$\Rightarrow I_{BQ} = \frac{V_{EE}-V_{BE(on)}}{R_B+(1+\beta)\cdot R_E}$$

$$= \frac{3.3-0.7}{100k+(1+120)\times 12k}$$

$$= 1.675\,\mu A$$

Step 5 : Collector Current, $I_{CQ} = \beta I_{BQ}$.

$\Rightarrow I_{CQ} = 120\times 1.675\,\mu A = 0.201\,mA$

Step 6 : Emitter Current, $I_{EQ} = (1+\beta)I_{BQ}$

$\Rightarrow I_{EQ} = (1+120)\times 1.675\mu A = 0.203\,mA$

Step 7 : V_{CEQ}, KVL around C-E loop

$\Rightarrow V_{CC} = V_{CEQ} + I_{EQ}\cdot R_E - V_{EE}$

$\Rightarrow V_{CEQ} = V_{CC}+V_{EE} - I_{EQ}\cdot R_E$

$$= 3.3+3.3-0.203m\cdot 12k$$

$$= 4.164\,V$$

(b) $r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{120 \times 26m}{0.201m} = \cancel{1.55k\Omega} = 15.52k$

$g_m = \frac{\beta}{r_\pi} = \frac{120}{1.55k} = 7.731 \ mA/V$

$r_o = \frac{V_A}{I_{CQ}} = \frac{\infty}{0.201m} = \infty$

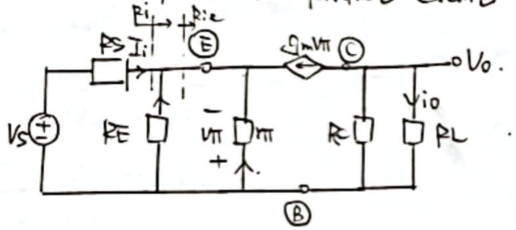
which means that we can neglect Early Effect

(c) Step 1 : For the AC Analysis,

we set DC sources to 0

Step 2 : Draw the Small-Signal

hybrid-π Equivalent Circuit



Step 3 : KCL at Emitter Node.

$$\Rightarrow g_m V_\pi + \frac{V_\pi}{r_\pi} + \frac{V_\pi}{R_E} + \frac{V_s - (-V_\pi)}{R_S} = 0$$

$$\Rightarrow V_\pi = \frac{-V_s}{R_S} \cdot \frac{1}{g_m + \frac{1}{r_\pi} + \frac{1}{R_E} + \frac{1}{R_S}}$$

$$g_m = \frac{\beta}{r_\pi}$$

$$\Rightarrow V_\pi = \frac{-V_s}{R_S}\left(\frac{r_\pi}{1+\beta} \parallel R_E \parallel R_S\right)$$

Step 4 : $V_o = -g_m V_\pi \cdot (R_C \parallel R_L)$

Step 5 : $A_V = \frac{V_o}{V_S} = (-g_m)(R_C \parallel R_L) \cdot \frac{\frac{-V_s}{R_S} \cdot \left(\frac{r_\pi}{1+\beta} \parallel R_E \parallel R_S\right)}{V_S}$

$$\Rightarrow A_v = g_m \cdot \frac{R_C \parallel R_L}{R_S} \cdot \left[\frac{r_\pi}{1+\beta} \parallel R_E \parallel R_S\right]$$

$$\Rightarrow A_v = 7.731m \cdot \frac{\frac{12k \times 6k}{12k+6k}}{500k} \times \frac{1}{\frac{1+120}{\cancel{1.55k}\ 15.52} + \frac{1}{12k} + \frac{1}{500k}}$$

$\cancel{\Rightarrow A_v = 7.4847 \times 10^{-3}}$ $A_v = 7.847$

(d) Step 1 : ~~Put~~ KCL at Emitter Node.

$$\Rightarrow g_m V_\pi + \frac{V_\pi}{r_\pi} + \frac{V_\pi}{R_E} + i_i = 0$$

$$\Rightarrow i_i = -V_\pi \cdot \left(\frac{1+\beta}{r_\pi} + \frac{1}{R_E}\right)$$

$$\Rightarrow i_i = -V_\pi \cdot \left(\frac{r_\pi}{1+\beta} \parallel R_E\right)^{-1}$$

Step 2 : Ohm's Law at Collector Node

$$\Rightarrow i_o = -g_m V_\pi \cdot \frac{R_C}{R_C + R_L}$$

Step 3 : $A_i = \frac{i_o}{i_i}$

$$\Rightarrow A_i = \frac{i_o}{i_i}$$

$$= \frac{(-g_m) \cdot V_\pi \cdot \frac{R_C}{R_C+R_L}}{(-1) \cdot V_\pi \cdot \left(\frac{r_\pi}{1+\beta} \parallel R_E\right)^{-1}}$$

$$= g_m \cdot \cancel{V_\pi} \frac{R_C}{R_C+R_L} \cdot \left[\left(\frac{r_\pi}{1+\beta}\right) \parallel R_E\right]$$

$$= 7.731m \cdot \frac{12k}{12k+6k} \cdot \frac{\frac{15.52k}{1+120} \times 12k}{\frac{15.52k}{1+120} + 12k}$$

$$= 0.654$$

(e) Step 1 : R_i : Input Resistance

~~$R_i = R_E \parallel R_{ie}$~~ $R_i = R_E \parallel R_{ie}$

$$R_{ie} = \frac{-V_\pi}{-\left(g_m V_\pi + \frac{V_\pi}{r_\pi}\right)}$$

$$= \frac{1}{g_m + \frac{1}{r_\pi}}$$

$$= \frac{1}{7.731m + \frac{1}{15.52k}}$$

$$= 0.128 k\Omega$$

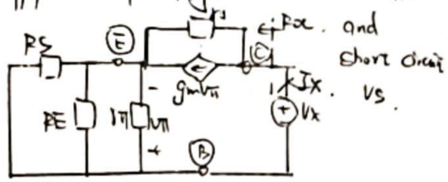
$\cancel{R_i = \frac{R_E \times R_{ie}}{R_E + R_{ie}}}$ $R_i = \frac{R_E \times R_{ie}}{R_E + R_{ie}}$

$\cancel{= \frac{12k \cdot 0.128k}{12k + 0.128k}}$ $= \frac{12k \cdot 0.128k}{12k + 0.128k}$

$\cancel{= 0.127 k\Omega}$ $= 0.127 k\Omega$

Step 2 : R_o.

Apply a test voltage source near Collector and short circuit V_S.



$R_{oc} = \frac{V_x}{I_x}$.

Apply KCL at output node, $I_x = g_m V_\pi + \frac{V_x + V_\pi}{r_o}$

Apply KCL at emitter node, $\frac{V_\pi}{R_S \parallel R_E \parallel r_\pi} + g_m V_\pi + \frac{V_x + V_\pi}{r_o} = 0$

$\Rightarrow$ Thus, $R_{oC} = \frac{V_x}{I_x} = r_o \left[1 + g_m (R_S \parallel R_E \parallel r_\pi) + R_S \parallel R_E \parallel r_\pi\right]$

For $r_o = \infty$, so $R_{oC} = \infty$.

Since $R_o = R_{oC} \parallel R_C$

$\Rightarrow$ Therefore $R_o = R_C = 12 k\Omega$