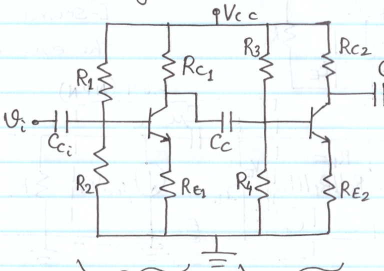
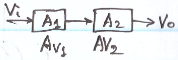
$$f_{3db\,(BJT)\ \text{ext. ckt.}} = \frac{1}{2\pi (R_B \| r_\pi)(C_\pi + C_M)} \quad \text{(LPF like)}$$

16. Two-stage amplifier: Obtains a larger gain w/o bandwidth reduction & phase preservation ($\phi = 0°$)

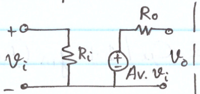




Gain: $A_V = |A_{V_1}| \cdot |A_{V_2}|$ $\qquad \phi = \phi_1 + \phi_2$

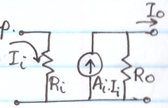
17. Equivalent 2-port networks:

a) V-amp.



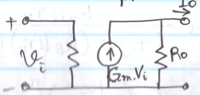
$V_{in} \rightarrow V_{out}$

b) I-amp.



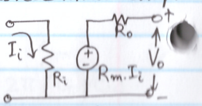
$I_{in} \rightarrow I_{out}$

c) Transconductance amp.



$V_{in} \rightarrow I_{out}$

d) Transresistance amp.



$I_{in} \rightarrow V_{out}$

Tutorial (BJTs)

1. Calculate β, α & I_C if $I_B = 10.2\mu A$ & $I_E = 0.9mA$

Sol^n. $I_E = (1+\beta) I_B$

$$\Rightarrow \beta = \frac{I_E}{I_B} - 1 = \frac{0.9\times10^{-3}}{10.2\times10^{-6}} - 1 = 87.23 \quad \text{(Ans)}$$ No unit

Now, $\alpha = \dfrac{\beta}{1+\beta} = \dfrac{87.23}{87.23+1} = 0.988$ ← No unit (Ans)

And, $I_C = \alpha \cdot I_E = (0.988)(0.9\times10^{-3}) = 0.889\ mA$ (Ans)

2. Find r_o if $V_A = 190V$ & $I_C = 2.2mA$

Sol^n. $r_o = \dfrac{V_A}{I_C} = \dfrac{190}{2.2\times10^{-3}} = 86.363\ k\Omega$ (Ans)

3. Find I_C at $V_{CE} = 12V$. Given, $I_C = 1.3\ mA$ @ $V_{CE} = 1.5V$ & $V_A = 200V$. Assume $V_{BEon} \overset{=0.7V}{}$ is constant.

Sol^n. We know, $I_C = \left[I_S \cdot \left(e^{\frac{V_{BE}}{V_T}}\right)\right]\left(1+\frac{V_{CE}}{V_A}\right) = I_o \cdot \left(1+\frac{V_{CE}}{V_A}\right)$

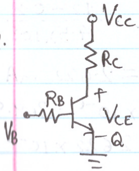
$$\Rightarrow 1.3\times10^{-3} = I_o \cdot \left(1 + \frac{1.5}{200}\right)$$

$$\Rightarrow I_o = 1.29\times10^{-3}\ A$$

$\therefore$ At $V_{CE} = 12V$,

$$I_C = 1.29\times10^{-3}\left(1+\frac{12}{200}\right) = 1.367\ mA \ @\ V_{CE} = 12V \quad \text{(Ans)}$$

4.



Let, $V_{CC} = 5V$, $V_B = 2.2V$, $R_C = 4.2k\Omega$, $R_B = 220k\Omega$, $\beta = 150$, $V_{BE(on)} = 0.7V$.

Calculate I_B, I_C, V_{CE} & $P_{transistor}$.

Sol^n: $I_B = \dfrac{V_B - V_{BE(on)}}{R_B} = \dfrac{2.2-0.7}{220\times10^{-3}} = 6.818\,\mu A$ (Ans)

$I_C = \beta . I_B = 6.818\times10^{-6}\times150 = 1.022\,mA$ (Ans)

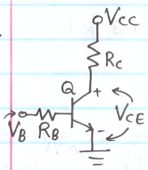
$V_{CE} = V_{CC} - I_C . R_C = 5-[(1.022\times10^{-3})(4.2\times10^{+3})]$

$= 0.707\,V$, Forward active mode (Ans)

$P_{transistor} = I_B . V_{BEon} + I_C . V_{CE}$

$= (6.818\times10^{-3})(0.7) + (1.022\times10^{-3})(0.707)$

$= 5.495\ mW$ (Ans)

5. 

Calculate I_B, I_C, I_E, V_{CE}, if $V_{BEon} = 0.7V$, $\beta = 110$, $V_{CEsat} = 0.2V$ & $V_B = 1.5V$ to $7V$, $V_{CC} = 12V$, $R_B = 240k\Omega$, $R_C = 4.5k\Omega$.

Sol^n: $I_{B\,@V_B=1.5V} = \dfrac{V_B - V_{BEon}}{R_B} = \dfrac{1.5-0.7}{240\times10^{3}} = 3.333\,\mu A$ (Ans)

$I_{B\,@V_B=7V} = \dfrac{7-0.7}{240\times10^{3}} = 26.25\,\mu A$ (Ans)

$I_{C_{1.5V}} = \beta . I_B = 110\times3.333\times10^{-6} = 366.630\,\mu A$ (Ans)

$V_{CE} = V_{CC} - I_C R_C \Rightarrow V_{CE} > 0.2V$

$I_{C_{7V}} \Rightarrow$ Transistor is likely in saturation mode.

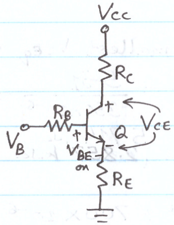
$\therefore I_{C_{7V}} = \dfrac{V_{CC} - V_{CEsat}}{R_C} = \dfrac{12-0.2}{4.5\times10^{3}}$

$= 2.622\ mA$ (Ans)

$I_{E_{1.5V}} = (1+\beta) I_B = (1+110)3.333\times10^{-6} = 369.963\,\mu A$ (Ans)

$I_{E_{7V}} = I_B + I_C = 26.25\times10^{-6} + 2.622\times10^{-3}$

$= 2.648\ mA$ (Ans)

6. 

$V_{CC} = 15V$, $V_B = 9V$, $R_B = 33k\Omega$, $R_C = 0.5k\Omega$, $R_E = 1.5k\Omega$, $\beta = 80$, $V_{BE(on)} = 0.7V$. Calculate: I_B, I_C, I_E & V_{CE}. (quiescent point parameters)

Sol^n: $I_B = \dfrac{V_B - V_{BE(on)}}{R_B + (1+\beta)R_E} = \dfrac{9-0.7}{33\times10^{3} + (1+80)\times1.5\times10^{3}}$

$= 53.721\,\mu A$ (Ans)

$I_C = \beta . I_B = 80\times53.721\times10^{-6}$

$= 4.297\ mA$ (Ans)

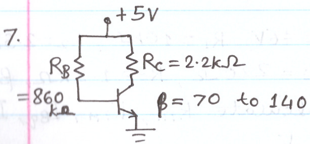
$I_E = (1+\beta) I_B = (1+80)\times53.721\times10^{-6}$

$= 4.351\ mA$ (Ans)

$V_{CE} = V_{CC} - I_C . R_C - I_E . R_E$

$= 15 - (4.297\times10^{-3})(0.5\times10^{3}) - (4.351\times10^{-3}\times1.5\times10^{3})$

$= 6.325\ V$ (Ans)

7. 

Find a new R_C such that the q-pt will be in the range $V_{CEq} = 1$ to $3V$. What is the actual range of V_{CEq} for the new R_C?

Assume, $V_{BEon} = 0.7V$ (Si)

Sol^n: $I_{Bq} = \dfrac{V_{CC} - V_{BEon}}{R_B} = \dfrac{5-0.7}{860\times10^{3}} = 5\,\mu A$

For $\beta = 70$, $I_{Cq} = \beta . I_{Bq} = 70\times5\times10^{-6} = 350\,\mu A$

For $\beta = 140$, $I_{Cq} = 140\times5\times10^{-6} = 700\,\mu A$

Largest I_{cq} leads to smallest V_{CEq} & vice-versa

For $\beta = 70$, $R_C = \dfrac{V_{CC} - V_{CEq}}{I_{cq}} = \dfrac{5-3}{350\times10^{-6}} = 5.714\,k\Omega$ (Ans)

For $\beta = 140$, $R_C = \dfrac{5-1}{700\times10^{-6}} = 5.714\,k\Omega$ (Ans)

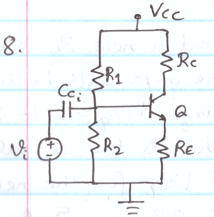
Nominal $I_{cq_{nom.}} = \dfrac{350\times10^{-6} + 700\times10^{-6}}{2} = 525\,\mu A$

Nominal $V_{CEq_{nom.}} = \dfrac{1+3}{2} = 2\,V$

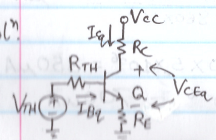
Nominal $R_{C_{nom.}} = \dfrac{V_{CC} - V_{CEq_{nom.}}}{I_{cq}} = \dfrac{5-2}{525\times10^{-6}} = 5.714\,k\Omega$

For $I_{cq} = 350\,\mu A$, (@$\beta = 70$) $V_{CEq} = V_{CC} - I_{cq}.R_C$
$= 5 - [(350\times10^{-6})(5.714\times10^{3})]$
$= 3\,V$ (Ans)

For, $I_{cq} = 700\,\mu A$, (@$\beta = 140$) $V_{CEq} = 5 - [(700\times10^{-6})(5.714\times10^{3})]$
$= 1\,V$ (Ans)

8. 

$V_{CC} = 6V$, $R_1 = 10k\Omega$, $R_2 = 2.5k\Omega$, $R_E = 220\,\Omega$, $R_C = 1.2k\Omega$, $\beta = 160$. Calculate R_{TH}, V_{TH}, I_{Bq}, I_{cq}, & V_{CEq}.

Sol^n 

$R_{TH} = R_1 // R_2 = \dfrac{10k\times2.5k}{10k+2.5k}$
$= 2\,k\Omega$ (Ans)

$V_{TH} = \dfrac{R_2}{R_1+R_2}.V_{CC} = \dfrac{2.5k}{10k+2.5k}\times6 = 1.2V$ (Ans)

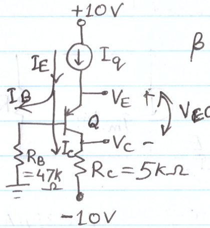
Assume, $V_{BE_{on}} = 0.7V$

$I_{Bq} = \dfrac{V_{TH} - V_{BE_{on}}}{R_{TH} + (1+\beta)R_E} = \dfrac{1.2-0.7}{2\times10^{3}+(1+160)\,220} = 13.361\,\mu A$ (Ans)

$I_{cq} = \beta.I_{Bq} = 160\times 13.361\times10^{-6} = 2.137\,mA$ (Ans)

$I_{Eq} = (1+\beta)\,I_{Bq} = 2.151\,mA$

$V_{CEq} = V_{CC} - I_{cq}.R_C - I_{Eq}.R_E = 6 - [(2.137\times10^{-3})(1.2\times10^{3}) + (2.151\times10^{-3})(220)]$
$= 2.960\,V$ (Ans)

9. 

$\beta = 60$, $I_q = 1.2mA$. Find V_C & V_E & V_{EC}

Sol^n. $I_E = 1.2\,mA$; $I_C = \underbrace{\left(\dfrac{\beta}{1+\beta}\right)}_{\alpha} I_E = \dfrac{50}{1+50}\times1.2\times10^{-3}$

$= 1.176\,mA$

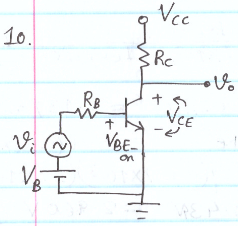
$V_C = I_C.R_C + V_{EE}$
$= (1.176\times10^{-3})(5\times10^{3}) - 10 = -3.12V$ (Ans)

$I_B = \dfrac{I_C}{\beta} = \dfrac{1.176\times10^{-3}}{60} = 19.6\,\mu A$

$V_E = I_B.R_B + V_{BE_{on}} = (19.6\times10^{-6})(47\times10^{3}) + 0.7$
$= 1.621\,V$ (Ans)

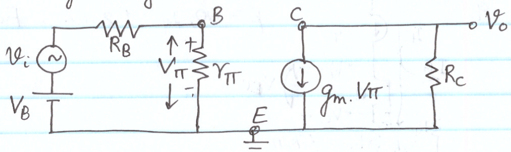
$V_{EC} = V_E - V_C = 1.621 - (-3.12)$
$= 4.74\,V$ (Ans)

10.



$V_{CC} = 6V$, $V_B = 2V$, $R_B = 640\,k\Omega$, $R_C = 12\,k\Omega$, $V_{BEon} = 0.7V$, $\beta = 90$. Draw the small signal hybrid-π model. Find q-pt values, g_m, r_π. Calculate small-signal V-gain.

Sol^n. Small signal hybrid-π model:



$$I_{Bq} = \frac{V_B - V_{BEon}}{R_B} = \frac{2-0.7}{640\times10^3} = 2.031\,\mu A \quad \text{(Ans)}$$

$$I_{Cq} = \beta.I_{Bq} = 90\times 2.031\times10^{-6} = 182.812\,\mu A \quad \text{(Ans)}$$

$$V_{CEq} = V_{CC} - I_{Cq}R_C = 6 - [182.812\times10^{-6}\times 12\times10^3] = 3.806\,V \quad \text{(Ans)}$$

$$I_{Eq} = I_{Bq} + I_{Cq} = 2.031\mu + 182.812\mu A = 184.843\,\mu A \quad \text{(Ans)}$$

$$g_m = \frac{I_{Cq}}{V_T} = \frac{182.812\times10^{-6}}{0.026} = 7.031\,mA/V \quad \text{(Ans)}$$

Assume $V_T = 26\,mV$

$$r_\pi = \frac{\beta.V_T}{I_{Cq}} = \frac{90\times0.026}{182.812\times10^{-6}} = 12.800\,k\Omega \quad \text{(Ans)}$$

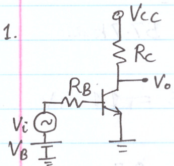
$$\frac{V_o}{V_i} = A_v = -g_m.R_C\left(\frac{r_\pi}{r_\pi + R_B}\right) \qquad [\because A_v = -g_m.V_\pi R_C]$$

$$= -(7.031\times10^{-3})\times(12\times10^3)\times\left(\frac{12.8\times10^3}{12.8\times10^3 + 640\times10^3}\right)$$

$$= -1.654 \quad \text{(Ans)}$$

No unit

11.



$V_{CC} = 7V$, $V_B = 1V$, $V_A = 200V$, $\beta = 120$, $R_C = 15\,k\Omega$, $V_{BEon} = 0.7V$, $R_B = 120\,k\Omega$. Calculate g_m, r_π, r_o & A_v.

r_o must be shown in hybrid-π

Sol^n.

$$g_m = \frac{I_{Cq}}{V_T} = \frac{\beta.I_{Bq}}{V_T} = \frac{\beta.\left(\frac{V_B - V_{BEon}}{R_B}\right)}{V_T}$$

$$= \frac{\cancel{120}\times\left(\frac{1-0.7}{\cancel{120}\times10^3}\right)}{0.026} = 11.538\,mA/V \quad \text{(Ans)}$$

$$r_\pi = \frac{\beta.V_T}{I_{Cq}} = \frac{120\times0.026}{\cancel{120}\times\left(\frac{1-0.7}{\cancel{120}\times10^3}\right)} = 10.4\,k\Omega \quad \text{(Ans)}$$

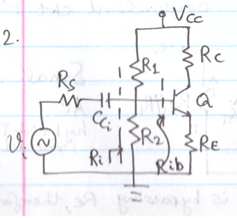
$$r_o = \frac{V_A}{I_{Cq}} = \frac{200\times10^3}{0.3} = 666.666\,k\Omega \quad \text{(Ans)}$$

$$A_v = \frac{V_o}{V_i} = -g_m\left(\frac{r_\pi}{r_\pi + R_B}\right)(r_o // R_C)$$

$$= -(11.538\times10^{-3})\left(\frac{10.4k}{10.4k+120k}\right)(666.666k // 15k)$$

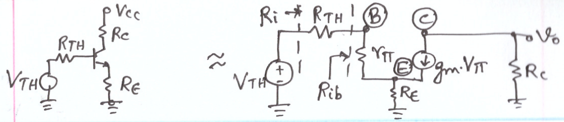
$$= -13.499 \quad \text{(Ans)}$$

12.



$V_{CC} = 5V$, $R_C = 5.6\,k\Omega$, $R_E = 0.6\,k\Omega$, $\beta = 120$, $R_1 = 250\,k\Omega$, $R_2 = 75\,k\Omega$, $V_A = \infty$, $R_S = 0.5\,k\Omega$ & $V_{BEon} = 0.7V$.

Find: R_{ib} & R_i.



Sol^n $R_{TH} = R_1 // R_2 = \dfrac{250k \times 75k}{250k + 75k} = 57.7\,k\Omega$

$V_{TH} = \dfrac{R_2}{R_1+R_2} V_{cc} = \dfrac{75k}{75k+250k} \cdot 5 = 1.154V$

$I_{Bq} = \dfrac{V_{TH} - V_{BEon}}{R_{TH} + (1+\beta)R_E} = \dfrac{1.154 - 0.7}{57.7 - (120+1)(0.6k)} = 3.48\mu A$

$I_{cq} = \beta \cdot I_{cq} = 120 \times 3.48 \times 10^{-6} = 0.418\ mA$

$g_m = \dfrac{I_{cq}}{V_T} = \dfrac{0.418 \times 10^{-3}}{0.026} = 16.08\ mA/V$

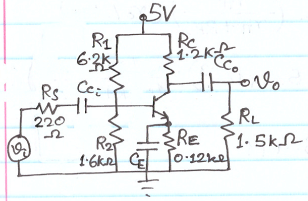
$r_\pi = \dfrac{\beta \cdot V_T}{I_{cq}} = \dfrac{120 \times 0.026}{0.418 \times 10^{-3}} = 7.46\ k\Omega$

× $V_o = -g_m \cdot V_\pi \cdot R_c$

$R_{ib} = r_\pi + (1+\beta) R_E = 7.46k\Omega + (1+120)(0.6 \times 10^3)$

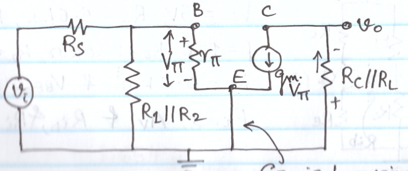
$= 80.1\ k\Omega$ (Ans)

$R_i = R_1 || R_2 + R_{ib} = 57.7k + 80.1k = 137.8\ k\Omega$ (Ans)

13. 

$\beta = 200$, $r_o = \infty$

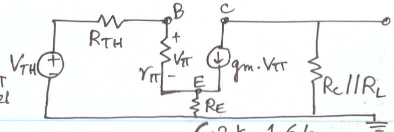
Find small signal hybrid-π parameters after drawing an equivalent ckt. Find Av

Sol^n. 

Small-signal AC hybrid-π model

C_E is bypassing R_E, therefore a short.

Small Signal DC hybrid-π model



Assume, $V_\pi = V_{BEon} = 0.7V$ & $V_T = 26\ mV$

$R_{TH} = R_1 // R_2 = \dfrac{6.2k \cdot 1.6k}{6.2k + 1.6k} = 1.271k\Omega$

$V_{TH} = \dfrac{R_2}{R_1+R_2} \cdot V_{cc} = \dfrac{1.6k}{6.2k+1.6k} \cdot 5 = 1.025V$

$I_{Bq} = \dfrac{V_{TH} - V_{BE\,on}}{R_{TH} + (1+\beta)R_E} = \dfrac{1.025 - 0.7}{1.271k + (1+200)0.12k}$

$= 12.799\ \mu A$

$I_{cq} = \beta \cdot I_{Bq} = 200 \times 12.799 \times 10^{-6} = 2.559mA$

$I_{cq} = (1+\beta) I_{Bq} = 2.572\ mA$ (Ans)

$V_{CEq} = V_{cc} - I_{cq} \cdot R_c - I_{Eq} \cdot R_E$

$= 5 - (2.559m)(1.2k) - (2.572m)(0.12k)$

$= 1.620V$ (Ans)

$r_\pi = \dfrac{\beta \cdot V_T}{I_{cq}} = \dfrac{200 \times 0.026}{2.559 \times 10^{-3}} = 2.032\ k\Omega$

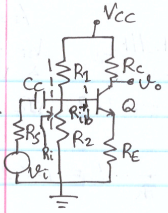
$g_m = \dfrac{I_{cq}}{V_T} = \dfrac{2.559 \times 10^{-3}}{0.026} = 98.423\ mA/V$ (Ans)

$A_v = -g_m \cdot \left[\dfrac{R_1 || R_2 || r_\pi}{(R_1||R_2||r_\pi) + R_s}\right](R_c // R_L)$

$= -98.423m \left[\dfrac{6.2k || 1.6k // 2.032k}{(6.2k || 1.6k // 2.032k) + 220}\right](1.2k // 1.5k)$

$= -$ (Ans)

14. (Ex7.3)



$R_S = 0.1\,k\Omega$, $R_1 = 20k$, $R_2 = 2.2k$, $R_E = 0.1k$, $R_C = 2k$, $C_C = 47\mu F$, $V_{CC} = 10V$, $V_{BEon} = 0.7V$, $\beta = 200$, $V_A = \infty$.

Find τ_s & f_c & $A_{v_{mid\text{-}band}}$.

Sol^n:

$$\tau_s = (R_i + R_s).C_c$$

$$f_c = \frac{1}{2\pi \tau_s}$$

$$R_{TH} = R_1 // R_2 = \frac{20k \cdot 2.2k}{20k + 2.2k} = 1.98\,k\Omega$$

$$V_{TH} = \frac{R_2}{R_1 + R_2} \cdot V_{CC} = \frac{2.2k}{20k + 2.2k} \cdot 10 = 0.990\,V$$

$$I_{Bq} = \frac{V_{TH} - V_{BEon}}{R_{TH} + (1+\beta)R_E} = \frac{0.990 - 0.7}{1.98k + (1+200)\,0.1k} = 13.2\,\mu A$$

$$I_{cq} = \beta \cdot I_{Bq}$$

$$I_{cq} = 200 \cdot 13.2\mu = 2.636\,mA$$

$$r_\pi = \frac{\beta \cdot V_T}{I_{cq}} = \frac{200 \times 0.026}{2.636m} = 1.97k\Omega$$

$$g_m = \frac{I_{cq}}{V_T} = \frac{2.636m}{0.026} = 101.4\,mA/V$$

$$R_{i_b} = r_\pi + (1+\beta).R_E = 1.97k + (1+200)\,0.1k = 22.1\,k\Omega$$

$$R_B = R_1 || R_2 = 1.98\,k\Omega$$

$$R_i = R_B || R_{i_b} = \frac{1.98k \cdot 22.1k}{1.98k + 22.1k} = 1.817\,k\Omega$$

$$\therefore \tau_s = (R_i + R_s).C_c = (1.817k + 0.1k).47\mu = 90.099\,ms \quad \text{(Ans)}$$

$$f_c = \frac{1}{2\pi \tau_s} = \frac{1}{2\pi \times 90.099m} = 1.77\,Hz \quad \text{(Ans)}$$

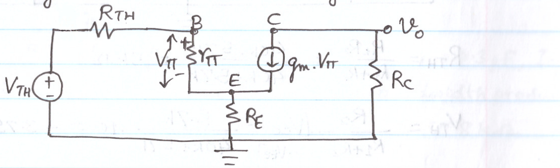
(I/P High pass)

$$A_{v_{mid\text{-}band}} = \frac{-\beta \cdot R_C}{r_\pi + (1+\beta)R_E} \cdot \frac{R_i}{R_i + R_s}$$

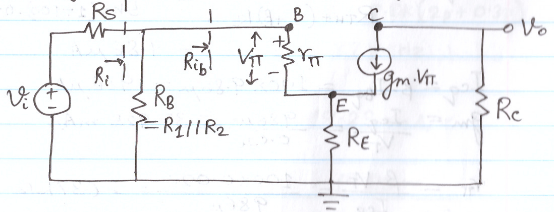
$$= \frac{-(200)(2k)}{1.97k + (1+200)(0.1k)} \cdot \frac{1.817k}{1.817k + 0.1k}$$

$$= -17.2 \quad \text{(Ans)}$$

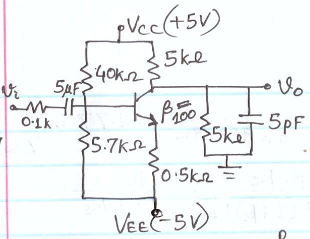
DC hybrid-π model: Small-signal

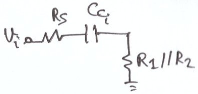


AC hybrid-π model: Small signal



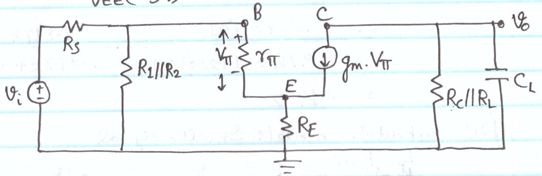
15.
(Ex 7.7)





Find: Ic, hybrid-π model parameters, f_{BW} & corner frequencies.

Solⁿ.



$$R_{TH} = \frac{R_1 R_2}{R_1+R_2} = \frac{40k \cdot 5.7k}{40k+5.7k} = 5k\Omega$$

$$V_{TH} = \frac{R_2}{R_1+R_2} \cdot [V_{cc} - V_{EE}] = \frac{5.7k}{40k+5.7k} \cdot 10 = -3.752V$$

$$I_{Bq} = \frac{V_{TH} - V_{BEon} - V_{EE}}{R_{TH} + (1+\beta) R_E} = \frac{-3.752 - 0.7 + 5}{5k + (1+100) \cdot 0.5k}$$

$$= 9.86\ \mu A$$

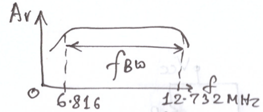
$$I_{cq} = \beta \cdot I_{Bq} = 100 \times 9.86\mu = 986\ \mu A \quad \text{(Ans)}$$

$$g_m = \frac{I_{cq}}{V_T} = \frac{986\mu}{0.026} = 37.925\ mA/V \quad \text{(Ans)}$$

$$r_\pi = \frac{\beta \cdot V_T}{I_{cq}} = \frac{100 \times 0.026}{986\mu} = 2.637k\Omega \quad \text{(Ans)}$$

$$\tau_L = (R_c // R_L)\, C_L = \frac{5k \cdot 5k}{5k+5k} \cdot 5pF = 12.5\ ns$$

$$R_i = r_\pi + (1+\beta) R_E = 2.637k + (1+100) 0.5k$$
$$= 53.137\ k\Omega$$



$$\tau_S = (R_i // R_{TH} + R_S)\, C_c = \left(\frac{53.137k \cdot 5k}{53.137k + 5k} + 0.1k\right) \cdot 5\mu$$

$$= 23.349\ ms$$

$$\therefore f_L = \frac{1}{2\pi \tau_S} = \frac{1}{2\pi \times 23.349m} = 6.816\ Hz \quad \text{(Ans)}$$

$$\therefore f_H = \frac{1}{2\pi\, \tau_L} = \frac{1}{2\pi \times 12.5n} = 12.732\ MHz \quad \text{(Ans)}$$

$$f_{bandwidth} = f_H - f_L \cong 12.732\ MHz \quad \text{(Ans)}$$

↖ Ckt. BW

16.
(Ex 7.9)

A BJT has $\beta_o = 150$, $C_\pi = 2pF$, $C_\mu = 0.3pF$, $I_q = 0.5mA$, find f_β (bandwidth) & f_T (gain-bandwidth product).

Solⁿ.

$$r_\pi = \frac{\beta_o \cdot V_T}{I_{cq}} = \frac{150 \times 0.026}{0.5m} = 7.8k\Omega$$

$$f_\beta = \frac{1}{2\pi\, r_\pi (C_\pi + C_\mu)} = \frac{1}{2\pi \times 7.8k(2p + 0.3p)}$$

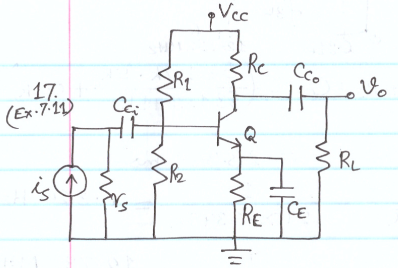
↗ BJT's BW

$$= 8.87\ MHz \quad \text{(Ans)}$$

$$g_m = \frac{I_{cq}}{V_T} = \frac{0.5m}{0.026} = 19.23\ mA/V$$

$$f_T = \frac{g_m}{2\pi (C_\pi + C_\mu)} = \frac{19.23m}{2\pi (2p + 0.3p)} = 1.330\ GHz \quad \text{(Ans)}$$

17.
(Ex. 7.11)

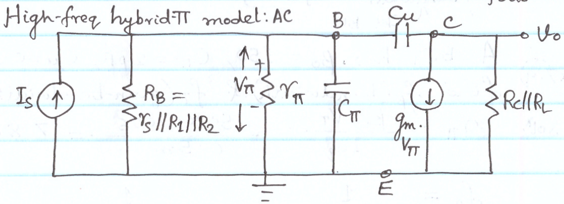


Draw the high-freq. hybrid-π ckt.

$R_1 = 200k\Omega$, $R_2 = 220k\Omega$, $R_C = 2.2k\Omega$, $R_E = 1k\Omega$, $r_s = 100k\Omega$, $R_L = 4.7k\Omega$, $V_{cc} = 5V$, $\beta_o = 100$, $V_{BEon} = 0.7V$, $V_A = \infty$, $C_\mu = 2pF$, $C_\pi = 10pF$.

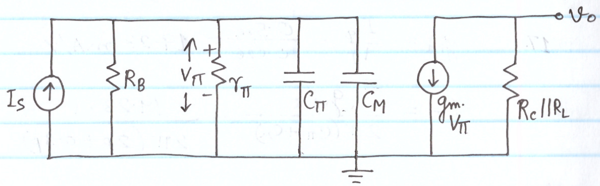
Find: C_M & f_{3db}.

Sol^n. High-freq hybrid-π model: AC



(Note: R_E & C_E are shorted/ignored at high freq.)

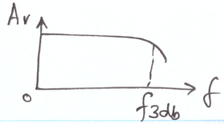
Modified hybrid-π model with C_M (Miller cap.): AC



$$R_{TH} = R_1 // R_2 = 200k // 220k = 104.8\,k\Omega$$

$$V_{TH} = \frac{R_2}{R_1 + R_2} V_{cc} = \frac{220k}{200k + 220k} \cdot 5 = 2.619V$$

$$I_{Bq} = \frac{V_{TH} - V_{BEon}}{R_{TH} + (1+\beta) R_E}$$



$$I_{cq} = \beta \cdot I_{Bq} =$$

$$g_m = \frac{I_{cq}}{V_T} =$$

$$r_\pi = \frac{\beta \cdot V_T}{I_{cq}} =$$

$$C_M = C_\mu [1 + g_m (R_C // R_L)]$$
$$=$$ (Ans)

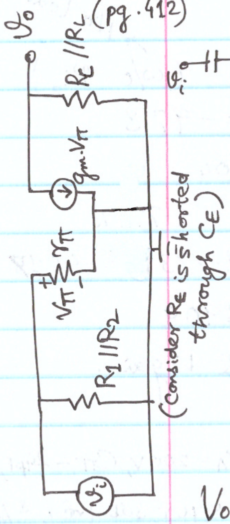
$$R_B = r_s // R_1 // R_2 =$$

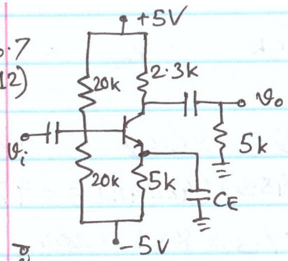
$$f_{3db} = \frac{1}{2\pi (R_B // r_\pi)(C_\pi + C_\mu)}$$

Ckt. BW at high freq.

$$=$$ (Ans)

TYU6.7
(pg.412)





$\beta = 125$, $V_{BEon} = 0.7V$, $V_A = 200V$, Find A_v & R_o

$R_{TH} = R_1 // R_2 = 10k\Omega$

$$I_{Bq} = \frac{0 - 0.7 - (-5)}{10 + (126 \times 5)} = 6.72\mu A$$

$$I_{Cq} = 125 \times 6.72\mu A = 0.84mA$$

$$r_\pi = \frac{\beta . V_T}{I_{Cq}} = \frac{125 \times 26\,\cancel{m}V}{0.84\,\cancel{m}A} = 3.87k\Omega$$

$$g_m = \frac{I_{Cq}}{V_T} = \frac{0.84m}{0.026} = 32.3\,mA/V$$

$$r_o = \frac{V_A}{I_{Cq}} = \frac{200}{0.84m} = 238k\Omega$$

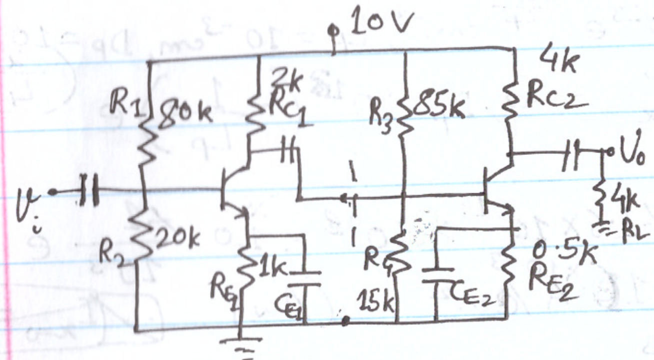
$$V_o = -g_m . V_\pi (r_o // R_C // R_L) \quad \& \quad V_\pi = V_i$$

$$\therefore A_v = \frac{V_o}{V_i} = -g_m (r_o // R_C // R_L) = -(32.3)(238k // 2.3k // 5k)$$

$$= -50.5 \quad \text{(Ans)}$$

$$R_o = r_o // R_C = 238k // 2.3k = 2.28k\Omega \quad \text{(Ans)}$$

6.64
pg.466



$\beta = 100$, $V_A = \infty$, Find Av. while considering loading.

$V_{TH1} = (80k \,//\, 20k) \, V_{cc} = 16k \times 10 = 2V$

$I_{B1} = \dfrac{2 - 0.7}{16 + (101)(1k)} = 0.0111 \, mA$

$I_{C1} = 100 \times 0.0111m = 1.11 \, mA$

$g_{m1} = \dfrac{I_{cq}}{V_T} = \dfrac{1.111m}{26m} = 42.74 \, mA/V$

$r_{\pi_1} = \dfrac{\beta . V_T}{I_{cq}} = \dfrac{100 \times 26m}{1.11m} = 2.34k$

$r_{o1} = \dfrac{V_A}{I_{cq}} = \dfrac{\infty}{1.11m} = \infty$

$V_{TH2} = (85k \,//\, 15k) \, V_{cc} = 1.5V$

$R_{TH2} = R_3 // R_4 = 12.75k.$

$I_{B2} = \dfrac{1.5 - 0.7}{12.75k + \underbrace{(101)(0.5)}_{(1+\beta) R_E}}$; $I_{C2} = 1.265 mA$; $g_{m2} = \dfrac{1.265m}{0.026} = 48.65 mA/V$

$r_{\pi_2} = \dfrac{100 \times (0.026)}{1.265m} = 2.06k$; $r_{o2} = \infty$

$Av_1 = -g_{m1} R_{C1} = -(42.7)(2) = -85.48$ (w/o Ri_2) No loading

$Av_2 = -g_{m2} (R_{C2} // R_L) = -(48.5)(4k // 4k) = -97.3$

$Av = Av_1 . Av_2 = 85.48 \times 97.3 = 8317.204$

$Ri_2 = R_3 // R_4 // r_{\pi 2} = 15k // 85k // 2.06k = 1.773k$

$Av_1' = -g_m (R_{C1} // Ri_2) = -(42.7)(2k // 1.773k) = -40.17$

$\therefore Av' = Av_1' . Av_2 = 40.17 \times 97.3 = 3909$

$\therefore$ Loading of stage 2 reduces overall V-gain.