Department of Electrical & Electrical Engineering

BRAC University

Semester- Fall 2025

EEE205

Electronic Circuits I

Section: 04

Design Project : BJT Amplifier Design

Group Number: 4

Group Members:

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Submitted to

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EEE205 Design Project:

Section : 04

Group : 04

$A_v = 35+4+4$
$= 43$

$R_i > 20+\frac{4}{2}$
$= 22$

Objective: To design and analyze a small-signal amplifier with a voltage gain of $A_v = 43$ and input resistance $R_i > 22k\Omega$ using either an npn BJT or NMOS transistor.

Methodology: For this project, we will initially select a pre built configuration and find out the large and small signal parameters through large signal (DC) analysis and small signal (AC) analysis. Then we will derive expressions for those parameters. (I_C, V_{CE}, V_{TH}, R_{TH}) and approximate further for our convenience. And we have to used a fixed universal value of β for our ~~and~~ BJT analysis corresponding to the model, then we will Assume values of the resistors, I_C and others through a trial and error basis where we will run simulations till we find our desired output.

Technical Specifications:

We will use 3 different configurations for 3 members. For the transistor, we will use the npn BJT Q2N760 which has a β value of 393.6. Our design requires 2 voltage sources, one AC and one DC. The DC source can either be a 10V single or double 5V source. Our circuit will consist of multiple resistors and capacitors depending on the configuration. We will use the PSpice simulation software to design and simulate our amplifier.

For constraints, our simulation will be run using the closest standard values of our components, this may yield slight errors.

Configuration 2

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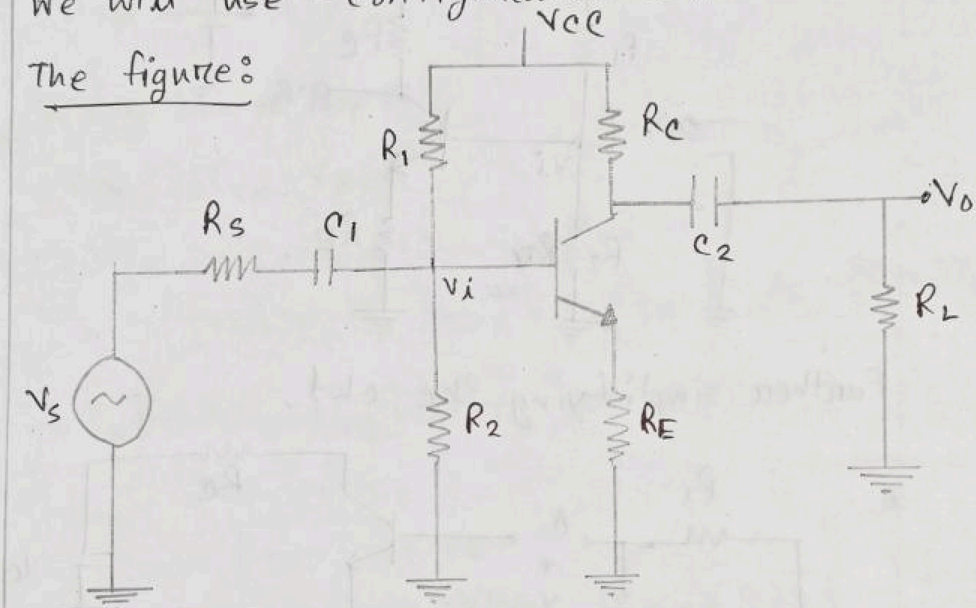
For our Common Emitter Amplifier we will use - Configuration 02,

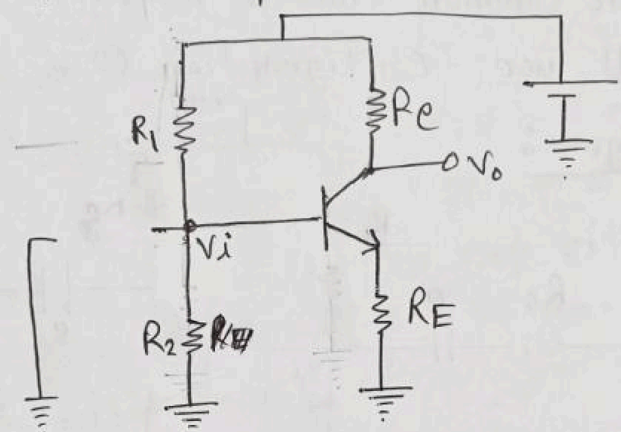
The figure :



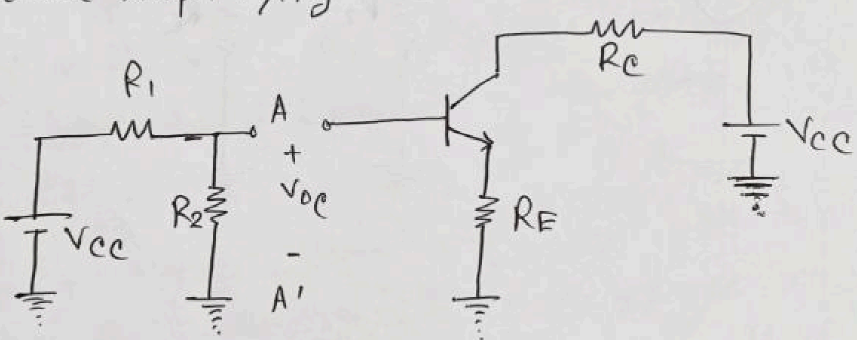
Large signal analysis:

Turning of all AC sources,

Open all the capacitors,



Further simplifying the ckt.



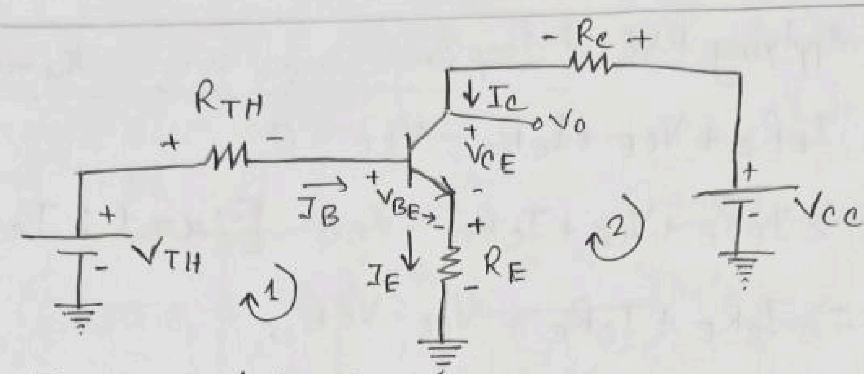
Here, $V_{TH} = V_{OC} =$

Where,

$$R_{TH} = R_1 \| R_2 = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$\therefore V_{TH} = \frac{R_2}{R_1 + R_2} \cdot V_{CC}$$

As it is an amplifier the BJT is in Active region and α / β is allowed.



Applying KVL at loop 1,

$+V_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$

$\Rightarrow V_{TH} = I_E R_E + V_{BE} + I_B R_{TH}$

$= (1+\beta) I_B R_E + V_{BE} + I_B R_{TH}$ $[\because I_E = (\beta+1) I_B]$

$\Rightarrow I_B [(1+\beta) R_E + R_{TH}] = V_{TH} - V_{BE}$

$$\Rightarrow I_B = \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E}$$

$$\Rightarrow I_C = \beta \times \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E} \quad [\because I_C = \beta I_B]$$

As, $R_{TH} << (1+\beta) R_E$, so, $\cancel{R_{TH}}^{0} + (1+\beta) R_E$ [$\because$ Approximation]

$$\therefore I_C = \frac{\beta (V_{TH} - V_{BE})}{(1+\beta) R_E}$$

as, $\beta \approx (1+\beta)$, we can write, [$\because$ Approximation]

$$I_C = \frac{\beta (V_{TH} - V_{BE})}{\beta (R_E)}$$

$$\therefore I_C = \frac{V_{TH} - V_{BE}}{R_E} \quad \text{—— (1)}$$

Applying KVL at loop2,

$$I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

$$\Rightarrow I_E R_E + V_{CE} + I_C R_C = V_{CC} \quad [\because \alpha \approx 1 \,;\, I_C \approx I_E]$$

$$\Rightarrow I_C R_E + I_C R_C = V_{CC} - V_{CE}$$

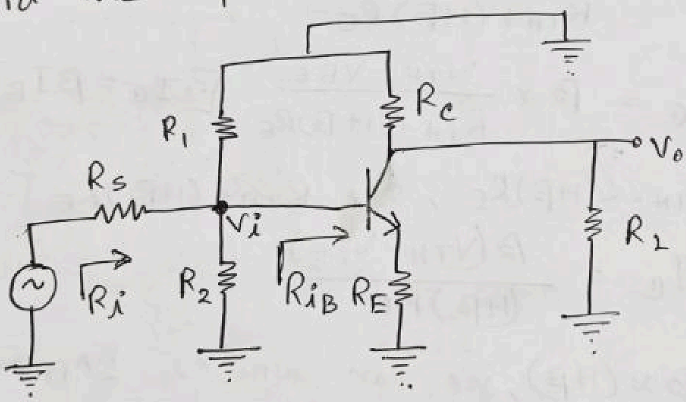
$$\Rightarrow I_C (R_E + R_C) + V_{CE} = V_{CC}$$

$$\Rightarrow V_{CE} = V_{CC} - I_C (R_E + R_C) \quad \text{(11)}$$

Now,

Small signal analysis:

Turn off DC sources,
short the capacitors,



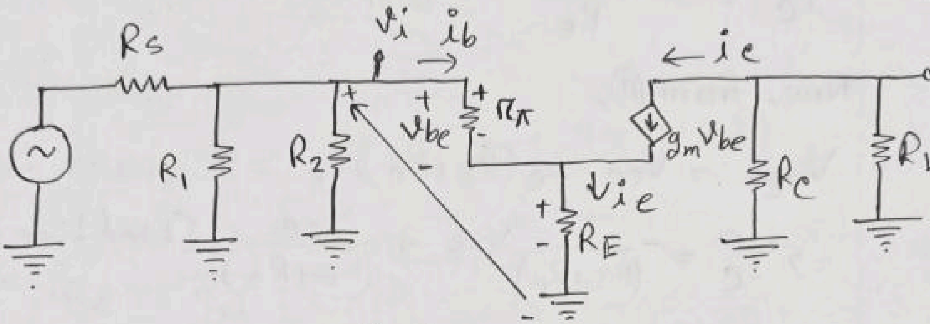
To draw the small signal equivalent ckt

We will use Hybrid π model.

~~Here,~~ $\cancel{R_i = R_{iB} \| R_1 \|} R_2$

Small signal equivalent ckt : Hybrid π model

$\left[i_b = \frac{v_{be}}{r_\pi} \right]$



Determining voltage, V_i [Input]

$\left[i_e = (1+\beta) i_b \right]$

$V_i - i_b r_\pi - i_e R_E = 0$

$\Rightarrow i_b r_\pi + i_e R_E = V_i \quad \Rightarrow i_b r_\pi + (1+\beta) i_b R_E = V_i$

$\Rightarrow i_b \left[r_\pi + (1+\beta) R_E \right] = V_i$

We know,

$$R_{iB} = \frac{V_i}{i_b} = \frac{i_b \left[r_\pi + (1+\beta) R_E \right]}{i_b} = r_\pi + (1+\beta) R_E$$

And, $R_i = R_{iB} \| R_1 \| R_2$

Determining output, V_o

$V_o = (R_C \| R_L) \times (-i_c)$ [Using ohm's law]

$\Rightarrow V_o = -g_m v_{be} (R_C \| R_L) \quad [\because i_c = g_m v_{be}]$

$\left[\because i_b = \frac{v_{be}}{r_\pi} \right]$

$$\therefore A_v = \frac{V_o}{V_i} = \frac{-g_m v_{be} (R_C \| R_L)}{i_b \left[r_\pi + (1+\beta) R_E \right]} \quad \left[\because \frac{v_{be}}{i_b} = r_\pi \right]$$

$$= \frac{-g_m r_\pi (R_C \| R_L)}{r_\pi + (1+\beta) R_E} = \frac{-\beta (R_C \| R_L)}{r_\pi + (1+\beta) R_E} \quad \text{--- (iii)}$$

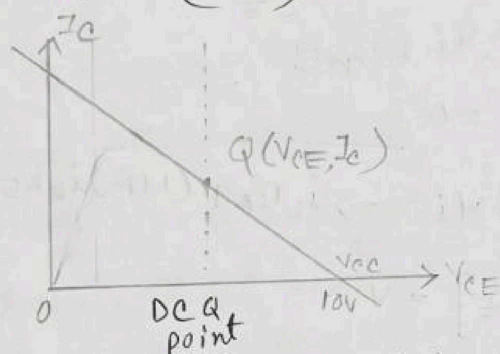
∴ Approximations,

$$I_C = \frac{V_{TH} - V_{BE}}{R_E} \quad [\text{Approximated}]$$

Now, from (ii),

$$V_{CE} = V_{CC} - I_C(R_E + R_C)$$

$$\Rightarrow I_C = -\frac{1}{(R_E+R_C)} V_{CE} + \frac{V_{CC}}{(R_E+R_C)} \quad [\text{Load Line eq}]$$



$$\therefore V_{EC} \approx \frac{V_{CC}}{2}$$

from (iii) $A_V = \frac{-\beta(R_C \| R_L)}{r_\pi + (1+\beta)R_E} = \frac{\beta(R_C \| R_L)}{r_\pi + (1+\beta)R_E}$ [Here (-) indicates the direction of the output]

$$= \frac{\beta(R_C \| R_L)}{\beta(R_E)} \quad \left[\begin{array}{l}\text{Here, } (1+\beta)R_E \gg r_\pi \therefore \cancel{r_\pi}^{0} + (1+\beta)R_E \\ \text{and } (1+\beta) \approx \beta\end{array}\right]$$

$$= \frac{R_C \| R_L}{R_E} \qquad \therefore A_V = \frac{R_C \| R_L}{R_E}$$

Again, $R_C \| R_L = \frac{R_C \times R_L}{R_C + R_L}$ [As R_L is not given, Assuming $R_L = \infty$, $R_L \gg R_C$ ∴ $\cancel{R_C}^{0} + R_L = R_L$]

$$= \frac{R_C \times R_L}{R_L}$$

$$= R_C$$

$$\therefore A_V = \frac{R_C}{R_E}$$

We know,

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

and $r_e = \dfrac{\alpha}{g_m} = \dfrac{V_T}{I_E}$

We know, $\alpha = \dfrac{\beta}{1+\beta} \simeq 1 \quad \left[\because \beta \approx (1+\beta)\right]$

$$\therefore r_e = \frac{1}{g_m} = \frac{r_\pi}{\beta}$$

$$\therefore r_e = \frac{r_\pi}{\beta} \Rightarrow r_\pi = \beta r_e$$

$R_i = (20 + \frac{4}{2}) = 22$ gain $= (35 + 4 + 4) = 43$

<u>Trial : 1</u> We used BJT Q2N760 ∴ $\beta = 393.6$, $V_{CC} = 10V$

$\therefore A_v = \frac{V_o}{V_i} \Rightarrow 43 = \frac{R_c}{R_E}$ $\left[A_v = \frac{R_c}{R_E}\right]$

Assumming $R_E = 240\Omega = 0.24k\Omega$

$\therefore R_c = 43 \times 0.24 = 10.32 k\Omega$ $\left[V_{CE} \approx \frac{V_{CC}}{2}\right]$

Finding I_c, $V_{CE} = V_{CC} - I_c(R_c + R_E)$

$\Rightarrow 5 = 10 - I_c(10.32 + 0.24)$

$\Rightarrow I_c = \frac{10-5}{10.56} = 0.473 mA$

∴ Finding V_{TH} > $I_c = \frac{V_{TH} - V_{BE}}{R_E} \Rightarrow V_{TH} = I_c R_E + V_{BE}$

$\therefore V_{TH} = (0.473 \times 0.24) + 0.7 = 0.8135V$

Now, $V_{TH} = \frac{R_2}{R_1 + R_2} \times V_{CC}$ [Assumming $R_2 = 20k\Omega$]

$\Rightarrow 0.8135 = \frac{20}{R_1 + 20} \times 10 \Rightarrow R_1 = 225.85 k\Omega$

finding r_e, $r_e = \frac{V_T}{I_c}$ [$V_T = 25mV$ @ $T = 300K$]

$= \frac{25}{0.473} = 52.85\Omega$

$\therefore r_\pi = \beta r_e = 20801.76 = 20.8 k\Omega$

$\therefore R_{iB} = r_\pi + (1+\beta)R_E = [20.8 + (393.6+1)0.24] k\Omega$

$= 115.504 k\Omega$

$\therefore R_i = R_{iB} \| R_1 \| R_2 = \left(\frac{1}{115.5} + \frac{1}{225.85} + \frac{1}{20}\right)^{-1} = 15.85 k\Omega$

As, $R_i = 15.85 k\Omega < 22$

∴ condition not satisfied,

BJT won't meet expectations.

Simulation gain, $A_v = 150.3$

Trial #2.

$A_v = 43 = \frac{R_C}{R_E}$ [Assuming $R_E = 1k\Omega$] | $\beta = 393.6$, $V_{CC} = 10V$

$\Rightarrow R_C = 43 \times 1 = 43 k\Omega$

$\therefore$ ~~Dee~~ $V_{CE} = V_{CC} - I_C(R_C + R_E)$

$\Rightarrow I_C = \frac{V_{CC} - V_{CE}}{R_C + R_E} = \frac{10-5}{1+43} = 0.114 mA$

$\therefore V_{TH} = I_C R_E + V_{BE}$ [$\cancel{V_{TH}}$ $I_C = \frac{V_{TH} - V_{BE}}{R_E}$]

$= 0.114 \times 1 + 0.7 = 0.814 V$

Now, $V_{TH} = \frac{R_2}{R_1 + R_2} \times V_{CC}$ [Assuming $R_2 = 39 k\Omega$)

$\Rightarrow 0.814 = \frac{39}{R_1 + 39} \times 10$; $R_1 = 440.115 k\Omega$

$\therefore r_e = \frac{V_T}{I_C} = \frac{25}{0.118} = 211.86 = 0.212 k\Omega$

$\therefore r_\pi = \beta r_e = 393.6 \times 0.212 = 83.44 = 83.44 k\Omega$

$\therefore R_{iB} = r_\pi + (1+\beta) R_E = [83.44 + (394.6 \times 1)] = 478.04 k\Omega$

$\therefore R_i = R_{iB} \| R_1 \| R_2 = \left(\frac{1}{478.04} + \frac{1}{440.1} + \frac{1}{39}\right)^{-1} = 33.33 k\Omega$

As, $R_i = 33.33 > 22$

$\therefore$ Condition is satisfied.

But after simulation was done,

gain, $A_v = 79.34$ which doesn't meet the expectations. Hence, this trial is Rejected.

Trial #3

$A_v = 43 = \frac{R_C}{R_E}$ [Assuming $R_E = 10k\Omega$] | $\beta = 393.6$, $V_{cc} = 10V$

$\Rightarrow R_C = 43 \times 10 = 430 k\Omega$

Now,

$V_{CE} = V_{CC} - I_C(R_C + R_E)$

$\Rightarrow I_C = \frac{V_{CC} - V_{CE}}{R_C + R_E} = \frac{10-5}{430+10} = 0.0114 mA$

Now, $V_{TH} = \cancel{\frac{R_2}{R_1+R_2} \times V_{cc}}\ I_C R_E + V_{BE}$

$= (0.0114 \times 10) + 0.7 = 0.814V$

Again,

$V_{TH} = \frac{R_2}{R_1+R_2} \times V_{cc}$ [Assuming $R_2 = 56k$]

$\Rightarrow 0.814 = \frac{56}{R_1 + 56} \times 10$ ~~631.96 kΩ~~

$\Rightarrow R_1 = 631.96 k\Omega$

$\therefore r_e = \frac{V_T}{I_C} = \frac{25 mV}{0.0114 mA} = 2192.98\Omega = 2.193k\Omega$

$\therefore r_\pi = \beta r_e = 393.6 \times 2.193 = 863.16 k\Omega$

$\therefore R_{iB} = r_\pi + (1+\beta)R_E = 863.16 + (394.6 \times 10)\ k\Omega$

$= 4809.16\ k\Omega$

$\therefore R_i = R_{iB} \| R_1 \| R_2 = \left(\frac{1}{4809.16} + \frac{1}{631.96} + \frac{1}{56}\right)^{-1}$

$= 50.897 k\Omega$

$\therefore R_i = 50.897 k\Omega < 22 k\Omega$

$\therefore$ Condition is satisfied.

Simulation shows a gain of ~~40~~. $A_v = 41.94$ which is very close to expectation.

PSpice Circuit Setup

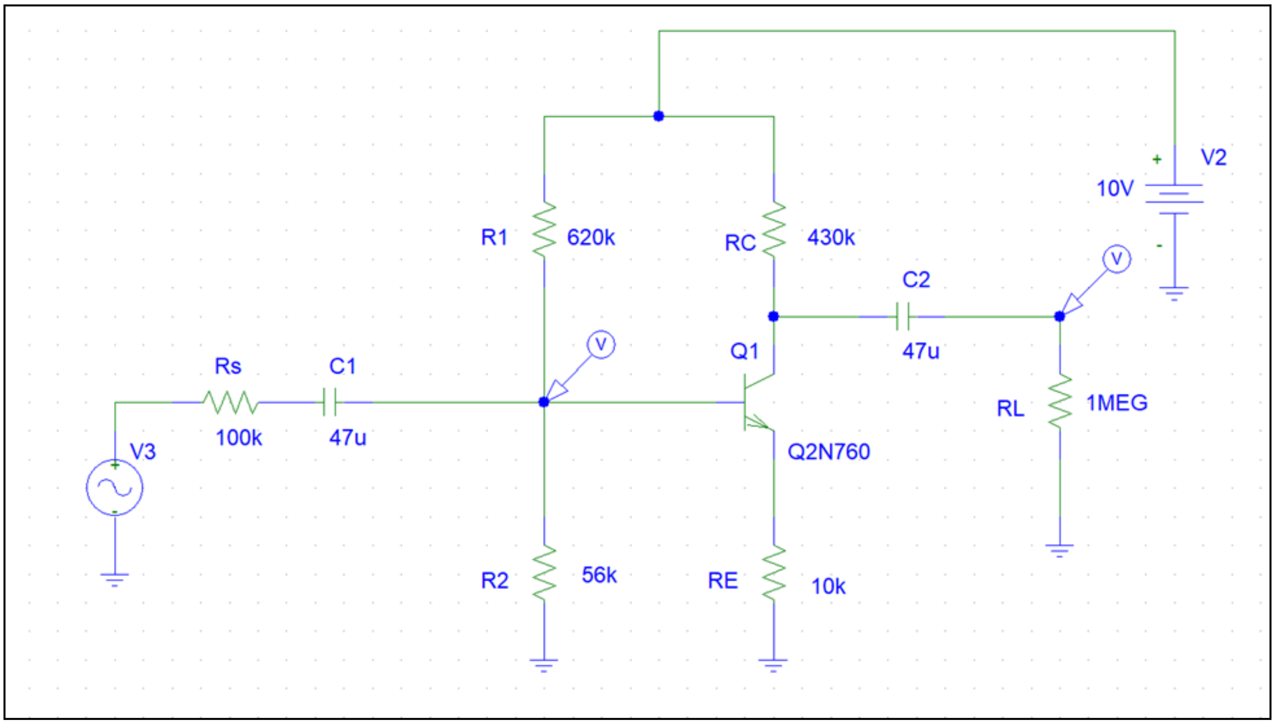
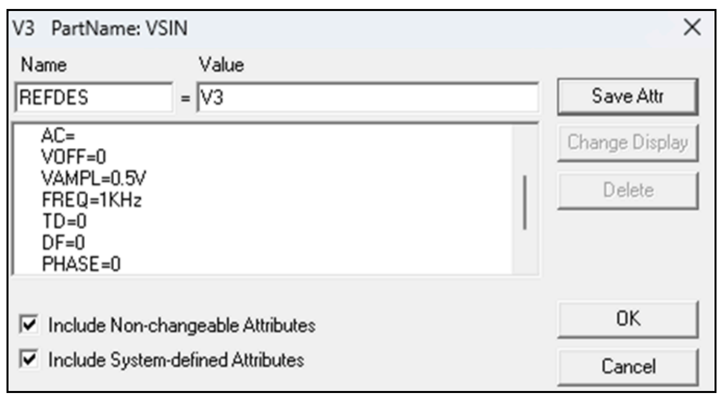
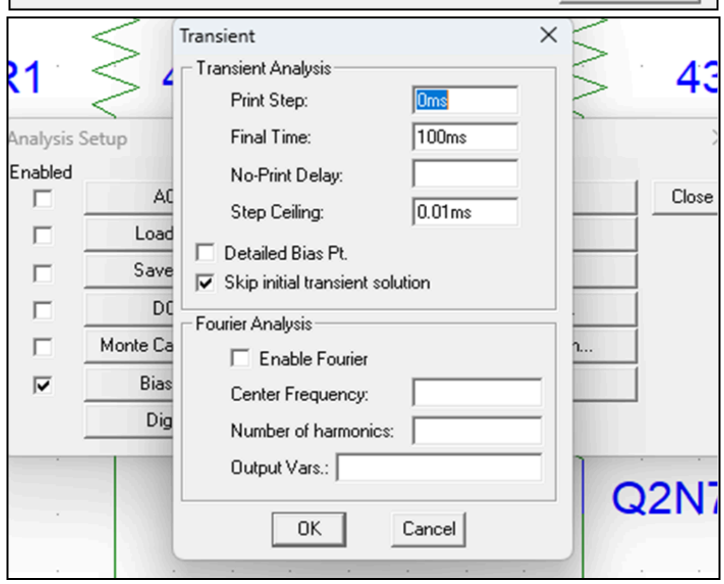


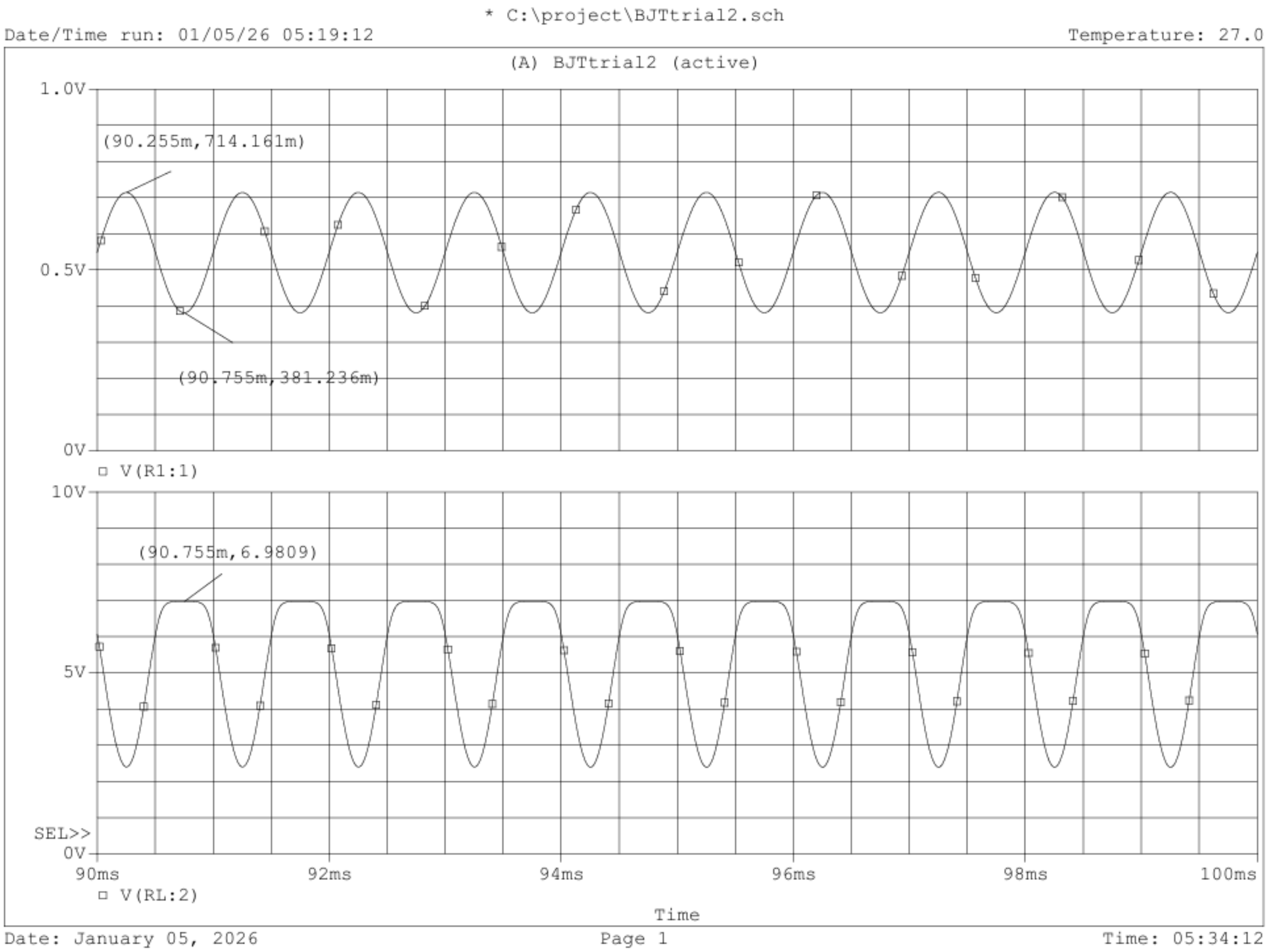
Figure of Circuit running on 3rd Trial parameters

	Q2N760
	NPN
IS	5.911000E-15
BF	393.6
NF	1
VAF	62.37
IKF	.01243
ISE	5.911000E-15
NE	1.271
BR	1.372
NR	1
RB	10
RC	1.61
CJE	4.973000E-12
MJE	.4146
CJC	4.017000E-12
MJC	.3174
TF	818.200000E-12
XTF	7
VTF	4
ITF	.35
TR	4.761000E-09
XTB	1.5
CN	2.42
D	.87





Simulation Graph : V_{input} vs V_{output}



Graph after running simulation on trial 3
Plot 1 showing V(input) and Plot 2 showing V(output)

Table of calculations and used parameters

Trial no.		*Trial 1*	*Trial 2*	***Trial 3***
Found Values	**R_1(kΩ)**	225.8	440	631.96
	R_2(kΩ)	20	39	56
	R_E(kΩ)	0.24	1	10
	R_C(kΩ)	10.32	43	430
Corresponding Standard Values	**R_1(kΩ)**	220	430	620
	R_2(kΩ)	20	39	56
	R_E(kΩ)	0.24	1	10
	R_C(kΩ)	10	43	430
Input Impedance, Ri(kΩ)		15.85	33.33	**50.897**
Gain, Av		150.3	79.34	**41.94**
Result Acceptance		Rejected	Rejected	**Accepted**

~~Table of Results~~:

Result Analysis:

Through Trial #3, We found the best possible values, adhering to our expectations.

We found, $R_E = 10k\Omega$

$R_C = 430k\Omega$

$R_1 = 631.96k\Omega$

$R_2 = 56k\Omega$

For, R_1 we used the closest corresponding standard value of $620k\Omega$. The rest are already standard values

~~Fro~~ To calculat gain, A_v, [From the simulation graph]

Find $V_i = \frac{714.161 - 381.236}{2 \times 1000} V = 0.1664625 V$

$V_0 = 6.9809$

$\therefore A_v = \frac{V_0}{V_i} = \frac{6.9809}{0.1664625} = 41.936 \approx 41.94$

$\therefore$ Error % $= \frac{41.94 \sim 43}{43} \times 100\% = 2.46\%$

The error is quite small but we have to keep in mind that, for our ~~pu~~ calculation purposes we have done a lot of approximations which range from neglecting small impedences to changing the values of β slightly for our convenience. Therefore, the output is not extremely precise, but quite close.

Comments and Conclusion:

Using standard values slightly affect the desired output. We also used the generic NPN BJT Model Q2N760 from PSpice Library which has a fixed $\beta = 393.6$.

Overall, the results have been satisfactory as the designed common emitter amplifier has yielded the expected gain with less than $\pm 5\%$ error while satisfying other circuit conditions. Therefore, the design is successful in amplifying.

Configuration 6

Attempted By : Oshiul Alim Ornob
Student ID : 24121268

(Name): Oshiul Alim Ornob

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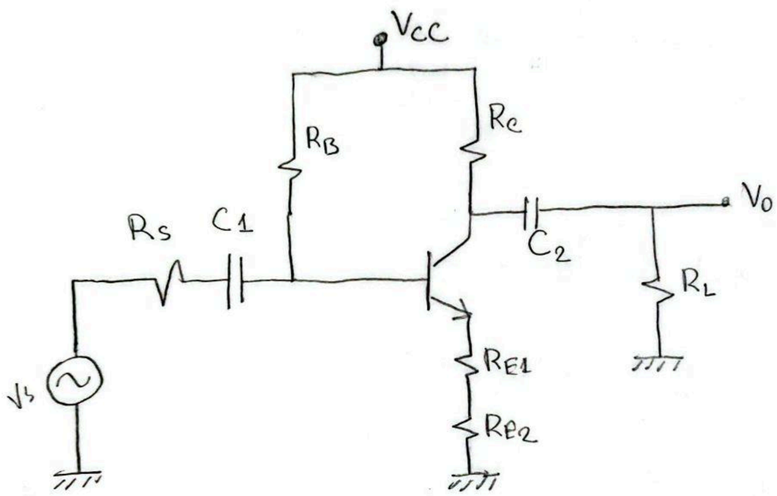
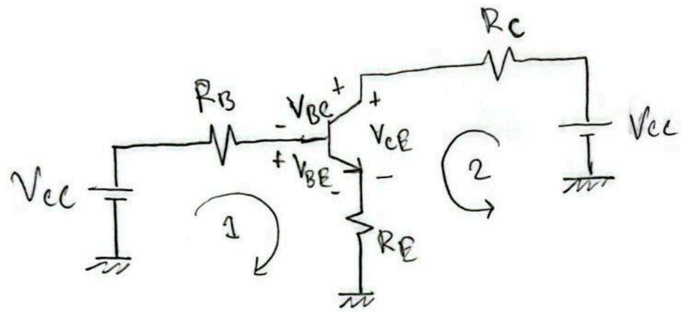
Configuration 6



we can write $R_{E1} + R_{E2} = R_E$ as they're in series.

DC equivalent ckt. (Large signal equivalent ckt.)



Applying KVL @ loop 1,

$$-V_{CC} + I_B R_B + V_{BE} + I_E R_E = 0$$

$$\Rightarrow I_B R_B - V_{CC} + V_{BE} - I_E R_E = 0$$

$$\Rightarrow I_B R_B - V_{CC} + V_{BE} - (1+\beta) I_B R_E = 0$$

$$\Rightarrow I_B \left[R_B - (1+\beta) R_E \right] = V_{CC} - V_{BE}$$

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B - (1+\beta) R_E} \quad \text{------ (1)}$$

$$I_E = (1+\beta) I_B$$

Applying KVL @ loop 2,

$$-V_{CC} + I_C R_C + V_{CE} + I_E R_E = 0$$

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

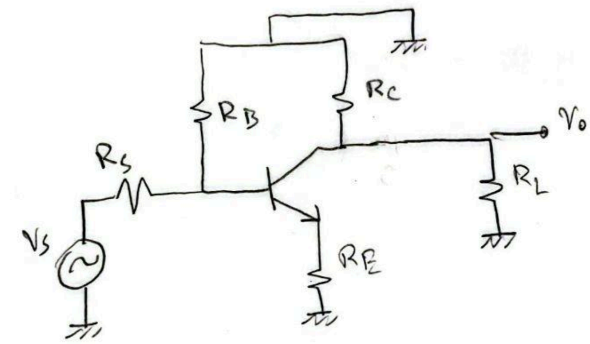
$$\Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E) \quad \dots (\text{ii})$$

$I_C \approx I_E$

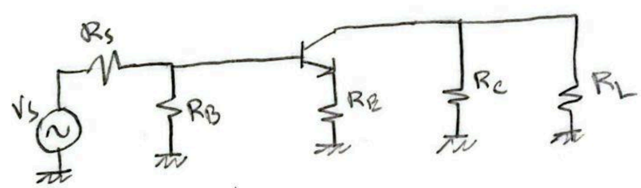
and, $I_C = \beta I_B$

$$\text{so, } I_C = \frac{\beta (V_{CC} - V_{BE})}{R_B + (1+\beta) R_E} \quad \dots (\text{iii})$$

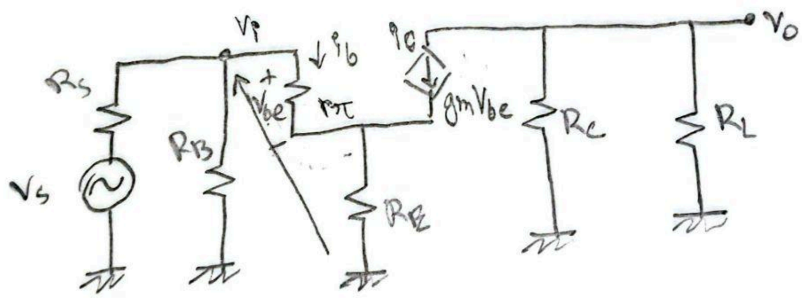
Small signal equivalent ckt.



or,



as Hybrid π model,



here,

$$v_i = i_e R_E + i_b r_\pi$$

and, $v_o = i_o (R_c \| R_L)$

$$= -i_e (R_c \| R_L)$$

$$= g_m v_{be} (R_c \| R_L)$$

$$\therefore R_{ib} = \frac{v_i}{i_b} = \frac{i_e R_E + i_b r_\pi}{i_b} = \frac{i_b r_\pi + i_e R_E}{i_b}$$

$$= \frac{i_b (1+\beta) R_E + i_b r_\pi}{i_b}$$

$$= \frac{i_b \{(1+\beta) R_E + r_\pi\}}{i_b}$$

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

or, $(1+\beta) R_E$ --- (iv)

since $(1+\beta) R_E \gg r_\pi$

$$A_V = \frac{v_o}{v_i} = \frac{-g_m v_{be} (R_c \| R_L)}{i_e R_E + i_b r_\pi} = \frac{-g_m v_{be} (R_c \| R_L)}{i_b (1+\beta) R_E + i_b r_\pi}$$

$$= \frac{-g_m r_\pi \cancel{i_b} (R_c \| R_L)}{[r_\pi + (1+\beta) R_E] \cancel{i_b}} \quad [v_{be} = i_b r_\pi]$$

$$= \frac{-g_m r_\pi (R_c \| R_L)}{(1+\beta) R_E}$$

$[(1+\beta) R_E \gg r_\pi]$

$$= \frac{-\beta\,(R_c \| R_L)}{(1+\beta)\,R_E} \quad \text{---- (v)}$$

The BJT we will be using will have a

large β value. $\therefore$ $1+\beta \approx \beta$

$\therefore$ from eq. (iv) $\longrightarrow$ $(1+\beta)R_E \approx \beta R_E = R_{ib}$

and eq. (v) $\longrightarrow$ $\dfrac{-\beta\,(R_c \| R_L)}{(1+\beta)\,R_E}$

$$\approx \frac{-\beta\,(R_c \| R_L)}{\beta R_E}$$

$$= \frac{-(R_c \| R_L)}{R_E} = A_v$$

[Trial - 1]

Setting R_c to $4.7k\Omega$, a standard resistor. And R_L has to be big ; $R_L = 1M\Omega$

$$A_v = \frac{-(R_c \parallel R_L)}{R_E} \Rightarrow R_E = \frac{(R_c \parallel R_L)}{A_v}$$

eliminating the (-) sign as it only indicates the direction of the output.

Now,
$$R_E = \frac{4.7k \parallel 1M}{43} = 99.57\ \Omega$$
$$\approx 100\ \Omega$$

Since,
$$V_{CE} = \frac{V_{cc}}{2} = \frac{10}{2} = 5\,V$$

and,
$$V_{CE} = V_{cc} - I_c (R_c + R_{E1} + R_{E2})$$

Since R_E has to be around 100 and it is $(R_{E1} + R_{E2})$, picking 2 51Ω resistors will be better than 2 47Ω. (Both are standard Resistors)

1/2

We will be using BJT → Q2N760

running a simple circuit in PSpice, we get it's β value to be 393.6

$\therefore \beta = 393.6$

For our Section → 4 & Group → 4

Requirements for $A_v = 35 + S + G = 43$

and $R_i > 20 + \frac{G}{2} = 22\ \Omega$

We will be using a single 10V DC power source. which is V_{cc} in our circuit.

$\therefore V_{cc} = 10V$

$$\therefore \; V_{CE} = V_{CC} - I_C \left(R_C + R_{E1} + R_{E2} \right)$$

$$\Rightarrow \; 5 = 10 - I_C \left(4700 + 51 + 51 \right)$$

$$\Rightarrow \; I_C = \cancel{\frac{(4700+51+51)}{(10-5)}} \quad \frac{10-5}{4700+51+51}$$

$$= 1.04 \text{ mA.}$$

Here,

$$I_C = \frac{\beta \left(V_{CC} - V_{BE} \right)}{R_B + (\beta+1)(R_{E1} + R_{E2})}$$

$$\Rightarrow \; I_C R_B + I_C (\beta+1)(R_{E1} + R_{E2}) = \beta (V_{CC} - V_{BE})$$

$$\Rightarrow \; I_C R_B = \beta (V_{CC} - V_{BE}) - I_C (\beta+1)(R_{E1} + R_{E2})$$

$$\Rightarrow \; R_B = \frac{1}{I_C} \left[\beta (V_{CC} - V_{BE}) - I_C (\beta+1)(R_{E1} + R_{E2}) \right]$$

$$= \frac{1}{1.04 \times 10^{-3}} \left[393.6 (10 - 0.7) - 1.04 \times 10^{-3} (393.6 + 1) \left(\overset{102}{\cancel{0.102k}} \; \cancel{51+51} \right) \right]$$

$$= \cancel{3479.44} \quad \cancel{\text{or}} \Rightarrow 3.479 \times 10^{6} \text{ V}$$

$$\cancel{\approx 3500 \text{ or } 3.5k} \quad \text{or } 3.5 \text{ M}\Omega$$

we can opt for a ~~3.5MΩ~~ 3.6MΩ resistor for R_B.

Now, $R_{ib} = \beta \times R_E$

$= 3936\ \Omega$

and, $R_i = R_B \parallel R_{ib}$

$$= \frac{R_B \times R_{ib}}{R_B + R_{ib}}$$

$= 3931.55\ \Omega$

but, $R_i \ngtr 22k$.

there fore, this trial didn't fulfill all the conditions.

$$A_v = \cancel{-5-(-5)}\ \frac{-5.5562-(-6.4501)}{+0.49-(-0.49)}$$

$= 0.91$

[Trial 2]

assuming $R_c = 22k\Omega$

$\therefore$ ~~R_E~~ $A_v = \frac{R_C}{R_E}$ for $R_L = \infty$

$R_E = \frac{R_c}{A_v} = \frac{22k}{43} = 511.6279\ \Omega$

and $V_{CE} = V_{cc} - I_C (R_C + R_{E1} + R_{E2})$

$5 = \cancel{100}\ 10 - I_C (22k + 511.6279)$

$\Rightarrow I_C = \frac{5}{22511.63} = 0.22\ mA.$

$R_B = \frac{1}{I_C} \cdot [\beta (V_{cc} - V_{BE}) - I_C (\beta+1)(R_{E1} + R_{E2})]$

$= \cancel{1.2452}\ 16.28\ M\Omega$

$\therefore R_i = \beta R_E = 201.37\ k\Omega$

$\therefore R_{ib} = R_B \| R_{ib} = 198.91\,k$

$R_{ib} > 22K.$

But after running it through PSpice, it doesn't seem to maintain the average gain.

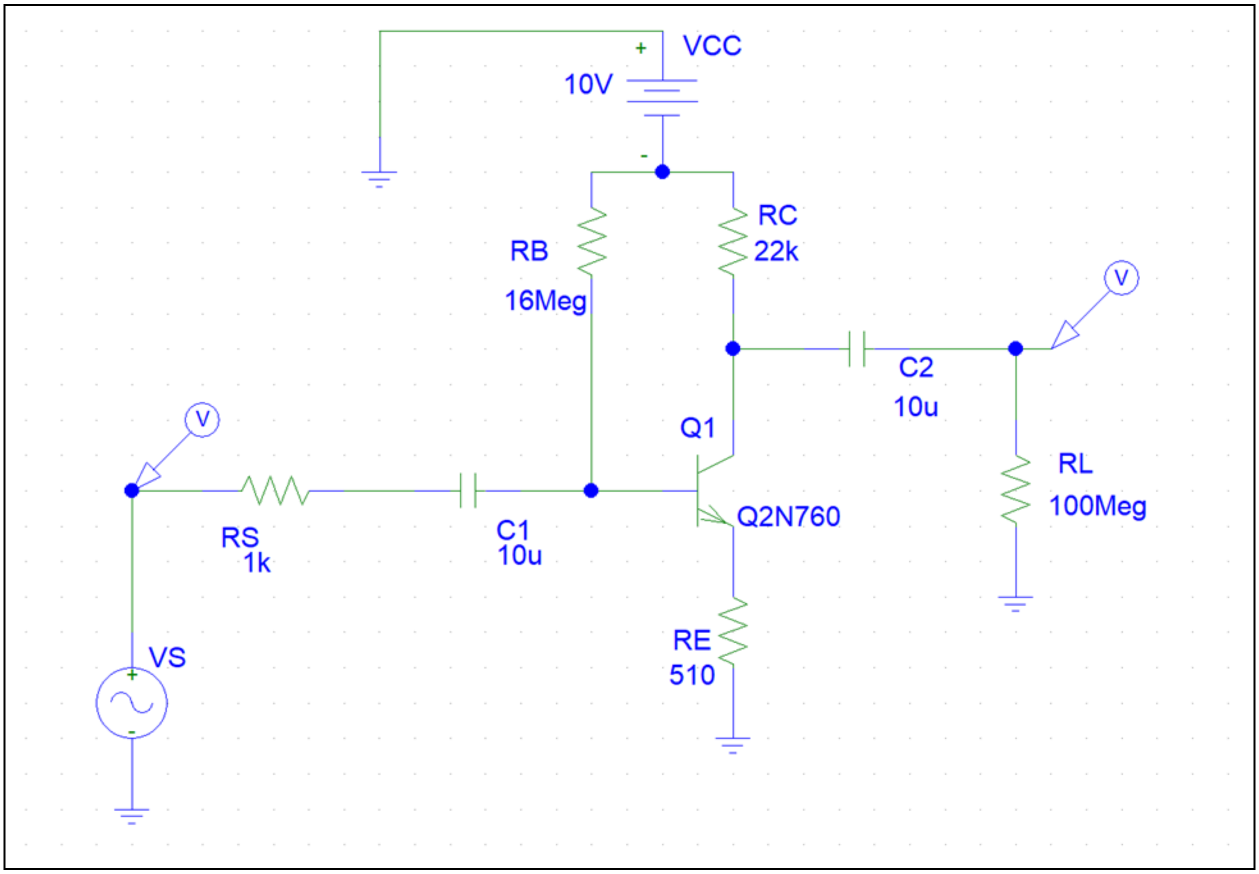
$$A_v = \cancel{\frac{500 - (-500)}{}} \quad \cancel{\frac{0.51 - (-0.5)}{-1.873 - (-2.843)}}$$

$$= \frac{-1.873 - (-2.843)}{-5 - (-5)}$$

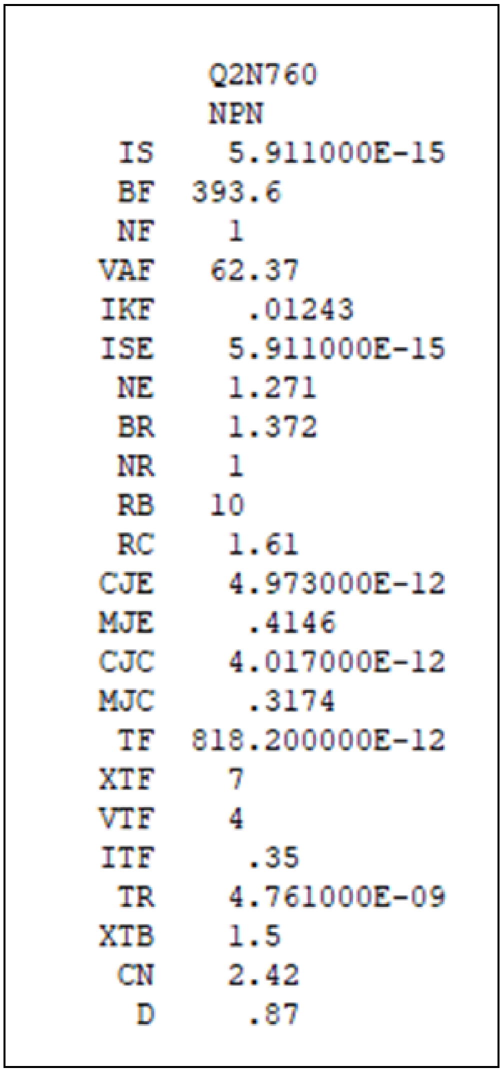
$$= \cancel{1.03} \quad 0.97$$

where it was supposed to be 43.

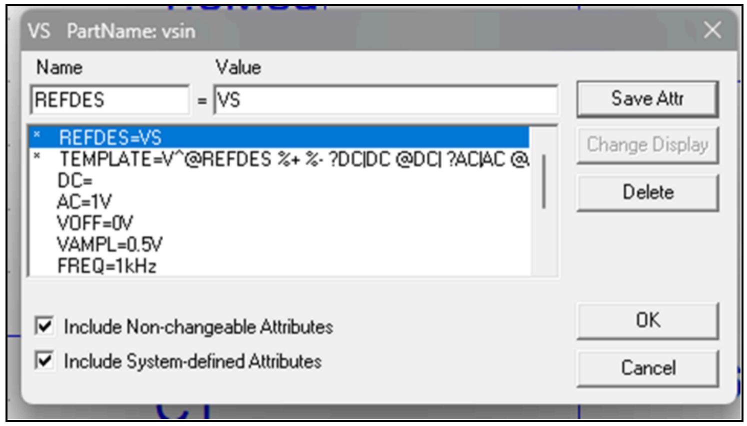
therefore this trial was also a failure.

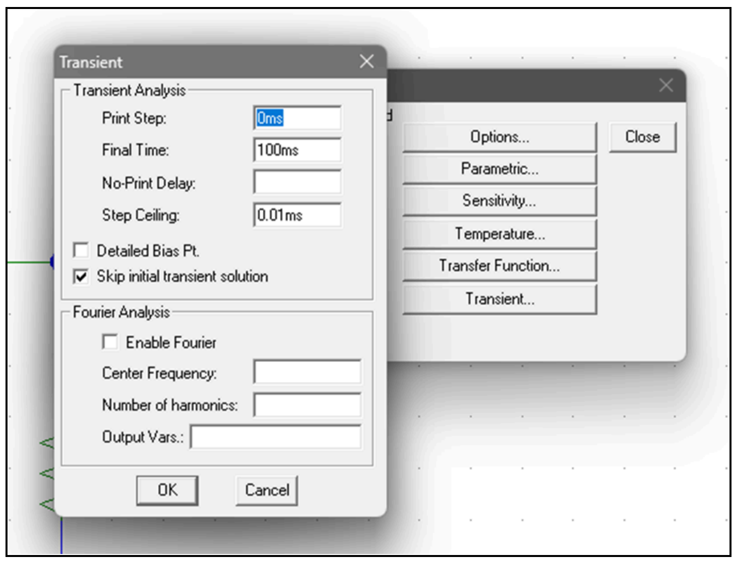


Config 6 done in PSpice

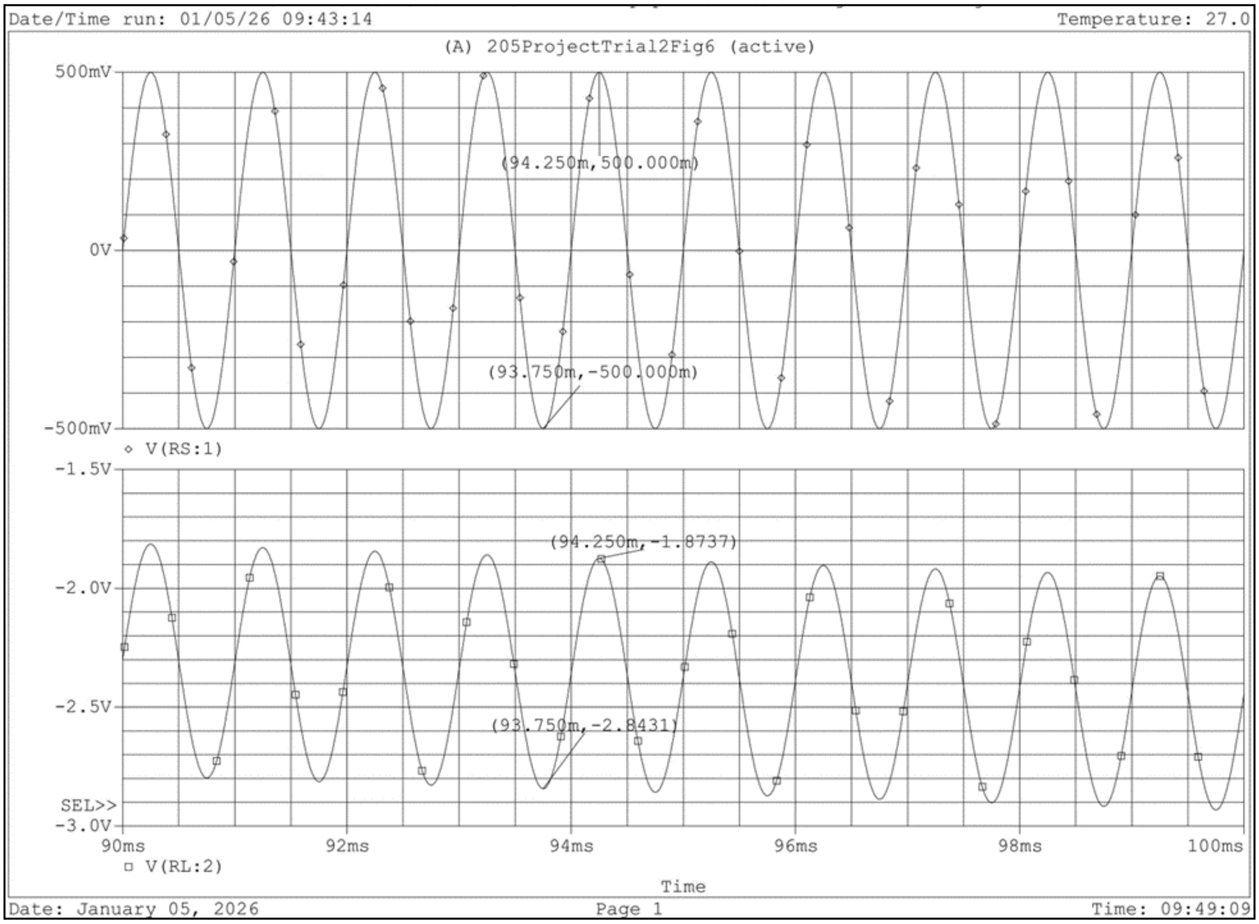


	Q2N760
	NPN
IS	5.911000E-15
BF	393.6
NF	1
VAF	62.37
IKF	.01243
ISE	5.911000E-15
NE	1.271
BR	1.372
NR	1
RB	10
RC	1.61
CJE	4.973000E-12
MJE	.4146
CJC	4.017000E-12
MJC	.3174
TF	818.200000E-12
XTF	7
VTF	4
ITF	.35
TR	4.761000E-09
XTB	1.5
CN	2.42
D	.87





Setup



Simulation Results

		Trial 1	*Trial 2*
Found Values	**RC(kΩ)**	4.7	22
	RE(kΩ)	0.1	510
	RB(kΩ)	3479	16280
Corresponding Standard Values	**RC(kΩ)**	4.7	22
	RE1(kΩ)	0.051	510
	RE2(kΩ)	0.051	
	RB(kΩ)	3600	16000
Input Impedance, Ri(kΩ)		3.9	198.91
Gain, Av		0.91	0.97
Result Acceptance		Rejected	Rejected

Comments :

Having voltage gain set to be around medium range may have caused some degree of discrepancy as the condition of configuration 6 was designed around high voltage gain.

While R_E and R_C weren't in proximity of each other as their values were far apart, but R_B was far greater ; which was also mentioned in the descreption of this configuration.

Even after a long time in simulations (around 0 to 1 seconds) , the graph ~~b~~ of the output had a slope which was affected when capacitors were changed but the slope was not removed fully .

Configuration 5

Attempted By : Souvik Barman Ratul
Student ID : 24121205

EEE205

Design Assignment

Name: Souvik Barman Ratul

ID : 24121205

Group: 04

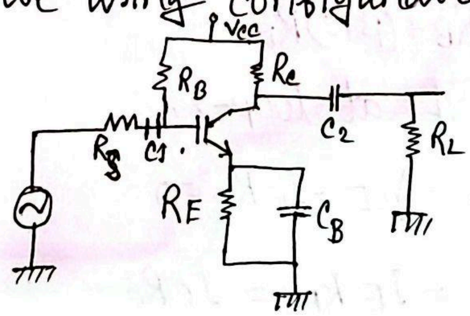
Section: 04

Here,
S = 4 [section number]
G = 4 [Group number]

now,
voltage gain $|A_V| = \frac{V_o}{V_i} = (35+S+G)$
$= (35+4+4)$ V
$= 43$ V

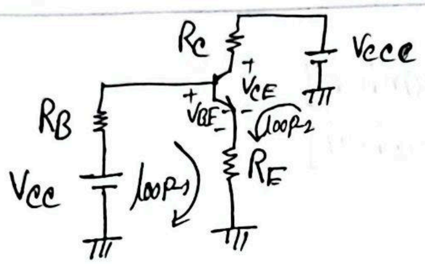
Input resistance $R_i > (20+\frac{G}{2})$ KΩ
$R_i > (20+\frac{4}{2})$ KΩ
$R_i > 22$ KΩ

Here we using configuration-5,



Step-1
DC equivalent circuit (open all capacitor)

Step-2
AC equivalent circuit (short all capacitor)



now,

Applying KVL at loop-1,

$$-V_{CC} + I_B R_B + V_{BE} + I_E R_E = 0.$$

$$\Rightarrow -V_{CC} + I_B R_B + V_{BE} + I_B(\beta+1) R_E = 0$$

$$\Rightarrow I_B R_B + I_B(\beta+1) R_E = V_{CC} - V_{BE}$$

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} \quad \cdots \text{(i)}$$

Applying KVL at loop-2,

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

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

$$\Rightarrow R_C = \frac{V_{CC} - V_{CE} - I_E R_E}{I_C} \quad \cdots \text{(ii)}$$

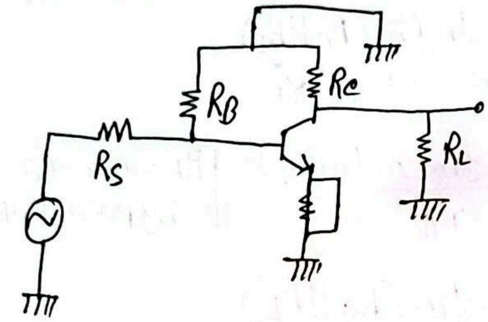
now,

$$I_C = \beta I_B$$

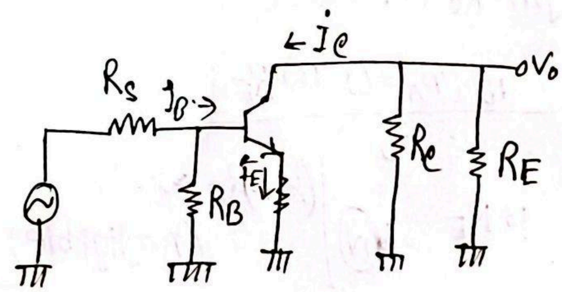
$$= \beta \left(\frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} \right) \quad \cdots \text{(iii)}$$

now,

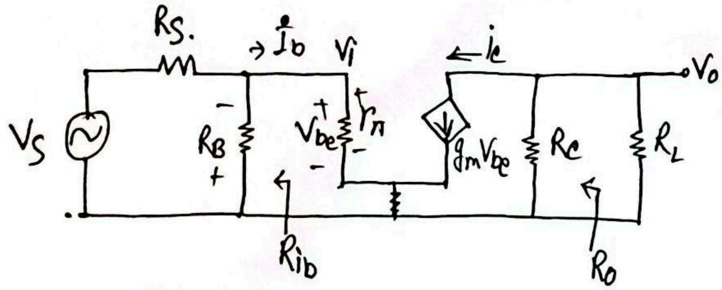
The AC equivalent circuit,



Redraw the circuit



now we replaceing this circuit with π-model.



$V_{in} = i_b r_\pi + i_e R_E$

$\Rightarrow V_{in} = i_b \left[r_\pi + (1+\beta) R_E\right]$

and,

$V_o = -(\beta i_b)(R_c \| R_L)$

$$A_v = \frac{V_o}{V_{in}} = \frac{-\beta(i_b)(R_C \| R_L)}{i_b[r_\pi + (1+\beta)R_E]}$$

$$= \frac{-g_m r_\pi (R_C \| R_L)}{r_\pi + (1+\beta)R_E}$$

$$= \frac{-g_m \cancel{r_\pi}(R_C \| R_L)}{\cancel{r_\pi}} \quad \left[R_E = 0 \text{ ; for the bypass capacitor}\right]$$

$$= -g_m (R_C \| R_L)$$

$$|A_v| = g_m (R_C \| R_L) \ldots \text{(V)}$$

$$\therefore R_{ib} = \frac{V_{in}}{i_b} = \frac{\cancel{i_b}[r_\pi + (1+\beta)R_E]}{\cancel{i_b}}$$

$$R_{ib} \approx \beta R_E \ldots \text{(iv)} \quad \left[(1+\beta)R_E >>> r_\pi \text{ (negligible)}\right]$$

Trial-1

Let, $\beta = 393.6$

$$V_{CE} = \frac{V_{CC}}{2} = \frac{10}{2} = 5V$$

$$V_T = 0.026V, \quad I_C = 35\ mA \approx I_E$$

$$R_B = 100\ k\Omega, \quad R_L = 100K$$

(iii) $\Rightarrow$

$$I_C = \beta \left(\frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} \right)$$

$$\Rightarrow 35 = 393.6 \left(\frac{10 - 0.7}{100 + 393.6 \times R_E} \right)$$

$$\Rightarrow 35 = \frac{3660.48}{100 + (393.6 R_E)}$$

$$\Rightarrow 3660.48 = 3500 + 13776 R_E$$

$$\Rightarrow R_E = 0.012\ k\Omega$$

(ii) $\Rightarrow$

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

$$= \frac{10 - 5 - (35 \times 0.012)}{35}$$

$$= 0.131\ k\Omega$$

now,

$$g_m = \frac{I_C}{V_T} = \frac{35}{0.026} = 1346.16 \text{ mS.}$$

$$R_\pi = \frac{\beta}{g_m} = \frac{393.6}{1346.16} = 0.292 \text{ k}\Omega$$

$$\therefore R_{iB} = R_\pi = 0.292 \text{ k}\Omega$$

$$R_I = (R_{iB} \| R_B) = (0.292^{-1} + 100^{-1})$$
$$= 3.43 \text{ k}\Omega$$

now,

$$A_V = g_m(R_C \| R_L)$$
$$= 1346.16(0.131^{-1} + 100^{-1})$$
$$= 102.8$$

now,

$$A_V = 102.8 > 43 \text{ V}$$

and $R_I = 3.43 < 22 \text{ k}\Omega$

$\therefore$ The trial is not successful.

Traial-2

Let, $\beta = 393.6$

$V_{CE} = \frac{V_{CC}}{2} = \frac{10}{2} = 5V.$

$V_T = 0.026V, \quad I_C = 15mA \approx I_E$

$R_B = 10K\Omega \quad , \quad R_L = 100k\Omega$

(iii) ⇒

$$I_C = \beta\left(\frac{V_{CC} - V_{BE}}{R_B + (\beta+1)R_E}\right)$$

$$\Rightarrow 15 = 393.6\left(\frac{10 - 0.7}{10 + 394.6 \times R_E}\right)$$

$$\Rightarrow 3660.48 = 150 + 1919 R_E$$

$$\Rightarrow R_E = 1.83 k\Omega$$

(ii) $R_C = \frac{V_{CC} - V_{CE} - I_C R_E}{I_C}$

$$= \frac{10 - 5 - (15 \times 1.83)}{15}$$

$$= -1.497 K\Omega$$

now,

$$g_m = \frac{I_C}{V_T} = \frac{15}{0.026} = 576.92 mS.$$

$$R_\pi = \frac{\beta}{g_m} = \frac{393.6}{576.92} = 0.68 \, k\Omega$$

$$R_{i\beta} = R_\pi = 0.68 \, k\Omega$$

$\cancel{R_i(R}\ R_i = (R_{iB} \| R_B)$

$= (0.68^{-1} + 10^{-1})$

$= 1.58\,k\Omega$

$A_V = g_m (R_C \| R_L)$

$= 576.92((-1.497)^{-1} + (100)^{-1})$

$= 391.15$

now,

$A_V = 391.15 > 43V.$

$R_i = 1.58 < 2.2\,k\Omega$

This trial is not successful.