K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Single Stage BJT Amplifier

Numerical 1:

For the common base configuration in figure 1,

a. Determine r_π

b. Find Z_i & Z_o

c. Calculate A_v

Given : $\alpha = 0.998$, $r_o = 1\text{M}\Omega$

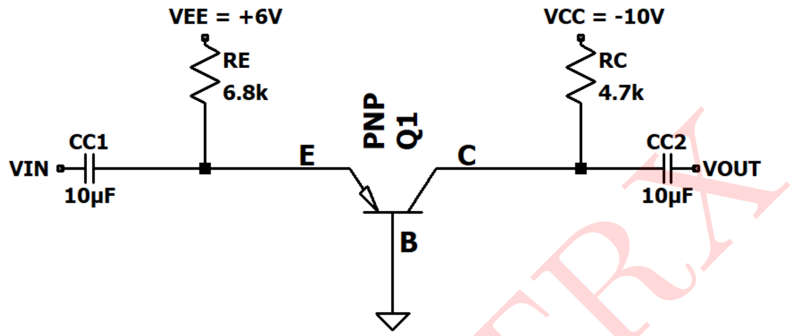

Figure 1: Circuit 1

Solution: The given circuit 1 is a commom base BJT amplifier employing a pnp BJT

DC Analysis:

We remove the capacitors,

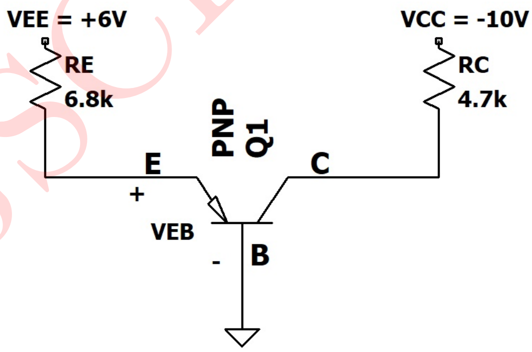

Figure 2: DC Equivalent Circuit

Applying KVL to Base-Emitter loop,

$V_{EE} - I_{EQ}R_E - V_{EB} = 0$

$6 - (I_{EQ})(6.8k\Omega) - 0.7 = 0$

$I_{EQ} = \dfrac{6 - 0.7}{6.8k\Omega} = \mathbf{0.7793mA}$

For a Common Base configuration,

$I_C = \alpha I_E$

$\therefore I_{CQ} = \alpha I_{EQ}$

$= (0.998)(0.7794\text{mA})$

$= \mathbf{0.77784mA}$

Small signal Anaysis:

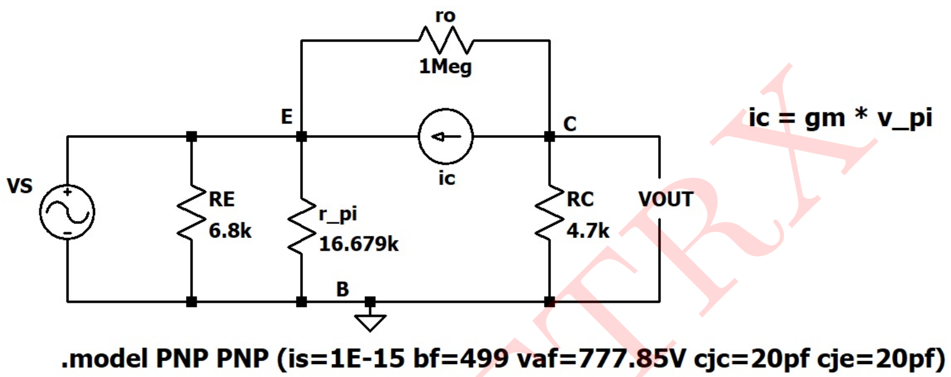

Figure 3: Small Signal Equivalent Circuit

$$g_m = \frac{I_{CQ}}{V_T} = \frac{0.7784mA}{0.026V} = \mathbf{29.9169mA/V}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$\therefore V_A = r_o \times I_{CQ}$

$= (1M\Omega)\ (0.77784mA)$

$= \mathbf{777.84V}$

$$r_\pi = \frac{\beta \times V_T}{I_{CQ}}$$

Since, $\alpha = 0.998$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.998}{1-0.998} = 499$$

$$\therefore r_\pi = \frac{499 \times 0.026}{0.77784mA} = \mathbf{16.679k\Omega}$$

$$\text{Voltage Gain } (A_V) = \frac{V_{OUT}}{V_{IN}}$$

$A_V = g_m(R_C \parallel r_o)$

$= 29.9169mA/V \times (4.7k\Omega \parallel 1M\Omega)$

$$= 29.9169 \times \frac{(4.7k\Omega)(1M\Omega)}{4.7k\Omega + 1M\Omega}$$

$= \mathbf{139.951}$

Input and Ouput Impedance:

Input Impedance $(Z_i) = \left(\dfrac{1}{g_m}\right) \parallel R_E \parallel r_\pi \parallel r_o$

$Z_i = \left(\dfrac{1}{29.9169mA/V}\right) \parallel 6.8k\Omega \parallel 16.679k\Omega \parallel 1M\Omega$

$= \mathbf{33.195\Omega}$ [Low input impedance for common base configuration]

Output Impedance $(Z_o) = R_C \parallel r_o$

$Z_o = 4.7k\Omega \parallel 1M\Omega = \mathbf{4.678k\Omega}$

SIMULATED RESULTS

The above circuit is simulated in LTspice and results are presented below:

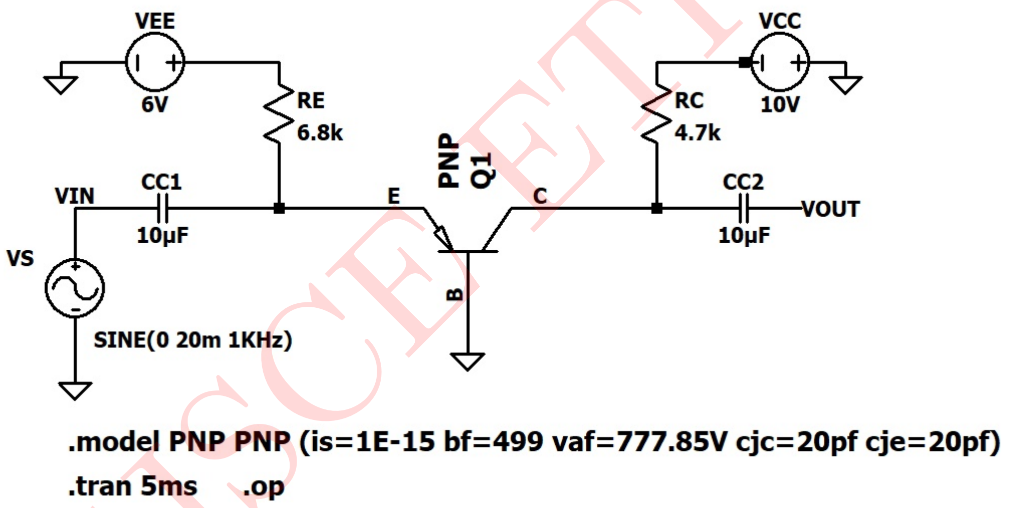

Figure 4: Circuit Schematic

The input and output waveform are shown in figure 5

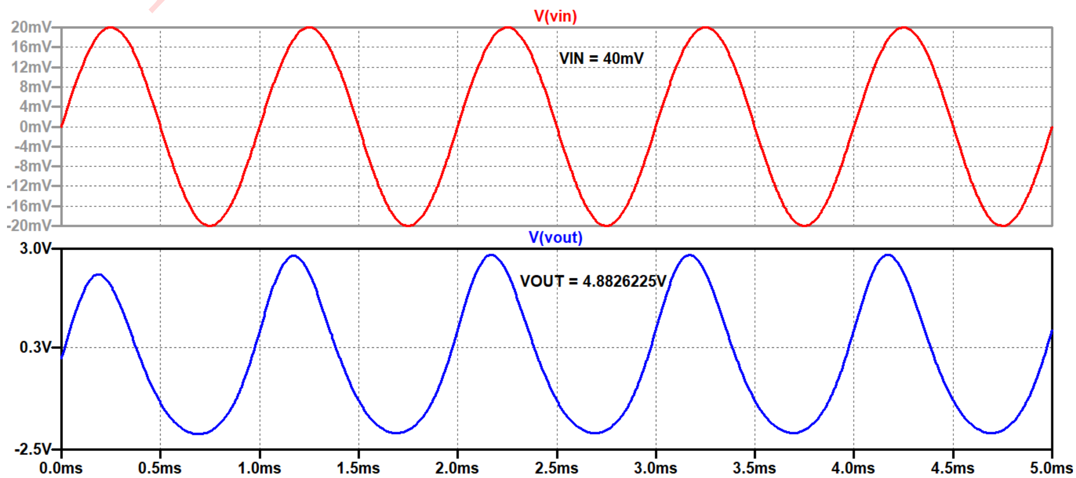

Figure 5: $V_{IN}(t)$ & $V_{OUT}(t)$

Comparison of Theoretical and Simulated results:

Parameters	Theoretical	Simulated
I_{CQ}	$0.77784mA$	$0.776735mA$
I_{EQ}	$0.7794mA$	$0.77827mA$
A_V	139.951	122.065

Table 1: Numerical 1

Numerical 2:

For the circuit shown in figure 6, determine

a. r_π b. Z_i c. Z_o d. A_V

Given: $\beta = 140$, $r_o = 30k\Omega$

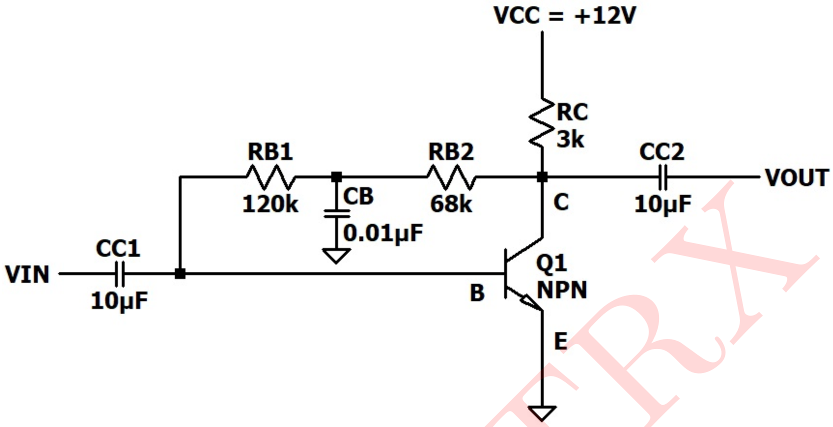

Figure 6: Circuit 2

Solution: The above circuit 2 is a Common Emitter BJT amplifier employing a npn BJT in Collector to Base bias configuration

DC Analysis:

We remove all the capacitors,

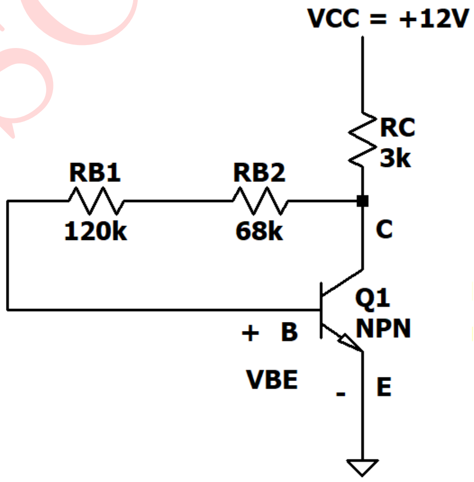

Figure 7: DC Equivalent Circuit

Applying KVL to the Base Emitter loop,

$V_{CC} - I_{CQ}R_C - I_{BQ}(R_{B_1} + R_{B_2}) - V_{BE} = 0$

$V_{CC} - \beta I_{BQ}R_C - I_{BQ}(R_{B_1} + R_{B_2}) - V_{BE} = 0$ [Since, $I_C = \beta I_B$]

$$
\begin{aligned}
I_{BQ} &= \frac{V_{CC} - V_{BE}}{\beta R_C + (R_{B_1} + R_{B_2})} \\
&= \frac{12 - 0.7}{(140)(3k\Omega) + (120k\Omega + 68k\Omega)} \\
&= \frac{11.3V}{608k\Omega} \\
&= \mathbf{18.585\mu A}
\end{aligned}
$$

$$I_{CQ} = \beta I_{BQ} = 140\ (18.585\mu A) = \mathbf{2.6019mA}$$

Small Signal Analysis:

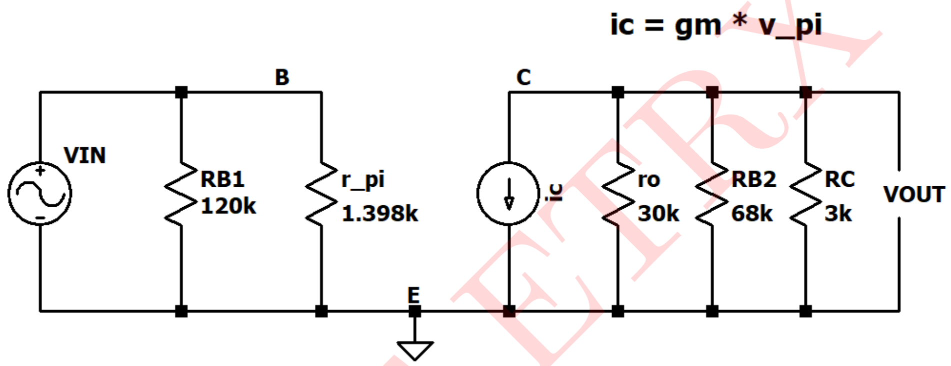

Figure 8: Small Signal Equivalent Circuit

$$g_m = \frac{I_{CQ}}{V_T} = \frac{2.6019mA}{0.026V} = \mathbf{100.073mA/V}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{140 \times 0.026V}{2.6019mA} = \mathbf{1.398k\Omega}$$

Now, given that $r_o = 30k\Omega$

But, $r_o = \dfrac{V_A}{I_{CQ}}$

$$
\begin{aligned}
\therefore V_A &= r_o \times I_{CQ} \\
&= (30k\Omega)\ (2.6019mA) \\
&= \mathbf{78.057V}
\end{aligned}
$$

Input and Ouput Impedance:

Input Impedance $(Z_i) = R_{B_1} \parallel r_\pi$

$$
\begin{aligned}
(Z_i) &= 120k\Omega \parallel 1.398k\Omega \\
&= \frac{120k\Omega \times 1.398k\Omega}{120k\Omega + 1.398k\Omega} \\
&= \mathbf{1.381k\Omega}
\end{aligned}
$$

Ouput Impedance $(Z_o) = r_o \parallel R_{B_2} \parallel R_C$

$$
\begin{aligned}
(Z_o) &= 30k\Omega \parallel 68k\Omega \parallel 3k\Omega \\
&= \mathbf{2.622k\Omega}
\end{aligned}
$$

Voltage Gain $(A_V) = \frac{V_{OUT}}{V_{IN}}$

From figure 8,

$$\begin{aligned} A_V &= -g_m(r_o \parallel R_C \parallel R_{B_2}) \\ &= -(100.1538mA/V)\ (30k\Omega \parallel 3k\Omega \parallel 68k\Omega) \\ &= -(100.1538mA/V)\ (2.622k\Omega) \\ &= -\mathbf{262.6} \qquad \text{[Voltage Gain of given CE Amplifier]} \end{aligned}$$

The negative sign indicates that the Input and Ouput signals are 180° out of phase

SIMULATED RESULTS

The above circuit is simulated in LTspice and results are presented below:

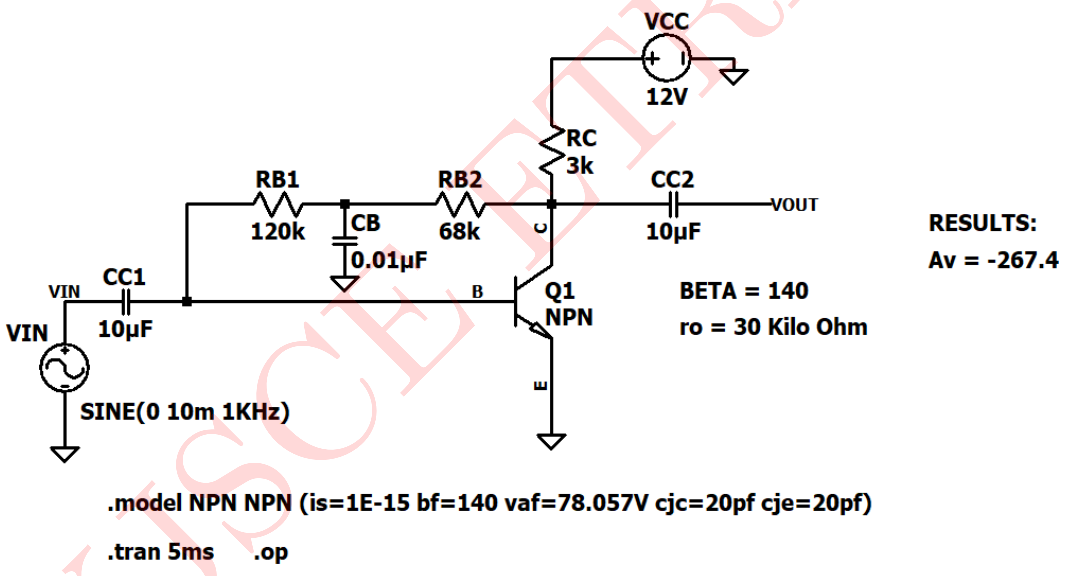

Figure 9: Circuit Schematic

The input and output waveform are shown in figure 10

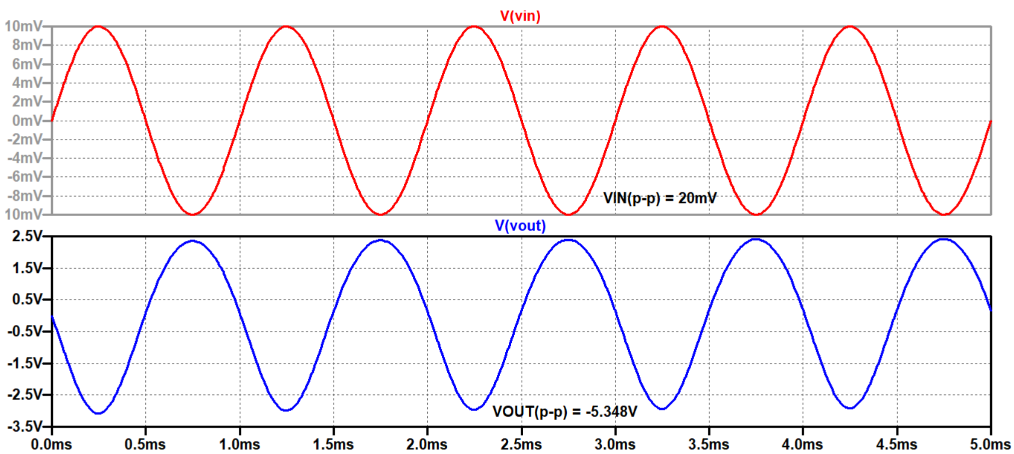

Figure 10: $V_{IN}(t)$ & $V_{OUT}(t)$

Comparison of Theoretical and Simulated results:

Parameters	Theoretical	Simulated
I_{CQ}	$2.6019mA$	$2.61418mA$
I_{BQ}	$18.585\mu A$	$17.9\mu A$
A_V	-262.6	-267.4

Table 2: Numerical 2

Numerical 3:

Determine the following for the circuit shown in figure 11,

a. Small signal voltage gain

b. Input Impedance

c. Output Impedance

Given: $\beta = 100$, $V_A = 80V$

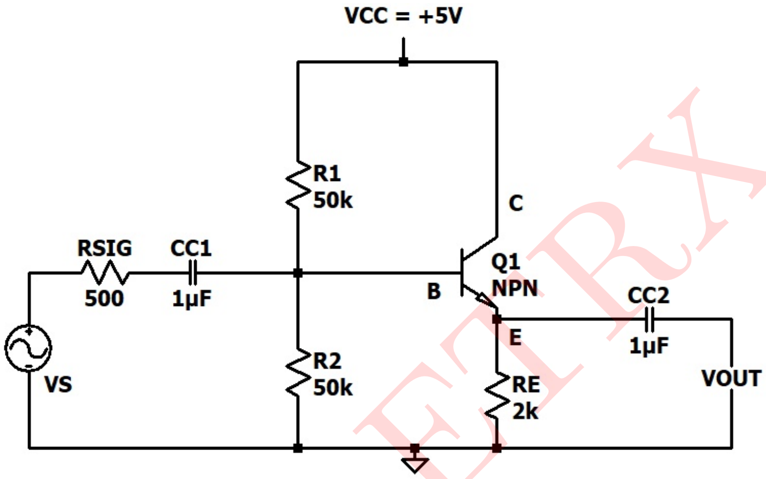

Figure 11: Circuit 3

Solution: The above circuit 3 is a Common Collector amplifier using npn BJT

DC Analysis:

We remove all the capacitors,

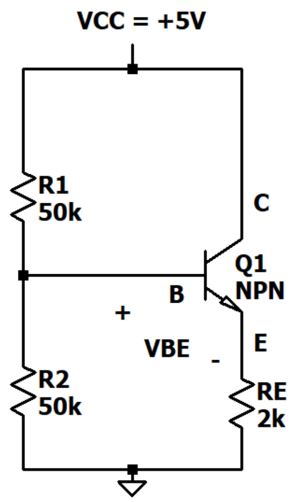

Figure 12: DC Equivalent Circuit

Applying Thevenin's equivalent circuit to input side i.e at base,

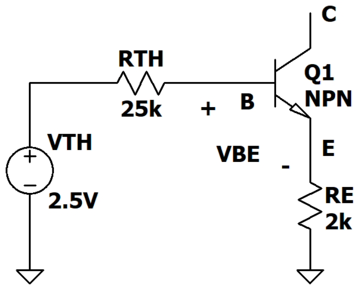

Figure 13: Thevenin's Equivalent Circuit

$$V_{TH} = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{50k\Omega \times 5}{50k\Omega + 50k\Omega} = \mathbf{2.5V}$$

$$R_{TH} = R_1 \parallel R_2 = 50k\Omega \parallel 50k\Omega = \mathbf{25k\Omega}$$

Applying KVL to Base Emitter loop,

$V_{TH} - I_{BQ}R_{TH} - V_{BE} - I_{EQ}R_E = 0$

$V_{TH} - I_{BQ}R_{TH} - V_{BE} - (1+\beta)I_{BQ}R_E = 0$

$$\begin{aligned} I_{BQ} &= \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta)R_E} \\ &= \frac{2.5 - 0.7}{25k\Omega + (101 \times 2k\Omega)} \\ &= \mathbf{7.93\mu A} \end{aligned}$$

$$I_{CQ} = \beta I_{BQ} = (100)(7.93\mu A) = \mathbf{0.793mA}$$

Applying KVL to Commom Emitter loop,

$V_{CC} - V_{CEQ}$ - $I_{EQ}R_E = 0$

$$\begin{aligned} V_{CEQ} &= V_{CC} - (1+\beta)I_{BQ}R_E \qquad \text{[Since, } I_E = (1+\beta)I_B\text{]} \\ &= 5V - (101)(7.93\mu A)(2k\Omega) \\ &= \mathbf{3.4V} \end{aligned}$$

Small Signal Analysis:

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100 \times 0.026V}{0.793mA} = \mathbf{3.278k\Omega}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{0.793mA}{26mV} = \mathbf{30.5mA/V}$$

$$r_o = \frac{V_A}{I_{CQ}} = \frac{80V}{0.793mA} = \mathbf{100.88k\Omega}$$

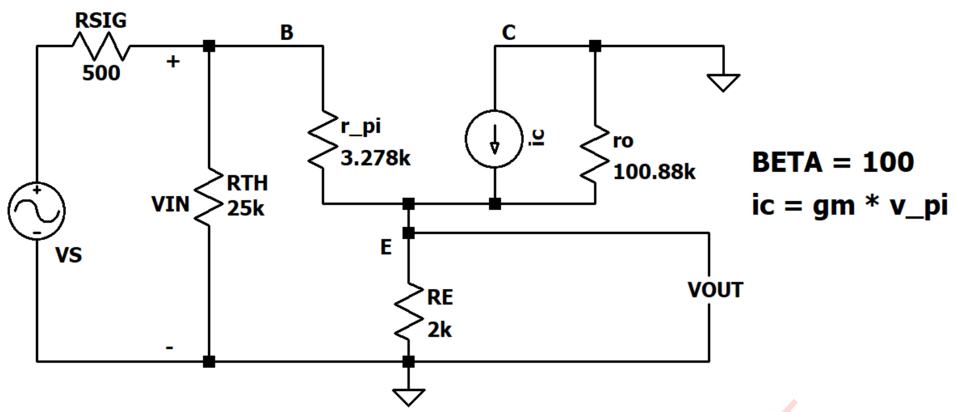

Figure 14: Small Signal Equivalent Circuit

Input and Ouput Impedance:

Input Impedance $(Z_i) = R_{TH} \parallel [r_\pi + (1+\beta)(R_E \parallel r_o)]$

$r_o \parallel R_E = 100.88k\Omega \parallel 2k\Omega$

$r_o \parallel R_E = 1.96k\Omega$

$r_\pi + (1+\beta)(r_o \parallel R_E) = 3.278k\Omega + (101)(1.96k\Omega)$

$r_\pi + (1+\beta)(r_o \parallel R_E) = 201.24k\Omega$

$\therefore Z_i = 25k\Omega \parallel 201.24k\Omega = \mathbf{22.24k\Omega}$

Ouput Impedance $(Z_o) = R_E \parallel \left(\frac{1}{g_m}\right) \parallel r_o$

$$Z_o = 2k\Omega \parallel \left(\frac{1}{30.5mA/V}\right) \parallel 100.88k\Omega$$
$$= 2k\Omega \parallel 32.78 \parallel 100.88k\Omega$$
$$= 32.25 \parallel 100.88k\Omega$$
$$= \mathbf{32.24\Omega}$$

Small Signal Voltage Gain ($\mathbf{A_V}$):

$$A_{VS} = \frac{V_O}{V_S} = \frac{V_O}{V_{IN}} \times \frac{V_{IN}}{V_S} = A_V \times \frac{V_{IN}}{V_S}$$

$$A_V = \frac{R_E \parallel r_o}{\left(\frac{1}{g_m}\right) + (R_E \parallel r_o)}$$

$R_E \parallel r_o = 2k\Omega \parallel 100.88k\Omega = 1.96k\Omega$

$$\frac{1}{g_m} = \frac{1}{30.5mA/V} = 32.78\Omega$$

$$\therefore A_V = \frac{1.96k\Omega}{32.78\Omega + 1.96k\Omega} \approx 0.9835$$

$$A_{VS} = A_V \times \frac{V_{IN}}{V_S}$$

$$\frac{V_{IN}}{V_S} = \frac{Z_i}{Z_i + R_{SIG}} = \frac{22.24k\Omega}{22.24k\Omega + 500\Omega}$$

$$\frac{V_{IN}}{V_S} = 0.978$$

$$\therefore A_{VS} = \frac{V_O}{V_S} = 0.9835 \times 0.978$$

$A_{VS} = \mathbf{0.962}$ [Small signal voltage gain of CC amplifier]

SIMULATED RESULTS

The above circuit is simulated in LTspice and results are presented below:

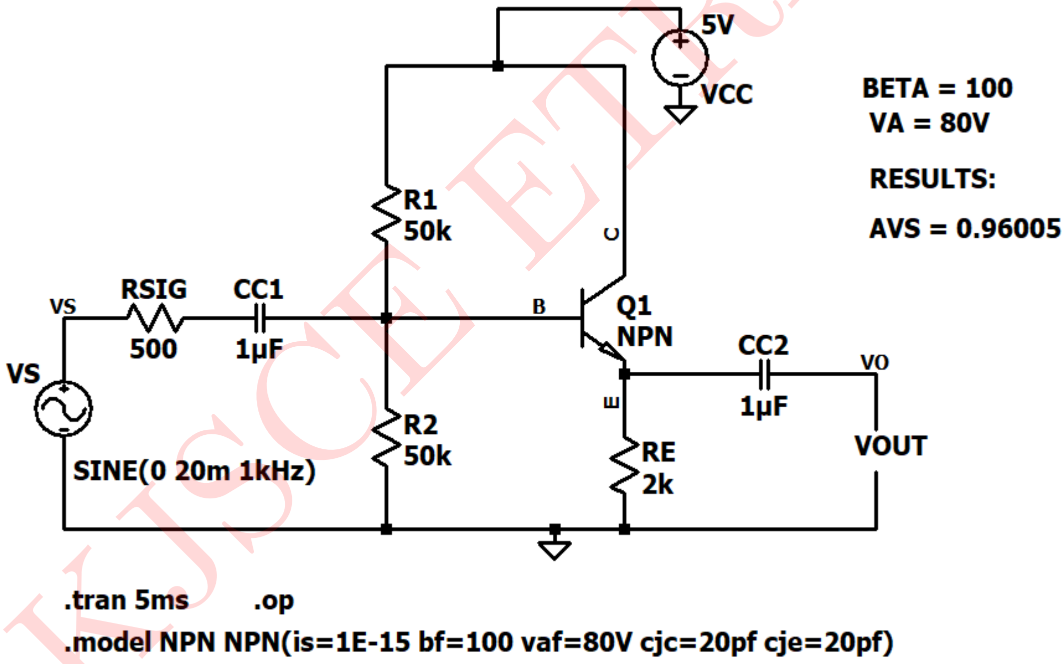

Figure 15: Circuit Schematic

The input and output waveform are shown in figure 16

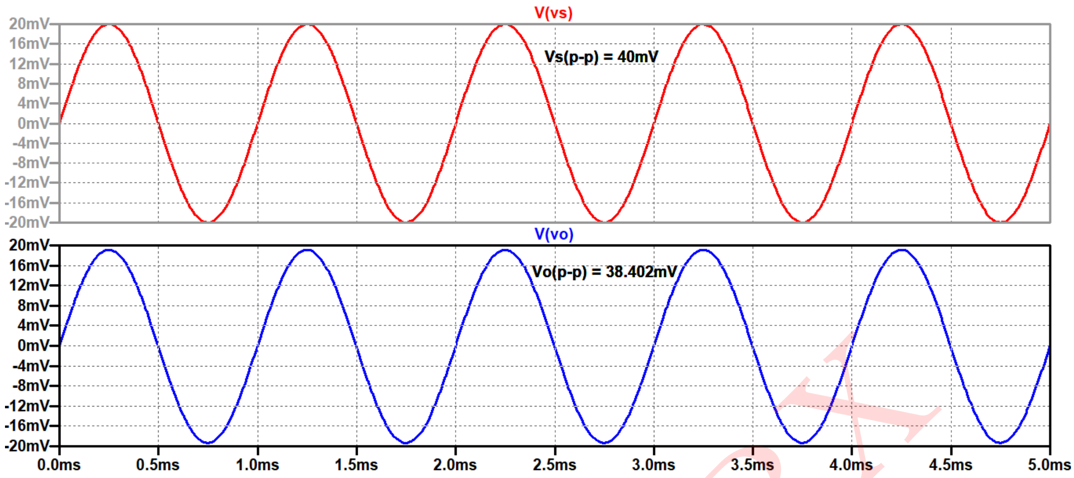

Figure 16: $V_{IN}(t)$ & $V_{OUT}(t)$

Comparison of Theoretical and Simulated results:

Parameters	Theoretical	Simulated
I_{CQ}	$0.793mA$	$0.7926mA$
I_{BQ}	$7.93\mu A$	$7.668\mu A$
V_{CEQ}	$3.4V$	$3.399V$
A_{VS}	0.962	0.96005

Table 3: Numerical 3

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