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

11^{th} **July, 2020** **Numericals**

Numerical 1: For the circuit shown below in figure 1. Determine:

a) r_π

b) Z_i and Z_o

c) A_v (voltage gain)

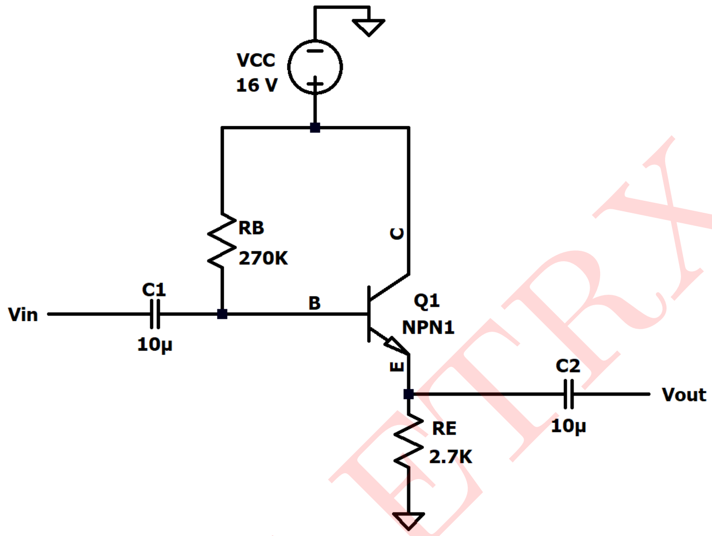

Figure 1: Circuit 1

Solution: DC ANALYSIS:

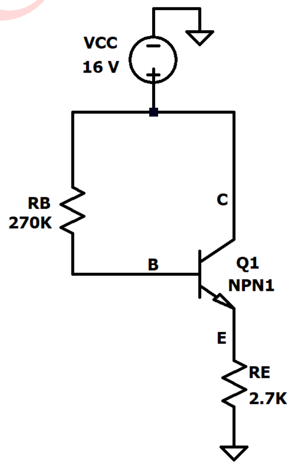

Figure 2: DC Equivalent Circuit

By applying KVL to base - emitter loop,

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

$I_E = (\beta + 1) I_B$

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

$$\therefore I_B = \frac{V_{CC} - V_{BE}}{[R_B + (\beta + 1) R_E]} = \frac{16 - 0.7}{[270k + (11)(2.7k)]} = \frac{15.3}{5697 \times 10^3} = \mathbf{26.8\mu A}$$

$I_C = \beta I_B = 110 \times 26.8 \times 10^{-6} = \mathbf{2.95mA}$

Applying KVL to the collector emitter loop:

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

$V_{CE} = V_{CC} - (1 + \beta) I_B R_E = 16 - (111)(26.8 \times 10^{-6})(2.7 \times 10^3) = \mathbf{8V}$

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

AC ANALYSIS:

a) Small Signal Parameter:

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

Here, $V_T = 26mV$

$$g_m = \frac{2.95 \times 10^{-3}}{26 \times 10^{-3}} = 0.11346 = \mathbf{113.46mA/V}$$

$r_o = 50k\Omega$ (given)

$$r_\pi = \frac{V_T}{I_{BQ}} = \frac{26 \times 10^{-3}}{26.8 \times 10^{-6}} = \mathbf{970.14\Omega}$$

b) Small-Signal Equivalent Circuit shown in figure 3.

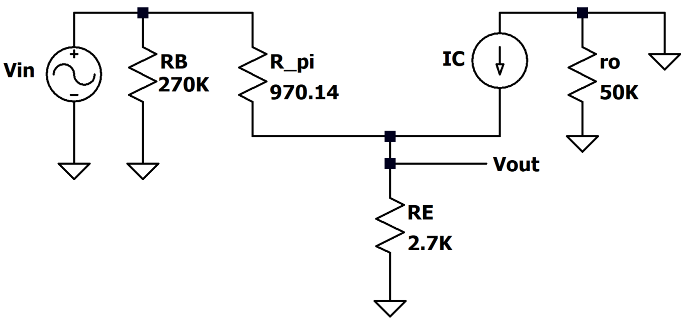

Figure 3: Small Signal Equivalent Circuit

c) Z_i **(Input Impedence)**

$$Z_i = R_B \;||\; (r_\pi + (1+\beta)R_E) = 270 \times 10^3 \;||\; (970.14 + (111)(2.7 \times 10^3))$$

$$Z_i = 270 \times 10^3 \;||\; 300.67 \times 10^3 = \mathbf{142.25k\Omega}$$

d) Z_o **(Output Impedence)**

$$Z_o = R_E \;||\; \frac{1}{g_m} \;||\; r_o = (R_E \;||\; r_o) \;||\; \frac{1}{g_m} = 270 \times 10^3 \;||\; 50 \times 10^3 \;||\; \frac{1}{113.46 \times 10^{-3}} = \mathbf{0.113\Omega}$$

e) A_V **(Voltage Gain)**

$$\frac{V_{out}}{V_{in}} = A_V = \frac{g_m R_E}{1 + g_m R_E} = \frac{113.46 \times 10^{-3} \times 2.7 \times 10^3}{1 + (113.46 \times 10^{-3})(2.7 \times 10^3)} = 1$$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and the result is as follows:

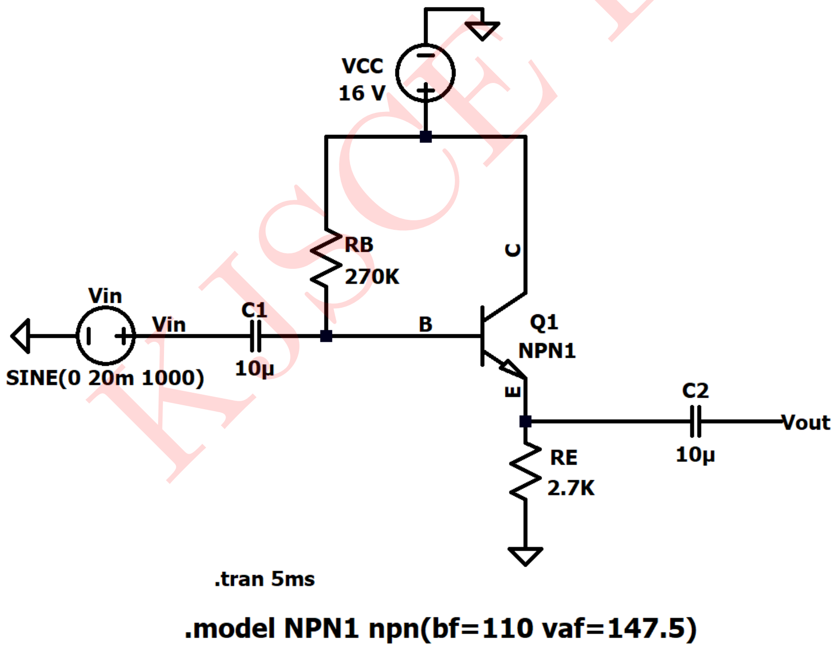

Figure 4: Circuit Schematic

The input and output waveforms are shown in figure 5.

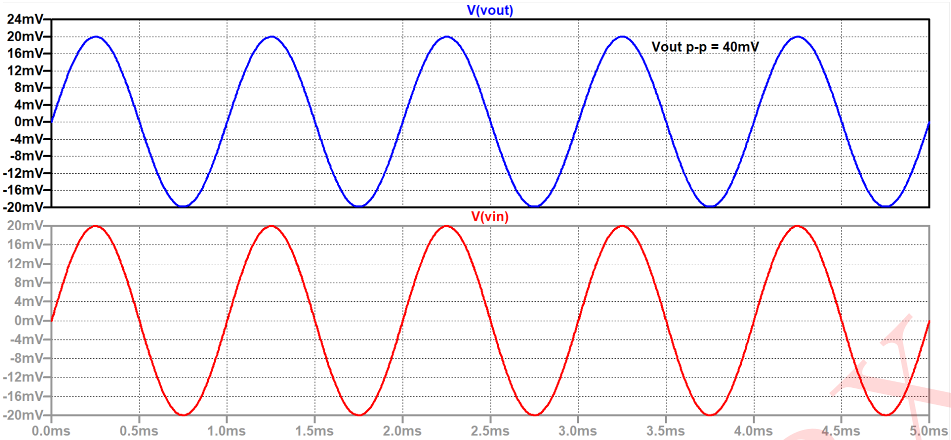

Figure 5: Input and output waveform

Comparison between Theoretical and Simulated values :-

Parameter	Simulated	Theoretical
I_C	2.9mA	2.95mA
I_B	$26\mu A$	$26.8\mu A$
V_{CE}	7.9V	8V
A_V	1	1

Table 1: Numerical 1

Numerical 2: For the circuit shown below in figure 6. Determine:

a) r_π

b) Z_i and Z_o

c) A_v (voltage gain)

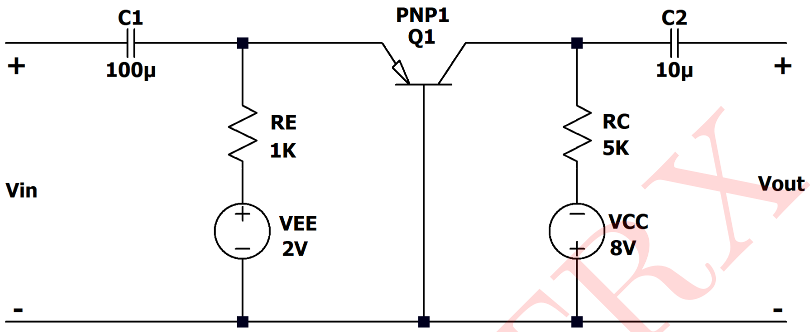

Figure 6: Circuit 2

Solution: The above circuit consists of a common base configuration employing pnp configuration

DC ANALYSIS:

For DC equivalent circuit, $f = 0$, $X_C = \dfrac{1}{2\pi fc} = \infty$

So capacitors are replaced by an open circuit

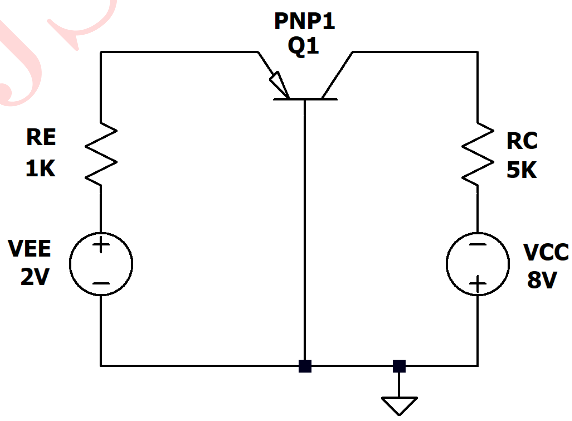

Figure 7: DC Equivalent Circuit

By applying KVL to base - emitter loop,

$$V_{EE} - I_E R_E - V_{BE} = 0$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E} = \frac{2 - 0.7}{1 \times 10^3} = \mathbf{1.3mA}$$

$$I_C = \alpha I_E = 0.98 \times 1.3 \times 10^{-3} = \mathbf{1.27mA}$$

AC ANALYSIS:

All the DC souces are open circuited and the capacitors are replaced by short circuit.

a) Small Signal Parameter:

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

Here, $V_T = 26mV$

$$g_m = \frac{1.27 \times 10^{-3}}{26 \times 10^{-3}} = 0.049 = \mathbf{49mA/V}$$

$$r_o = 1M\Omega$$

$$r_\pi = \frac{\beta V_T}{I_{BQ}}$$

$$\alpha = 0.98$$

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.98}{1 - 0.98} = \mathbf{49}$$

$$r_\pi = \frac{49 V_T}{I_{BQ}} = \frac{49 \times 26 \times 10^{-3}}{1.27 \times 10^{-3}} = \mathbf{1003.14\Omega}$$

b) Small-Signal Equivalent Circuit shown in figure 8.

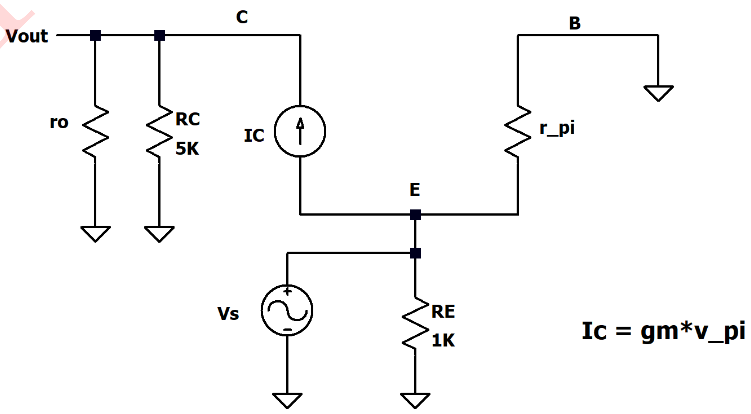

Figure 8: Small Signal Equivalent Circuit

c) A_V **(Small Signal Voltage Gain)**

$$\frac{V_{out}}{V_{in}} = A_V = g_m(R_C \ || \ r_o) = 49 \times 10^{-3} \times (5 \times 10^3 \ || \ 1 \times 10^6) = \mathbf{245}$$

d) Z_i **(Input Impedance)**

$$Z_i = \frac{1}{g_m} \ || \ R_E = \frac{1}{49 \times 10^{-3}} \ || \ 1 \times 10^3 = 20.408 \ || \ 1000 = 20\Omega$$

e) Z_o **(Output Impedance)**

$$Z_o = R_C \ || \ r_o = 1M \ || \ 5k = 4975.12\Omega$$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and the result is as follows:

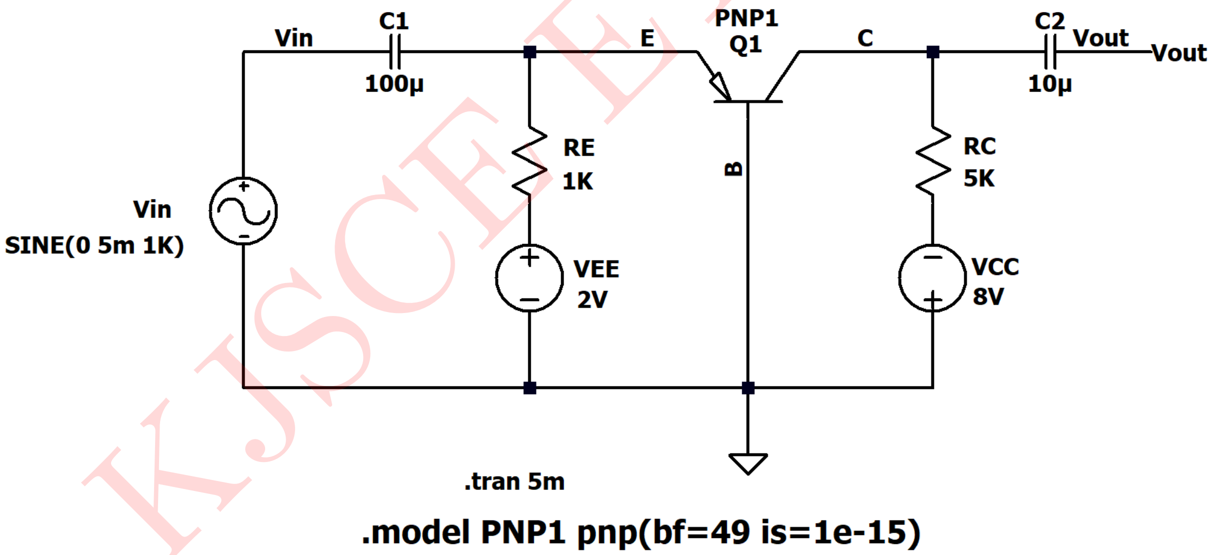

Figure 9: Circuit Schematic

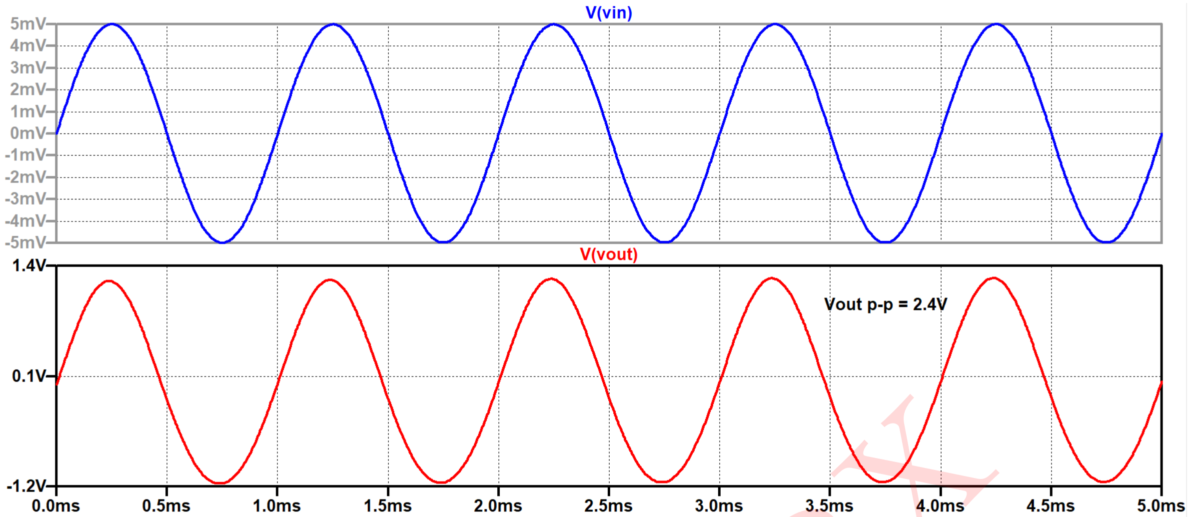

Figure 10: Input and Output Waveforms

Comparison between Theoretical and Simulated values :-

Parameter	Simulated	Theoretical
I_{CQ}	1.2mA	1.27mA
A_V	240	245

Table 2: Numerical 2

Numerical 3: The transistor in the circuit shown in figure 11 has $\beta = 100$ and $V_A = \infty$ Determine: a) I_{CQ} and V_{ECQ} b) Small - Signal voltage gain $A_V = V_{out}/V_{in}$

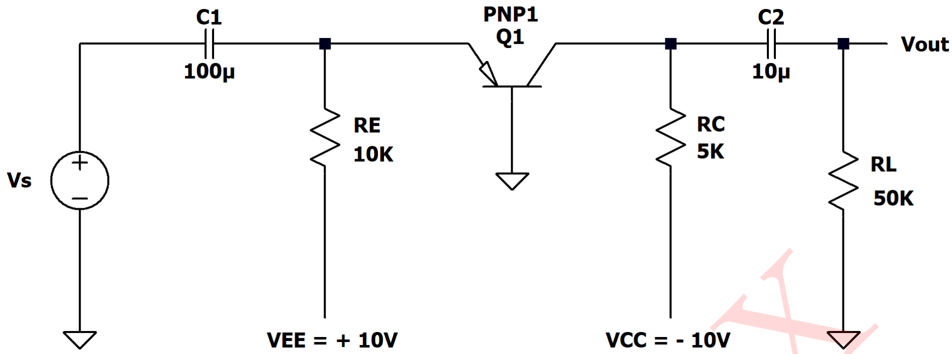

Figure 11: Circuit 1

Solution: The above circuit consists of a common base configuration employing pnp configuration

DC ANALYSIS:

By applying KVL to base - emitter loop,

$$V_{EE} - I_E R_E - V_{BE} = 0$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E} = \frac{10 - 0.7}{10 \times 10^3} = \mathbf{0.93mA}$$

$$I_C = \frac{\beta}{\beta + 1} I_E = \frac{100}{101} \times 0.93 \times 10^{-3} = \mathbf{0.92mA} \qquad (\text{As } I_C = \beta I_B \text{ and } I_E = (\beta + 1))$$

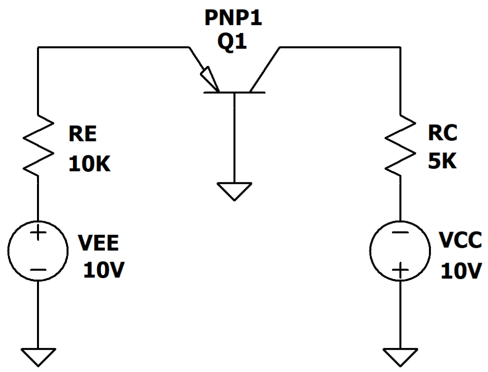

Figure 12: DC Equivalent Circuit

Applying KVL to the emitter - collector loop,

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

As $V_{EC} = -V_{CE}$

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

$= (0.93 \times 10^{-3})(10 \times 10^3) + (0.92 \times 10^{-3})(5 \times 10^3) - 10 - 10 = \mathbf{-6.1V}$

$V_{ECQ} = \mathbf{6.1V}$

AC ANALYSIS:

All the DC sources are open circuited and the capacitors are replaced by short circuit.

a) Small Signal Parameter:

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

Here, $V_T = 26mV$

$$g_m = \frac{0.92 \times 10^{-3}}{26 \times 10^{-3}} = \mathbf{35.38mA/V}$$

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

$$r_\pi = \frac{100 \times 26 \times 10^{-3}}{0.92 \times 10^{-3}} = \mathbf{2826\Omega}$$

b) Small-Signal Equivalent Circuit shown in figure 13.

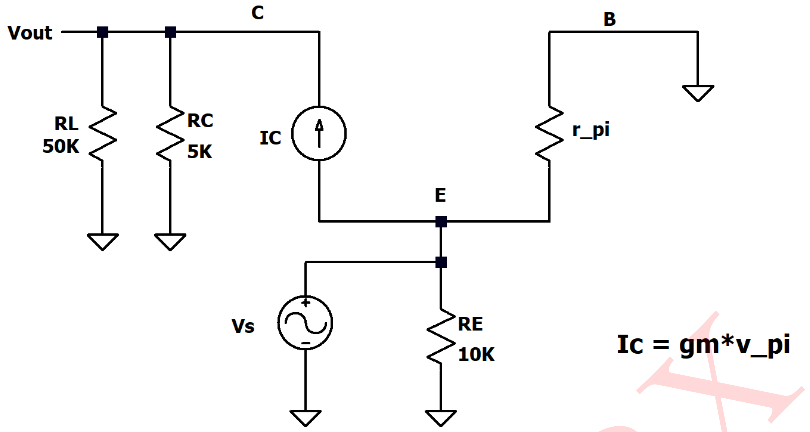

Figure 13: Small Signal Equivalent Circuit

c) A_V **(Small Signal Voltage Gain)**

$$\frac{V_{out}}{V_{in}} = A_V = g_m(R_C \; || \; R_L) = 35.38 \times 10^{-3} \times (5 \times 10^3 \; || \; 50 \times 10^3) = \mathbf{160}$$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and the result is as follows:

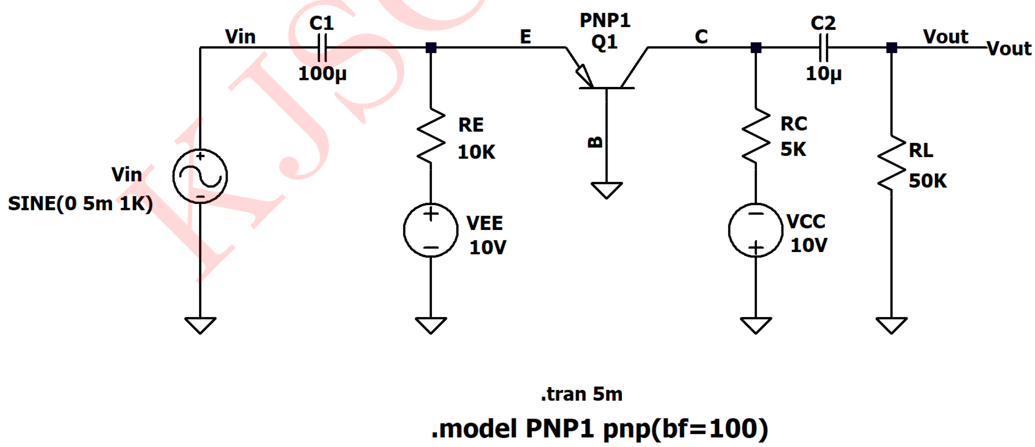

Figure 14: Circuit Schematic

The input and output waveforms are shown in figure 15.

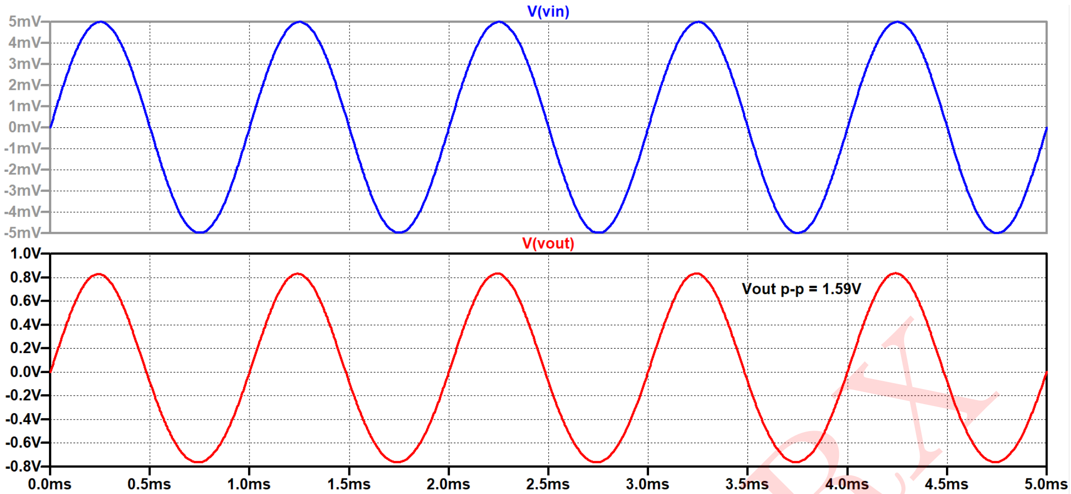

Figure 15: Input and Output Waveforms

Comparison between Theoretical and Simulated values :-

Parameter	Simulated	Theoretical
I_{CQ}	0.92mA	0.914mA
V_{ECQ}	6.1V	6.2V
A_V	160	159

Table 3: Numerical 3

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