**K. J. SOMAIYA COLLEGE OF ENGINEERING**
**DEPARTMENT OF ELECTRONICS ENGINEERING**
**ELECTRONIC CIRCUITS**
**Design of single-stage Amplifier**

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

**Design 1:** Design a single stage RC coupled BJT Amplifier for following specification:
$V_{orms} = 5V$, $V_{CC} = 20V$, $f_L \leq 20Hz$, $S \leq 10$ and $|A_V| \geq 150$
Select transistor BC 147A from datasheet

**Solution:**

1. Data given:

   $V_{orms} = 5V$, $V_{CC} = 20V$, $f_L \leq 20Hz$, $S \leq 10$ and $|A_V| \geq 150$

2. Selection of transistor:

   The transistor selected is BC 147A and its specification are:

   $h_{ie} = 2.7k\Omega$, $V_{CE(sat)} = 0.25V$

   $h_{FE(min)} = 115$, $h_{FE(typ)} = 180$, $h_{FE(max)} = 220$

   $h_{fe(min)} = 125$, $h_{fe(typ)} = 220$, $h_{fe(max)} = 260$

3. Selection of the biasing network:

   Voltage divider biasing network is selected to keep Q point independant of variation in $\beta$ or temperature.

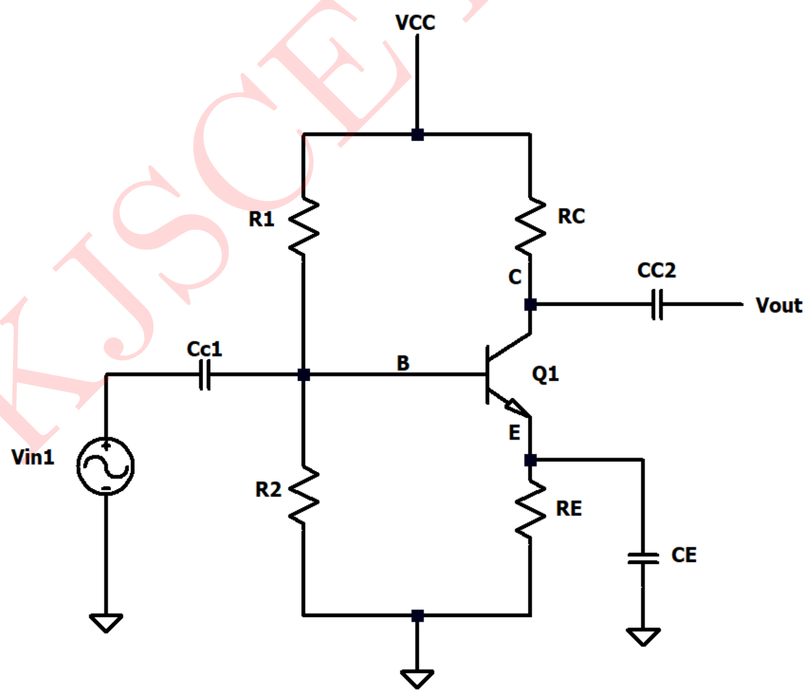


Figure 1: Circuit 1

4. Selection of $R_C$:

$$A_V = \frac{h_{fe(min)} R_C}{h_{ie}}$$

$$150 = \frac{125 R_C}{2.7 \times 10^3}$$

$$R_C = \frac{150 \times 2.7 \times 10^3}{125} = \mathbf{3.24k\Omega}$$

Selecting higher standard value of $R_C$ to increase the gain

$$\therefore R_C = \mathbf{3.3k\Omega, 1/4W}$$

5. Selection of Q point:

$$V_{CC} = 20V \qquad \text{(given)}$$

$$V_{CE} = \frac{V_{CC}}{2} = \frac{20}{2} = \mathbf{10V}$$

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

$$V_E = 10\% \text{ of } V_{CC} = \frac{10}{10} \times 20 = \mathbf{2V} \qquad .....1$$

$$I_C = \frac{20 - 10 - 2}{3.3 \times 10^3} = \mathbf{2.424mA}$$

Q point is $(V_{CEQ}, I_{CQ})$ which is $(10V, 2.424mA)$

6. Calculations of $R_E$

$$V_E = V_{RE} = 2V \qquad \text{(from 1)}$$

Now, $V_E = V_{RE} = I_{EQ} \times R_E$

$$R_E = \frac{V_E}{I_{EQ}}$$

$$I_{EQ} \approx I_{CQ}$$

$$\therefore I_{EQ} = 2.424mA$$

$$R_E = \frac{2}{2.424 \times 10^3} = \mathbf{825\Omega}$$

Selecting lower standard value of $R_E$

$$\therefore R_e = \mathbf{820\Omega, 1/4W}$$

7. Calculations of biasing resistors ($R_1 \& R_2$):

$$S \leq 10$$

$$\beta = h_{fe(max)} = 220$$

$$S = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_E+R_B}\right)}$$

$$10 = \frac{1+220}{1+(220)\left(\frac{820}{820+R_B}\right)}$$

$$1220 = 10 + (2200)\left(\frac{820}{820+R_B}\right)$$

$$\frac{221}{2200} = \frac{820}{820+R_B}$$

$$820 + R_B = \frac{820 \times 2200}{211}$$

$$R_B = 8549.76 - 820 = 7729.76$$

$$R_{TH} = R_B = \frac{R_1 R_2}{R_1 + R_2} \qquad .....2$$

From the Thevenin equivalent circuit shown in figure 2 we get to know that,

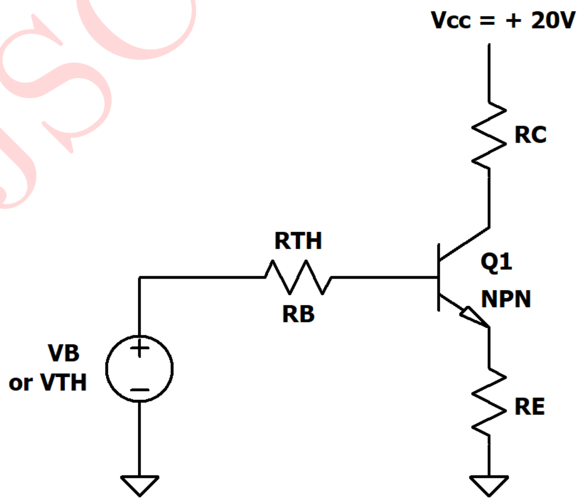


Figure 2: Thevenin Equivalent Circuit

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

$$\therefore V_B - \frac{I_C}{\beta} R_{TH} - V_{BE} - I_C R_E = 0$$

$$\therefore V_B = V_{BE} + I_C R_E + \frac{I_C}{\beta} R_{TH} = 0.7 + (2.424 \times 10^{-3})(825) + \frac{2.424 \times 10^{-3}}{180}(7729.76)$$

$$= 0.7 + 1.9998 + 0.1041 = \mathbf{2.803V}$$

$V_{TH} = V_B = 2.803V$

From 2, $V_B = 2.803 = \frac{R_2}{R_1 + R_2} \times V_{CC}$

$\therefore \frac{R_2}{R_1 + R_2} = \frac{2.803}{20} = 0.14019$ .....3

From 2 and 3 we get;

$7729.76 = R_B = R_{TH} = R_1(0.14019)$

$R_1 = \frac{7729.76}{0.14019} = \mathbf{55.135k\Omega}$

Selecting higher standard value of $R_1$:

$R_1 = \mathbf{56l\Omega, 1/4W}$

Also, $\frac{R_2}{R_2 + 56k} = 0.14019$

$\therefore R_2 = 0.14019R_2 + (56 \times 10^3)(0.14019) = \frac{56 \times 10^3 \times 0.14019}{0.8589} = \mathbf{9.1307k\Omega}$

Selecting lower standard value of $R_2$:

$R_2 = \mathbf{9.1k\Omega, 1/4W}$

8. Calculation of coupling capacitors:

a. Finding out $C_{C_1}$ :

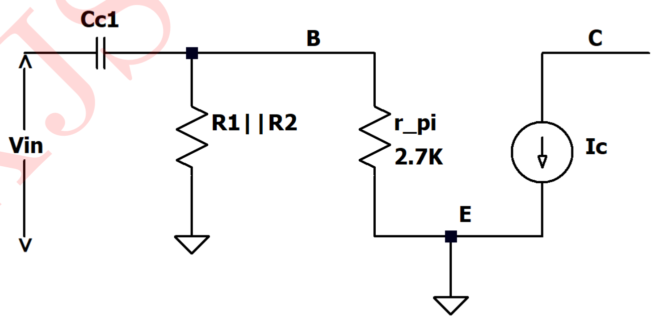


Figure 3: Small signal low frequency equivalent circuit for $C_{C_1}$

$C_{C_1} = \frac{1}{2\pi R_{eq} f_L}$

here, $R_{eq} = R_1 \ || \ R_2|| \ h_{ie} = 56k \ || \ 9.1k|| \ 2.7k = 7827.95 \ || \ 2.7k = 2.0075$

$C_{C_1} = \frac{1}{2\pi(2.0075 \times 10^3)(20)} = \mathbf{3.964\mu F}$

Selecting higher standard value for $C_{C_1}$

$C_{C_1} = \mathbf{4.2\mu F/25V}$

b. Finding out $C_{C_2}$:

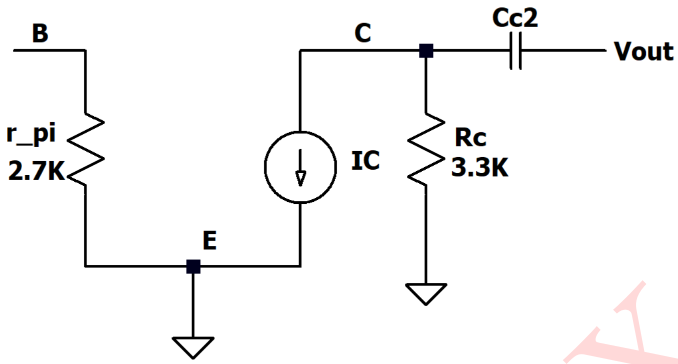


Figure 4: Small signal low frequency equivalent circuit for $C_{C_2}$

$$C_{C_2} = \frac{1}{2\pi R_C f_L} = \frac{1}{2\pi(3.3\times 10^3)20} = \mathbf{2.411\mu F}$$

Selecting $C_{C_2} = \mathbf{2.7\mu F/25V}$

9. Selecting $C_E$:

$$X_{CE} = \frac{R_E}{10} = 0.1R_E = \frac{820}{10} = \mathbf{82}$$

$$C_E = \frac{1}{2\pi f_L(X_{CE})} = \frac{1}{2\pi \times 20 \times 82} = \mathbf{97.04\mu F}$$

Selecting higher standard value for $C_E$

$C_E = \mathbf{100\mu F/25V}$

10. Verification of overall gain $A_V$:

$A_V = -g_m R_C$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{2.424\times 10^{-3}}{26\times 10^{-3}} = \mathbf{93.2mA/V}$$

$|A_V| = -(93.2\times 10^{-3} \times 3.3\times 10^3) = \mathbf{-304}$

**FINAL DESIGN:**

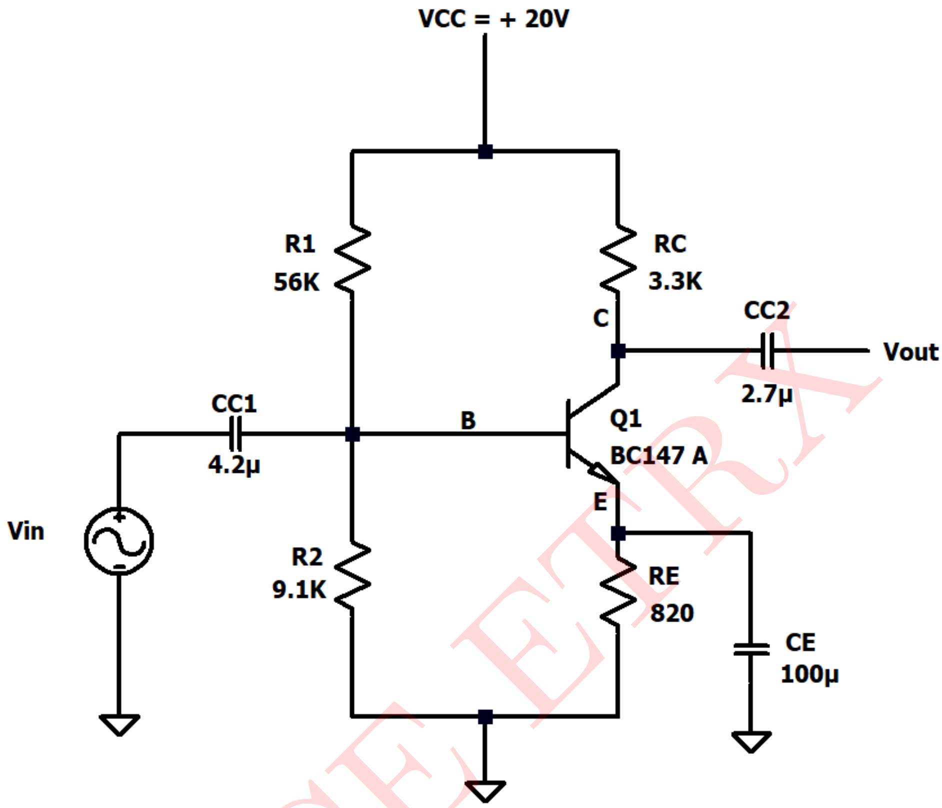


Figure 5: Designed Circuit

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

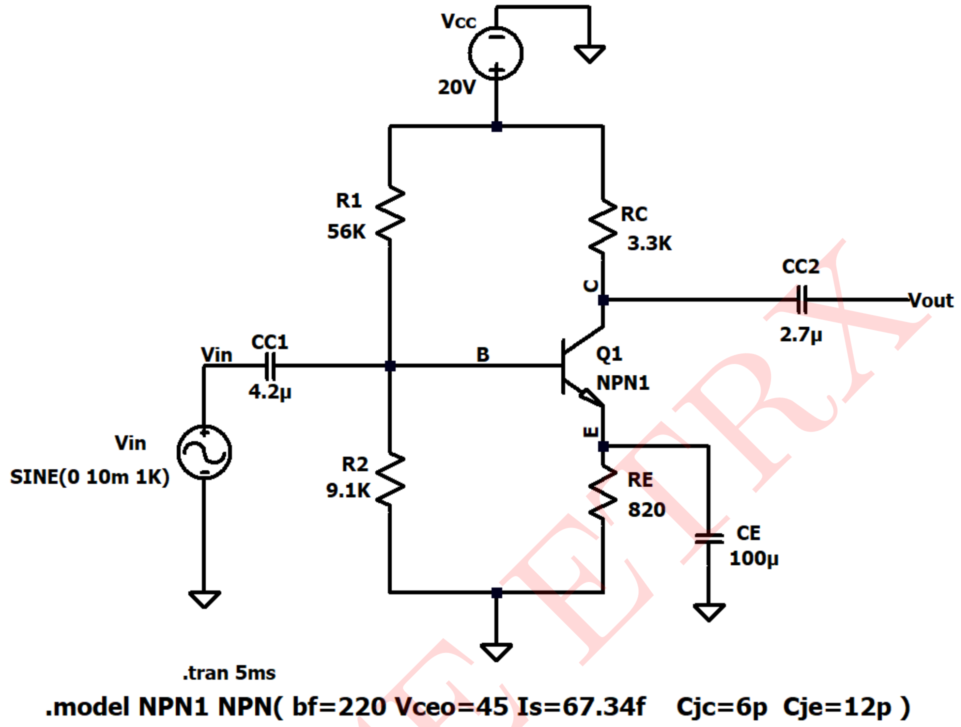


Figure 6: Circuit Schematic

The input and output waveforms are shown in figure 7.

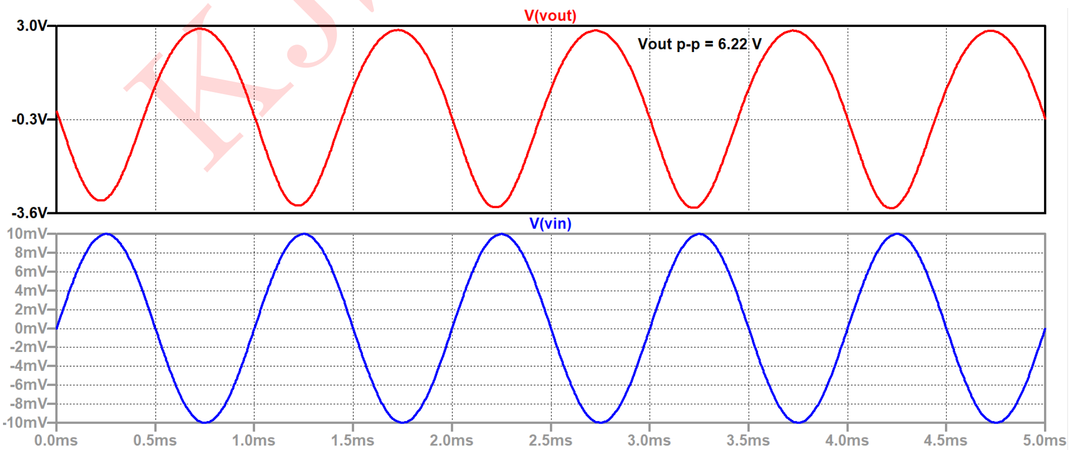


Figure 7: Input and Output Waveforms

**Comparison between Theoretical and Simulated values :-**

| Parameter | Simulated | Theoretical |
|---|---|---|
| $I_{CQ}$ | 2.424mA | 2.5mA |
| $V_{CEQ}$ | 10V | 9.61V |
| $A_V$ | $-304$ | $-311$ |

Table 1: Design 1

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