EAST WEST UNIVERSITY

Department of EEE

LAB PROJECT

Section: 01

Course Code: EEE102

Course Title: Electronics Circuits I

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EXPERIMENT NAME

Design of a common emitter BJT amplifier.

REQUIREDMENTS

1. Minimum input impedance: 2KΩ
2. Maximum output impedance: 3.5kΩ
3. Gain: 60 (Minimum mid-band gain should be 60)
4. Maximum power consumption: 25 mW
5. $\beta = 150$
6. $V_{cc} = 12$V

OBJECTIVE

The objective of this experiment is to study the BJT CE amplifier and find the gain and input-output impedance of the circuit.

COMPONENTS

1. PSpice
2. npn BJT-Q2N2222
3. Resistor- 71KΩ, 16.4KΩ, 3.5KΩ, 1.159kΩ, 2kΩ.
4. Three capacitors- 10 µF

DIAGRAM

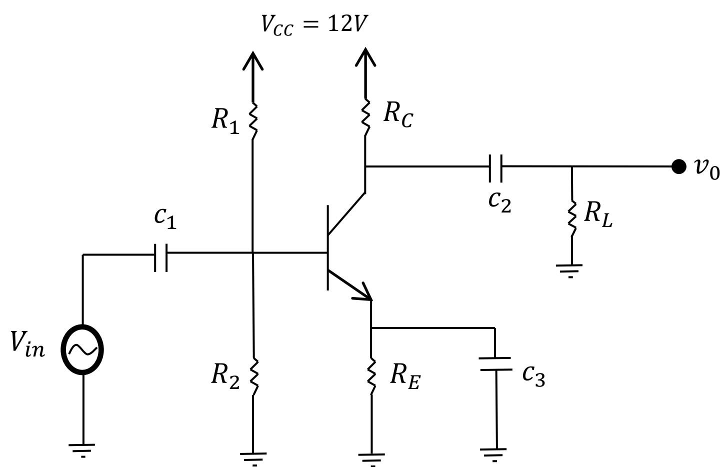


Fig 01: Circuit Diagram

Steps for Theoretically Calculation

DC Mode

1. At first, we consider $R_c = 3.5K\Omega$ because we know that in common emitter $R_o = R_c$ and the value is given in project definition which is 3.5 $K\Omega$.
2. Then we apply the classical biasing circuit rules and find out the values of V_{CE}, V_{RE}, V_{RC}.
3. After that we find out $\propto, I_C, I_E, I_B, R_E$ values.
4. We use $R_2 \leq {}^{(1+\beta)R_E}/_{10}$ this formula to find out R_2.
5. Calculating V_B we use $V_{BE} = 0.7$ and find out V_B.
6. After find out V_B, we calculate I_{R_2}, I_{R_1} & R_1.
7. At last, we calculate trans conductance (g_m), base resistance(r_π).

AC Mode

1. In this mode, at first we draw π −model.
2. Then, we find out v_{be}.
3. Applying nodal analysis at output voltage (v_o).
4. After calculating nodal analysis equation we get $A_v\left({}^{v_o}/_{v_i}\right)$.
5. We know that $R_c = R_o$ and we find out it.
6. Then, we calculate input impedance (R_i).
7. At last, we find out power consumption.

Steps for Simulation Part

1. At first, we draw DC circuit in Pspice simulation. That is Q_1, R_1, R_2, R_C, R_E & 12V source.
2. Set R_2 16.4 $K\Omega$ to get $V_{CE} = 6.02$V
3. Run the simulation with bias point calculation only. Check VCE. This should be approximately 6 V. If not, change the R_2 value and run again.
4. Write the values of VC, VE, and VB.
5. Find β.
6. Now add the rest of the components.
7. Set V1 as VSIN. Set the frequency to 20 kHz, amplitude to 25 mV, and VOFF to 0.
8. Setup simulation to transient. Set stop time to 200 us and step ceiling to 1 us.
9. Simulate the circuit and observe the output. Is it a sine wave?
10. Measure the peak-to-peak values of the output signal and input signal.
11. Observe the current through V_1 and measure its p-p value.

Theoretically Calculation

DC Mode,

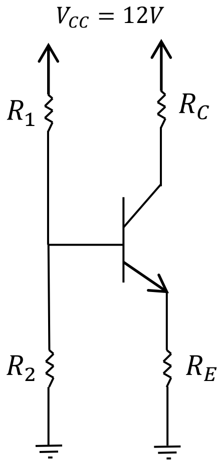


Fig 02: Dc Mode

In DC mode, open all capacitors.

Here,

Maximum output impedance$= 3.5k\Omega$

$\therefore R_o \leq 3.5k\Omega$

So, $R_C = R_O = 3.5K\Omega$

$V_{CC} = 12V$

$\beta = 150$

Using classical biasing circuit,

$\therefore V_{CE} = \frac{1}{2}V_{CC} = \frac{12}{2} = 6V$

$\therefore V_{RE} = \frac{1}{8}V_{CC} = \frac{12}{8} = 1.5V$

$\therefore V_{RC} = \frac{3}{8}V_{CC} = \frac{3\times12}{8} = 4.5V$

$\therefore \propto = \left({}^{\beta}\!/_{1+\beta}\right) = \frac{150}{151} = 0.99$

$\therefore I_C = V_{RC}/R_C = \frac{4.5}{3.5} = 1.2857\text{mA}$

$\therefore I_E = \frac{1+\beta}{\beta} I_C = \frac{151\times1.2857}{150} = 1.2943\text{mA}$

$\therefore I_B = I_E - I_C = (1.2943 - 1.2857) = 0.0086\text{mA}$

$\therefore R_E = \frac{V_{CC}}{8I_E} = \frac{12}{8\times1.2943} = 1.159K\Omega$

$\therefore R_2 \leq {(1+\beta)R_E}/{10}$

$\leq \frac{151\times1.159}{10}$

$\leq 17.5K\Omega$

$\therefore R_2 = 17K\Omega$

By default,

$V_{BE} = 0.7$

⇨ $V_B - V_E = 0.7$
⇨ $V_B = 0.7 + V_E = 0.7 + 1.5 = 2.2V$

$\therefore V_B = 2.2V$

$\therefore I_{R_2} = {V_B}/{R_2} = \frac{2.2}{17} = 0.1294\text{mA}$

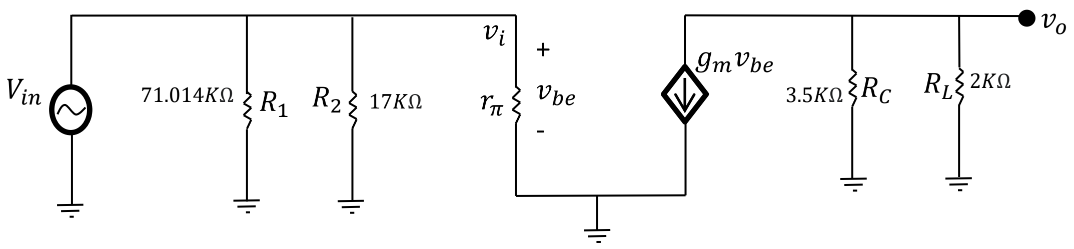
$\therefore I_{R_1} = I_{R_2} + I_B = (0.0086 + 0.1294) = 0.138\text{mA}$

$\therefore R_1 = \frac{V_{CC}-V_B}{I_{R_1}} = \frac{12-2.2}{0.138} = 71.014K\Omega$

Trans conductance, $g_m = \frac{I_C}{V_T} = {1.2857}/{0.026} = 49.45\ mA/V$

Base resistance, $r_\pi = {\beta}/{g_m} = \frac{150}{49.45} = 3.033K\Omega$

AC Mode,



We know,

$v_{be} = v_b - v_e = v_i - 0 = v_i$

$\therefore v_{be} = v_i$

Applying nodal analysis at node v_o,

$\frac{v_o}{R_L} + \frac{v_o}{R_C} + g_m v_{be} = 0$

⇨ $v_o\left(\frac{1}{R_L} + \frac{1}{R_C}\right) + g_m v_{be} = 0$

⇨ $v_o\left(\frac{1}{2} + \frac{1}{3.5}\right) + 49.45 v_i = 0$

⇨ $v_o\left({}^{11}/_{14}\right) + 49.45 v_i = 0$

⇨ $v_o\left({}^{11}/_{14}\right) = -49.45 v_i$

⇨ $\frac{v_o}{V_i} = -\frac{49.45 \times 14}{11} = -62.94\ V/V$

$\therefore A_v = -62.94\ V/V$

By convention positive current is always defined as flowing into the device. So if we have a NPN common emitter amplifier and the source current into the base input, it will flow out of the collector output. Since the current is flowing out, it is a negative current, hence the gain is negative.

But the gain is always positive.

$\therefore A_v = 62.94\ V/V$

From the data,

Gain: 60

$62.94 > 60$, gain is more than 60.

Output impedance, $R_O = R_c = 3.5K\Omega$

Input impedance, R_{in}

$$\frac{1}{R_{in}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{r_\pi}$$

$$\Rightarrow \frac{1}{R_{in}} = \frac{1}{71..014} + \frac{1}{17} + \frac{1}{3.033}$$

$$\Rightarrow \frac{1}{R_{in}} = 0.4026$$

$$\Rightarrow R_{in} = 2.484\ K\Omega$$

$\therefore R_{in} = 2.484\ K\Omega$

Input impedance, $R_{in} = 2.484$

$\therefore$ Power consumption, $P = V_{CC} \times (I_C + I_{R_1})$

$$= 12 \times (1.2857 + 0.138)\text{mW}$$

$$= 17.0844\text{ mW}$$

Simulation Part

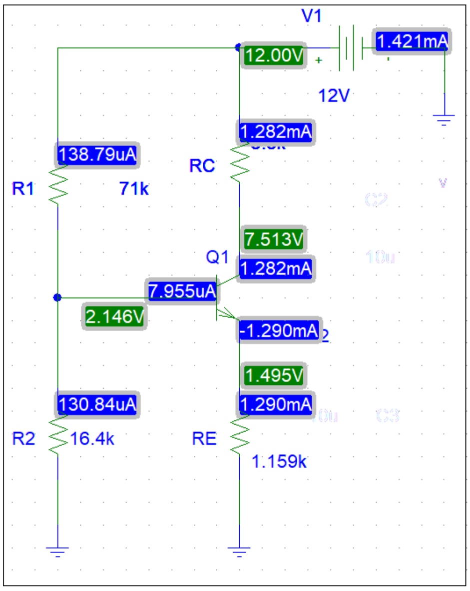


Fig: DC Circuit Simulation

Examine Output:

IB 7.95E-06

IC 1.28E-03

VBE 6.51E-01

VBC -5.37E+00

VCE 6.02E+00

BETADC 1.61E+02

GM 4.93E-02

Trans conductance, $g_m = \frac{I_C}{V_T} = {}^{1.28}/_{0.026} = 49.43\ mA/V$

Base resistance, $r_\pi = {}^{\beta}/_{g_m} = \frac{161}{49.43} = 3.26K\Omega$

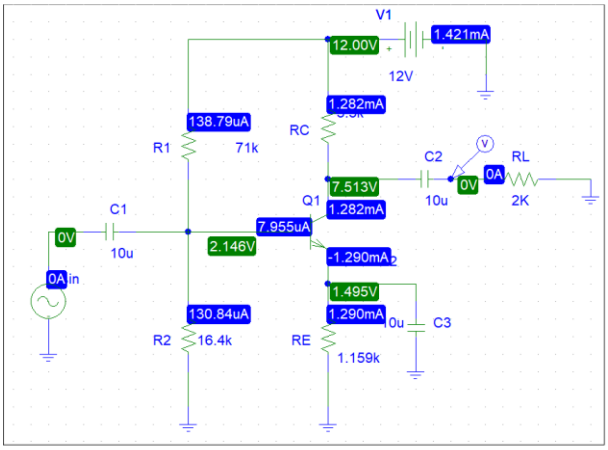
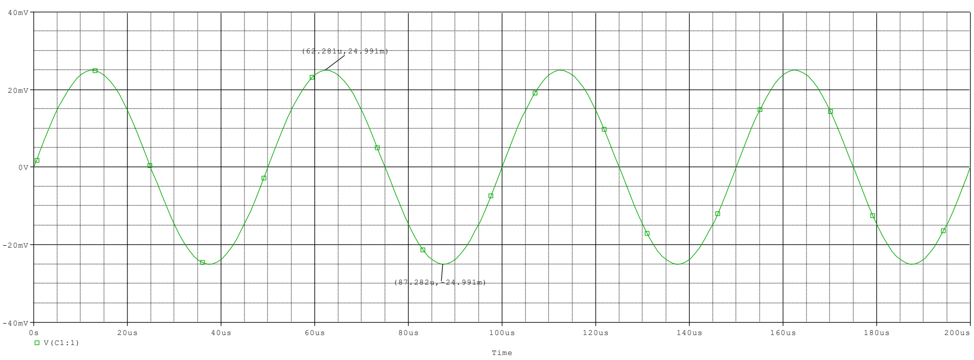


Fig: Full Amplifier Circuit Simulation



Plot 01: Peak to peak value of input signal

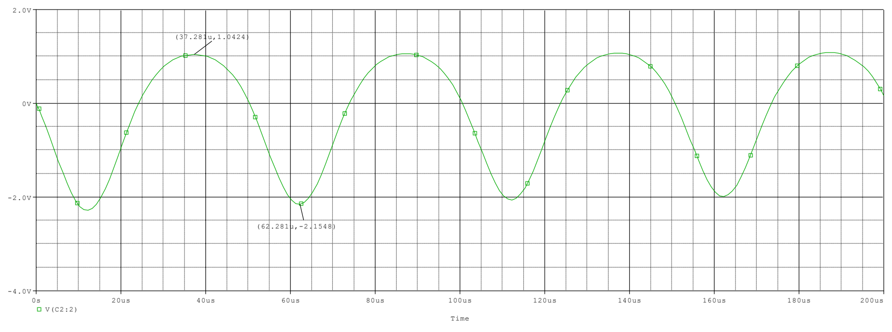
Value of Upper Voltage p-p: 24.991mV

Value of Lower Voltage p-p: -24.991mV

Peak to peak value of input signal: $\{24.991 - (-24.991)\} = 49.982 \approx 50\text{mV}$

$$= 50 \times 10^{-3}\text{V}$$

$\therefore$ Peak to peak value of input signal is 50×10^{-3}V



Plot 02: Peak to peak value of output signal

Value of Upper Voltage p-p: 1.0424mV

Value of Lower Voltage p-p: -2.1548V

Peak to peak value of output signal: $\{1.0424 - (-2.1548)\} = 3.1972$ V

Peak to peak value of output signal is 3.1972V.

Gain, $A_v = {}^{v_o}/_{v_i}$

$$= \frac{3.1972}{50\times10^{-3}} = 63.944\frac{V}{V}$$

Power Consumption:

$V_{cc} = 12V$

$I_C = 1.282\text{mA} = 1.282 \times 10^{-3}$A

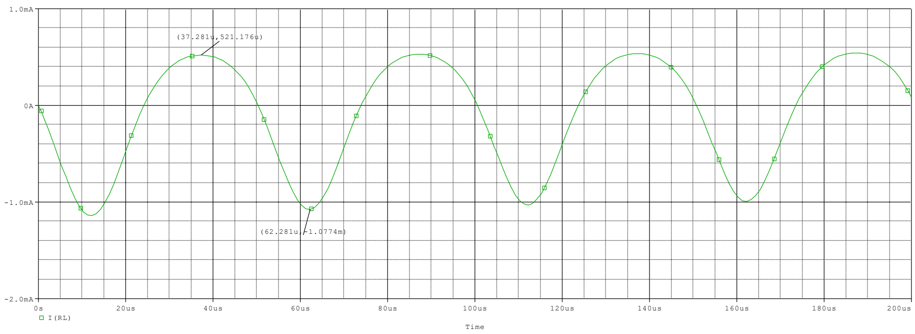
$I_1 = 138.79uA = 138.79 \times 10^{-6}$A

$\therefore P = V_{cc} \times (I_C + I_1)$

$$= 12 \times (1.282 \times 10^{-3} + 138.79 \times 10^{-6})$$

$$= 0.01705\text{W}$$

$$= 17.05\text{mW}$$

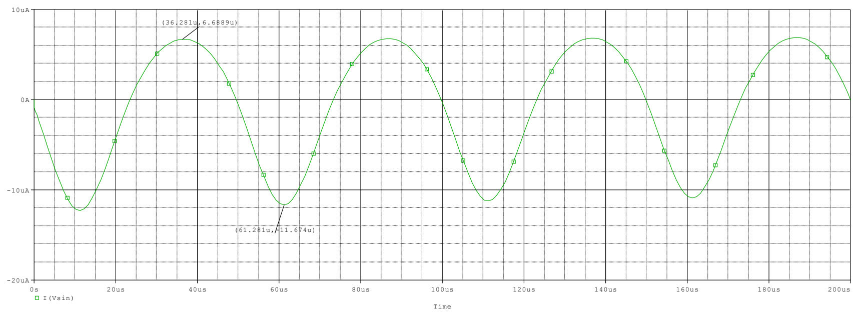


Plot 03: Peak to peak value of current though R_L(Output)

Value of Upper Current p-p: 521.176uA

Value of Lower Current p-p: -1.0774mA

Peak to peak value of output signal:$\{521.176 \times 10^{-3} - (-1.0774)\} = 1.599$ mA



Plot 04: Peak to peak value of current though V_{sin}(Input)

Value of Upper Current p-p: 6.6889uA

Value of Lower Current p-p: -11.674uA

Peak to peak value of input signal:$\{6.6889 - (-11.674)\} = 18.3629$ uA

$$R_{in} = {}^{V_{in}}/_{I_{in}}$$

$$= \frac{50\times10^{-3}}{18.3629\times10^{-6}}$$

$$= 2.723K\Omega$$

$$R_o = {}^{V_o}/_{I_o}$$

$$= \frac{3.1972}{1.599} = 1.99K\Omega \approx 2K\Omega$$

Data Table

- ✓ **Comparison between simulated and calculated data of output trans conductance and base resistance**

	g_m**(mA/V)**	r_π $(K\Omega)$
Simulation	49.43	3.26
Calculation	49.45	3.033

Comment: There is little bit difference between simulated and calculated trans conductance and base resistance.

- ✓ **Comparison between simulated and calculated data of** A_v

	A_v**(V/V)**
Simulation	63.944
Calculation	62.94

Comment: There is little bit difference between simulated and calculated gain (A_v).

- ✓ **Comparison between simulated and calculated data of output impedance(**R_o**) and input impedance(**R_i**)**

	$R_{in}(K\Omega)$	$R_o(K\Omega)$
Simulation	2.723	2
Calculation	2.484	3.5

Comment: There is little bit difference between simulated and calculated input impedance but there is a slight difference in output impedance.

- ✓ **Comparison between simulated and calculated data of output trans conductance and base resistance**

	p**(mW)**
Simulation	17.05
Calculation	17.0844

Comment: There is little bit difference between simulated and calculated power consumption.

Conclusion: This experiment helps us to learn how to experiment an amplifier using a BJT having the following specification. In this experiment we have calculated and simulated some voltages, currents and impedances.