15ECE381 Circuits and Communication Laboratory /
15ECE383 Linear Integrated Circuits Laboratory
B. Tech (ECE and EIE) – V Semester
Experiment – 1

Common Emitter Amplifier (BJT)

Objective :

The aim of this experiment is to revisit the biasing and operation of a BJT common emitter amplifier. As part of this experiment, you will determine the change in amplifier performance, with and without the presence of an emitter resistor.

Instructions:

1. When choosing the transistors, ensure that β is greater than 300 and the two transistors have widely differing β, at least by 10 %.
2. Ensure that you do not use electrolytic capacitors for coupling the input and outputs.
3. **Download the datasheet of the BC547 and look at how the various parameters associated with the transistor, vary**. (The datasheet is available at http://tinyurl.com/y7qb2rj3).

Procedure:

Operating Point and Stability Analysis

1. Connect up the circuit as shown in Fig. 1. Do not use the coupling capacitors (C_C) for the time being, as you are only determining the operating point and its stability at the moment.
2. Choose R_1 = 300 kΩ, R_2 = 33k kΩ, R_C = 2.2 kΩ and V_{CC} = 10 V. The transistor is the BC547. The coupling capacitors are 0.1 μF each.
3. Power up the circuit and note down the following measurements, as shown in Table 1.

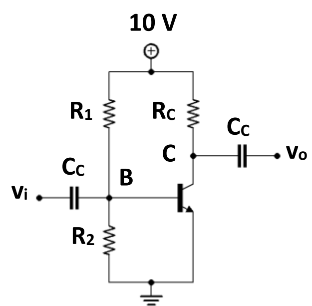


Fig. 1

Analysis:→

we know that

$$\text{Gain} = \frac{V_o}{V_i} = g_m R_C$$

where

$$\text{Gain} = 10+11 = \underline{\underline{21}}$$

$$g_m = \frac{I_C}{V_T}$$

{ assume $R_C = 2.2k\Omega$

$$\therefore \quad 21 = \frac{I_C}{25m}(2.2k)$$

$$\Rightarrow I_C = \frac{21 \cdot 25\mu}{2.2} = 0.238mA$$

and lets take $\boxed{R_1 = 9R_2}$

$$V_{TH} = \frac{V_{CC} R_2}{R_1+R_2} = \frac{10 \cancel{R_2}}{10\cancel{R_2}} = \underline{\underline{1}}$$

$$R_{TH} = \frac{R_1 R_2}{R_1+R_2} = \frac{9R_2 \cdot \cancel{R_2}}{10\cancel{R_2}} = \underline{\underline{0.9R_2}}$$

Input Loop Equation:→

$$V_{TH} - R_{TH}(I_B) - V_{be} = 0$$

$$1 - 0.9R_2(I_B) - 0.65 = 0$$

$$0.39 = R_2 I_B$$

$$R_2 I_B = 0.39$$

$$\beta = 10 + 11 = 21$$

$$\Rightarrow R_2 \frac{I_C}{\beta} = 0.39$$

$$\Rightarrow R_2 \frac{0.238m}{21} = 0.39$$

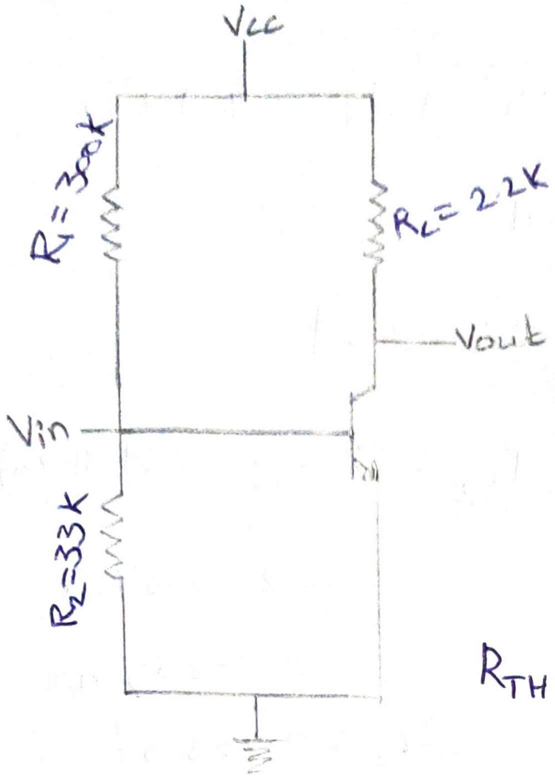
$$\Rightarrow R_2 = \frac{0.39 \times 21}{0.238m} = \frac{8.19}{0.238} k$$

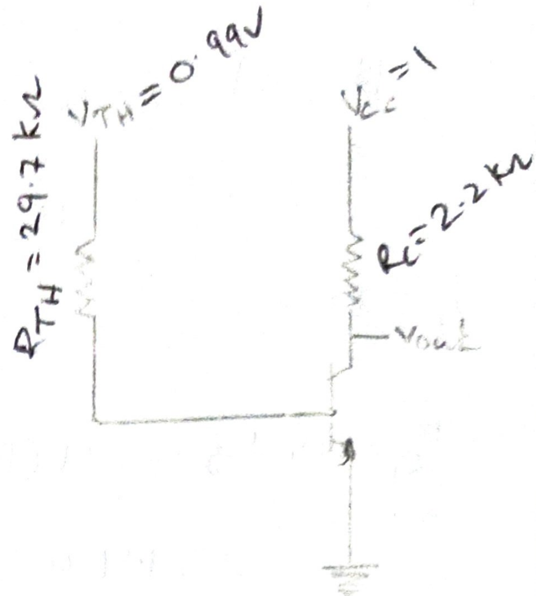
$$R_2 = 34.41 k\Omega \approx 33k$$

$$R_1 = 9R_2 = 9(33k) = 297k$$

$$\approx \underline{\underline{300k}}$$

Without Emitter Resistance





$$R_{TH} = \frac{R_1 R_2}{R_1+R_2} = \frac{(300)(33)k}{333}$$

$$= 29.7\,k\Omega$$

$$V_{TH} = \frac{V_{cc}\,R_2}{R_1+R_2} = \frac{10(33)k}{333\,k} = \frac{330}{333}$$

$$= 0.99V$$

Input Loop:→

$$V_{TH} - I_B R_{TH} - V_{BE} = 0$$

$$\frac{V_{TH}-V_{BE}}{R_{TH}} = I_B$$

$$\frac{0.99-0.65}{29.7k} = I_B$$

$$\Rightarrow \boxed{I_B = 11.4\,\mu A}$$

Output Loop:→

$$V_{cc} - I_c R_c - V_{CE} = 0$$

$$V_{CE} = 10 - I_c R_c$$

$$= 10 - \beta(11.4\mu)(2.2k)$$

$$= 10 - \beta(25.08m)$$

$$\boxed{V_{CE} = 10 - \beta(25.08m)}$$

Given

$$\beta_1 = 21 \quad , \quad \beta_2 = (10\% \cdot \beta_1) + \beta_1 = 2.1 + 21$$

$$\beta_2 = 23.1$$

$\beta_1 = 21$

$$I_{c_1} = \beta_1 I_B = 21(11.4\mu)$$

$$= 239.4\mu$$

$$\boxed{I_{c_1} = 0.239\,mA}$$

$$V_{CE_1} = 10 - \beta(25.08m)$$

$$= 10 - 0.526$$

$$= 9.474$$

$$\boxed{V_{CE_1} = 9.474V}$$

$\beta_2 = 23.1$

$$I_{c_2} = \beta_2 I_B = 23.1(11.4\mu)$$

$$= 263.34\mu$$

$$= 0.263\,mA$$

$$\boxed{I_{c_2} = 0.263m}$$

$$V_{CE_2} = 10 - \beta(25.08m)$$

$$= 10 - 23.1(25.08m)$$

$$= 10 - 0.579$$

$$= 9.421V$$

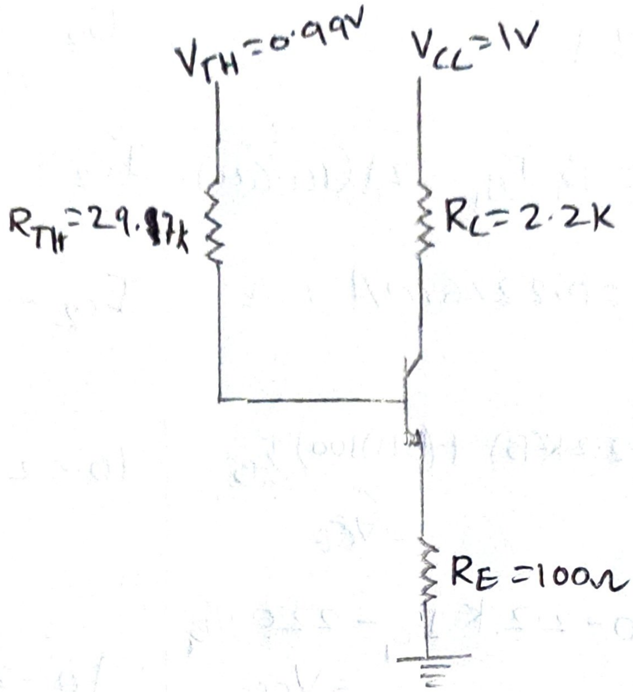
$$\boxed{V_{CE_2} = 9.421V}$$

$$\Delta\beta = \frac{\beta_2 - \beta_1}{\beta_1} \times 100 = \frac{2.1}{21} \times 100 = 10\%$$

$$\Delta V_{CE_2} = \frac{V_{CE2} - V_{CE1}}{V_{CE1}} \times 100 = \frac{0.053}{9.474} \times 100 = -0.559$$

$$\text{Sensitivity} = \frac{\Delta V_{CE}}{\Delta\beta} \times 100 = \frac{-0.559}{10} \times 100 = -5.59$$

With Emitter Resistance:



$R_{TH} = 29.7k\Omega$

$R_C = 2.2k\Omega$

$R_E = 100\Omega$

$V_{TH} = 0.99V$

Input Loop ↦

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

$0.99 - I_B(29.7k) - 0.65 - (\beta+1) I_B (100) = 0$

$0.34 = I_B (29.7k + 100(\beta+1))$

Output Loop ↦

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

$10 - 2.2k I_C - (\beta+1) 100 I_B = V_{CE}$

$10 - (2.2k(\beta) + (\beta+1)100) I_B = V_{CE}$

$B_1 = 21$

$0.34 = I_B (29.7k + 2200)$

$\frac{0.34}{31.9K} = I_B$

$\boxed{I_B = 10.6 \mu A}$

$B_2 = 23.1$

$0.34 = I_B (29.7k + 2.41k)$

$0.34 = 32.11k$

$\boxed{I_B = 10.5 \mu A}$

$B_1 = 21$

$I_{C_1} = B_1 I_{B_1} = 21(10.6u)$

$I_{C_1} = 0.2226mA$

$\cancel{10 = (2.2K(B) + (B+1)100) I_B = V_{CE}}$

$10 - 2.2K I_{C_1} - 2200 I_{B_1} = V_{CE_1}$

$10 - 2.2K(0.226m) - 2.2K(10.6u) = V_{CE_1}$

$10 - 0.4972 - 0.023 = V_{CE_1}$

$\boxed{V_{CE1} = 9.4798V}$

$B_2 = 23.1$

$I_{C_2} = B_2 I_{B_2} = (23.1)(10.5u)$

$I_{C_2} = 0.242mA$

$10 - 2.2K I_{C_2} - 2410 I_{B_2} = V_{CE_2}$

$10 - 2.2K(0.242m) - 2.41K(10.5u) = V_{CE_2}$

$10 - 0.0253 - 0.5324 = V_{CE2}$

$\boxed{V_{CE_2} = 9.4423}$

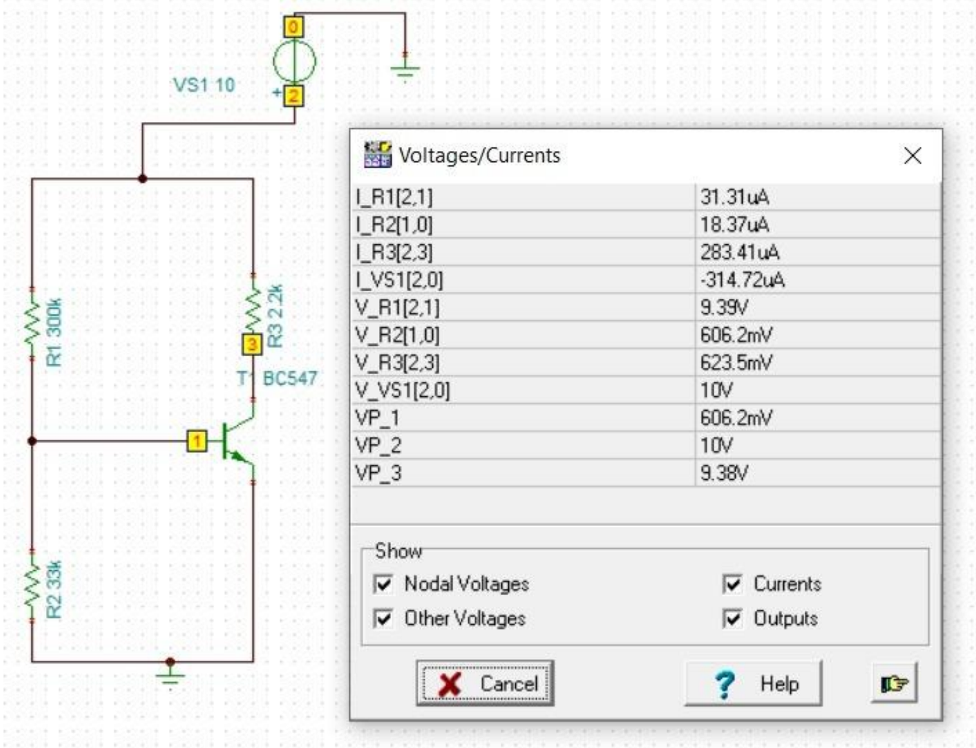
$$\Delta B = \frac{B_2 - B_1}{B_1} \times 100 = \frac{2.1}{21} \times 100 = 10\%$$

$$\Delta V_{CE2} = \frac{V_{CE2} - V_{CE1}}{V_{CE1}} \times 100 = \frac{-0.0367}{9.479} \times 100 = -0.387$$

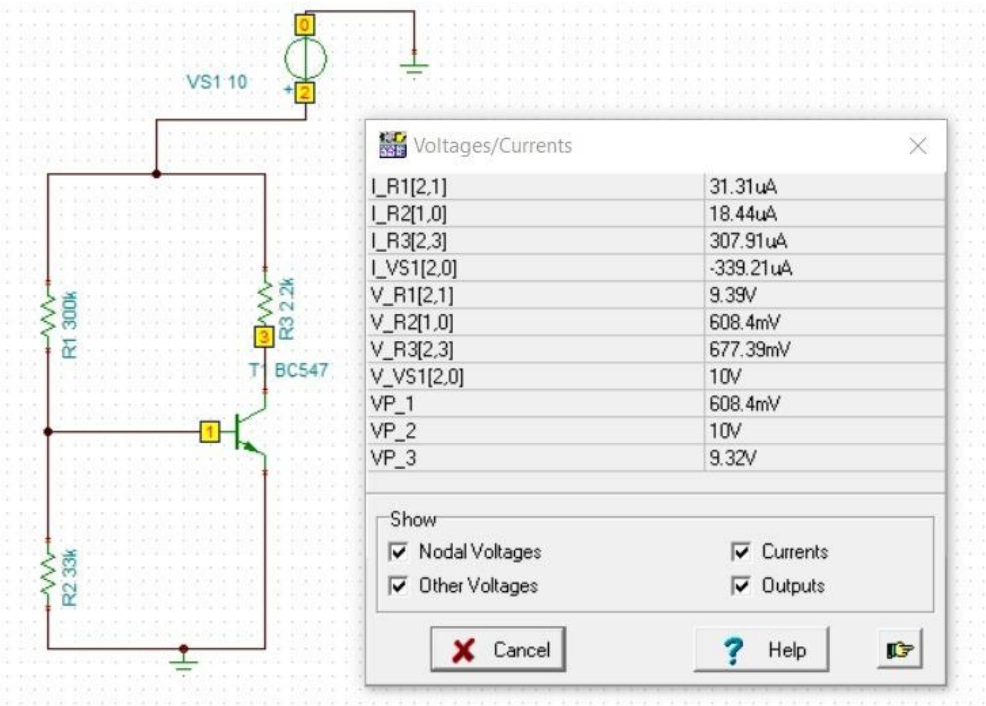
$$\text{Sensivity} = \frac{\Delta V_{CE}}{\Delta B} \times 100 = \frac{-0.387}{10} \times 100 = -3.87$$

WITHOUT Re:

Beta 1

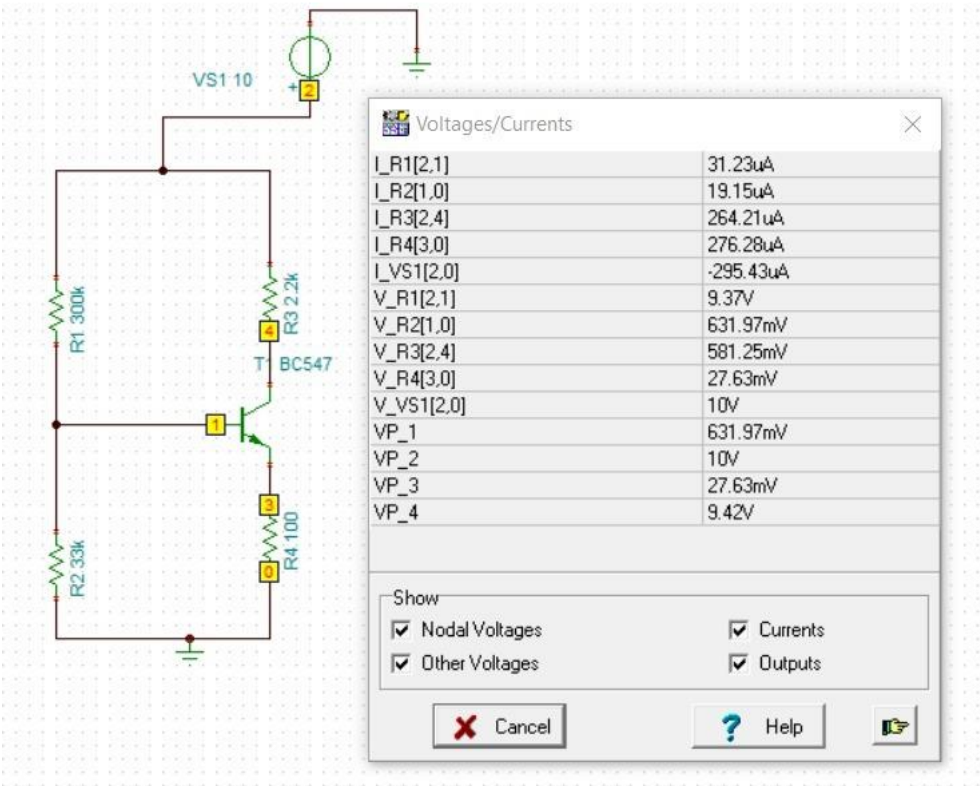


Beta 2

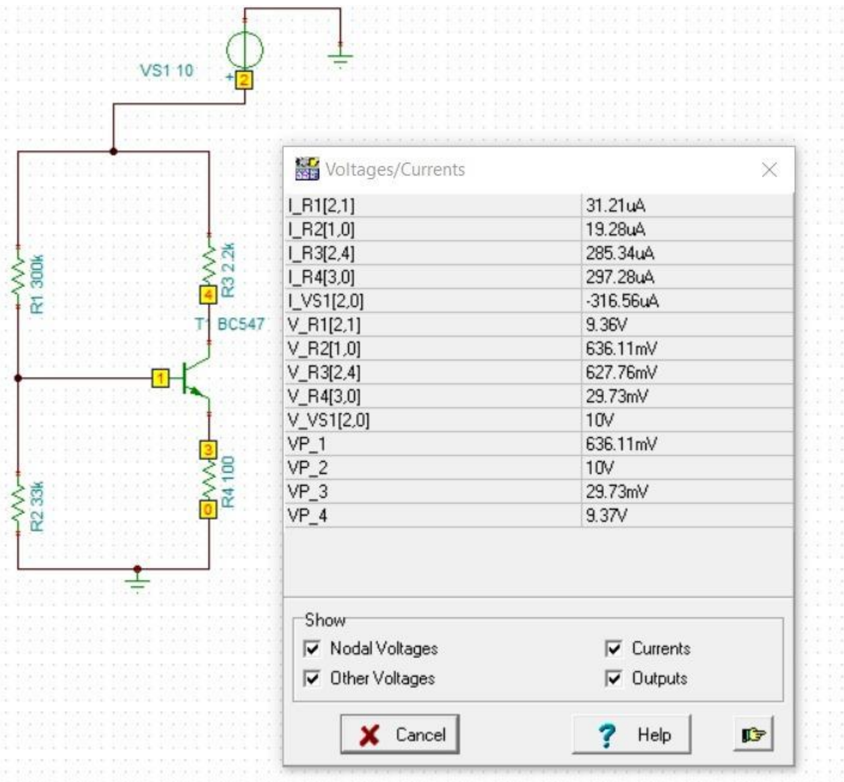


WITH Re:

Beta 1



Beta 2



After Simulation:→

① without R_E

$\beta_1 = 21$	$\beta_2 = 23.1$
$V_{CE_1} = 9.38V$	$V_{CE_2} = 9.32V$
$I_{C_1} = 0.28341 mA$	$I_{C_2} = 0.30791 mA$

$$\Delta\beta = \frac{\beta_2 - \beta_1}{\beta_1} \times 100 = \frac{2.1}{21} \times 100 = \underline{10\%}$$

$$\Delta V_{CE_2} = \frac{V_{CE2} - V_{CE1}}{V_{CE1}} \times 100 = \frac{-0.06}{9.38} \times 100 = -0.639$$

$$\text{Sensivity} = \frac{\Delta V_{CE}}{\Delta\beta} \times 100 = \frac{-0.639}{10} \times 100 = -6.39$$

② With R_E

$\beta_1 = 21$	$\beta_2 = 23.1$
$V_{CE_1} = 9.42 - 0.02763 = 9.39237V$	$V_{CE_2} = 9.37 - 0.02973 = 9.34027V$
$I_{C_1} = 0.26421 mA$	$I_{C_2} = 0.28534 mA$

$$\Delta V_{CE_2} = \frac{V_{CE2} - V_{CE1}}{V_{CE1}} \times 100 = \frac{-0.0521}{9.39237} \times 100 = -0.5547$$

$$\text{Sensivity} = \frac{\Delta V_{CE}}{\Delta\beta} \times 100 = \frac{-0.5547}{10} \times 100 = -5.547$$

After Simulation:→

1. without R_E

$\beta_1 = 21$

$V_{CE_1} = 9.38V$

$I_{C_1} = 0.28341 mA$

$\beta_2 = 23.1$

$V_{CE_2} = 9.32V$

$I_{C_2} = 0.30791 mA$

$$\Delta\beta = \frac{\beta_2 - \beta_1}{\beta_1} \times 100 = \frac{2.1}{21} \times 100 = 10\%$$

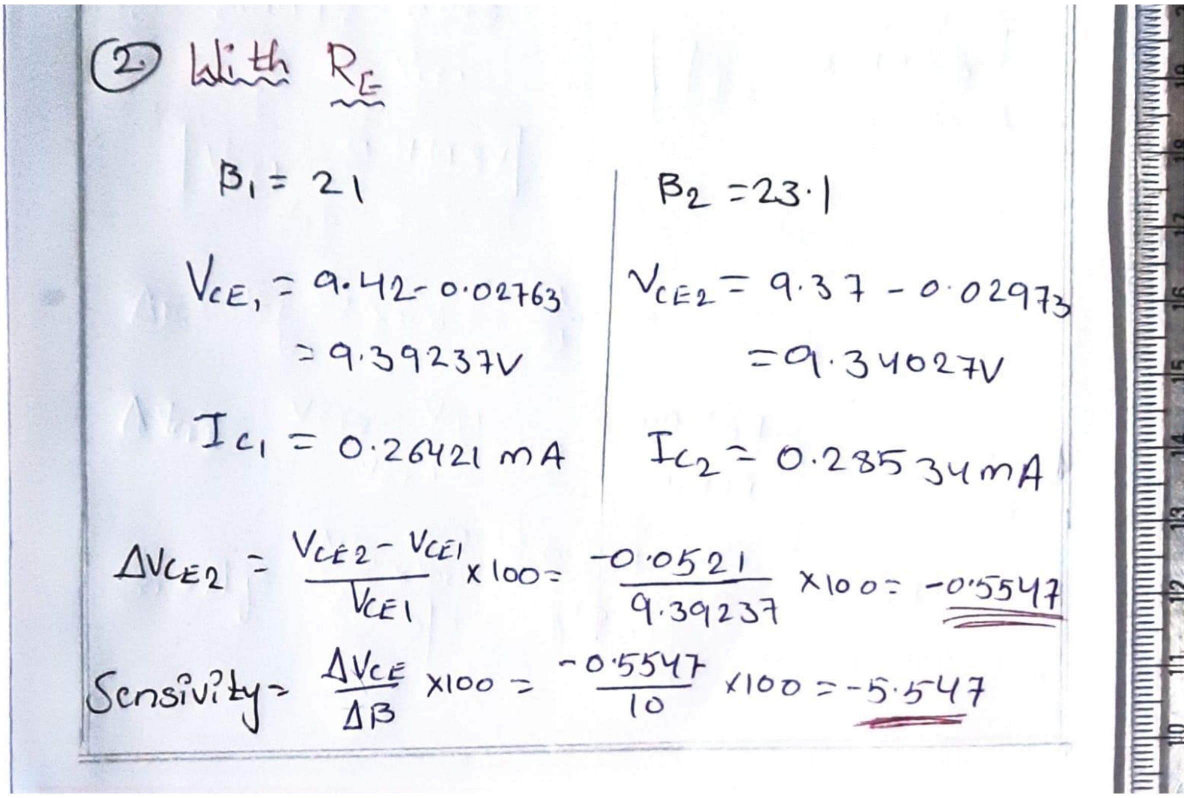
$$\Delta V_{CE_2} = \frac{V_{CE2} - V_{CE1}}{V_{CE1}} \times 100 = \frac{-0.06}{9.38} \times 100 = -0.639$$

$$\text{Sensitivity} = \frac{\Delta V_{CE}}{\Delta\beta} \times 100 = \frac{-0.639}{10} \times 100 = -6.39$$

Table 1 Common Emitter Amplifier without emitter resistance

	Analysis			Simulation	
		β1 =	β2 =	β1 =	β2 =
V_{BE} (V)		0.65	0.65	0.65	0.65
V_{CE} (V)		9.474	9.421	9.38	9.32
I_C (mA)		0.239	0.263	0.283	0.307
Δβ (%)	$\frac{\beta_2-\beta_1}{\beta_1} * 100$ =10			10	
ΔV_{CE} (%)	$\frac{V_{CE,2}-V_{CE,1}}{V_{CE,1}} * 100$ =-0.559			-0.639	
Sensitivity (%)	$\frac{\Delta V_{CE}}{\Delta\beta} * 100$ =-5.59			-6.39	

Now, insert an emitter resistor (R_E) of 100 Ω. Repeat the measurements of Step 3 and note down the measurements in Table 2. Again, the analysis is to be completed before Simulation.


② With R_E

$\beta_1 = 21$

$V_{CE_1} = 9.42 - 0.02763$
$= 9.39237V$

$I_{C_1} = 0.26421\ mA$

$\beta_2 = 23.1$

$V_{CE_2} = 9.37 - 0.02973$
$= 9.34027V$

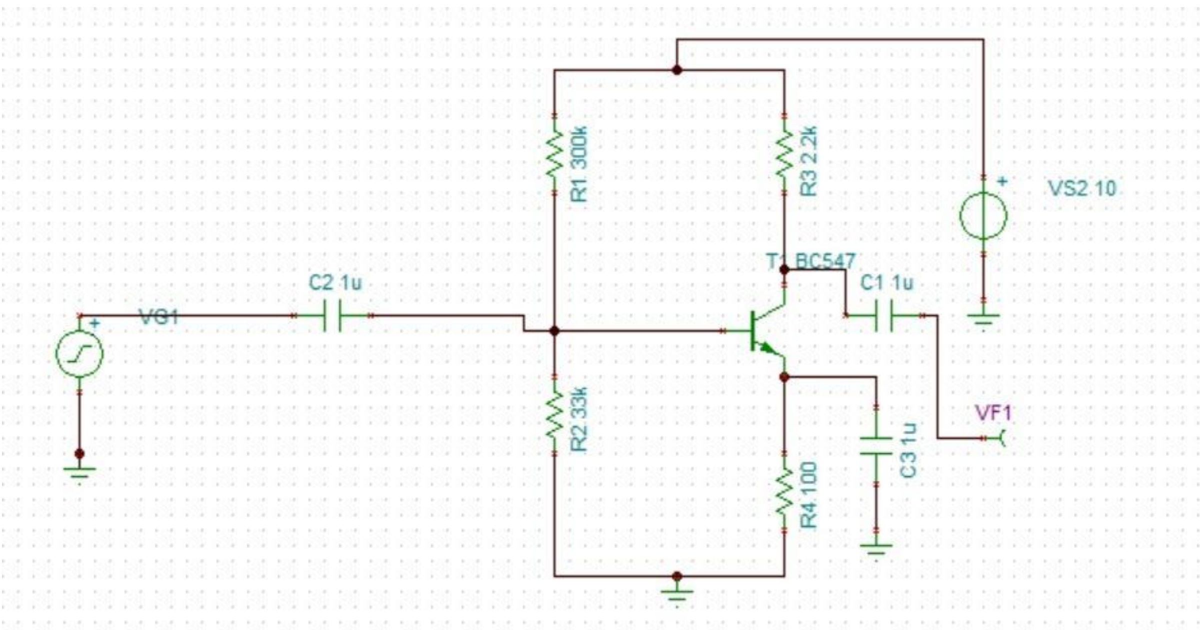
$I_{C_2} = 0.28534\ mA$

$$\Delta V_{CE_2} = \frac{V_{CE2} - V_{CE1}}{V_{CE1}} \times 100 = \frac{-0.0521}{9.39237} \times 100 = -0.5547$$

$$\text{Sensitivity} = \frac{\Delta V_{CE}}{\Delta \beta} \times 100 = \frac{-0.5547}{10} \times 100 = -5.547$$

Table 2 Common Emitter Amplifier with emitter resistance (R_E) of 100 Ω

	Analysis			Experiment	
		β1 =	β2 =	β1 =	β2 =
V_{BE} (V)		0.65	0.65	0.65	0.65
V_{CE} (V)		9.479	9.442	9.392	9.340
I_C (mA)		0.222	0.242	0.264	0.285
Δβ (%)	$\frac{\beta_2-\beta_1}{\beta_1} * 100$ =10			10	
ΔV_{CE} (%)	$\frac{V_{CE,2}-V_{CE,1}}{V_{CE,1}} * 100$ =-0.387			-0.5547	
Sensitivity (%)	$\frac{\Delta V_{CE}}{\Delta\beta} * 100$ =-3.87			-5.47	



Inference for the Sensitivity of CE Amplifier:

Comparing the values of sensitivities for the CE Amplifier, we notice that the change in the values which are dependant on the value of DC Current Gain β is very negligible when we have connected an emitter resistance w.r.t when we have not connected any emitter resistance. The objective of a CE Amplifier circuit is to stabilise the DC biased input voltage to the amplifier and thus only amplify the required AC signal which is achieved by the usage of an Emitter Resistance which provides the required amount of automatic biasing needed for a common emitter amplifier since the change in the voltages or current results in the change in Emitter Voltage which automatically provides feedback to compensate for the change.