EE 236: Experiment 6
Bipolar Junction Transistor

Rohan Rajesh Kalbag, 20D170033

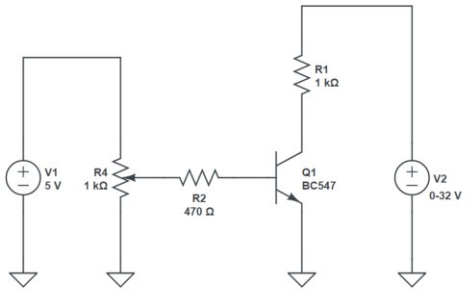
October 7, 2022

1 Aim

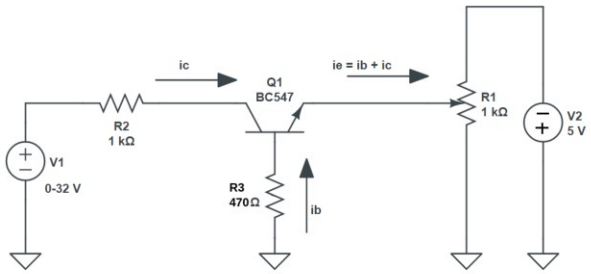
To measure the forward active and reverse active parameters in CB and CE configurations for a Bipolar Junction Transistor. Plot the output DC characteristics in CE configuration. To plot the Gummel Plot and study the dependence of β_{DC} with I_C. To calculate r_π and other small signal parameters for a BJT.

2 Lab Experiment

2.1 Circuits Used



Circuit for Common Emitter Configuration

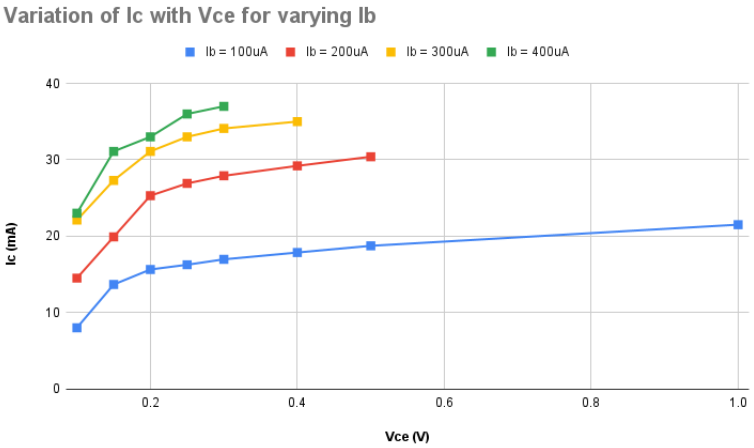


Circuit for Common Base Configuration

2.2 Observations and Plots Obtained

2.2.1 Part 1: BJT Parameters in CE Configuration

Voltage	Collector Current Obtained I_C in mA			
V_{CE} (V)	$I_B = 100\mu$A	$I_B = 200\mu$A	$I_B = 300\mu$A	$I_B = 400\mu$A
0.1	8	14.5	22.1	23
0.15	13.66	19.9	27.3	31.1
0.2	15.63	25.3	31.1	33
0.25	16.25	26.9	33	36
0.3	16.96	27.9	34.1	37
0.4	17.85	29.2	35	
0.5	18.73	30.4		
1	21.5			



Variation of I_C with V_{BE} for different values of I_B

To calculate the **average value** of β the following approach was used. It is also mentioned to assume the value of $\gamma = 1$. The value of $\frac{I_C}{I_B}$ was found for all values of $I_B = 100\mu$A, 200μA, 300μA.

The values for $400\mu A$ weren't taken as the data points were very less for this due to small range while measuring and the values of β used obtained here as outliers could adversely affect the value of mean.

Ratio of I_C and I_B ($\frac{I_C}{I_B}$)		
$I_B = 100\mu$A	$I_B = 200\mu$A	$I_B = 300\mu$A
80	72.5	73.67
136.6	99.5	91
156.3	126.5	103.67
162.5	134.5	110
169.6	139.5	113.67

The average value of $\beta = \frac{1}{15} \cdot \sum_{i=1}^{15} \beta_i = 117.96$.

Additionally, the following relation was invoked to find the value of α

$$\alpha = \frac{\beta}{1+\beta}$$

Thus β and α for **CE configuration** was found to be **117.96** and **0.9915**

To calculate **Early Voltage** (V_A) the equation of the interpolating line at the largest two values of V_{CE} was found and then the **x-intercept** was taken. The same procedure was performed for all I_B curves and the average value of the **x-intercept** (magnitude) was taken as the early voltage.

The values for $I_B = 400\mu A$ were not taken for the same reason as above

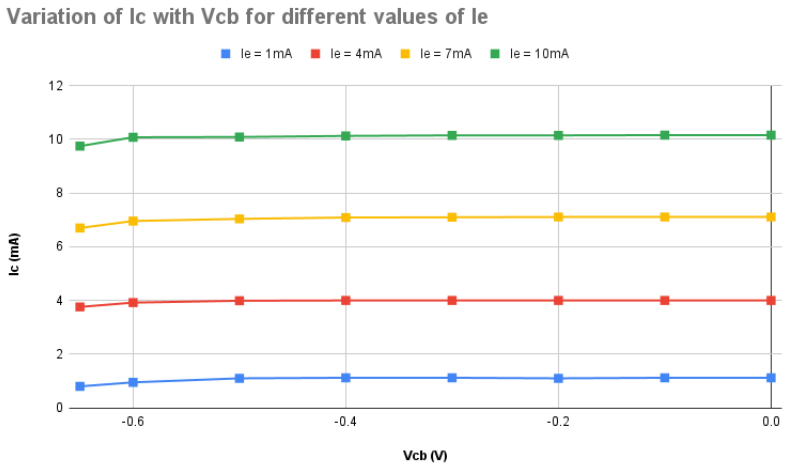
	$I_B = 100\mu$A	$I_B = 200\mu$A	$I_B = 300\mu$A
Line Equation	$y = 0.00554x + 0.01596$	$y = 0.012x + 0.0244$	$y = 0.009x + 0.03139$
x Intercept (p_i)	-2.881	-2.033	-3.489

The average value of V_A = -($\frac{1}{3} \cdot \sum_{i=1}^{3} p_i$) = 2.801 V

Thus the **Early Voltage** (V_A) obtained for the **CE configuration = 2.801 V**

2.2.2 Part 2: BJT Parameters in CB configuration

Voltage	Collector Current Obtained I_C in mA			
V_{CB}	$I_E = 1$mA	$I_E = 4$mA	$I_E = 7$mA	$I_E = 10$mA
-0.65	0.8	3.76	6.7	9.75
-0.6	0.95	3.92	6.96	10.08
-0.5	1.1	3.99	7.04	10.09
-0.4	1.12	4	7.09	10.13
-0.3	1.12	4	7.1	10.15
-0.2	1.1	4	7.11	10.15
-0.1	1.12	4	7.11	10.16
0	1.12	4	7.11	10.16



Variation of I_C with V_{CB} for different values of I_E

The value of $\alpha = \frac{I_C}{I_E} = \frac{7}{7.11} \approx \frac{10}{10.16} = 0.9842$. (For $I_E = 7$mA, 10mA)

Additionally, the following relation was invoked to find the value of β

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

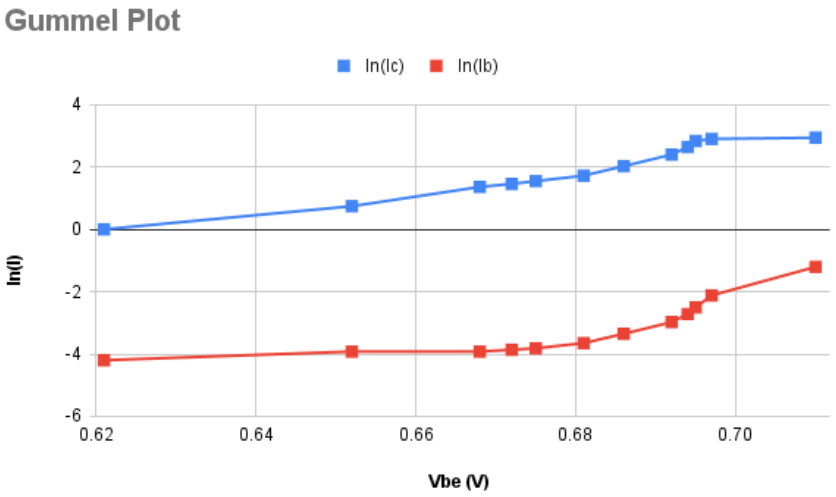
Hence, we get $\alpha = \frac{0.9843}{1-0.9843} = 62.5$

Thus the value of β and α was found to be **62.5** and **0.9842**, given $\gamma = 1$

2.2.3 Part 3: Gummel Plot and Variation of β_{DC} with I_C

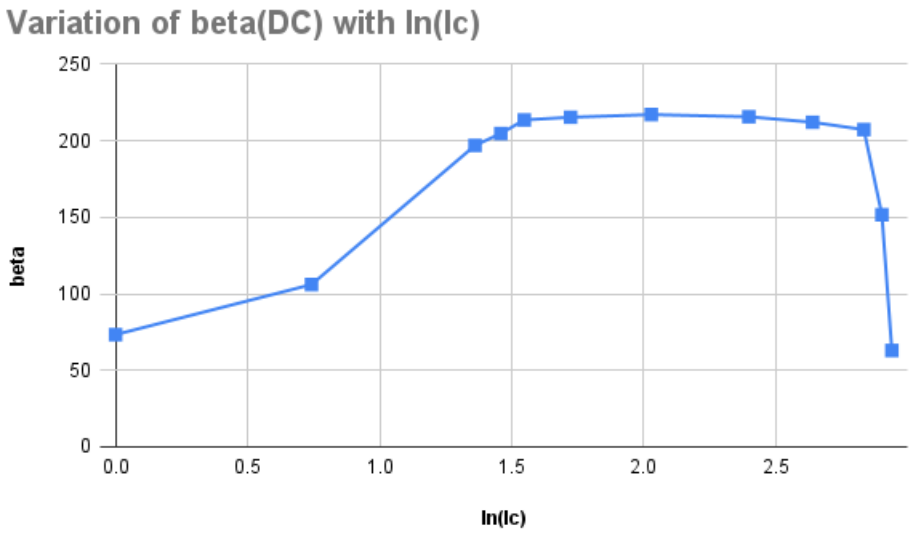
The value of V_{CB} was chosen to be 4.3V for this experiment

V_{BE}	I_C	I_B (mA)	β_{DC}	$ln(I_C)$	$ln(I_B)$
0.621	1.1	0.015	73.33333333	0.0002045454545	-4.199705078
0.652	2.1	0.0198	106.0606061	0.7419373447	-3.922073341
0.668	3.9	0.0198	196.969697	1.360976553	-3.922073341
0.672	4.3	0.021	204.7619048	1.458615023	-3.863232841
0.675	4.7	0.022	213.6363636	1.547562509	-3.816712826
0.681	5.6	0.026	215.3846154	1.722766598	-3.649658741
0.686	7.6	0.035	217.1428571	2.028148247	-3.352407217
0.692	11	0.051	215.6862745	2.397895273	-2.975929646
0.694	14	0.066	212.1212121	2.63905733	-2.718100537
0.695	17	0.082	207.3170732	2.833213344	-2.501036032
0.697	18.2	0.12	151.6666667	2.901421594	-2.120263536
0.71	18.9	0.3	63	2.939161922	-1.203972804



Gummel Plot Obtained

The values of $ln(I_B)$ and $ln(I_C)$ were plotted in semi-log scale against V_{CB}. The **high level injection** behaviour of $ln(I_C)$ is seen close to **0.7V** as given in the handout. However the **R-G component** behavior of $ln(I_B)$ is not seen clearly in this plot. If more readings were taken for $V_{BE} < 0.6V$ were taken we could see this much more apparent which **wasn't possible due to time constraints in the laboratory**.



Variation of β_{DC} with $ln(I_C)$

Thus as expected in the handout, we see that the value of β is high in the middle region where the value of I_C is significantly greater than that I_B and decreases as I_C becomes comparable with I_B which is at higher and lower values.

2.2.4 Part 4: Small Signal Parameters for Common Emitter BJT

The biasing point is $I_C = 4.5$ mA and $V_{CE} = 5$ V. The calculated values of β and V_A from **Part 1** are used here to find the small signal parameters

$$g_m = \frac{I_C}{V_T} = \frac{4.5\ mA}{26\ mV} \approx 173.07\ mS$$

$$r_\pi = \frac{\beta}{g_m} = \frac{117.96}{0.173} \approx 681.84\ \Omega$$

$$r_o = \frac{V_A}{I_C} = \frac{2.801\ V}{4.5\ mA} \approx 622.44\ \Omega$$

$g_m = 173.07\ mS,\ r_\pi = 681.84\ \Omega,\ r_o = 622.44\ \Omega$ are the small signal parameters of the BJT