EE236: Lab 6
Analysis of Bipolar Junction Transistors

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1 Aim of the experiment

1. To measure the forward active and reverse active parameters in common base and common emitter configurations.
2. To plot the output DC characteristics in CE configuration.
3. To plot combined I_C and I_B vs V_{BE} of a BJT on a semi-log scale (also called Gummel plot).
4. To plot β_{DC} vs I_C characteristics for constant V_{BC} .
5. To calculate r_π model small signal parameters.

2 Design & Working

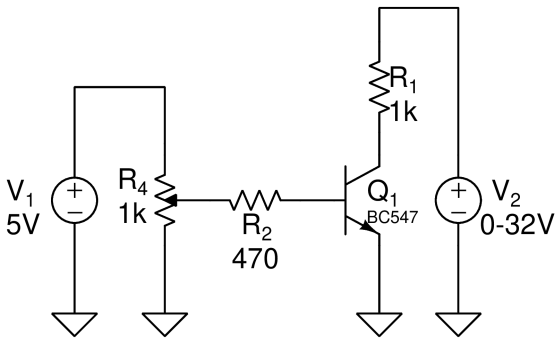

Fig. CE Circuit

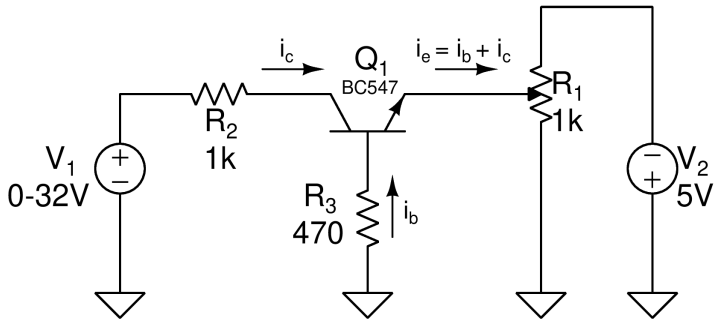

Fig. CB Circuit

3 Experimental Results

3.1 Part - 1

Given below are my readings for V_{CE} and I_C for the BJT for $I_B = 100\mu A$:

V_{CE} (in V)	I_C (in mA)
0.0094	0.067
0.0341	0.865
0.0521	1.80
0.0687	2.87
0.0778	3.99
0.086	4.82
0.106	6.78
0.123	8.66
0.143	11.0
0.163	12.9
0.209	15.1
0.346	16.8
0.59	18.5
0.961	20.3
1.849	21.7
3.51	21.8
5.94	22.4
7.45	23.1
8.99	24.1

We obtain $\alpha = i_C/i_E = 0.9959$, $\beta = i_C/i_B = 241$, $V_A = 64.52V$.

Given below is the plot for I_C vs V_{CE} for $I_B = 100\mu A$:

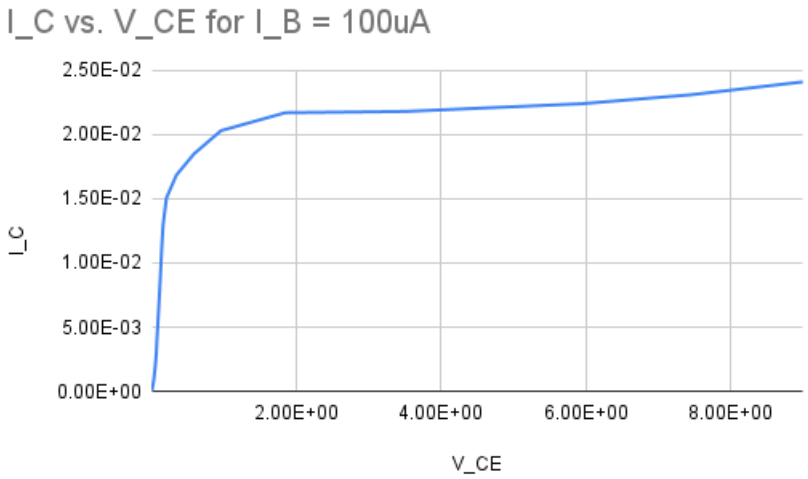

Fig. I_C-V_{CE} Characteristics for the BJT for $I_B = 100\mu A$

Given below are my readings for V_{CE} and I_C for the BJT for $I_B = 200\mu A$:

V_{CE} (in V)	I_C (in mA)
0.0066	0.069
0.0215	0.875
0.0357	1.98
0.0455	2.89
0.0535	4.02
0.0626	4.84
0.0755	6.81
0.0859	8.70
0.0996	11.0
0.11	13.0
0.123	15.1
0.138	17.1
0.155	18.9
0.169	21.1
0.209	23.2
0.25	25.2
0.29	27.4
0.52	30.0
0.72	32.1

We obtain $\alpha = i_C/i_E = 0.9938$, $\beta = i_C/i_B = 160.5$, $V_A = 2.507V$.

Given below is the plot for I_C vs V_{CE} for $I_B = 200\mu A$:

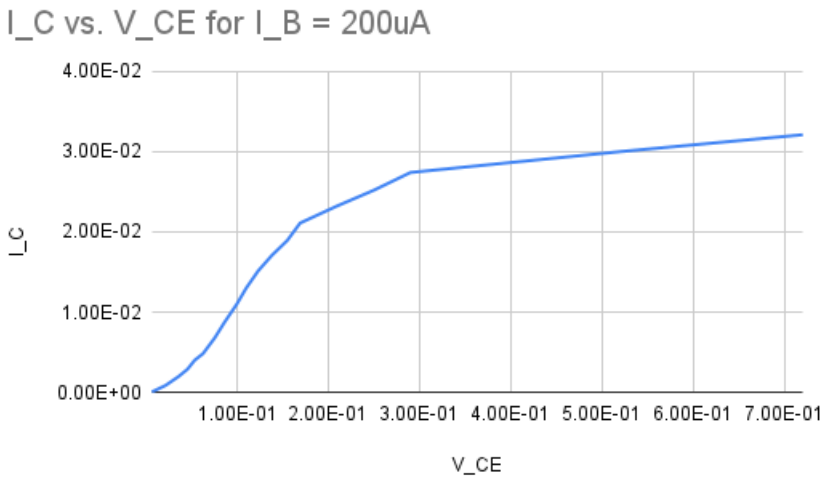

Fig. I_C-V_{CE} Characteristics for the BJT for $I_B = 200\mu A$

Given below are my readings for V_{CE} and I_C for the BJT for $I_B = 300\mu A$:

V_{CE} (in V)	I_C (in mA)
0.0057	0.07
0.0161	0.879
0.0276	1.99
0.0356	2.90
0.0428	4.02
0.0482	4.85
0.0606	6.82
0.0707	8.72
0.0800	11.0
0.0906	13.0
0.101	15.2
0.109	17.1
0.118	19.0
0.13	21.2
0.144	23.3
0.147	25.4
0.16	27.7
0.19	30.4
0.23	33.0

We obtain $\alpha = i_C/i_E = 0.991$, $\beta = i_C/i_B = 110$, $V_A = 0.366V$.

Given below is the plot for I_C vs V_{CE} for $I_B = 300\mu A$:

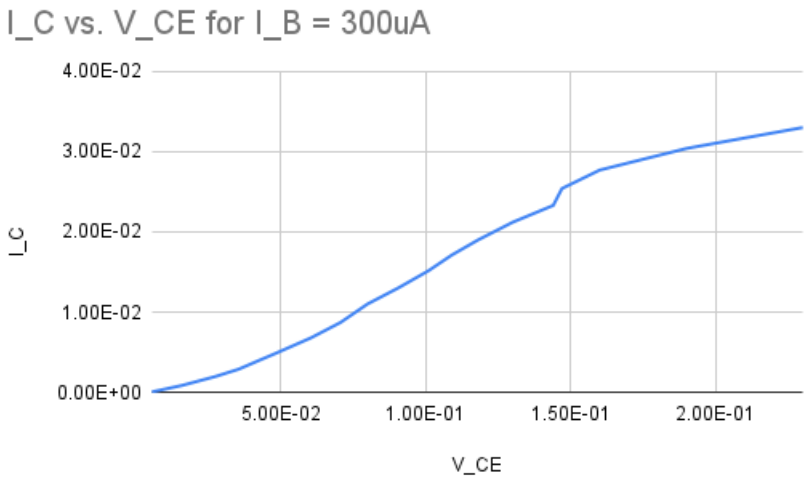

Fig. I_C-V_{CE} Characteristics for the BJT for $I_B = 300\mu A$

Given below are my readings for V_{CE} and I_C for the BJT for $I_B = 400\mu A$:

V_{CE} (in V)	I_C (in mA)
0.0052	0.700
0.0135	0.881
0.0229	1.99
0.0301	2.91
0.0365	4.04
0.0406	4.86
0.0516	6.83
0.0600	8.73
0.0709	11.0
0.0791	13.0
0.088	15.2
0.095	17.1
0.104	19.0
0.113	21.2
0.122	23.3
0.125	25.4
0.13	27.7
0.15	30.5
0.17	33.1

We obtain $\alpha = i_C/i_E = 0.98806$, $\beta = i_C/i_B = 82.75$, $V_A = 0.205V$.

Given below is the plot for I_C vs V_{CE} for $I_B = 400\mu A$:

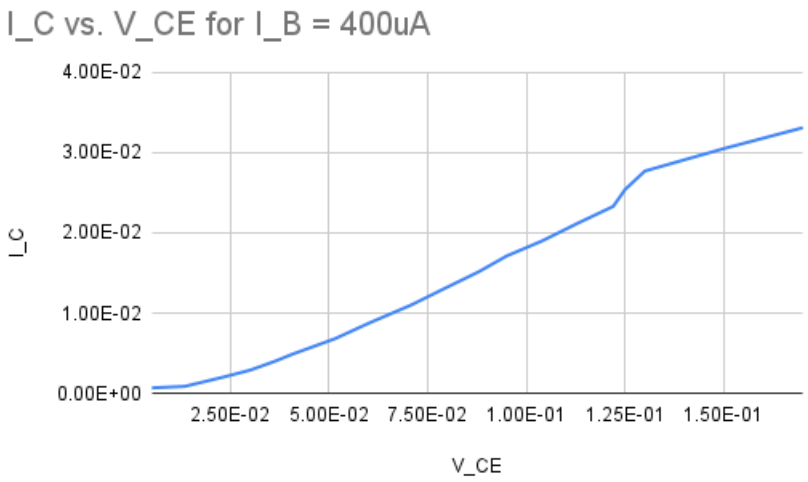

Fig. I_C-V_{CE} Characteristics for the BJT for $I_B = 400\mu A$

4 Part - 2

Given below are my readings for V_{CB} and I_C for the BJT for $I_E = 1mA$:

V_{CB} (in V)	I_C (in mA)
-0.66	0.75
0.96	0.98
3.26	1.01
5.95	1.02
8.09	1.00
10.2	0.97
12.67	0.94
14.68	0.96
16.71	0.96
18.97	0.97

We obtain $\alpha = i_C/i_E = 0.97$, $\beta = i_C/i_B = 32.33$.

Given below is the plot for I_C vs V_{CB} for $I_B = 1mA$:

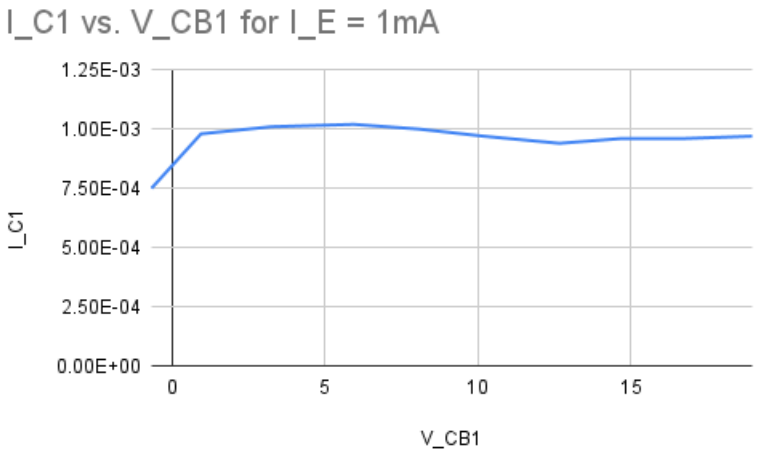

Fig. I_C-V_{CB} Characteristics for the BJT for $I_B = 1mA$

Given below are my readings for V_{CB} and I_C for the BJT for $I_E = 4mA$:

V_{CB} (in V)	I_C (in mA)
-0.74	1.76
-0.71	3.06
0.25	3.98
2.91	3.98
4.96	4.02
7.19	3.96
9.36	3.98
11.61	3.99
13.38	4.01
15.7	3.97

We obtain $\alpha = i_C/i_E = 0.9925$, $\beta = i_C/i_B = 132.33$.

Given below is the plot for I_C vs V_{CB} for $I_B = 4mA$:

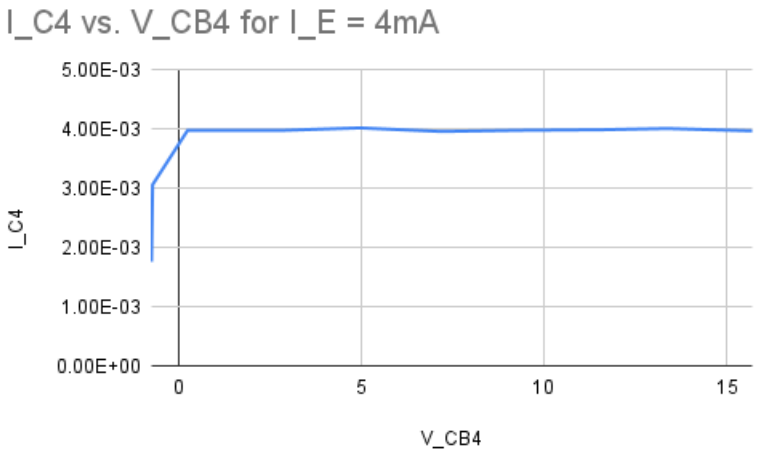

Fig. I_C-V_{CB} Characteristics for the BJT for $I_B = 4mA$

Given below are my readings for V_{CB} and I_C for the BJT for $I_E = 7mA$:

V_{CB} (in V)	I_C (in mA)
-0.76	2.71
-0.74	4.04
-0.72	5.57
-0.09	7.01
1.9	7.09
4.1	7.01
6.42	6.96
8.51	6.99
10.37	6.96
12.38	6.97

We obtain $\alpha = i_C/i_E = 0.9957$, $\beta = i_C/i_B = 232.33$.

Given below is the plot for I_C vs V_{CB} for $I_B = 7mA$:

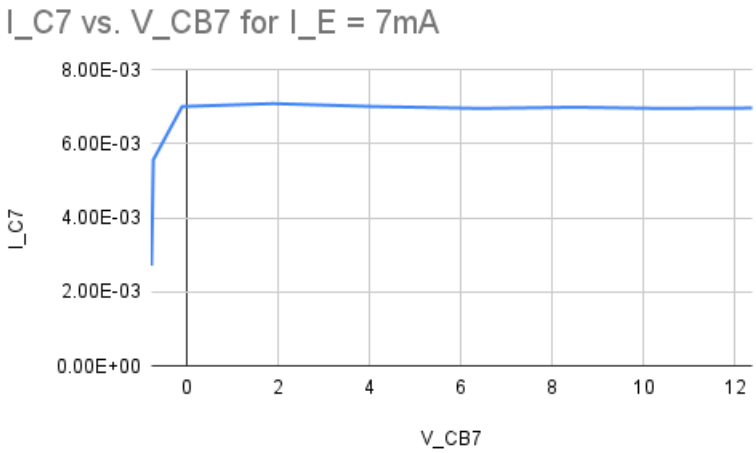

Fig. I_C-V_{CB} Characteristics for the BJT for $I_B = 7mA$

Given below are my readings for V_{CB} and I_C for the BJT for $I_E = 10mA$:

V_{CB} (in V)	I_C (in mA)
-0.77	3.68
-0.77	5.05
-0.75	6.55
-0.72	8.36
-0.65	9.66
1.25	9.86
3.5	9.91
5.65	9.90
7.55	9.96
8.49	9.95

We obtain $\alpha = i_C/i_E = 0.9950$, $\beta = i_C/i_B = 199$.

Given below is the plot for I_C vs V_{CB} for $I_B = 10mA$:

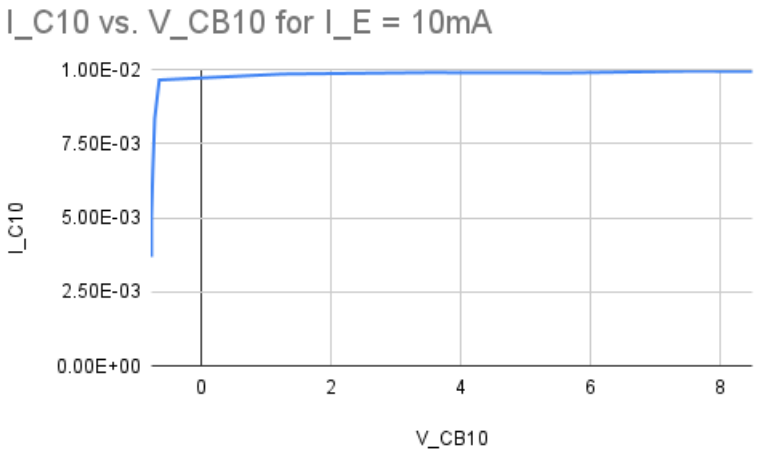

Fig. I_C-V_{CB} Characteristics for the BJT for $I_B = 10mA$

5 Part - 3

Given below are my readings for V_{BE}, I_B and I_C for the BJT at a fixed V_{CB}:

V_{BE} (in V)	I_B (in mA)	I_C (in mA)
0	0	0
0.39	0	0
0.50	0	0.004
0.55	0.0002	0.03
0.59	0.0007	0.133
0.61	0.0014	0.268
0.62	0.0023	0.476
0.64	0.0044	0.930
0.65	0.0063	1.33
0.67	0.0347	6.49
0.68	0.0378	7.17
0.7	0.0446	9.18
0.72	0.146	11.6
0.74	0.791	11.9
0.76	1.62	12.4
0.78	3.72	13.4
0.79	4.44	13.7
0.80	5.65	14.3
0.81	7.63	15.3
0.817	8.88	15.9

Given below is the plot for I_C and I_B vs V_{BE} for a fixed V_{CB}:

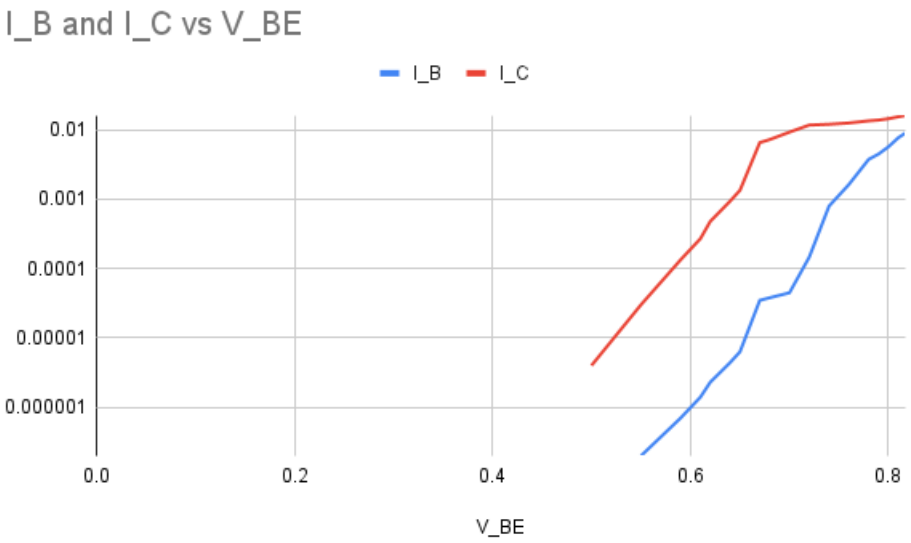

Fig. $I_C - V_{BE}$ and $I_B - V_{BE}$ Characteristics for the BJT for a fixed V_{CB}

Given below is the Gummel plot i.e. β_{DC} vs $\ln(I_C)$ plot for a fixed $V_{CB} = 0.45V$:

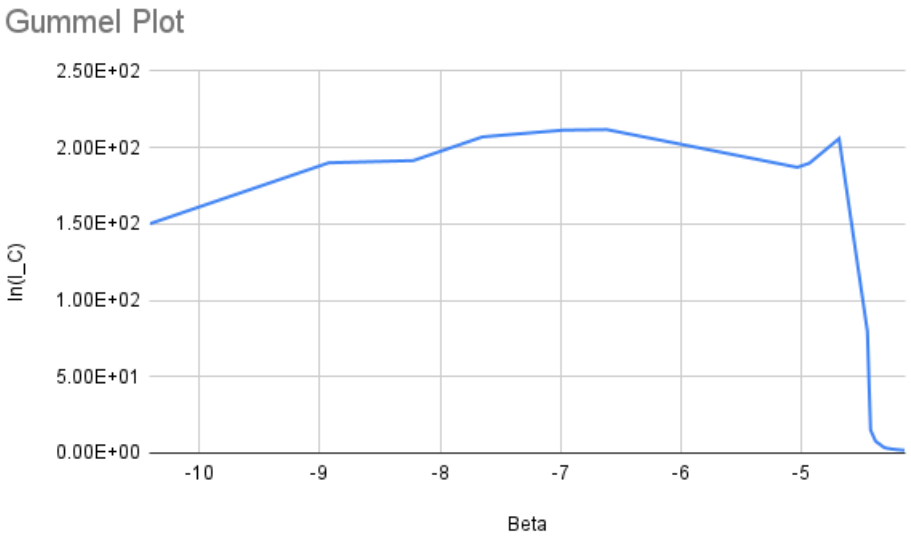

Fig. $I_C - V_{BE}$ and $I_B - V_{BE}$ Characteristics for the BJT for a fixed V_{CB}

Since $\beta_{DC} = I_C/I_B$, we can observe from the I_C and I_B vs V_{BE} plot that the

difference in the logarithm plot remains constant i.e. β_{DC} remains constant until a certain V_{BE} and then decreases as the difference between $\ln(I_C)$ and $\ln(I_B)$ reduces. Similarly for low values of I_C, the difference between the two log plots is small and thus β_{DC} is small.
Thus for small I_C, β_{DC} is small and then it becomes constant due to the constant gap and then again becomes small for high values of I_C.

6 Part - 4

Fixing $V_{CE} = 5V$ and $I_C = 4.5mA$, we obtain $I_B = 21.1\mu A$ which gives a $\beta = 213$. We had earlier calculated the Early Voltage $V_A = 64.52V$. Using these values we obtain the following parameters:

$$\begin{aligned} g_m &= I_C V_t = 1.17 \times 10^{-4} \\ r_\pi &= \beta g_m = 0.025\Omega \\ r_o &= V_A I_C = 0.29\Omega \end{aligned}$$