PH3204: Electronics Lab

Study of an npn Bipolar Junction Transistor(BJT)

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Contents

1 Aim

The aim of this experiment is two fold, we want to study the input and output characteristics of an npn Bipolar Junction Transistor (BJT) and also to determine the current gain of the BJT.

- To study the input characteristics of an npn BJT.
- To study the output characteristics of an npn BJT.
- To determine the current gain of the BJT.

2 Theory

The Bipolar Junction Transistor(BJT) used in the amplifications of signals and also as switches in circuits. There are two types of BJT, namely , npn and pnp. In this experiment we will be studying the npn BJT. The npn BJT consists of three layers of semiconductors, namely, the emitter, base and collector. The emitter is heavily doped, the base is lightly doped and the collector is moderately doped. The BJT has two junctions, the emitter-base junction and the collector-base junction.

The BJT can be used in many different configurations, here we will study it in the Common Emitter(CE) configuration. In this configuration, the input is given to the base and the output is taken from the collector. The emitter is common to both the input and output. The input characteristics of the BJT is the plot of the base current(I_b) vs the base-emitter voltage(V_{BE}) for a fixed collector voltage(V_{CC}). The output characteristics of the BJT is the plot of the collector current(I_c) vs the collector-emitter voltage(V_{CE}) for a fixed base current(I_b).

Here, we also study the current gain of the BJT. When the BJT is used as an amplififer,the base emitter junction is forward biased and the collector base junction is reverse biased. In the forward bias, the electrons flow from the emitter to the base and in the reverse bias, the electrons flow from the base to the collector. There is a small amount of recombination in the base region, which gives rise to the base current I_b. The collector current I_c is almost equal to the I_c and is given by the formula:

$$I_c = \alpha I_E \tag{1}$$

where α should be close to 1. Thus the current gain is given by

$$\beta = \frac{I_c}{I_b} \tag{2}$$

where $\beta = \dfrac{\alpha}{1-\alpha}$, which should be quite large.

The circuit we use for the experiment is given below.

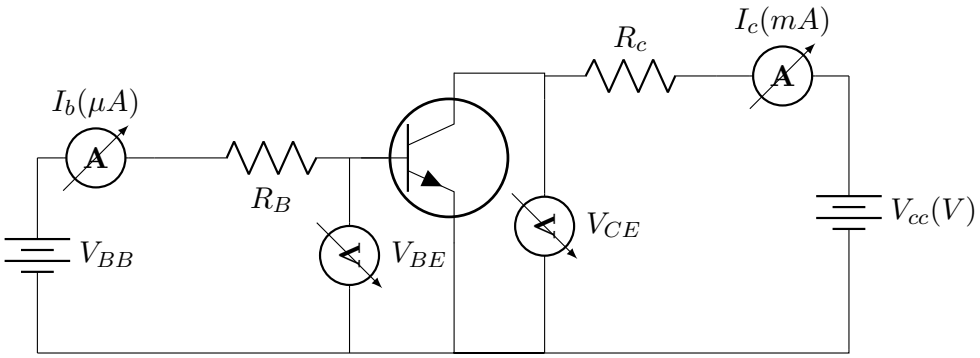

Figure 1: Circuit diagram of an npn BJT.

3 Data and Analysis

3.1 Input Characteristics of an npn BJT

For this part we wish to study the input characteristic curve of the given transistor. We fix the collector to emitter voltage(V_{CE}) and then vary the base bias voltage(V_{BB}) and measure the base current(I_b). We take three Datasets for input voltage, with $V_{CC} = 2V, 3V, 4V$. The data is given in the Supplementary section section 8(table 1, table 2, table 3). We plot the input characteristics below.

We set $R_B = 1k\Omega$ and $R_C = 1\Omega$ for this part of the experiment. For the experiment we do not put in R_C at all, but the value is taken small enough to show that R_c should be neglected.

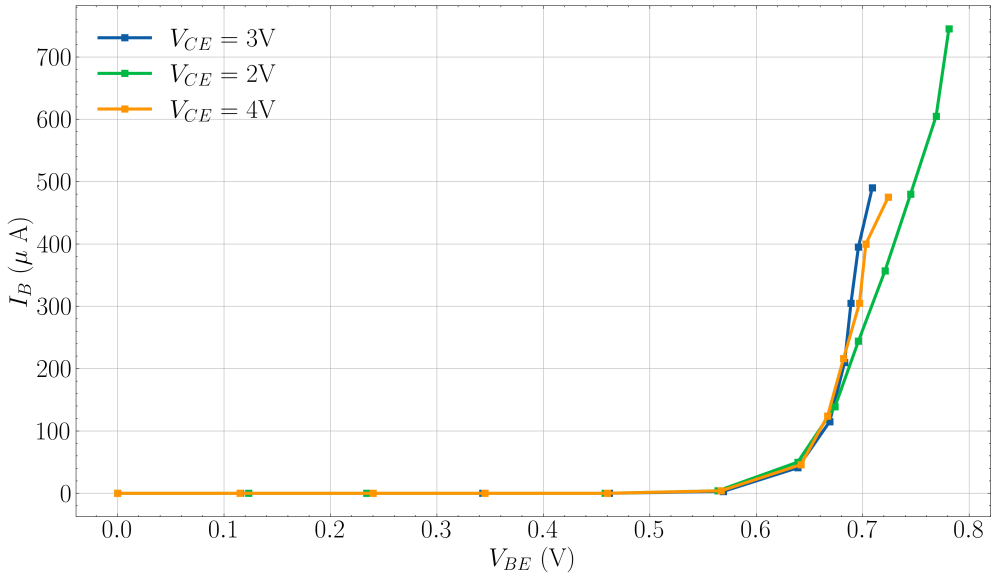

Figure 2: Input Characteristics of an npn BJT

Note: We expect the $4V$ line to be right of the $3V$ line which in turn should be in the right of the $2V$ line. However, experimentally, we observe something different. The $4V$ line lies to the right of the $3V$ line but both the lines lie to the left of the $2V$ line.

3.2 Output Characteristics of an npn BJT

For this part we wish to study the output characteristic curve of the given transistor. We fix the base current(I_b) and then vary the collector voltage(V_{CE}) and measure the collector current(I_c). We take three Datasets for input voltage, with $I_b = 10\mu A, 20\mu A, 30\mu A$. For this experiment, we used $R_B = 220\Omega$ and $R_C = 1k\Omega$. The data is given in the Supplementary section section 8(table 4, table 5, table 6). We plot the output characteristics below. We see that the plot agrees with theory, where the collector current increases with the collector-emitter voltage and then saturates.

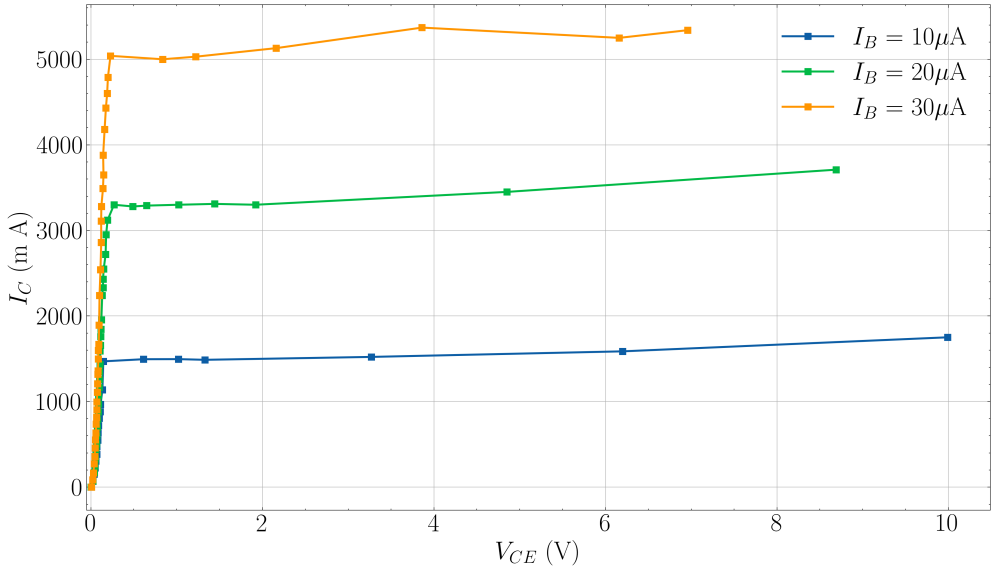

Figure 3: Output Characteristics of an npn BJT

4 Current gain of the BJT

The current gain of the BJT is given by the formula:

$$\beta = \frac{I_c}{I_b} \tag{3}$$

We plot I_c vs I_b which we obtained for the input characteristics. We then take a linear fit to find the slope and ultimately we get the average value of β for different V_{BB}. The β values are given below as $\beta_{V_{BB}}$,

$$\beta_{2V} = 131.2 \pm 0.31 \tag{4}$$
$$\beta_{3V} = 195 \pm 2.6 \tag{5}$$
$$\beta_{4V} = 205 \pm 3.6 \tag{6}$$

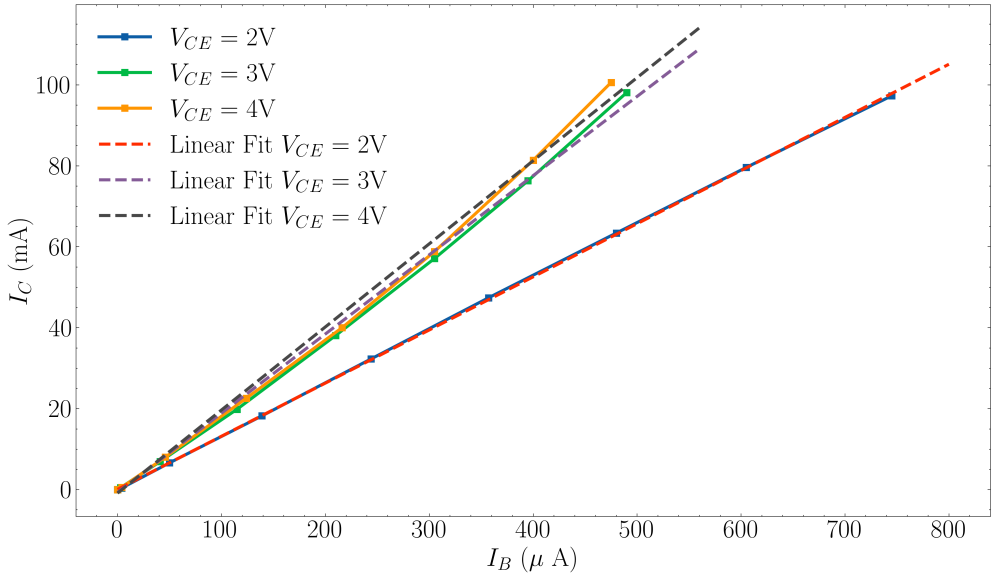

Figure 4: Current Gain of the BJT

5 Results

We have plotted the input and output characteristics with a small experimental anomaly. The current gain of the BJT is found to be $\beta_{2V} = 131.2 \pm 0.31, \beta_{3V} = 195 \pm 2.6, \beta_{4V} = 205 \pm 3.6$, which as expected, is quite large.

6 Sources of Error

- For the output characteristics, I_b was fluctuating a lot , so the values are correct upto ± 3 in the corresponding units.
- There are room temperature fluctuations which can affect the readings.
- As always, the least counts of the multimeters are a source of error.
- The source has voltage fluctuations which can affect the readings.

7 Conclusion

We conclude the experiment by finding the input and output characteristics of the BJT and also the current gain of the BJT from the input characteristics. The current gain is found to be quite large, as expected.

8 Supplementary

V_BB	V_BE	I_b (μA)	I_c(mA)	V_CC	V_CE
0	0	0	0	2	2
0.1	0.1232	0	0	2	2
0.2	0.234	0	0	2	2
0.4	0.458	0	0.007	2	2
0.5	0.564	4	0.4	2	2
0.6	0.639	50	6.62	2	2
0.7	0.674	139	18.23	2	2
0.8	0.696	244	32.3	2	2
0.9	0.721	357	47.4	2	2
1	0.745	480	63.4	2	2
1.1	0.769	605	79.6	2	2
1.2	0.781	745	97.3	2	2

Table 1: BJT Input Characteristics at $V_{CC} = 2V$

V_BB	V_BE	I_b (μA)	I_c(mA)	V_CC	V_CE
0	0	0	0	3	3
0.1	0.1156	0	0	3	3
0.2	0.236	0	0	3	3
0.3	0.343	0	0	3	3
0.4	0.462	0	6.00E-03	3	3
0.5	0.569	3	4.88E-01	3	3
0.6	0.639	41	6.95	3	3
0.7	0.669	115	19.86	3	3
0.8	0.683	210	38.1	3	3
0.9	0.689	305	57.1	3	3
1	0.696	395	76.3	3	3
1.1	0.709	490	98.1	3	3
1.2	0.787	530	111.2	3	3

Table 2: BJT Input Characteristics at $V_{CC} = 3V$

V_BB	V_BE	I_b (μA)	I_c(mA)	V_CC	V_CE
0	0	0	0	4	4
0.1	0.115	0	0	4	4
0.2	0.24	0	0	4	4
0.3	0.345	0	0	4	4
0.4	0.46	0	0.01	4	4
0.5	0.567	4	0.556	4	4
0.6	0.642	46	8.03	4	4
0.7	0.667	124	22.6	4	4
0.8	0.682	216	40	4	4
0.9	0.697	305	58.8	4	4
1	0.703	400	81.4	4	4
1.1	0.724	475	100.6	4	4

Table 3: BJT Input Characteristics at $V_{CC} = 4V$

V_BB	**I_b** (μA)	**I_c**(μA)	**V_CC**	**V_CE**
0.44	10	0	0	0
0.46	10	70	0.1	0.0233
0.47	10	151	0.2	0.0367
0.47	10	226	0.3	0.0489
0.48	10	305	0.4	0.0584
0.5	10	385	0.5	0.0682
0.49	10	477	0.6	0.0677
0.49	10	549	0.7	0.0798
0.49	10	635	0.8	0.0837
0.49	10	720	0.89	0.0878
0.49	10	805	1	0.0978
0.5	10	882	1.1	0.1075
0.5	10	968	1.2	0.1122
0.5	10	1137	1.4	0.1335
0.51	10	1470	1.8	0.1444
0.51	10	1495	2.3	0.611
0.51	10	1.50E+03	2.7	1.021
0.51	10	1.49E+03	3	1.328
0.5	10	1522	4.98	3.27
0.5	10	1587	8	6.2
0.5	10	1751	11.97	9.99

Table 4: BJT Output Characteristics at $I_b = 10\ \mu A$

V_BB	**I_b** (μA)	**I_c**(μA)	**V_CC**	**V_CE**
0.47	20	0	0	0
0.49	20	72	0.1	0.0243
0.5	20	173	0.22	0.0393
0.5	20	251	0.31	0.0452
0.51	20	333	0.4	0.052
0.51	20	440	0.52	0.0562
0.52	20	508	0.6	0.0653
0.52	20	602	0.7	0.0686
0.52	20	696	0.8	0.0749
0.53	20	788	0.9	0.0781
0.53	20	878	1	0.0862
0.53	20	974	1.09	0.0876
0.53	20	1067	1.19	0.0894
0.53	20	1162	1.3	0.0955
0.53	20	1258	1.4	0.0997
0.53	20	1349	1.49	0.1004
0.53	20	1437	1.59	0.1051
0.54	20	1593	1.74	0.1063
0.54	20	1657	1.82	0.1102
0.54	20	1761	1.92	0.1146
0.54	20	1846	2	0.1179
0.54	20	1955	2.11	0.1214
0.54	20	2240	2.22	0.131
0.54	20	2330	2.32	0.141
0.54	20	2430	2.41	0.141
0.54	20	2550	2.52	0.149
0.54	20	2720	2.7	0.171
0.54	20	2950	2.9	0.177
0.54	20	3120	3.08	0.194
0.54	20	3300	3.33	0.269
0.54	20	3280	3.53	0.489
0.54	20	3290	3.7	0.65
0.54	20	3300	4.07	1.023
0.54	20	3310	4.5	1.443
0.54	20	3300	5	1.92
0.54	20	3450	8.05	4.85
0.54	20	3710	12.11	8.69

Table 5: BJT Output Characteristics at $I_b = 20\ \mu A$

V_BB	**I_b (μA)**	**I_c(μ A)**	**V_CC**	**V_CE**
0.47	30	0	0	0.0069
0.48	30	87	0.1	0.0202
0.49	30	167	0.2	0.0295
0.49	30	274	0.31	0.0382
0.5	30	358	0.4	0.0451
0.51	30	459	0.51	0.0472
0.51	30	551	0.61	0.0516
0.51	30	634	0.7	0.0581
0.51	30	737	0.8	0.0603
0.51	30	818	0.89	0.0662
0.51	30	904	0.99	0.0675
0.52	30	997	1.08	0.0686
0.52	30	1108	1.2	0.0735
0.52	30	1209	1.3	0.0771
0.52	30	1319	1.42	0.0803
0.53	30	1358	1.47	0.0815
0.53	30	1499	1.61	0.0865
0.53	30	1599	1.71	0.0861
0.53	30	1669	1.78	0.0911
0.53	30	1894	2.02	0.0951
0.53	30	2240	2.19	0.1002
0.54	30	2540	2.48	0.1112
0.54	30	2860	2.8	0.1197
0.54	30	3110	3.04	0.1191
0.54	30	3280	3.21	0.1213
0.54	30	3490	3.42	0.1404
0.54	30	3650	3.62	0.1464
0.54	30	3880	3.79	0.1422
0.55	30	4180	4.09	0.1595
0.55	30	4430	4.33	0.1743
0.55	30	4600	4.5	0.189
0.55	30	4790	4.71	0.198
0.55	30	5040	4.94	0.228
0.55	30	5000	5.53	0.837
0.55	30	5030	5.97	1.221
0.55	30	5130	7.02	2.16
0.55	30	5370	8.96	3.86
0.55	30	5250	11.13	6.16
0.55	30	5340	11.98	6.96

Table 6: BJT Output Characteristics at $I_b = 30\ \mu A$