PH3204: Electronics Laboratory

Experiment 02: Study of characteristics of an n-p-n bipolar junction transistor (BJT)

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1 Theory

1.1 Bipolar Juction Transistor (BJT)

A **Bipolar Junction Transistor (BJT)** is a three-terminal device having wide applications in the construction of amplifiers, gates, oscillators, etc. A BJT comprises three doped semiconductor regions, namely **emitter, base, and collector**. There are two p-n junctions in a transistor, one between the emitter and base and the other between the base and collector.The emitter is heavily doped, the base is lightly doped, and the collector is moderately doped. The emitter-base junction is forward-biased, and the base-collector junction is reverse-biased.
The BJT is classified into two types based on the majority charge carriers in the three regions, namely **n-p-n transistor** and **p-n-p transistor.**

- **n-p-n Transistor:** In an n-p-n transistor, the emitter and collector are doped with n-type impurities while the base is doped with p-type impurities.
- **p-n-p Transistor:** In a p-n-p transistor, the emitter and collector are doped with p-type impurities while the base is doped with n-type impurities.

Since, there are three terminals in a transistor, there exists three possible of operations, where one of the three terminals is common to both Input and Output. These modes are **Common Emitter(CE) Configuration, Common Base(CB) Configuration**, and **Common Collector(CC) Configuration**. Out of these three, the Common Emitter Configuration is the most widely used one. We define two parameters α and β to characterize the transistor as follows:

$$\alpha = \frac{I_C}{I_E} \quad \beta = \frac{I_C}{I_B}$$

In this experiment, we shall study the Input and Output Characteristics of an n-p-n BJT in the Common Emitter Configuration.

1.2 Common Emitter (CE) Configuration

Due to its high current,voltage and power gain, the Common Emitter Configuration is the most widely used configuration. The input is applied between the base and emitter, while the output is taken between the collector and emitter. The emitter is common to both input and output. The input characteristics of a CE configuration is the plot of the input current I_B versus the input voltage V_{BE}, and the output characteristics is the plot of the output current I_C versus the output voltage V_{CE}.

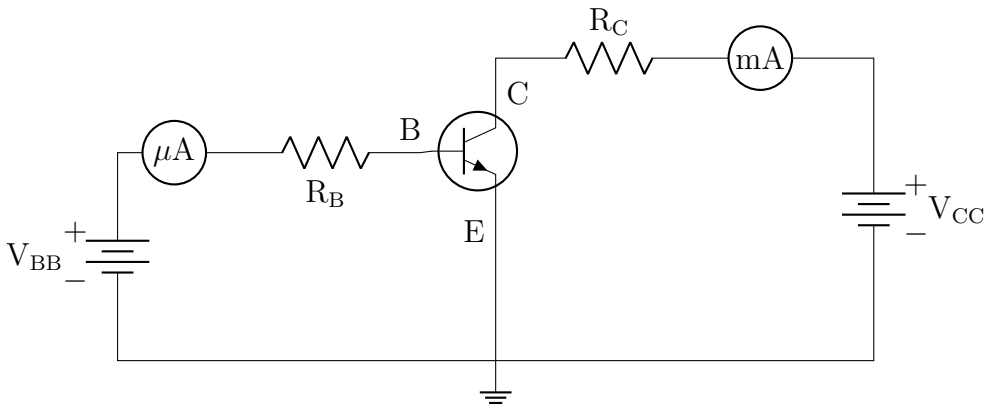

Figure 1: Circuit diagram of a n-p-n BJT in CE Configuration

2 CE Input Characteristics

We shall study the input characteristics of the CE configuration of the transistor. We vary the input voltage and measure the variation of I_B v/s V_{BE}, keeping the collector-emitter voltage (V_{CE}) constant. We have carried out the experiment for $I_B = 2V$ and $I_B = 3V$. The data obtained has been tabulated below.

V_{BB}(V)	V_{BE}(V)	$I_B(\mu A)$	V_{CC}(V)	V_{CE}(V)	I_C(mA)
0.01	0.01	0	1.98	2	0
0.1	0.11	0	1.98	2	0
0.2	0.21	0	1.98	2	0
0.3	0.31	0	1.98	2	0
0.4	0.41	0	1.98	2	0
0.5	0.51	0	1.98	2	0.05
0.6	0.6	7	2.11	2	1.1
0.7	0.65	45	2.03	2	7.2
0.8	0.664	110	2.07	2	17.7
0.9	0.68	195	2.19	2	32.8
1.0	0.692	257	2.25	2	43.8
1.1	0.701	279	2.49	2	48.1
1.2	0.701	443	2.88	2	79.5

Table 1: Table for Input characteristics for $V_{BE} = 2V$

V_{BB}(V)	V_{BE}(V)	$I_B(\mu A)$	V_{CC}(V)	V_{CE}(V)	I_C(mA)
0.01	0.01	0	2.99	3	0
0.1	0.11	0	2.99	3	0
0.2	0.21	0	2.99	3	0
0.3	0.31	0	2.99	3	0
0.4	0.4	0	2.99	3	0
0.5	0.5	0	2.99	3	0
0.6	0.6	8	2.99	3	1.3
0.7	0.641	51	3.09	3	8.1

V_{BB}(V)	V_{BE}(V)	$I_B(\mu A)$	V_{CC}(V)	V_{CE}(V)	I_C(mA)
0.8	0.663	127	3.13	3	21
0.9	0.672	197	3.21	3	33.5
1.0	0.674	286	3.22	3	50.8
1.1	0.68	369	3.21	3	68.5
1.2	0.696	455	3.21	3	86.1

Table 2: Table for Input characteristics for $V_{BE} = 3V$

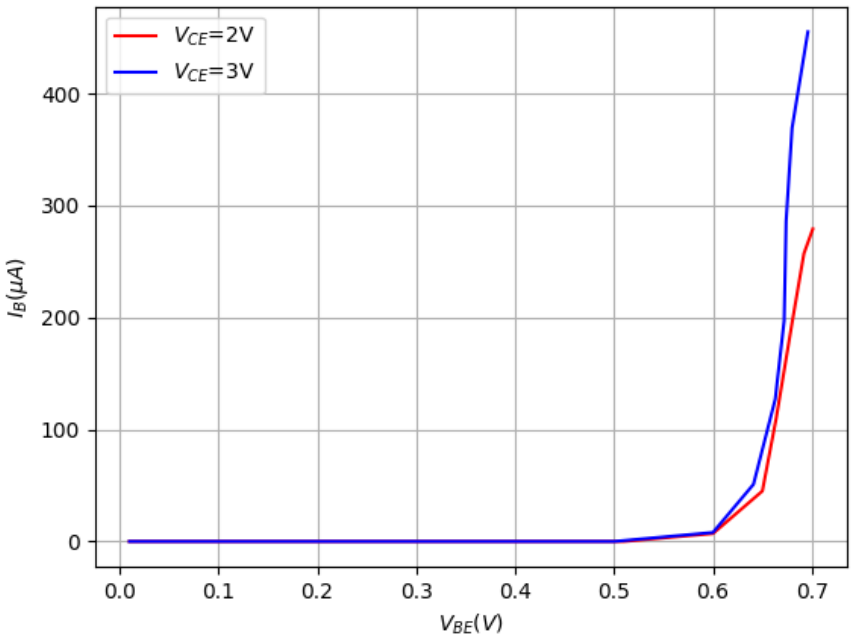

Figure 2: Input characteristics of BJT for $V_{CE} = 2V$ and $V_{CE} = 3V$

Note that, although, it was expected that the curve for $V_{CE} = 2V$ to be towards left of the curve corresponding to $V_{CE} = 3V$,it is not so. One possible reason may be that the values of V_{CE} were pretty close to each other and hence the curves overlapped.

3 CE Output Characteristics

We shall now study the output characteristics of a n-p-n transistor in CE configuration. We shall study the variation of I_C v/s V_{CE}., keeping the base current I_B constant. We have carried out the experiment for $I_B = 10\mu A$ and $I_B = 20\mu A$ and $I_B = 30\mu A$. The data obtained has been tabulated below.

$I_B(\mu A)$	V_{CC}(V)	V_{CE}(mV)	$I_C(\mu A)$
10	0.2	43	195
10	0.3	43	254
10	0.4	64	357

$I_B(\mu A)$	$V_{CC}(V)$	$V_{CE}(mV)$	$I_C(\mu A)$
10	0.5	66	458
10	0.6	69	524
10	0.7	82	623
10	0.8	106	670
10	0.9	105	731
10	1.0	115	834
10	1.2	115	1018
10	1.5	189	1231
10	1.8	249	1430
10	2.0	359	1472
10	2.5	861	1473
10	3.0	1400	1470

Table 3: Table for Output characteristics for $I_B = 10\mu A$

$I_B(\mu A)$	$V_{CC}(V)$	$V_{CE}(mV)$	$I_C(\mu A)$
20	0.1	15.6	73
20	0.2	23.8	184
20	0.3	30.9	229
20	0.4	39.7	336
20	0.5	44.2	422
20	0.6	49.0	493
20	0.7	47.9	582
20	0.8	53.4	720
20	0.9	64.4	810
20	1.0	65.9	840
20	1.2	70.1	1018
20	1.4	79.2	1250
20	1.6	83.5	1386
20	1.8	89.0	1555
20	2.0	102.8	1713
20	2.5	130.6	2390
20	3.0	290.0	2750
20	3.5	390.0	3110
20	4.0	957.0	3160
20	5.0	1855.0	3250

Table 4: Table for Output characteristics for $I_B = 20\mu A$

$I_B(\mu A)$	$V_{CC}(V)$	$V_{CE}(mV)$	$I_C(\mu A)$
30	0.1	15.6	105
30	0.2	20.9	183
30	0.3	30.0	267
30	0.4	35.5	385
30	0.5	43.2	472

$I_B(\mu A)$	$V_{CC}(V)$	$V_{CE}(mV)$	$I_C(\mu A)$
30	0.6	45.5	563
30	0.7	53.8	638
30	0.8	55.8	710
30	0.9	61.6	785
30	1.0	62.2	856
30	1.2	70.2	1026
30	1.5	81.9	1324
30	1.8	93.6	1503
30	2.0	98.6	1700
30	2.2	117.0	2130
30	2.4	127.9	2270
30	2.6	140.7	2520
30	2.8	153.7	2700
30	3.0	160.4	2830
30	3.5	190.1	3390
30	4.0	230.0	3890
30	5.0	510.0	4540
30	6.0	1500.0	4580

Table 5: Table for Output characteristics for $I_B = 30\mu A$

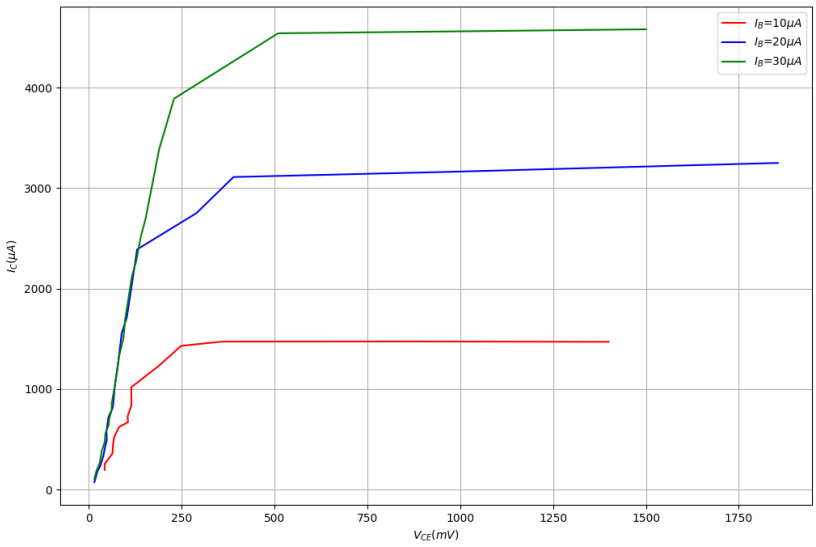

Figure 3: Output characteristics of BJT for $I_B = 10\mu A$, $20\mu A$ and $30\mu A$

As expected, we observe from the graph that the output current I_C increases with the increase in the collector-emitter voltage V_{CE} for a constant base current I_B.

4 Conclusion

In this experiment, we attempted to the study the input and output characteristics of a Bipolar Junction Transistor in CE mode. While verifying the input characteristics, we observed that , contrary to our expectations, the curve for $V_{CE} = 2V$ was not towards the left of the curve for $V_{CE} = 3V$. This may be due to some error in the experiment.
On the other hand, in output characteristics, we observed that the output current I_C increases with the increase in the collector-emitter voltage V_{CE} before reaching saturation for a fixed value of base current I_B.

Using, table 3, 4 and 5, we can calculate the value of β for the transistor using the formula $\beta = \frac{I_C}{I_B}$. The value of β for the transistor is found to be 147.0, 162.5 and 152.7 for $I_B = 10\mu$A, 20μA and 30μA respectively.

5 Sources of Error

- The multimeter used for measuring of voltage and current may not be accurate.
- The connections may be loose or improper and transistor may not be in a proper condition. Also, the resistance of the wires may not be negligible.
- During a lot of readings, the values fluctuated a lot and which could poetentially lead to errors.