Sub-Group: A-7
Experiment 2: Study of Transistor Characteristics

Sayan Karmakar
22MS163

1 Aim

To study input and output charecterestics of a common-emmiter configuration of a npn BJT transistor.

2 Theory

Transistors are a very common and useful device in modern days. It is used as oscillators, amplifiers, gates and many other instruments. One of the common type transistors are bipolar junction transistor. This bipolar junction transistor is a sandwich of semiconducting materials. In an npn transistor there is a p-type semiconductor in between two n-type semiconductors. And in a pnp transistor there is a n-type semiconductor in between two p-type semiconductors. In this experiment, we are going to study the input and output characteristics of npn semiconductors.

In an npn semiconductor, out of the two n-type semiconductors one of them is very heavily doped and the other is larger in size and lightly doped compared to the other n-type. The heavily doped semiconductor is called Emitter. The comparatively lightly doped semiconductor is called Collector. The p-type semiconductor is generally very thin and very lightly doped. There are two pn junctions present in the transistor - base emitter junction and the collector base junction. Normally when used as an amplifier, the base emitter junction is kept in forward bias and the collector base junction is kept in reverse bias. So, due to the forward bias of the base emitter junction electrons go from emitter to the base, this electrons get affected by the reverse bias of the collector base junction and as the base is very thin and lightly doped most of the electrons go to the collector. So the emitter current is almost equal to the collector current. It is actually slightly more than the emitter current. We define a parameter α as

$$\mathrm{I_C} = \alpha \mathrm{I_E}.$$

α is slightly smaller than 1. We can write also $\mathrm{I_E} = \mathrm{I_C} + \mathrm{I_B}$. So if we define β as $\mathrm{I_C} = \beta \mathrm{I_B}$ then we can write

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

Now as the transistor is a three terminal device one of the terminals has to be considered as a common terminal while studying input or output characteristics. Depending on the terminal we can define three types of configuration - common emitter configuration, common base, common collector configuration. This experiment concerns only common emitter configuration.

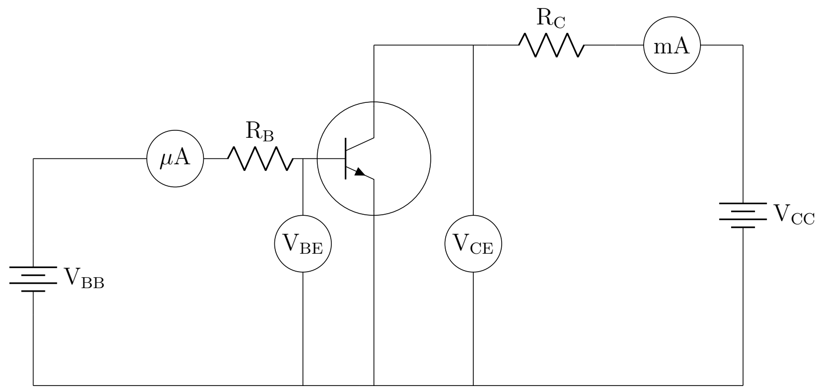

Figure 1: Circuit Diagram

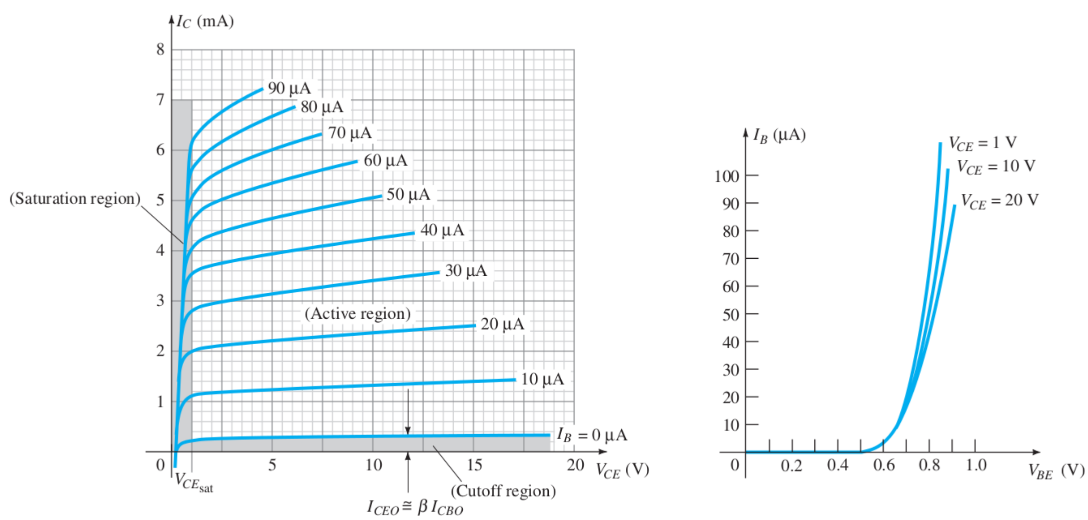

Figure 2: Output and Input Characterestics of an ideal Transistor

For studying three terminal devices two sets of characteristics are necessary. Input characteristics is the study of dependency of input current (I_B) and base emitter voltage (V_{BE}) while keeping the collector current (I_C) fixed and the output characteristics is the study of collector current(I_C) and base collector voltage (V_{CE}) fixed while keeping the base current (I_B) fixed.

3 Data and Calculation

3.1 Input Characteristics

Firstly we made the circuit with $R_B = 1k\Omega$ and $R_C = 1\Omega$. In the following two tables we noted down the values of necessary quantities for studying input characteristics. For the first table we set the output voltage V_{CE} to be 2 V and in the next table we set the output voltage V_{CE} to be 3 V. For these voltages, we took the measurements for the input voltage V_{BE} and the input current I_B.

Table 1: Table for $V_{CE} = 2$ V

V_{BB} (V)	V_{BE}(V)	I_B(mA)	I_C(mA)	V_{CC}(V)	V_{CE}(V)
0	0.036	0	0	2	2
0.1	0.178	0	0	2	2
0.2	0.251	0	0	2	2
0.3	0.378	0	0	2	2
0.4	0.449	0	0	2	2
0.5	0.589	3	5	2	2
0.6	0.655	28	4.7	2	2
0.7	0.698	91	16.3	2	2
0.8	0.729	182	32.6	2	2
0.9	0.738	226	41.1	2	2
1	0.762	338	61.6	2	2
1.1	0.778	414	76.1	2	2
1.2	0.792	499	92.3	2	2

Table 2: Table for $V_{CE} = 3$ V

V_{BB} (V)	V_{BE}(V)	I_B(mA)	I_C(mA)	V_{CC}(V)	V_{CE}(V)
0	0.038	0	0	3	3
0.1	0.19	0	0	3	3
0.2	0.259	0	0	3	3
0.3	0.355	1	0	3	3
0.4	0.466	1	0	3	3
0.5	0.607	9	1.6	3	3
0.6	0.642	27	5	3	3
0.7	0.684	88	16.2	3	3

V_{BB} (V)	V_{BE}(V)	I_B(mA)	I_C(mA)	V_{CC}(V)	V_{CE}(V)
0.8	0.71	158	29.4	3	3
0.9	0.729	242	45.9	3	3
1	0.749	334	64.8	3	3
1.1	0.767	449	87.2	3	3
1.2	0.765	468	93	3	3

From the above graphs we plotted the following graph. The graph shows the input characteristics of the transistor that is the dependency of input voltage and input current for different output voltage. We expected that for output voltage 3 V the graph to lie on the right of the graph for output voltage 2 V. But from our graph we see that the graph corresponding to 3 V lies to the right of 2 V. This is opposite of what we expected.

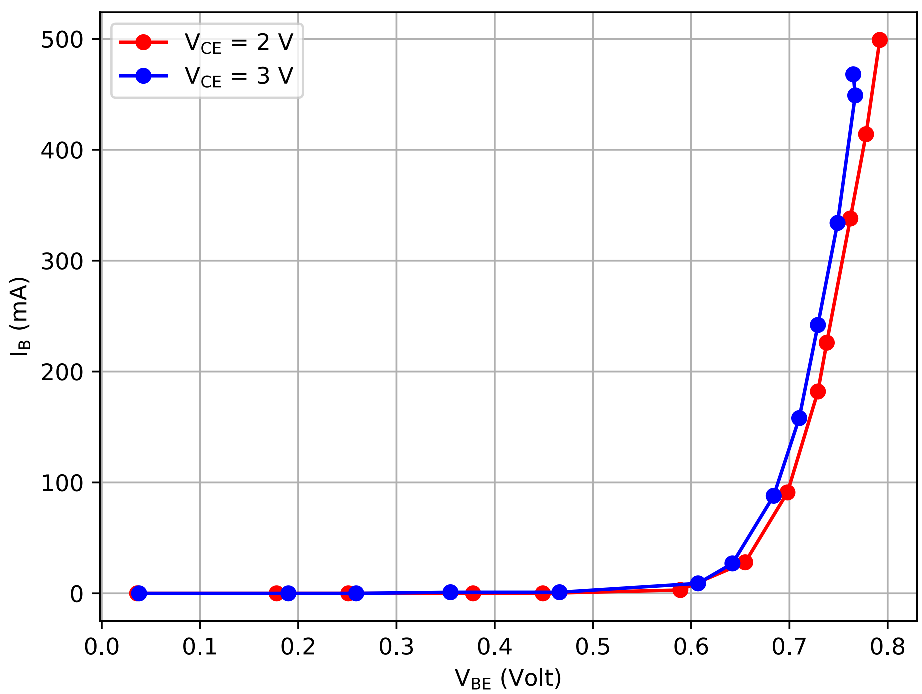

Figure 3: Input Characteristics of the Transistor

3.2 Output Characteristics

The following tables contain data for studying the output characteristics. Here we tabulated the collector current I_C and output voltage V_{CE} for different values of input current I_B. We took data corresponding to three different values of I_B 25 μA, 30

μA and 40 μA respectively. For the following data collection we set the resistance $R_B = 220\Omega$ and the resistance $R_C = 1k\Omega$.

Table 3: Table for $I_B = 25\ \mu$A

V_{CC} (V)	V_{CE} (V)	I_C (μA)	I_B (μA)	V_{BB} (V)
0	0.004	10	25	0.5
0.5	0.04	506	25	0.5
1	0.057	922	25	0.5
1.5	0.069	1308	25	0.5
2	0.081	1784	25	0.5
2.5	0.099	2390	25	0.5
3	0.107	2880	25	0.5
3.5	0.127	3350	25	0.5
4	0.15	3780	25	0.5
4.2	0.172	3960	25	0.6
4.4	0.2	4150	25	0.6
4.6	0.228	4340	25	0.6
4.8	0.42	4350	25	0.6
4.7	0.349	4380	25	0.6
5.2	0.696	4460	25	0.6
5.5	0.978	4460	25	0.6

Table 4: Table for $I_B = 30\ \mu$A

V_{CC} (V)	V_{CE} (V)	I_C (μA)	I_B (μA)	V_{BB} (V)
0	0.007	37	30	0.5
0.1	0.02	166	30	0.5
0.2	0.022	214	30	0.5
0.3	0.028	331	30	0.5
0.4	0.03	362	30	0.5
0.5	0.037	513	30	0.5
0.6	0.04	610	30	0.5
0.7	0.043	671	30	0.5
0.8	0.045	737	30	0.5
0.9	0.049	829	30	0.5
1	0.05	884	30	0.5
1.1	0.054	1016	30	0.5
1.2	0.058	1118	30	0.5
1.3	0.062	1294	30	0.5
1.4	0.063	1296	30	0.5

V_{CC} (V)	V_{CE} (V)	I_C (μA)	I_B (μA)	V_{BB} (V)
1.5	0.064	1335	30	0.5
1.8	0.072	1599	30	0.5
2	0.073	1770	30	0.5
3	0.098	2950	30	0.5
3.5	0.11	3420	30	0.6
4	0.122	3850	30	0.6
4.5	0.139	4350	30	0.6
4.6	0.14	4430	30	0.6
4.8	0.156	4630	30	0.6
4.9	0.166	4690	30	0.6
5	0.198	4820	30	0.6
5.5	0.27	5070	30	0.6
5.6	0.42	5110	30	0.6
5.8	0.58	5130	30	0.6
6	0.89	5090	30	0.6

Table 5: Table for $I_B = 40\ \mu$A

V_{CC} (V)	V_{CE} (V)	I_C (μA)	I_B (μA)	V_{BB} (V)
0	0.004	12	40	0.5
1	0.04	866	40	0.5
2	0.061	1724	40	0.5
3	0.08	2890	40	0.5
4	0.094	3740	40	0.5
5	0.109	4730	40	0.6
6	0.134	5730	40	0.6
6.5	0.147	6180	40	0.6
7	0.167	6700	40	0.6
7.2	0.188	6850	40	0.6
7.4	0.388	6890	40	0.6
7.6	0.533	6900	40	0.6
8	0.921	7000	40	0.6

In the following figure, we plotted the dependencies of I_C and V_{CE}. Here we see that initially the graphs are increasing, and then it reaches saturation after some point. We know for common emitter configuration, after initial increasing phase when the output characteristics graph saturates it does not saturate to a constant value. It gradually increases very slowly (as can be seen in figure 2). This is not clear from the figure. From the figure we see that the saturation value remains almost same as I_B value increases. So may be the increasing rate is so small that it is getting suppressed by the fluctuation in V_{CE} values.

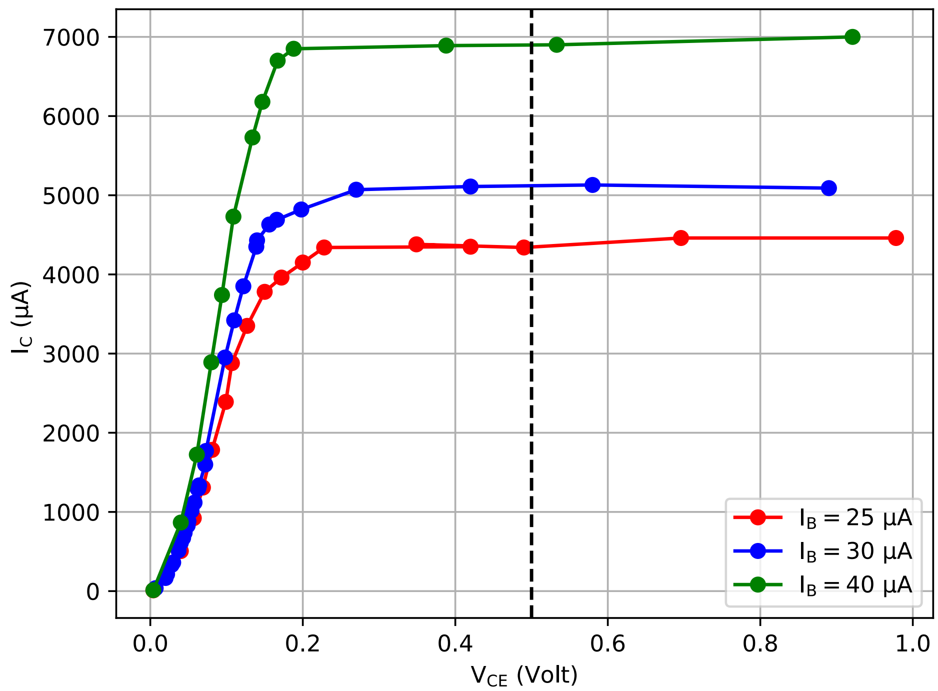

Figure 4: Output Characteristics of the Transistor

In this curve, we plotted another vertical line at $V_{CE} = 0.5$ V. We see that it intersects with the graph for $I_B = 25\ \mu$A at about $I_C = 4340\ \mu A$, the graph for $I_B = 30\ \mu$A at about $I_C = 5110\ \mu A$, the graph for $I_B = 40\ \mu$A at about $I_C = 6890\ \mu A$. We know $I_C = \beta I_B$. So, we get

I_B	I_C	β
25	4340	173.6
30	5110	170.33
40	6890	172.25

So, average value of β at 0.5 V is 172.06.

3.3 Sources of Error

The following can be the sources of error observed in this experiment:

- Different multimeters have different internal resistances. This affect the measurement of current and voltage. This can induce error while data collection.

- As I_B was taken in the microampere region, due to stability of the sources the value of I_B was fluctuating a lot. It was not constant as it was supposed to be. This sensitivity may have introduced error in experiment.

4 Discussion and Conclusion

In this experiment, we studied the input and output characteristics of a npn transistor in common emitter configuration. In input characteristics, the curve follows same pattern as the ideal input characteristics curve, but it was observed that the as the output voltages were increased the rate at which the curve increased, also increased, this is opposite of what we expected. One way to tackle it would be to check that this error is due to random fluctuation or not. An example of that is choosing two output voltage that are very different. But then the transistor gets limited by the maximum current that can pass through it. If the current through transistor reaches maximum limit then it gets destroyed from overheating.

In the output characteristics, we noticed initially sudden increase in the output current which is expected. But when it gets saturated it should increase linearly with output voltage slowly. It was not observed in our experiment. This could be due to error in measurements. From the plot we also saw that the parameter β has value about 170.06, which is expected as for transistors β is in the range 100 to 200.