Experiment 02: Study of Transistor Characteristics

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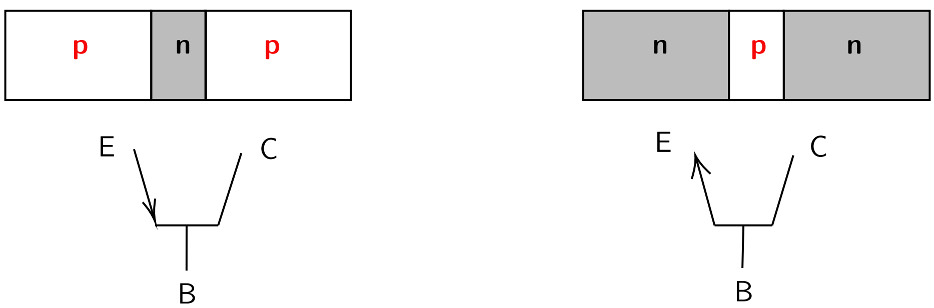
1 Aim

To obtain the input and output characteristics of a transistor in CE configuration.

2 Theory

2.1 Bipolar Junction Transistor (BJT)

The Bipolar Junction Transistor (BJT) is essentially a combination of two PN junction diodes. According to the order in which the diodes are connected, we have npn and pnp transistors. The emitter region is much smaller than the collector and much more strongly doped while the base is very thing and very lightly doped. A large collector is needed since it should have more surface area for dissipating the power generated there.



It is a three terminal device with the terminals named as emitter, base and collector but to act as an amplifier, we need four terminals. Hence, we make one terminal common. The most commonly studied configuration is the common emitter configuration where the emmiter is common to both input and output.

A BJT works in three modes: Active, Saturation and Cutoff Modes, according to which junction is forward or reverse biased.

2.2 Common Emitter Configuration of BJT

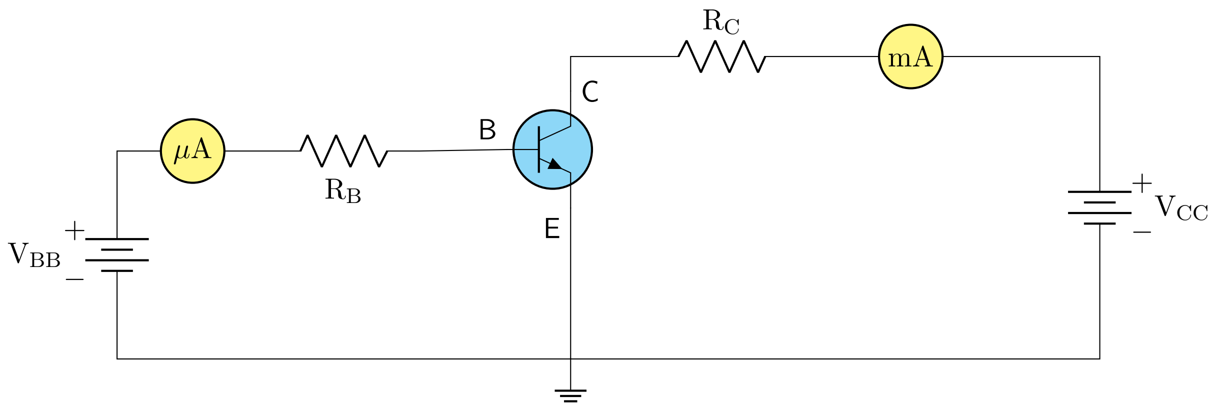


Figure 1: Circuit diagram of a common emitter configuration of a NPN transistor

The above figure shows the common emitter configuration of the transistor. From the figure, we can see:

$$\mathrm{I_E} = \mathrm{I_B} + \mathrm{I_C}$$

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. We define two parameters β and α for the transistor as follows:

$$\beta = \frac{\mathrm{I_C}}{\mathrm{I_B}}$$

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

From this, we get a relation between α and β as:

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

Generally β is much greater than 1 while α is very close to but less than 1 .

In the CE configuration the input current and voltage are $\mathrm{I_B}$ and $\mathrm{V_{BE}}$, while the output current and voltage are $\mathrm{I_C}$ and $\mathrm{V_{CE}}$. Thus, for the input characteristics, we plot $\mathrm{I_B}$ vs $\mathrm{V_{BE}}$ and for the output characteristics, we plot $\mathrm{I_C}$ vs $\mathrm{V_{CE}}$.

3 Data and Calculations

3.1 Input Characteristics

The following tables show the data obtained for the input characteristics of the transistor in CE configuration. The data was obtained by varying the base voltage V_{BB} from 0 to 1.2 V in steps of 0.1 V. The collector voltage V_{CC} was kept constant at almost $2\mathrm{V}$. The base current I_B and collector current I_C were measured for each value of V_{BB}. The base-emitter voltage V_{BE} and collector-emitter voltage V_{CE} were also measured for each value of V_{BB}. The data was obtained for two different values of V_{CC} as 2 V and 3 V.

V_{BB} (V)	V_{BE} (V)	I_B (µA)	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

V_{BB} (V)	V_{BE} (V)	I_B (µA)	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
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

We plotted the I_B vs. V_{BE} graph for the two values of V_{CC} and obtained the following graphs.

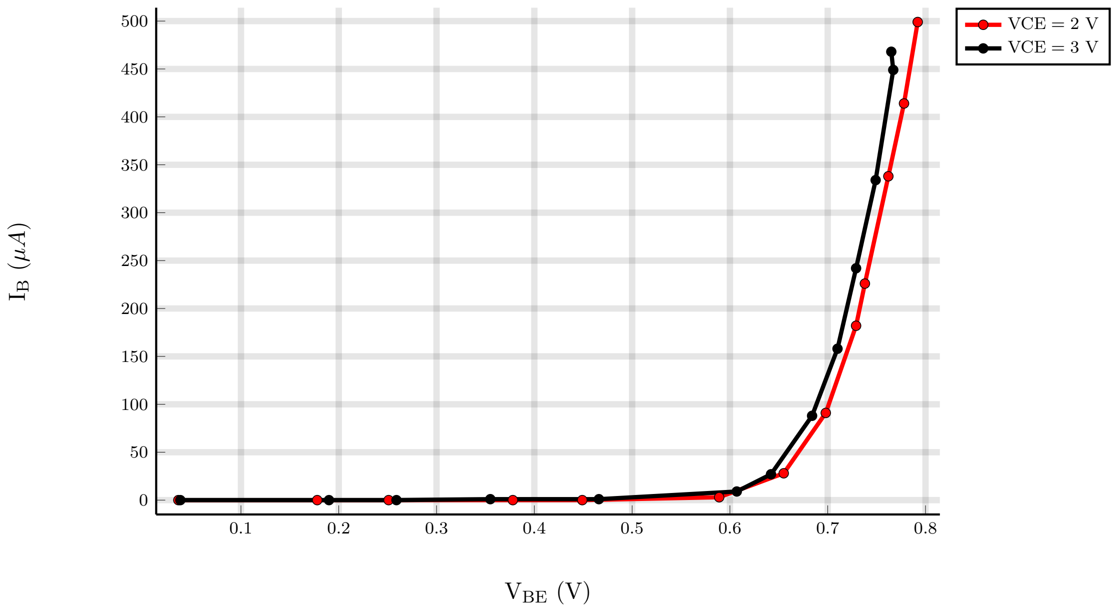


Figure 2: Input characteristics of a BJT transistor

We note that the input characteristics for the two values of V_{CC} are opposite of what is expected. The curve for $V_{CE} = 3V$ should be below that of $V_{CE} = 2V$. This can be due to the values being very close to each other, so these could not be clearly distinguished and hence the error.

3.2 Output Characteristics

The following tables show the data obtained for the output characteristics of the transistor in CE configuration. The data was obtained by varying the base voltage V_{CC}. The base voltage V_{BB} was kept constant at almost $0.5V$. The collector current I_C and collector-emitter voltage V_{CE} were measured. The data was obtained for three different values of I_B = 25 μA, 30 μA and 40 μA.

V_{BB} (V)	I_B (μA)	V_{CC} (V)	V_{CE} (V)	I_C (μA)
0.5	25	0.0	0.004	10
0.5	25	0.5	0.04	506
0.5	25	1.0	0.057	922
0.5	25	1.5	0.069	1308
0.5	25	2.0	0.081	1784
0.5	25	2.5	0.099	2390
0.5	25	3.0	0.107	2880
0.5	25	3.5	0.127	3350
0.5	25	4.0	0.15	3780
0.6	25	4.2	0.172	3960
0.6	25	4.4	0.2	4150
0.6	25	4.6	0.228	4340
0.6	25	4.8	0.42	4350
0.6	25	4.7	0.349	4380
0.6	25	5.0	0.49	4340
0.6	25	5.2	0.696	4460
0.6	25	5.5	0.978	4460

Table 1: Data obtained for output characteristics at I_B = 25 μA

V_{CC} (V)	V_{BB} (V)	I_B (μA)	V_{CE} (V)	I_C (μA)
0.0	0.5	30	0.007	37
0.1	0.5	30	0.02	166
0.2	0.5	30	0.022	214
0.3	0.5	30	0.028	331
0.4	0.5	30	0.03	362
0.5	0.5	30	0.037	513
0.6	0.5	30	0.04	610
0.7	0.5	30	0.043	671
0.8	0.5	30	0.045	737
0.9	0.5	30	0.049	829
1.0	0.5	30	0.05	884
1.1	0.5	30	0.054	1016
1.2	0.5	30	0.058	1118
1.3	0.5	30	0.062	1294
1.4	0.5	30	0.063	1296
1.5	0.5	30	0.064	1335
1.8	0.5	30	0.072	1599
2.0	0.5	30	0.073	1770
3.0	0.5	30	0.098	2950
3.5	0.6	30	0.11	3420
4.0	0.6	30	0.122	3850
4.5	0.6	30	0.139	4350
4.6	0.6	30	0.14	4430
4.8	0.6	30	0.156	4630
4.9	0.6	30	0.166	4690
5.0	0.6	30	0.198	4820
5.5	0.6	30	0.27	5070
5.6	0.6	30	0.42	5110
5.8	0.6	30	0.58	5130
6.0	0.6	30	0.89	5090

Table 2: Data obtained for output characteristics at $I_B = 30$ μA

V_{BB} (V)	I_B (μA)	V_{CC} (V)	V_{CE} (V)	I_C (μA)
0.5	40	0.0	0.004	12
0.5	40	1.0	0.04	866
0.5	40	2.0	0.061	1724
0.5	40	3.0	0.08	2890
0.5	40	4.0	0.094	3740
0.6	40	5.0	0.109	4730
0.6	40	6.0	0.134	5730
0.6	40	6.5	0.147	6180
0.6	40	7.0	0.167	6700
0.6	40	7.2	0.188	6850
0.6	40	7.4	0.388	6890
0.6	40	7.6	0.533	6900
0.6	40	8.0	0.921	7000

Table 3: Data obtained for output characteristics at $I_B = 40$ μA

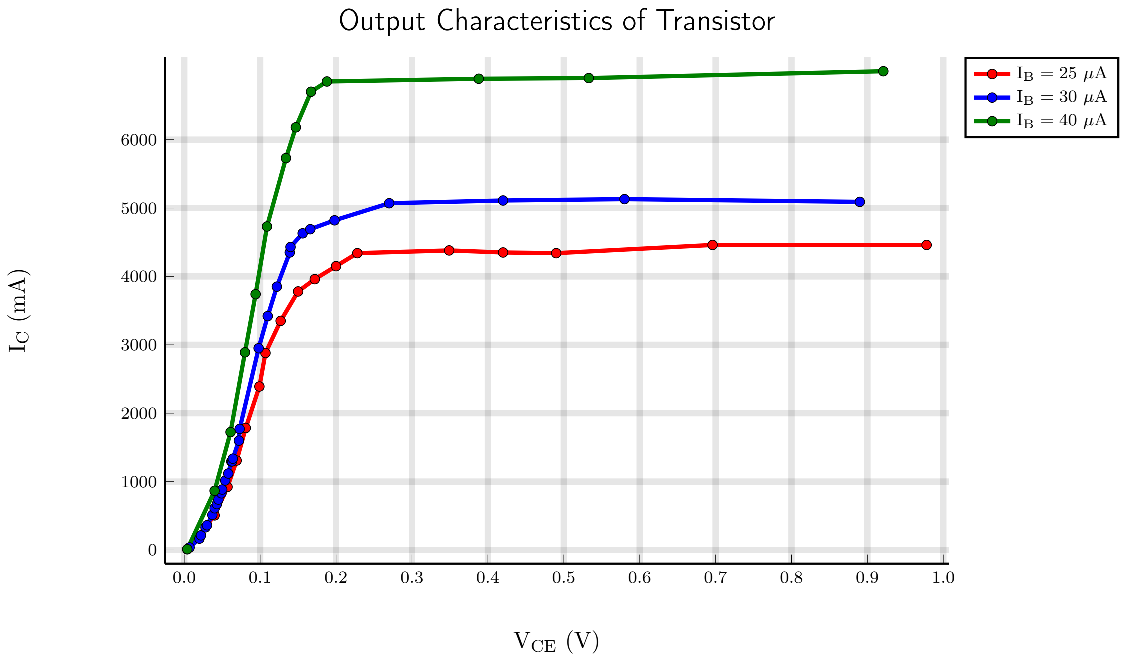


Figure 3: Output characteristics of BJT

We see that the collector current I_C initially increases steeply with the increase in V_{CE} but reaches saturation and remains almost constant after a certain value of the voltage.

4 Sources of Error

5 Discussion and Conclusion