ELEC-313
Lab 8: Bipolar Junction Transistor Characterization

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Date Performed:	November 13, 2013
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1 Objective

The objective is to plot the output characteristic of a common-emitter transistor circuit, and use it to determine the current gain and output conductance.

2 Equipment

Transistor: 2N7000	Power supply: HP E3631A
Function generator: HP 33120	Multimeter: HP 34401A
Oscilloscope: Agilent 54622D	Capacitors: 0.1 µF

Resistors: 100 Ω, 300 Ω, 470 Ω, 1 kΩ (x2) 33 kΩ, 100 kΩ (x2)

3 Schematics

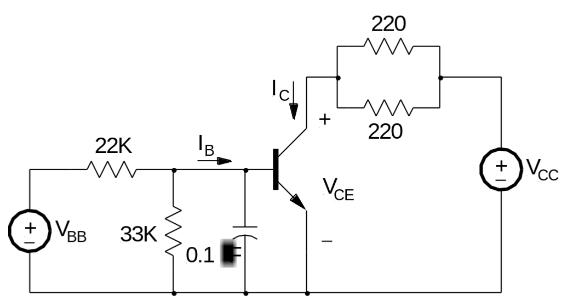

Figure 1: Common-emitter transistor circuit

4 Procedure

The following steps were observed to plot the output characteristic of a common emitter transistor circuit:

1. Construct the circuit of Figure 1. Use the +6 V power supply for V_{BB} and the +25 V supply for V_{CC}. Be sure to keep the connection distance between the capacitor and the transistor short. Use the HP multimeter to measure the base current (I_B) on the source side of the capacitor and Fluke multimeters to measure the collector voltage and current (V_{CE} and I_C).

2. Adjust V_{BB} so that base current (I_B) is 20 µA.

3. Adjust V_{CC} from 0.5 – 1.5 V in 0.25 V steps, then from 2 – 20 V in 2 V steps.

4. At each step measure the collector current, I_C, and the collector-to-emitter voltage, V_{CE}. If I_B has drifted, readjust V_{BB} before recording the values of I_C and V_{CE}.

5. Adjust V_{BB} for a base current of 50 µA, 80 µA, and 100 µA. Repeat steps 3 and 4 at each I_B value.

5 Results

V_{CC} (V)	I_C (mA)	V_{CE} (V)	β
0.50	0.232	0.454	11.60
0.75	0.233	0.705	11.65
1.00	0.234	0.954	11.70
1.25	0.237	1.204	11.85
1.50	0.237	1.454	11.85
2	0.242	1.954	12.10
4	0.25	3.95	12.30
6	0.25	5.95	12.60
8	0.26	7.95	12.75
10	0.26	9.96	12.85
12	0.26	11.95	13.10
14	0.27	13.94	13.30
16	0.27	15.95	13.40
18	0.27	17.95	13.50
20	0.27	19.95	13.70

Table 1: $I_B = 20\,\mu A$

V_{CC} (V)	I_C (mA)	V_{CE} (V)	β
0.50	2.73	0.178	54.60
0.75	4.34	0.236	86.80
1.00	4.96	0.41	99.20
1.25	4.95	0.662	99.00
1.50	4.97	0.91	99.40
2	4.98	1.41	99.60
4	5.15	3.39	103.00
6	5.25	5.38	105.00
8	5.39	7.36	107.80
10	5.58	9.34	111.60
12	5.77	11.31	115.40
14	5.97	13.28	119.40
16	6.21	15.26	124.20
18	6.45	17.23	129.00
20	6.69	19.20	133.80

Table 2: $I_B = 50\,\mu A$

V_{CC} (V)	I_C (mA)	V_{CE} (V)	β
0.50	3.08	0.135	38.50
0.75	4.95	0.163	61.88
1.00	6.8	0.191	85.00
1.25	8.58	0.229	107.25
1.50	9.1	0.421	113.75
2	9.4	0.881	117.50
4	10.79	2.71	134.88
6	11.03	4.68	137.88
8	11.45	6.63	143.13
10	11.99	8.56	149.88
12	12.72	10.47	159.00
14	13.41	12.39	167.63
16	14.20	14.29	177.50
18	15.05	16.20	188.13
20	15.85	18.10	198.13

Table 3: $I_B = 80\,\mu A$

V_{CC} (V)	I_C (mA)	V_{CE} (V)	β
0.50	3.21	0.12	32.10
0.75	5.11	0.143	51.10
1.00	7.02	0.164	70.20
1.25	8.93	0.186	89.30
1.5	10.79	0.214	107.90
2	10.33	0.77	103.30
4	11.33	2.67	113.30
6	13.95	4.34	139.50
8	15.63	6.14	156.30
10	16.60	8.02	166.00
12	17.98	9.95	179.80
14	19.20	11.70	192.00
16	20.70	13.69	207.00
18	22.40	15.53	224.00
20	23.80	17.37	238.00

Table 4: $I_B = 100\,\mu A$

I_B (µA)	β_{avg}
20	12.55
50	105.85
80	132.00
100	137.99

Table 5: Average values of β per I_B

I_B (µA)	I_C (mA)	β
20	0.25	12.26
50	5.20	104.00
80	11.10	138.75
100	14.67	146.68

Table 6: $V_{CE} = 5\,V$

I_B (µA)	I_C (mA)	β
20	0.26	12.97
50	5.64	112.84
80	12.47	155.88
100	18.00	180.00

Table 7: $V_{CE} = 10\,V$

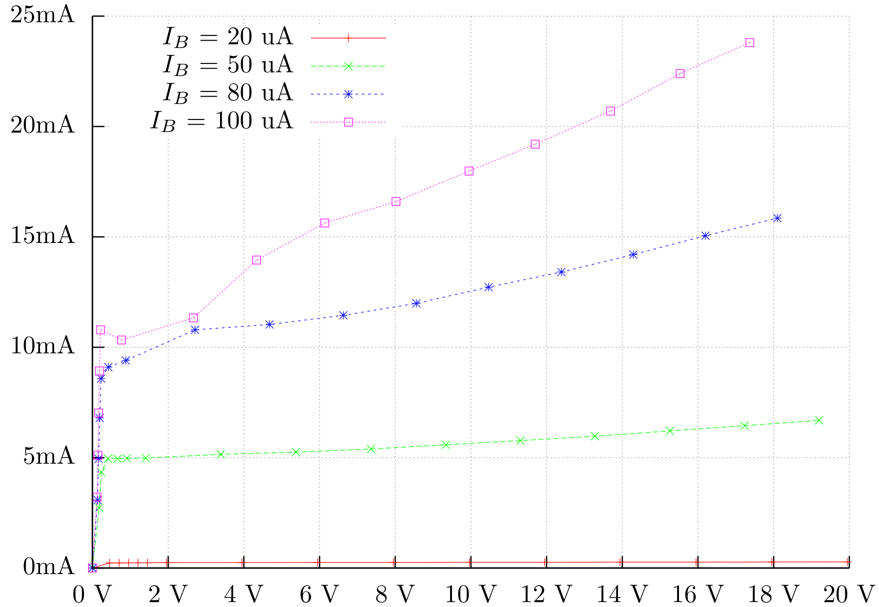

Figure 2: V_{CE} vs. I_C

I_B (µA)	I_C (mA)	β
20	0.27	13.32
50	6.18	123.61
80	14.50	181.25
100	22.93	229.30

Table 8: $V_{CE} = 15\,\text{V}$

V_{CE} (V)	β_{avg}
5	100.42
10	115.42
15	136.87

Table 9: Average values of β per V_{CE}

I_B (µA)	h_{oe}	r_o (kΩ)
20	1.700E-6	58.82
50	9.950E-5	10.10
80	3.669E-4	2.726
100	7.412E-4	1.349

Table 10: h_{oe} vs. r_o

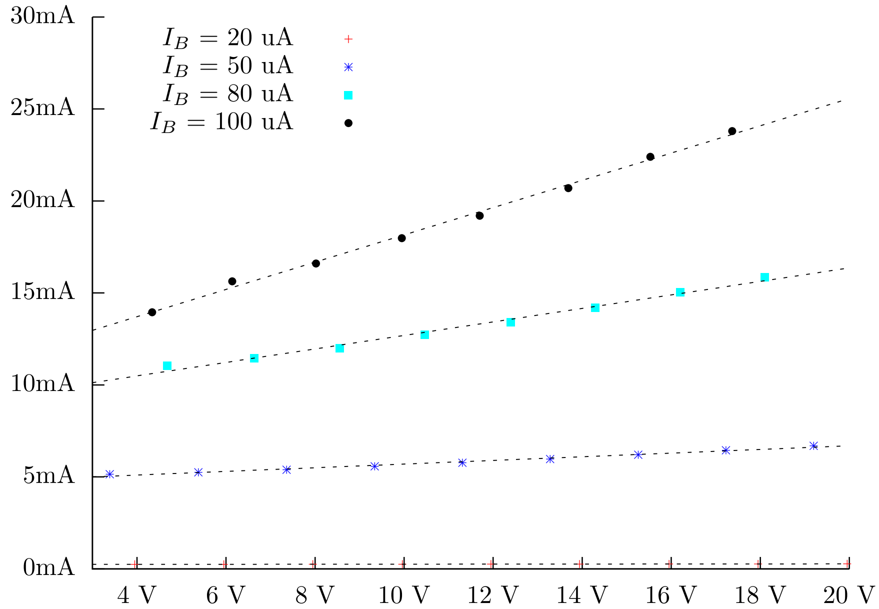

Figure 3: V_{CE} vs. I_C, $V_{CE} > 0$

6 Conclusion

As shown in Figure 2, the family of curves associated with the four I_B currents loosely follow the typical plots of Bipolar Junction Transistors (BJTs). The mode of operation of the transistor transitions to the forward-active mode when V_{CE} is greater than approximately 0.2 V. Also, as I_B increases, the slope of the I_C to V_{CE} increases.

Tables 1, 2, 3, and 4 show that as I_B increases, the ratio of I_C to I_B (current gain, β) also increases. This change in β seems to "taper off" as I_B increases such that if one were to plot mean β vs. I_B, it would resemble logarithmic growth.

Figure 3 shows the slope of each of the family of curves for V_{CE} values greater than 3 V. The output conductance (h_{oe}) was conducted with the slope of each of the four the trend line equations and Equation 2. As I_B increased, h_{oe} increased.

7 Equations

$$\beta = \frac{I_C}{I_B} \tag{1}$$

$$h_{oe} \approx \frac{1}{r_o} = \frac{\Delta I_C}{\Delta V_{CE}} \tag{2}$$