ELEC-313
Lab 8: Bipolar Junction Transistor Characterization

November 20, 2013

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

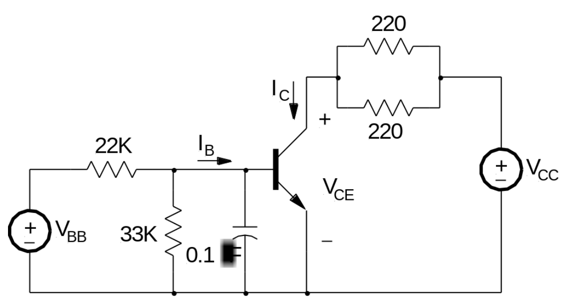

Figure 1: Common-emitter transistor circuit

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: $I_B = 50\,\mu\text{A}$

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: $I_B = 80\,\mu\text{A}$

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

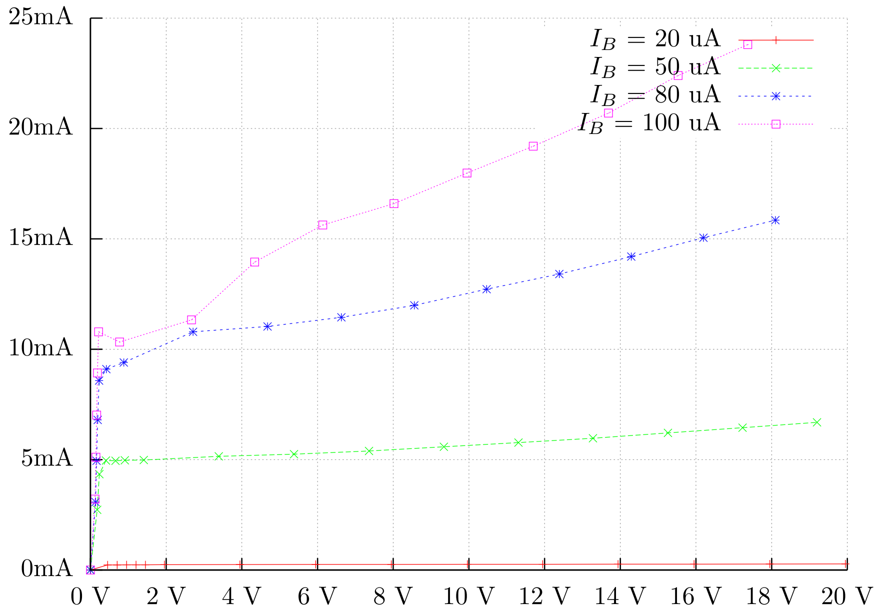

Figure 2: V_{CE} vs. I_C

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: $V_{CE} = 15\,\mathrm{V}$

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

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 2b, 2a1, 2a2, and 2a3 show that as I_B increases, the ratio of I_C to I_B (β [also known as the current gain]) increases. But, this change in β seems to taper off as the I_B current (Table 2b) increases such that if one were to plot mean β vs. I_B, it would resemble logarithmic growth. For each of the values of I_B; as I_C and V_{CE} increase, β increases as well (as shown in Table 2a). If one were to plot mean β vs. V_{CE} , I suspect it would resemble exponential growth though there is minimal evidence to prove this, considering only three data points are provided in Tables 2a1, 2a2, and 2a3.

Figure ?? 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 the Equation ??. As I_B increased, h_{oe} increased. Therefore, as I_B increased, current gain β because the output resistance r_o decreased.

7 Equations

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

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