Cover Page

EE 316-08
Electric Circuits & Electronics Design Lab

Lab 7 & 8: Characteristics of BJT and Amplification Behavior

By: Nolan Anderson

Lab Date: 03/22/2021

Lab Due: 03/25/2021

1. Introduction:

This lab introduces and expands the ideas and theory behind bipolar junction transistors (BJTs). We will first cover the theory behind BJTs in section 2 and then simulate them using Multisim in section 3. Afterwards, I will discuss the results and wrap the lab up with a short conclusion in section 6. Lastly, I will perform some simple hand calculations and they can be seen in the appendix.

2. Theoretical Analysis:
2.1 Construction (NPN)

A typical BJT has a collector, base, and emitter region. NPN bases' have P=type materials (ones with more holes) and emitters that are N-type that have more electrons. The emitter region of an NPN contains a higher density of electrons than the collector which allows current to flow from the collector to the emitter. A NPN can be seen in figure 1.
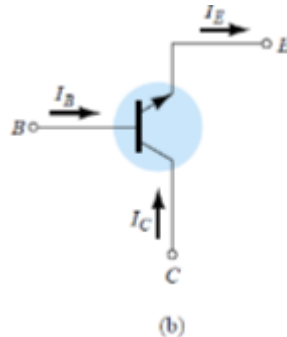

(b)

Figure 1: Basic NPN

2.2 Construction (PNP)

A typical BJT has a collector, base, and emitter region. PNP bases' have N-type materials and emitters that are P-type. The emitter region of an PNP contains a higher density of holes than the collector which allows current to flow from the emitter to the collector. A PNP can be seen in figure 2.
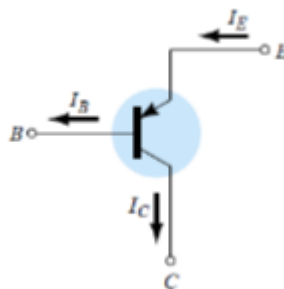

Figure 2: Basic PNP

2.3 Operation

Current flows through the base region if the transistor is in "forward" or "reverse-active mode". Forward means the DC current is flowing in the direction of the base-collector junction and in the opposite direction of the base-emitter junction. Reverse is just the opposite. Saturation mode is when max current flow is achieved, and no current flowing is cut-off mode. Figure 3 shows this visually.
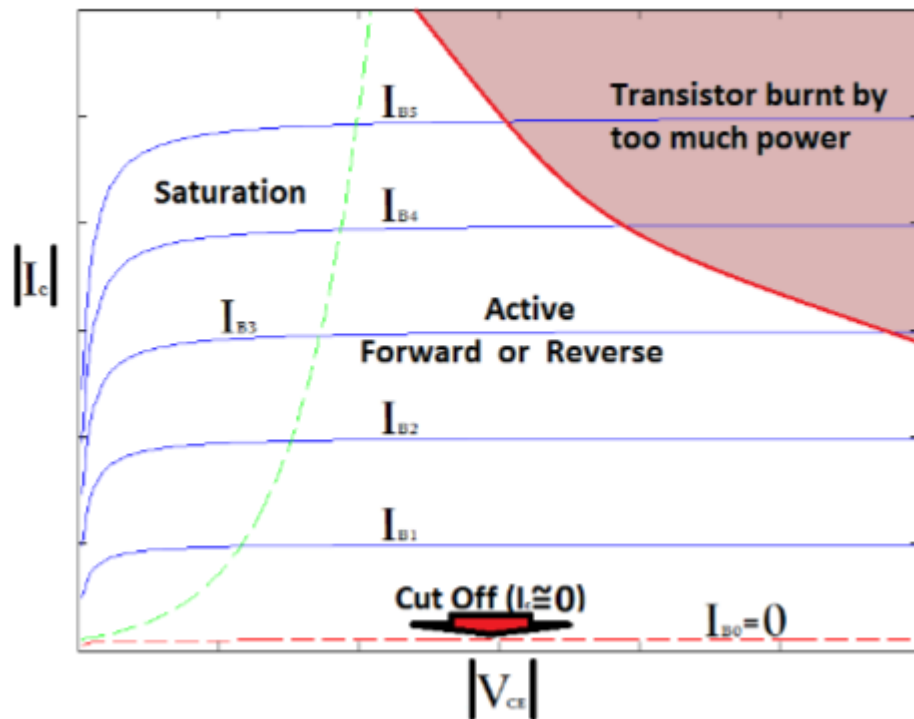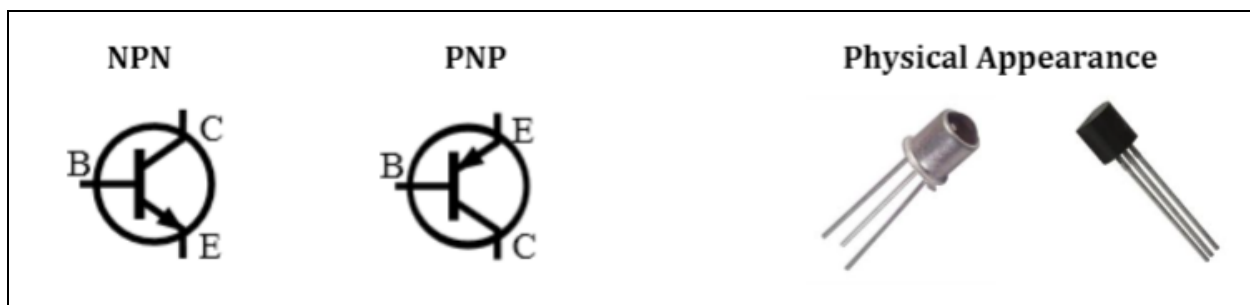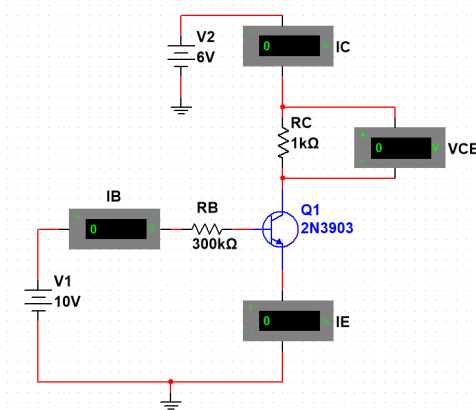

Figure 3: Output characteristics of a BJT

2.4 Appearance

3. Simulations:

3.1 Common collector circuit (Lab 7)

Circuit 1 shows the common collector circuit in multisim. I will then show the relationship between VCE and IC in table 1 and graph 1. Section 5 will comment on the results.
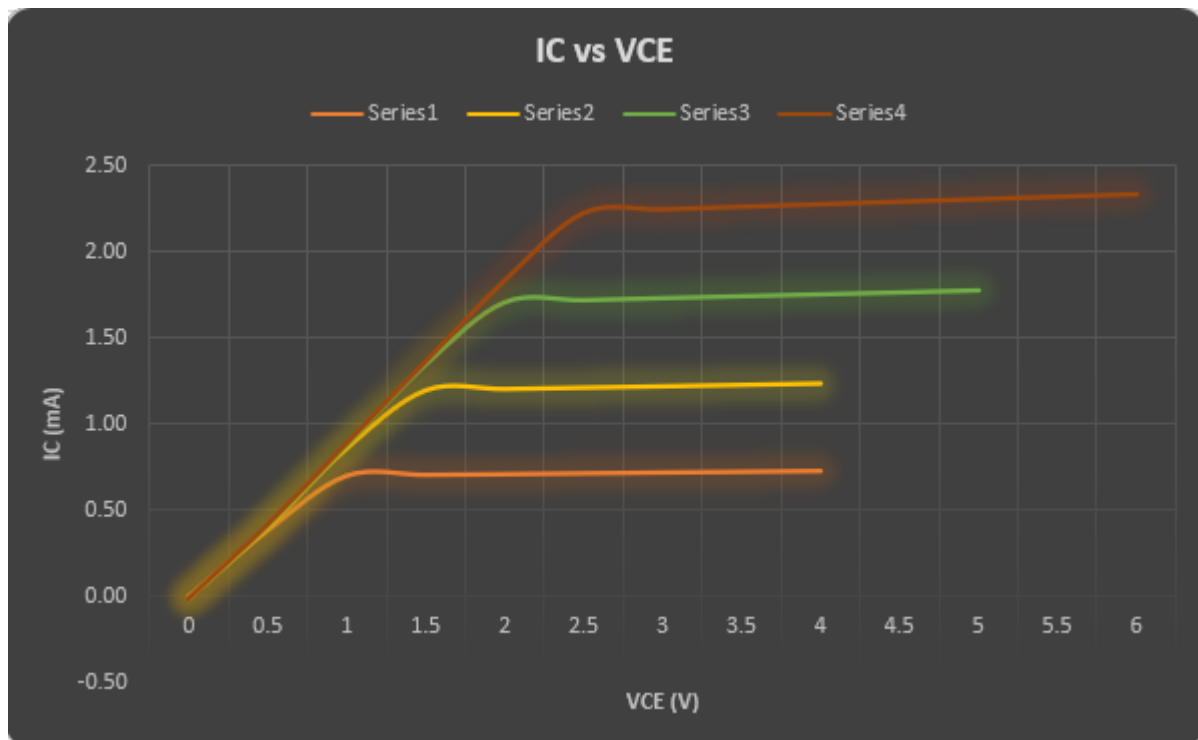

Circuit 1: Common collector circuit in multisim.

V1 (V)	V2 (V)	IB (mA)	IC (mA)	IE (mA)	VCE (V)	β
4	0	0.012	-0.01	0.00	-0.01	-0.661
4	0.5	0.011	0.379	0.39	0.379	34.455
4	1	0.011	0.701	0.712	0.701	63.727
4	1.5	0.011	0.707	0.718	0.706	64.273
4	2	0.011	0.711	0.722	0.711	64.636
4	2.5	0.011	0.716	0.727	0.716	65.091
4	3	0.011	0.721	0.732	0.721	65.545
4	3.5	0.011	0.725	0.736	0.725	65.909
4	4	0.011	0.73	0.741	0.73	66.364
6	0	0.018	-0.011	0.01	-0.011	-0.611
6	0.5	0.018	0.399	0.417	0.399	22.167
6	1	0.018	0.857	0.874	0.856	47.611
6	1.5	0.017	1.195	1.212	1.194	70.294
6	2	0.017	1.203	1.221	1.203	70.765
6	2.5	0.017	1.211	1.229	1.211	71.235
6	3	0.017	1.219	1.237	1.219	71.706
6	3.5	0.017	1.227	1.245	1.227	72.176
6	4	0.017	1.235	1.253	1.235	72.647
8	0	0.025	-0.012	0.012	-0.012	-0.480
8	0.5	0.025	0.41	0.434	0.41	16.400
8	1	0.025	0.878	0.903	0.878	35.120

|						
8	1.5	0.024	1.345	1.369	1.345	56.042
8	2	0.024	1.709	1.733	1.708	71.208
8	2.5	0.024	1.722	1.746	1.722	71.750
8	3	0.024	1.734	1.758	1.734	72.250
8	3.5	0.024	1.745	1.769	1.745	72.708
8	4	0.024	1.756	1.781	1.756	73.167
8	4.5	0.024	1.767	1.792	1.768	73.625
8	5	0.024	1.779	1.804	1.779	74.125
10	0	0.032	-0.014	0.018	-0.014	-0.438
10	0.5	0.032	0.417	0.448	0.417	13.031
10	1	0.032	0.89	0.921	0.89	27.813
10	1.5	0.032	1.367	1.398	1.367	42.719
10	2	0.032	1.838	1.867	1.838	57.438
10	2.5	0.032	2.232	2.263	2.231	69.750
10	3	0.032	2.254	2.285	2.254	70.438
10	3.5	0.032	2.269	2.3	2.269	70.906
10	4	0.032	2.284	2.315	2.283	71.375
10	4.5	0.032	2.299	2.329	2.298	71.844
10	5	0.032	2.313	2.344	2.313	72.281
10	5.5	0.032	2.328	2.359	2.328	72.750
10	6	0.032	2.342	2.374	2.342	73.188

Table 1 Multisim calculations

Graph 1 IC vs VCE

3.2 Common collector circuit for lab 8

Circuit 2 shows the common collector circuit in multisim. I will then show the relationship between gain and frequency in table 2 and graph 2. Section 5 will comment on the results.
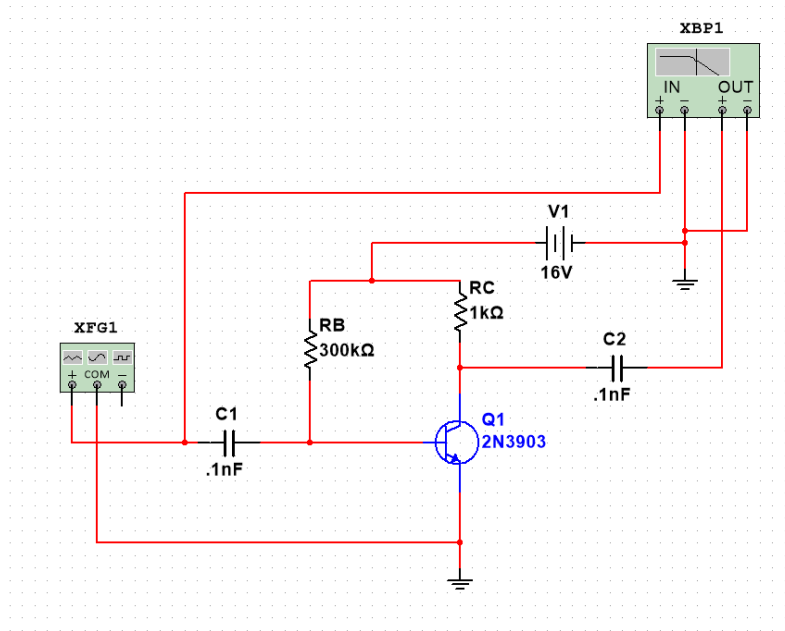

Circuit 2 Common Collector Circuit in Multisim

Frequency (Hz)	Vin (mV)	Vout (mV)	Gain (dB)
10	500	0.281	-65.000
30	500	0.846	-55.435
60	500	1.694	-49.401
100	500	2.801	-45.032
200	500	5.610	-39.000
500	500	13.947	-31.090
1000	500	28.117	-25.000
2000	500	57.302	-18.816
5000	500	139.018	-11.118
10000	500	281.171	-5.000
15000	500	428.519	-1.340
20000	500	571.110	1.155
50000	500	1416.022	9.042
75000	500	2120.655	12.550
100000	500	2811.707	15.000
150000	500	4173.208	18.430
200000	500	5465.375	20.773

500000	500	11430.626	27.182
750000	500	14325.837	29.143
1000000	500	16000.001	30.103
1500000	500	17640.870	30.951
2000000	500	18340.873	31.289

Table 2 VIN, VOUT, Gain according to frequency
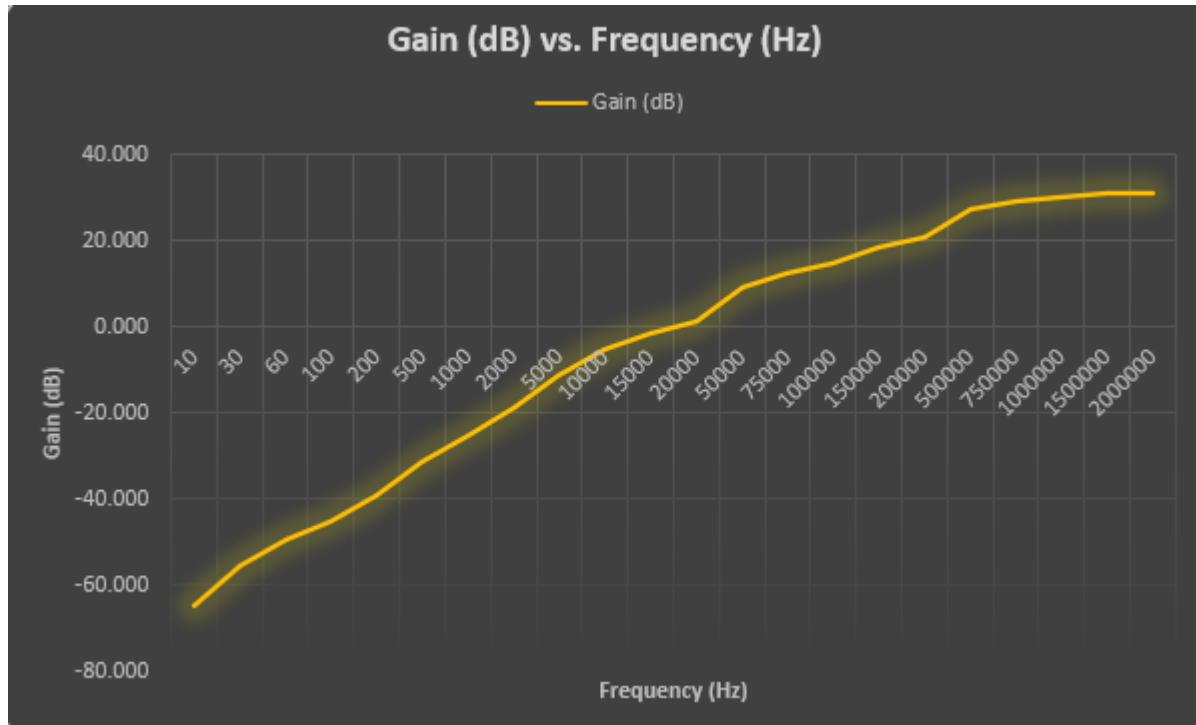
Graph 2 Gain vs Frequency

4. ~~Experimental:~~

We were not instructed to provide experimental results for this lab, see the following screenshot.

Summary

- Lab 7 and 8 Report is due Thursday 25th March 2021 by midnight.
- Prelab 9 and 10 is due Tuesday 30th March 2021 by midnight.

- Fill out Table 7.1 and 8.1 with results from...
  - Simulation
  - ~~Experimental results~~

5. Results and Discussion:

When analyzing the results from section 3.1, we can see that the results line closely with what we would expect. As we increase our voltages for each series, it takes longer to get to a higher value, which is what we would expect from a BJT. The B value also correlates to this trend. As we get higher in the V1 values, V2 has less immediate effect on B, but it does level out to a higher value. Overall, results are as expected.

For section 3.2, we achieve similar results. We do not necessarily get clipping in multisim, but I would guess it would be around 750Khz as we would begin to outgrow the capacitors at that point. If we wanted to reduce clipping, we would need to introduce larger capacitors into the circuit. If we introduce larger capacitors, our gain will shrink. When looking at the results for lab 8, they are not accurate at all, however. Doing the hand calculations seen in the appendix show very different values from that calculated in multisim. See appendix for details.

Figure 5.1 shows what vout should actually be instead of that calculated in the multisim circuit:

Frequency (Hz)	Vin (mV)	Vout (mV)	Gain (dB)
10	500	0.00014059	-65
30	500	0.00042285	-55.435
60	500	0.00084701	-49.401
100	500	0.00140068	-45.032

200	500	0.00280505	-39
500	500	0.00697333	-31.09
1000	500	0.01405853	-25
2000	500	0.02865101	-18.816
5000	500	0.06950883	-11.118
10000	500	0.14058533	-5
15000	500	0.21425946	-1.34
20000	500	0.28555516	1.155
50000	500	0.70801101	9.042
75000	500	1.06032746	12.55
100000	500	1.40585331	15
150000	500	2.08660387	18.43
200000	500	2.73268774	20.773
500000	500	5.71531286	27.182
750000	500	7.16291848	29.143
1000000	500	8.0000004	30.103
1500000	500	8.8204351	30.951
2000000	500	9.17043651	31.289

Figure 5.1: Expected vout values for lab 8.

6. Conclusion:

Overall, this lab was very helpful in expanding my knowledge of BJTs, NPN and PNP transistors. Being able to see the values changing in real time as I changed the input voltages showed me how these circuits work. Continually, it gave me the insight into how these circuits can be applied to real world problems. Lastly, doing some quick hand calculations shows that multisim is not always right, and the circuit implemented can give bad results. We can see this in the appendix for lab 8.

7. Appendix

Lab 7 quick hand calculation example

$R_B = 300k\Omega$

$R_c = 1k\Omega$

$\beta = I_c / I_B$

V_1 ✓	V_2 ✓	I_B mA	I_c mA	I_E mA	V_{CE} v	β
4v	1v	0.013	0.701	0.714	0.701	53.92
6v	2v	0.02	1.203	1.233	1.203	60.15
10v	3v	0.033	2.254	2.287	2.254	68.30

$V = IR \quad I = \frac{V}{R}$

$I_{B_4} = \frac{4v}{300k\Omega} = \frac{4}{300,000} = .013 \quad mA$

$I_{B_6} = \frac{6}{300k\Omega} = \frac{6}{300,000} = .02 \quad mA$

$I_{B_{10}} = \frac{10}{300k\Omega} = \frac{10}{300,000} = .033 \quad mA$

$V_{CE} = 0.701, 1.203, 2.254$

$I_E = I_c + I_B = .013 + 0.701 = 0.714$

$I_E = I_c + I_B = .02 + 1.203 = 1.223$

$I_E = I_c + I_B = .033 + 2.254 = 2.287$

$\beta_1 = .701/.013 = 53.92$

$\beta_2 = 1.203/.02 = 60.15$

$\beta_3 = 2.254/.0033 = 68.303$

Lab 8 quick hand calculations

Freq (Hz)	Vin (mv)	Vout (mv)	Gain (DB)
60	500	0.847mv	-49.401
1000	500	14.1mv	-25.00
75000	500	58.94mv	12.550

$V_{out_1} = 10^{\frac{-49.401}{20}}(250mv) = 0.847mv$

$V_{out_2} = 10^{\frac{-25.00}{20}}(250mv) = 14.1mv$

$V_{out_3} = 10^{\frac{12.550}{20}}(250mv) = 58.94mv$

Appendix 1: Hand calculations