

Electric Circuits & Electronics Design Lab

EE 316-01

Lab 7&8: BJTs and Amplification Behavior

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Lab Section 316-01

Lab Date: 7/6/22

Lab Due: 7/12/22

Introduction:

The purpose of this lab to examine the characteristics and concepts related to BJTs, which later is used to look at MOSFETs. This report will have 5 main sections. First is the theoretical analysis which is done as the pre-lab and includes Multisim simulations. This time there is no handwritten solutions for the circuit. Then we have the physical circuits which are constructed on breadboards in lab. Afterwards, we compare the results from those 3 sections and conclude with an analysis of the results.

Theoretical Analysis:

To start, we look at how a BJT is constructed and works. It has 3 parts: a collector, base, and emitter regions. The base allows current to flow through the other two parts. There are two types of BJTs: NPN which contains a higher density of electrons in the emitter versus the collector meaning current flows from the collector to emitter and PNP which is the opposite. Current flows through the base but only a small amount comes from the base itself. Maximum current flow is achieved in saturation mode and in cut off mode no current flows. Figure 1 gives the output characteristics of a BJT and Figure 2 shows how current flows through it. referring to Figure 5, figured out which parts of the wave were contributed by nodes C and D, the DC value of V_{OUT} , and the ripple frequency. This work can be seen in Appendix 1.

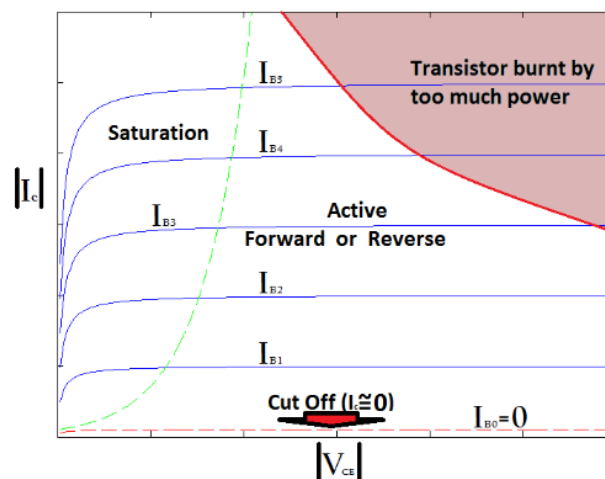


Figure 1. Output Characteristics of BJTs

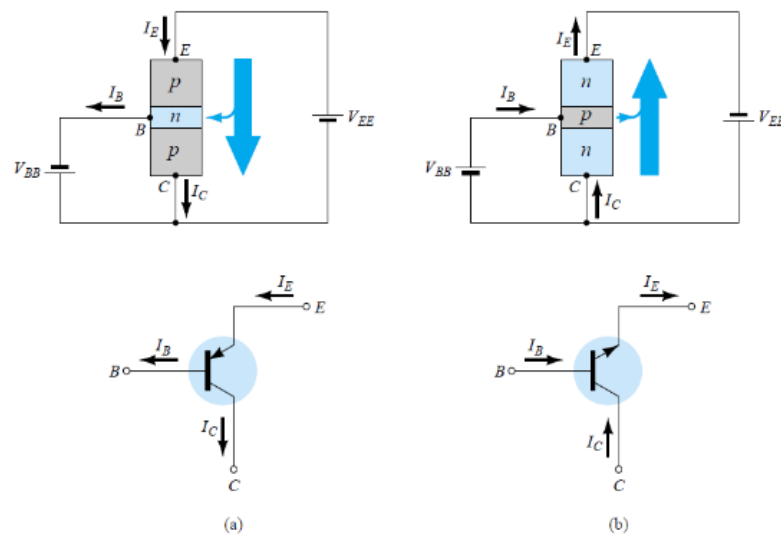


Figure 2. Current Flow through BJTs

Simulations:

For the next phase of the lab, we built the circuits shown in Figures 3 and 4 in Multisim. For Figure 3, we were looking at each current ($I_{b,c,e}$) for the BJT and then plotting an output characteristic graph.

For Figure 4, we were observing the amplification of the BJT and what the output and gain is at a range of frequencies. We then plotted the gain versus frequency and observed at what values the output is clipped at.

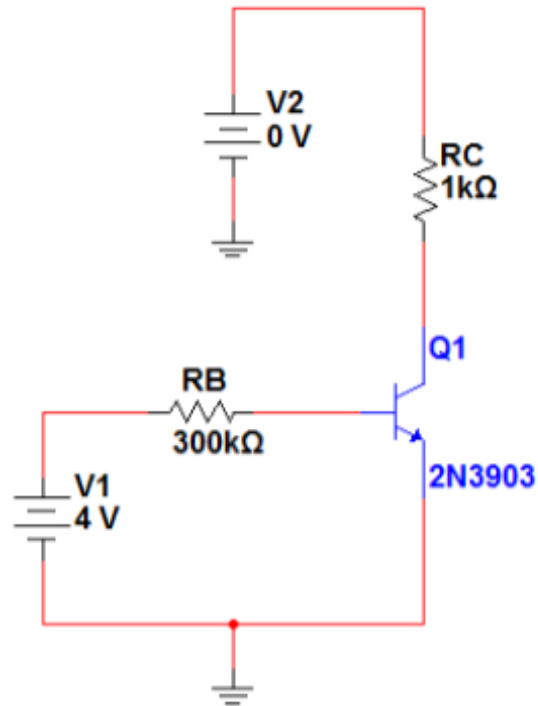


Figure 3: Common Collector Circuit

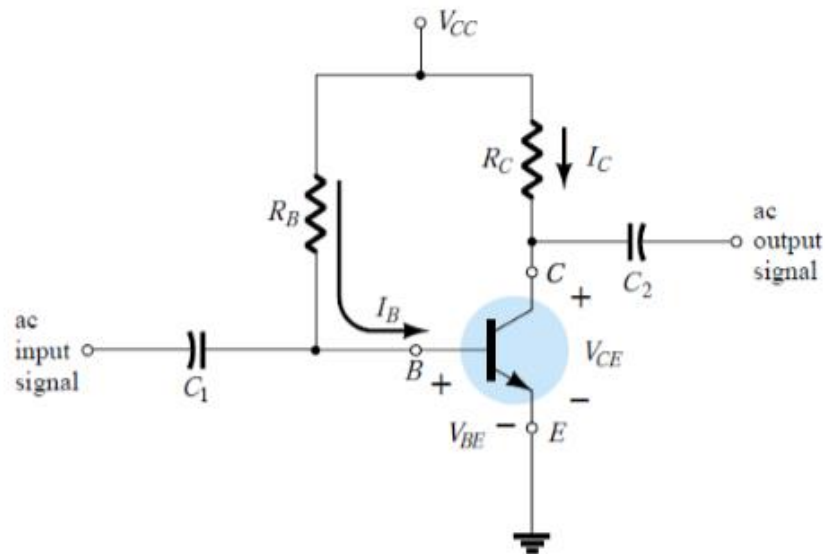


Figure 4. Common Collector Circuit (amplification)

Experimental:

For the last portion of the lab, we did the same things as prior but on a physical board to further validate the output results we obtained. For the first part, we looked at the characteristics output for a BJT. Excel was used for any calculations and plots. As a note, for plotting the V_{CE} from $V_1 = 10$ was used so that the plot looked better. Table 1 gives the values collected for $V_1 = 4, 6, 8,$ and 10 . Figure 5 is the characteristic plot. Unlike the simulation we did not measure the current for I_e . Since the saturation point seems to be around 4 mA and because of how we plotted the graph the highest V_{ce} is around 10 , the Q-point is around 2.3 mA and 5 volts . For each I_b itself this will vary a bit since we didn't continue taking data points to match the highest V_{ce} we got from the overall data.

For the second circuit, Table 2 contains the output voltage and gain observed for each frequency. Figure 6 is the plot of gain versus frequency and Figures 7 and 8 and the waveform outputs for the lowest and highest frequencies observed respectively. Figure 9, is a sample output of the waveform at 100 kHz . In lab, the lowest the peak to peak voltage would go for the sine wave was $520\text{-}540 \text{ mV}$.

Table 1. Data for I_b , I_c , V_{ce} and β

$V_1 = 4$	V_2	I_B	I_C	V_{CE}	β
	0	0.0112	0.0104	0.0167	0.928571
	0.4		0.31	0.15	27.67857
	0.8		0.6	0.18	53.57143
	0.9		0.75	0.19	66.96429
	1.1		0.88	0.21	78.57143
	1.4		1.2	0.25	107.1429
	1.7		1.34	0.33	119.6429
	2.5		1.4	1.1	125
	3		1.4	2.89	125
$V_1 = 6$	0	0.0183	0.146	0.026	7.978142
	0.3		0.25	0.13	13.6612
	0.6		0.44	0.144	24.04372
	0.9		0.82	0.17	44.80874
	1.2		1.02	0.18	55.7377
	1.5		1.36	0.2	74.31694
	1.8		1.58	0.21	86.3388

	2.3		2.04	0.26	111.4754
	2.6		2.25	0.38	122.9508
	2.9		2.26	0.68	123.4973
	3		2.3	0.74	125.6831
$V_1 = 8$	0	0.0249	0.016	0.03	0.64257
	0.5		0.44	0.13	17.67068
	1		0.8	0.15	32.12851
	1.5		1.35	0.18	54.21687
	1.8		1.64	0.19	65.86345
	2.2		2	0.21	80.32129
	2.5		2.32	0.22	93.17269
	2.9		2.67	0.25	107.2289
	3.3		3.1	0.32	124.498
	3.7		3.11	0.62	124.8996
	4.3		3.12	1.18	125.3012
	4.8		3.14	1.75	126.1044
	5.6		3.15	2.4	126.506
	7.7		3.2	4.56	128.5141
$V_1 = 10$	0	0.0317	0.02	0.0327	0.630915
	1		0.87	0.14	27.44479
	2		1.84	0.188	58.04416
	2.3		2.11	0.209	66.56151
	2.9		2.77	0.21	87.3817
	3.2		3	0.23	94.63722
	3.5		3.29	0.24	103.7855
	4.4		3.9	0.53	123.0284
	5.7		4	1.78	126.183
	7.9		4.05	3.9	127.7603
	9.7		4.09	5.63	129.0221
	10.4		4.11	6.3	129.653
	10.7		4.12	6.6	129.9685
	11.8		4.144	7.79	130.7256
	12.5		4.154	8.39	131.041
	13.3		4.15	9.23	130.9148
	14		4.2	9.8	132.4921

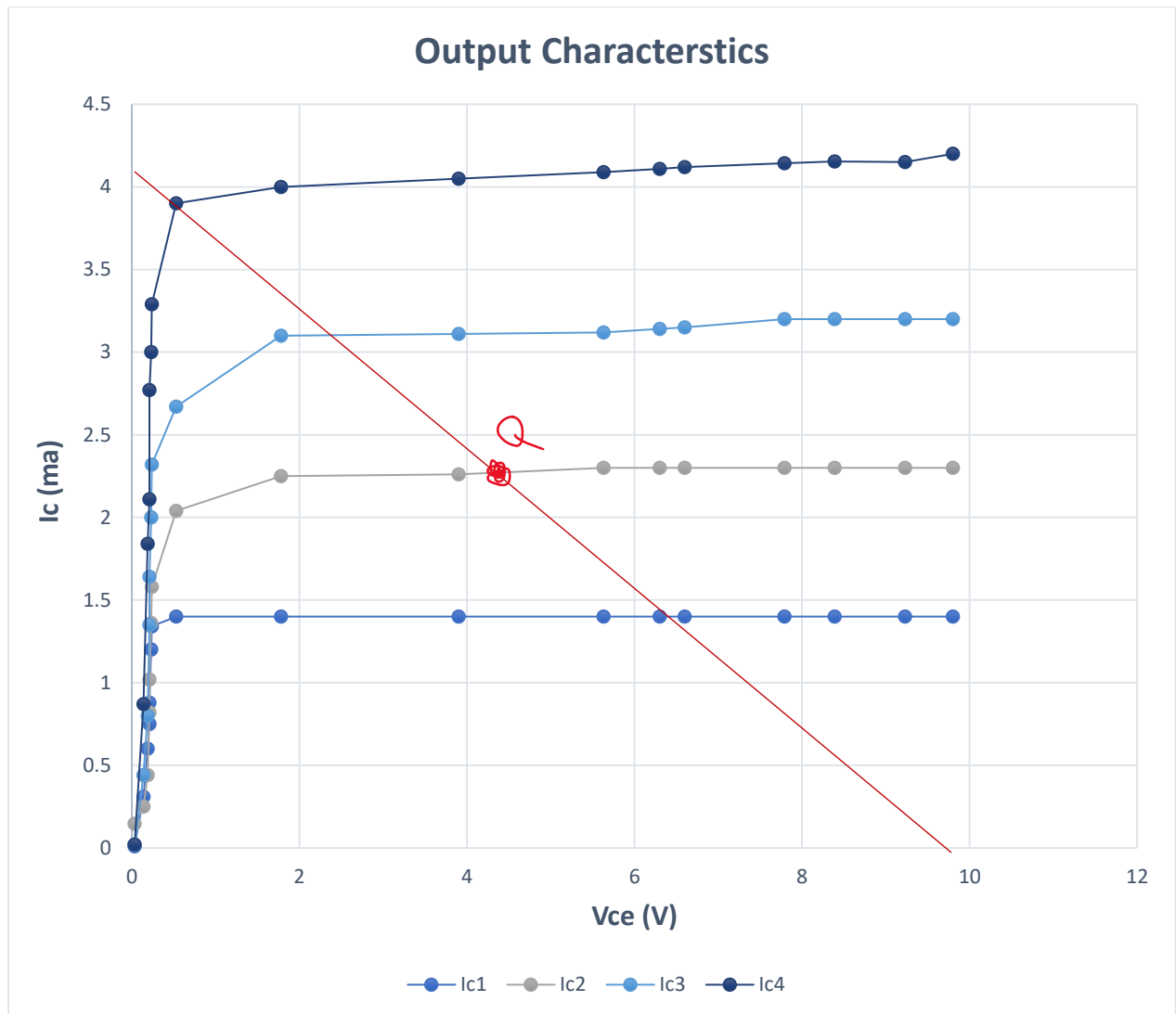


Figure 5. Output Characteristics

Table 2. Amplification observations

F(HZ)	V_{OUT}	Gain(db)
10	0.006	-38.757
30	0.07	-17.4181
60	0.072	-17.1734
100	0.084	-15.8345
200	0.096	-14.6746
1k	0.101	-14.2336
2k	0.113	-13.4239
5k	0.137	-11.7511

10k	0.221	-7.91941
15k	0.39	-2.98596
20k	0.57	0.310243
50k	0.78	3.034638
75k	1.85	10.53618
100k	2.69	13.78779
150k	3.46	16.13365
200k	4.9	19.15605
500k	5.6	20.31589
750k	6.4	21.47572
1M	6.4	21.47572
1.5M	6.4	21.47572
2M	6.4	21.47572

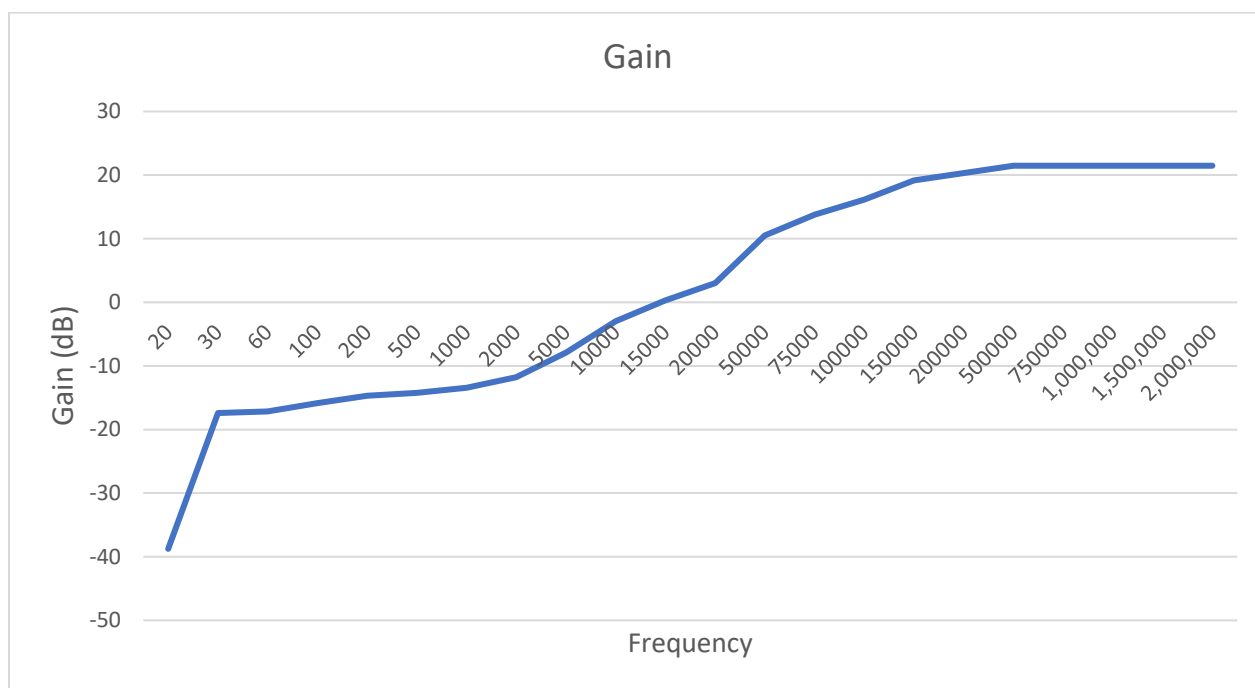


Figure 6. Gain vs Frequency

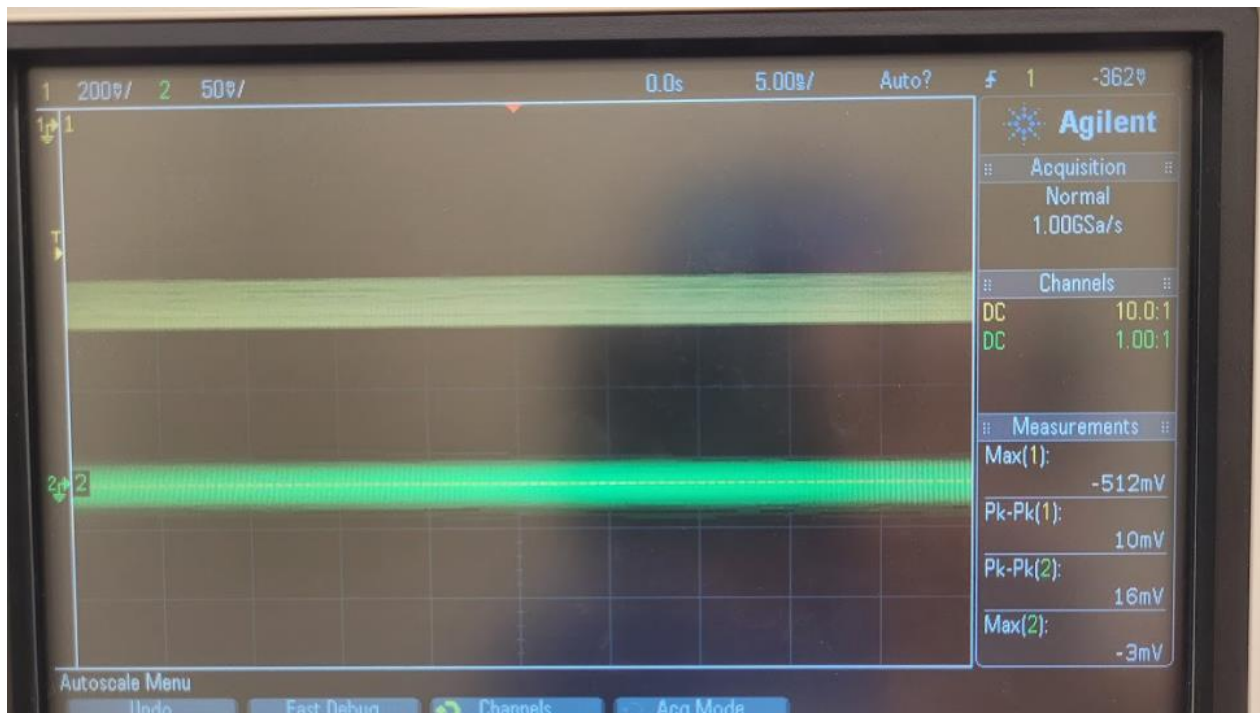


Figure 7. Lowest Frequency Waveform

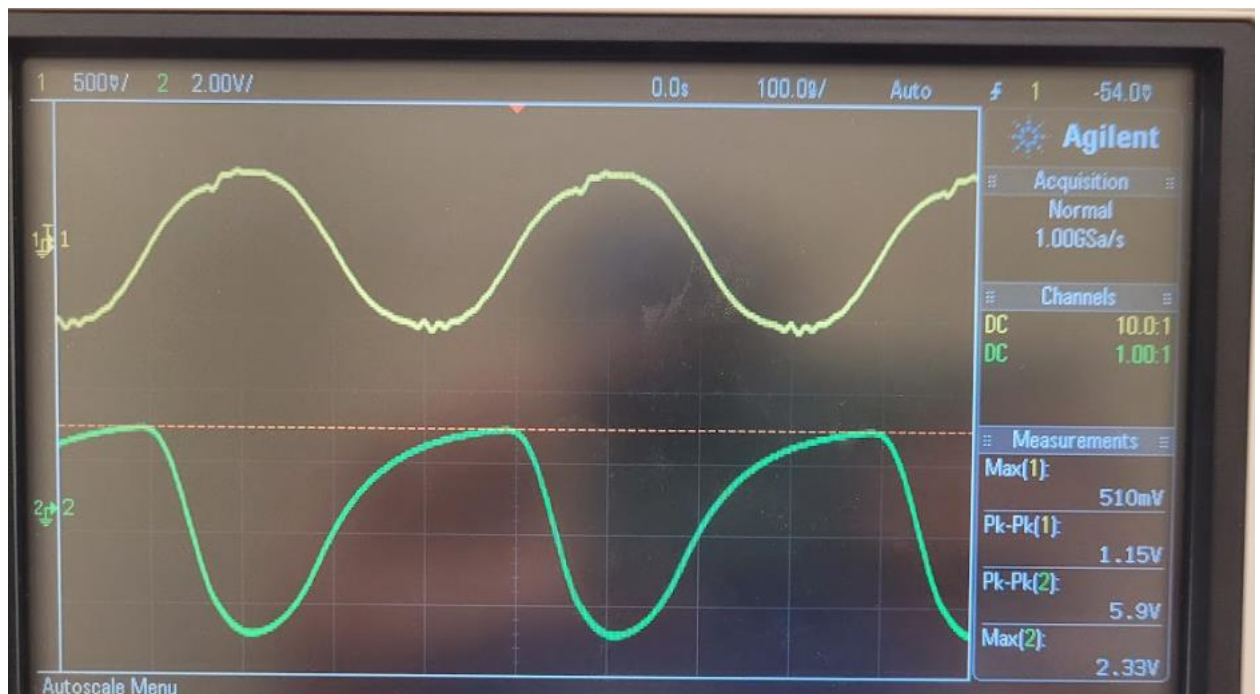


Figure 8. Highest Frequency Waveform

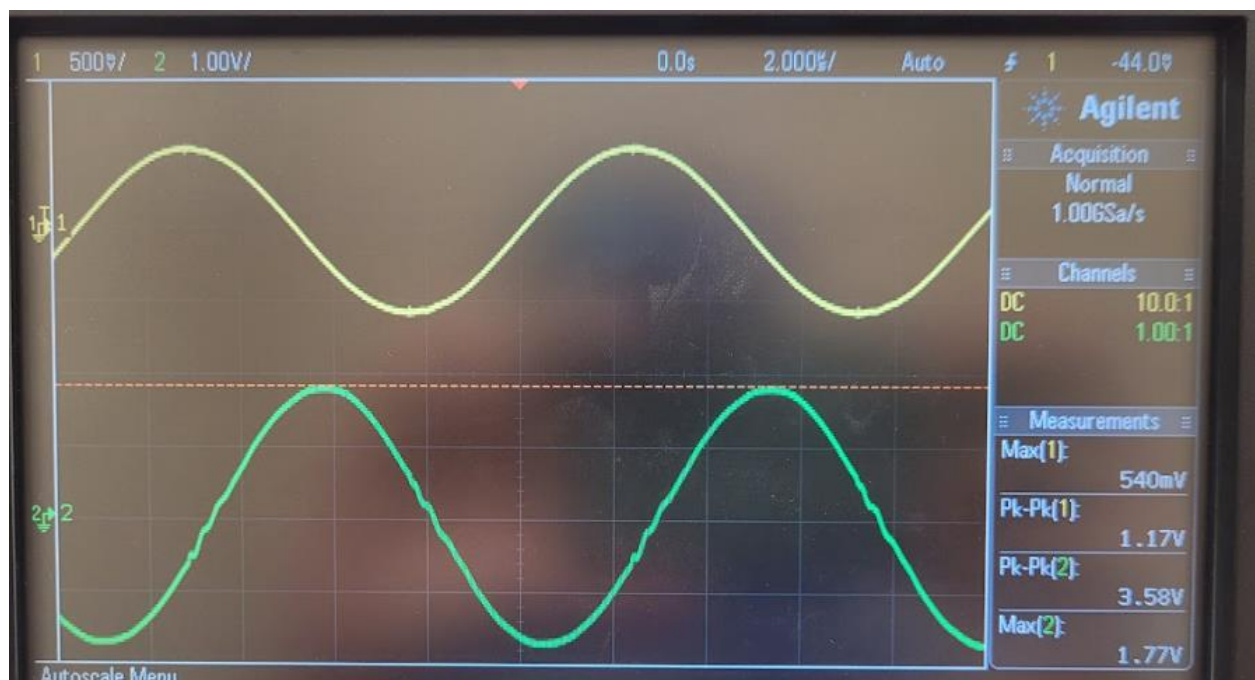


Figure 9. Waveform at 100k Hz

Results and Discussion:

The results of this lab were pretty in line with what we expected. The simulation data taken during prelab was wrong for the first part of the lab where we were looking at output characteristics of a BJT, due to not understanding how to increment V_2 and the proper way to get V_{ce} . However, the experimental portion was done correctly, the output lines more closely match what we were looking for. The second portion of the lab, where we were observing amplification with the BJT, did match our expectations and pre-lab results. However, in pre-lab the wrong thing was plotted on accident and the gain differed. However, this was a mistake in doing the equation wrong and both gain results still exhibited the same behavior of starting out really small and then increasing until it eventually clips and remains constant.

For the first portion, since the saturation point seems to be around 4 mA and because of how we plotted the graph the highest V_{ce} is around 10, the Q-point is around 2.3 mA and 5 volts. For each I_b itself this will vary a bit since we didn't continue taking data points to match the highest V_{ce} we got from the overall data. For the second portion, around 200k Hz is when we start to see the output start to clip.

Conclusion

Overall, the results of lab were in line with what we expected from the information gathered from the theoretical sections. Our results matched the characteristic trends in the data for the simulation and experimental portions, even though the actual data itself was written down wrong the simulation. It showed us what we should see as far as output, gain, waveforms, and current flow in a BJT which will be useful when we do MOSFETS. All together the lab gave us a better understanding of BJTs.

Appendix 1:

N/A

Appendix 2:

Signed lab results

	V_{out}	Gain	V_{in}
10	70		520
30	70		520
60	72		520
100	84		520
200	96		520
500	101		520
1k	113		530
2k	137		530
5k	221		
10k	390 mV		
15k	520 mV		
20k	780 mV		
50k	1.85		550 mV
75k	2.69		550 mV
100k	3.46		
150k	4.9		540
200k	5.6		
500k	clip		540
750k	6.4 (clip)		540
1M	6.4 (clip)		540 mV
1.5M	clip		
2M	6 clip		

Signed
6/10/2022

I_c	V_{CE}	V_{CE}
0	0.016	32.7 mV
0.5	0.44	0.18
1	0.8	0.15
1.5	1.35	0.18
1.8	1.64	0.19
2.2	2	0.21
2.5	2.32	0.22
2.9	2.67	0.25
3.3	3.10	0.32
3.7	3.11	0.62
4.3	3.12	1.18
4.8	3.14	1.75
5.6	3.15	2.14
7.7	3.2	4.56

I_c	V_{CE}	V_{CE}
0	0.02	32.7 mV
1	0.87	0.14
2	1.84	1.88
2.3	2.11	0.209
2.9	2.77	0.21
3.2	3	0.23
3.3	3.29	0.24
4.4	3.9	0.53
5.7	4	1.78
7.9	4.05	3.9
9.7	4.09	5.63
10.4	4.11	6.3
10.7	4.12	6.6
11.8	4.14	7.79
12.5	4.154	8.39
13.3	4.15	9.23
14	4.2	9.8

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07/06/2021

V_E	V_C	I_E (mA)	V_{CE} (mV)	V_E	I_B
4	0	0.0124	16.7	4	0.0112
0.4	0.31	0.15	0.15	6	0.0183
0.8	0.6	0.18	0.18	8	0.0249
1.2	0.9	0.23	0.23	10	0.0317
2.5	1.4	1.1	2.89		
3	1.4	0.75	0.19		
0.9	0.88	0.21	0.21		
1.1	1.2	0.25			
1.4					
V_E	0	0.0196	26 mV		
0.3	0.25	0.13			
0.6	0.44	0.144			
0.9	0.82	0.17			
1.2	1.02	0.18			
1.5	1.36	0.2			
1.8	1.58	0.21			
2.3	2.04	0.216			
2.6	2.25	0.38			
2.9	2.26	0.68			
3	2.73	0.74			

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Pictures of Circuits

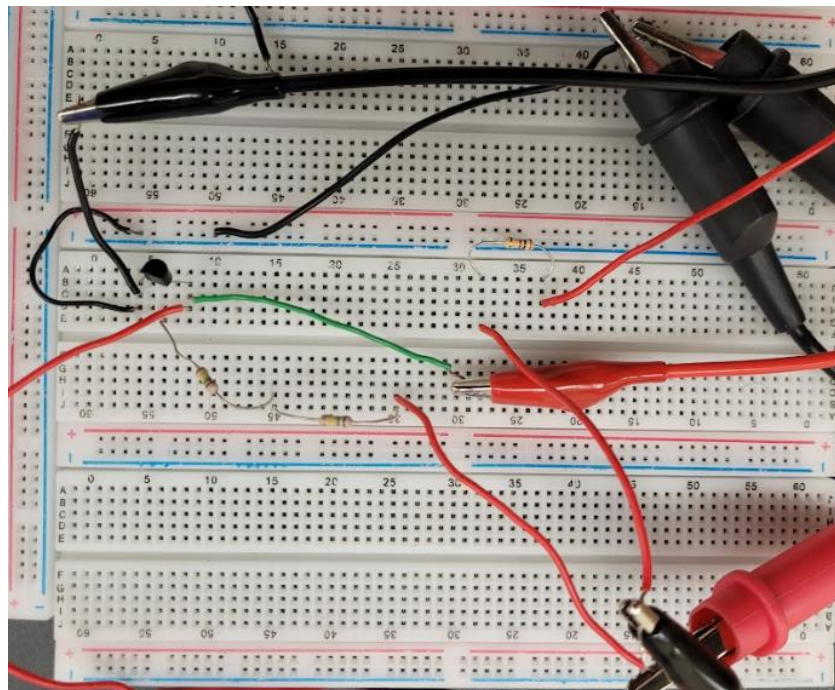


Figure 1. Common Collector Circuit (ref Figure 3)

