ENSC 225
LAB 3
Characterization of BJTs and single stage BJT amplifier

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Written on 2014 March

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Part 1: NPN transistor Characteristics

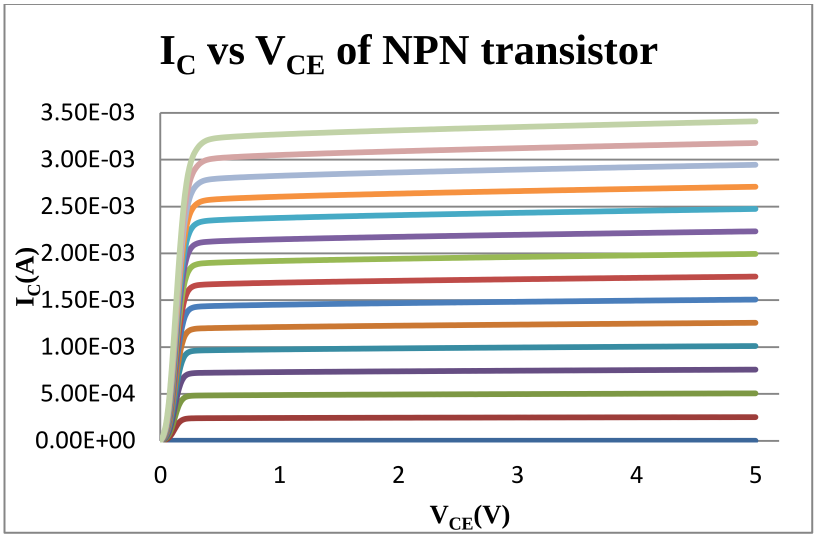

Figure 1: Characteristics of a NPN transistor

Part 2: PNP transistor Characteristics

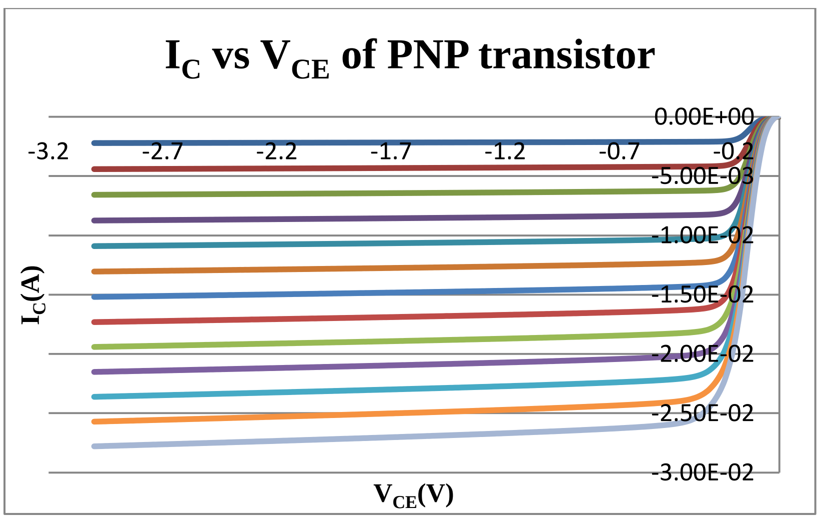

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Figure 2: Characteristics of a PNP transistor

Part 3: Forward current gain and Early Voltage determination

We figured out the current gain (β) from the formula

$$I_C/I_B = \beta$$

And then we figured out the early voltage (V_A) for the NPN from Fig.3.

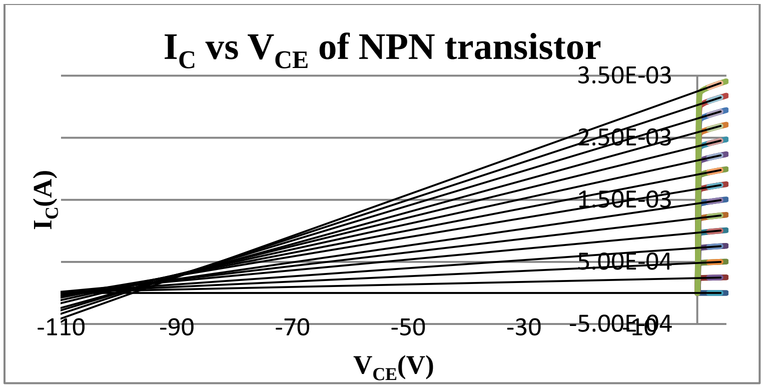

Figure 3: Figuring out the early voltage for NPN

Similarly, we figured out the early voltage (V_A) for the PNP from Fig. 4.

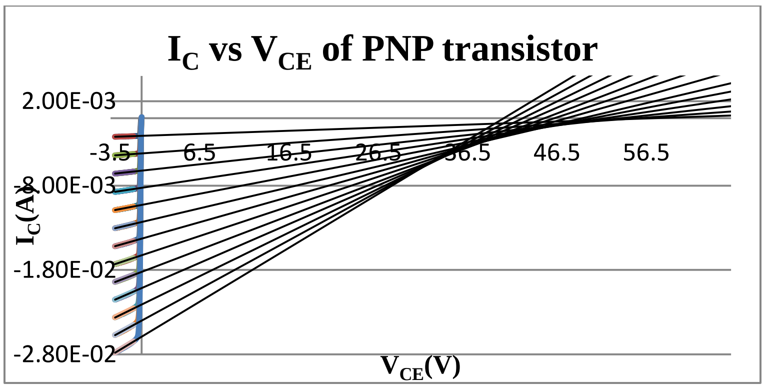

Figure 4: Figuring out the early voltage for PNP

For the NPN transistor we set V_{CE}=3V and we determined from the graph the DC β and the early voltage at I_C = 500µA, 1mA, and 2mA. Fig. 3 shows our data for the NPN transistor.

Ideal I_C	Actual I_C	I_B	β	Early Voltage (V_A)
500µA	498.39µA	$4.0\text{x}10^{-6}$	124.5975	-98V
1mA	0.99559mA	$8.0\text{x}10^{-6}$	124.4488	
2mA	1.9622mA	$1.6\text{x}10^{-5}$	122.6375	

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Figure 5: Data values from graph of NPN transistor

Our experimental values for β differ a bit from the typical values from the datasheet. For our I_C=2mA we can assume it should be the test condition I_C = 10mA and our forward current gain (β) was 122.6375 is somewhat close compared to the typical value of 100. The same goes for our I_C = 1mA and the datasheet's 1mA as their values are also close. However, there is a big difference between our I_C=500µA and the datasheet's I_C=10µA. The typical value is 54 while ours is 124.5975. We can conclude that the difference is because the I_C = 500 µA value is very far apart to its tested condition value compared to the other two test condition values. 5/5

For the PNP transistor we set V_{EC}=2V and we determined from the graph the DC β and the early voltage at I_C = 5mA and 10mA. Fig. 4 shows our data for the PNP transistor.

Ideal I_C	Actual I_C	I_B	β	Early Voltage (V_A)
5mA	-4.3448mA	-4.0×10^{-5}	108.62	50V
10mA	-10.7211mA	-8.0×10^{-5}	134.0138	

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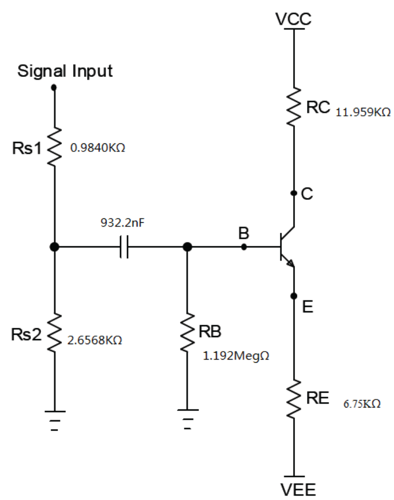
Figure 6: Data values from graph of PNP transistor

Our experimental values for β differ a bit from the typical values from the datasheet. For our I_C=5mA we can assume it should be the test condition I_C = 1mA and our forward current gain (β) was 108.62 is somewhat close compared to the typical value of 100. The same goes for our I_C = 10mA and the datasheet's 10mA as their values are also close. In the datasheet the values for I_C are in positive but we labeled ours as negative because there is no way to find β when the data points are all negative if we use positive values. 4/5

Part 4: Single stage transistor amplifier 25/40



why these resister values? you need to show all the design calculations
-8

Figure 7: Circuit for single stage transistor amplifier

Using the DMM we measured voltage at node B, C, and E (Figure 10). With these voltages we found our currents I_B to be -4.268E-6A, I_C to be 5.856E-4A, and I_E to be 8.954E-4A. We then compare our measured voltage to our simulated voltages form LTSpice.

	Experimental	Simulated
V_B(V)	-5.088	-5.399996
V_C(V)	2.9965	3.24976
V_E(V)	-6.044	-6.1594

Figure 8: Experimental and Simulated Voltage Results

Then we got our DC β value to be 137.207 from the formula

$$I_C/I_B = \beta$$

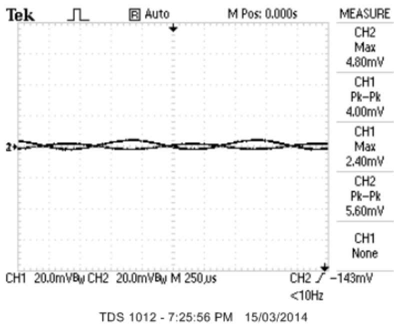


Figure 9: Small Signal Gain

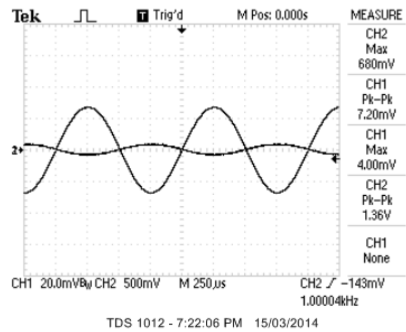
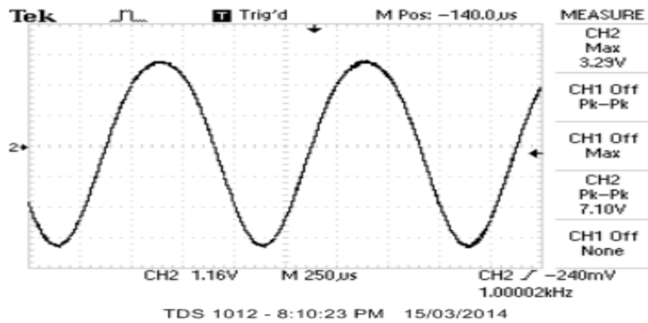


Figure 10: Emitter By-Pass Gain

Our small signal gain from the oscilloscope is 1.2 (Figure 9), and after by-passing the emitter resistor we get a gain of 188.888 (Figure 10).



no screen shots showing the distortion/clipping
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Figure 11: Maximum output without distortion

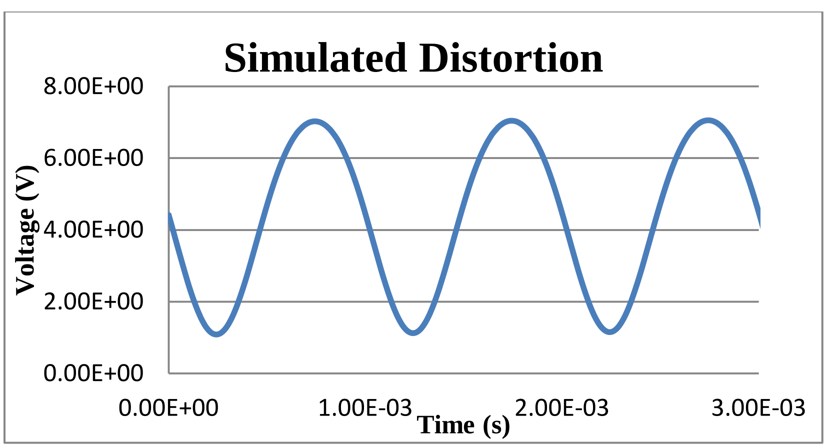

Figure 12: Simulated maximum output without distortion

We increased the amplitude of the function generator until we saw a distortion on our output. We saw that once we got to around 16.34V pk-pk from the function generator, our signal started getting distorted as seen above in Fig. 11. The simulated distortion seen above in Fig. 12 also starts distorting at around the same voltage 16V pk-pk. When we wanted to see the output saturated, we needed 32V pk-pk, which was not possible in our function generator but was possible in our simulation in LTSpice.

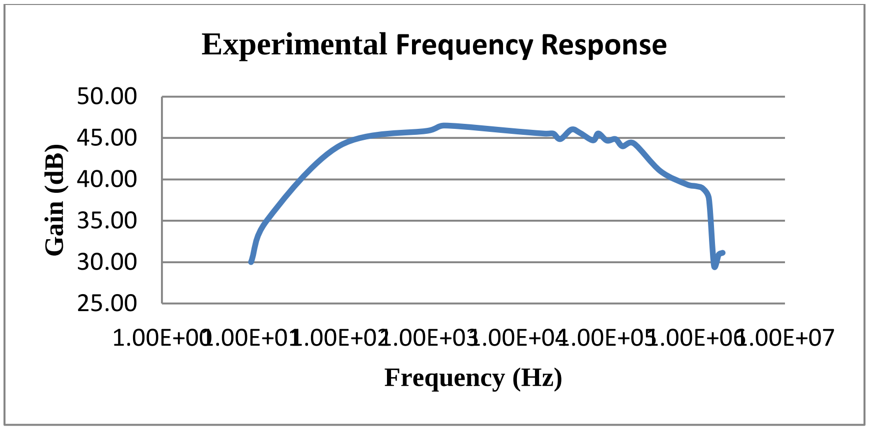

Figure 13: Experimental sweep of frequency from 10Hz to 2MHz

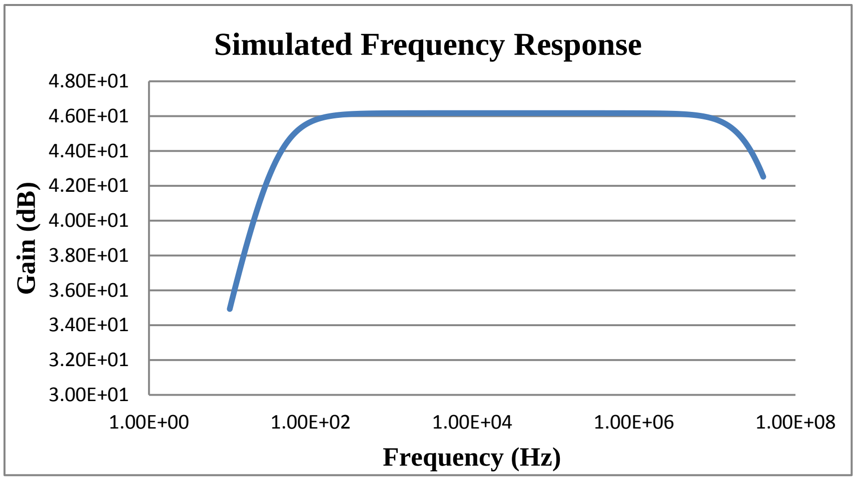

Figure 14: Simulated sweep of frequency from 10Hz to 40MHz

For the LTpice simulation we can see in Fig. 14 that the frequency response starts falling off at around 3MHz. In comparison our experimental frequency response overall follows the trend of the simulated response, but our experimental response starts falling off at around 1MHz.

To calculate the model mid-band gain we need to find g_m using the formula:

$$g_{m=}\frac{I_C}{V_T}$$

We assumed V_T=25mV and our simulated I_c from LTSpice is 564.448µA. Then we multiply g_m to R_C to get a gain of -270. The negative sign just means that the output has a 180º phase shift. Our experimental mid-band gain is 188.888 with 180º phase shift, and our simulated mid-band gain is 200 with 180º phase shift.

small signal model -3.5

layout/pgs: 9/10
Presentation: 9/10