Lab 7:

Characterization and DC Biasing of the BJT

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ECEN 325 Section 514

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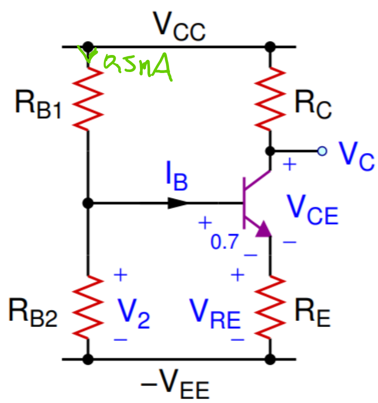
Lab Report Due Date: October 22, 2019

<u>**Calculations**</u>

(1)

NPN Resistive DC Biasing Circuit



NPN

I_C	$1mA$
V_C	$3.5V$
V_{CE}	$\geq 1V$
V_{RE}	$\geq 1V$
V_{CC}	$5V$
V_{EE}	0
β	100
V_T	$25mV$
I_{supply}	$\leq 2mA$

$R_C = 1.5k\Omega$

$V_{RE} = 2.222V$

$V_2 = 2.922V$

$R_E = 2.2k\Omega$

$R_{B1} = 4.156k\Omega$

$R_{B2} = 5.844k\Omega$

Assume $I_{supply} = 0.5mA$, $V_{RE} = 2.222V$, $V_2 = 2.922V$

$$R_C = \frac{5-3.5}{1mA} = \frac{1.5V}{1mA} = 1.5k\Omega$$

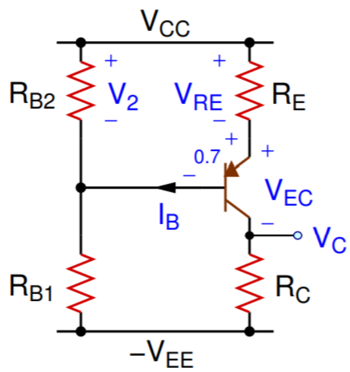
$$R_{B1} = \frac{5-2.922}{0.5mA} = 4.156k\Omega$$

$$I_E = \frac{100}{101} I_C = 0.99mA \qquad I_B = \frac{I_C}{100} = 0.01mA$$

$$R_{B2} = \frac{2.922}{0.5mA} = 5.844k\Omega$$

$$R_E = \frac{2.222V}{0.99mA} = 2.2k\Omega$$

PNP Resistive DC Biasing Circuit



PNP

I_C	$1mA$
V_C	$1.5V$
V_{EC}	$\geq 1V$
V_{RE}	$\geq 1V$
V_{CC}	$5V$
V_{EE}	0
β	100
V_T	$25mV$
I_{supply}	$\leq 2mA$

$R_C = 1.5K\Omega$

$V_{RE} = 2.222V$

$V_2 = 2.922V$

$R_E = 2.2K\Omega$

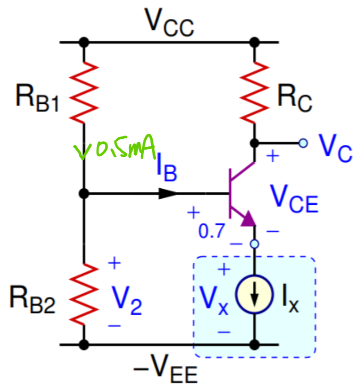
$R_{B1} = 4.156k\Omega$

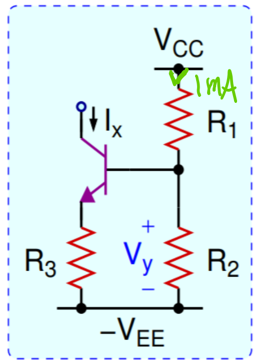
$R_{B2} = 5.844K\Omega$

All the values are the same as previous part. It is just flipped.

(2)

NPN DC Biasing Circuit





NPN

I_C	$2mA$
V_C	$3.5V$
V_{CE}	$\geq 1V$
V_x	$\geq 1.5V$
V_{CC}	$5V$
V_{EE}	0
β	100
V_T	$25mV$
I_{supply}	$\leq 5mA$

$R_C = 750\Omega$ $\quad R_1 = 3.8k\Omega$ $\quad R_2 = 1.2k\Omega$ $\quad R_3 = 250\Omega$

$R_{B1} = 4.6k\Omega$ $\quad R_{B2} = 5.4k\Omega$ $\quad V_x = 2V$ $\quad V_y = 1.2V$

$V_2 = 2.7V$

Assume $V_{CE} = 1.5V$ $\quad I_{supply} = 3.5mA$

$$R_C = \frac{5-3.5}{2mA} = 750\Omega$$

$$V_x = 3.5 - 1.5 = 2V$$

$$V_2 = 2 + 0.7 = 2.7V$$

$$R_{B1} = \frac{5-2.7}{0.5mA} = 4.6k\Omega$$

$$R_{B2} = \frac{2.7}{0.5mA} = 5.4k\Omega$$

$$V_{R3} = 2 - 1.5 = 0.5V$$

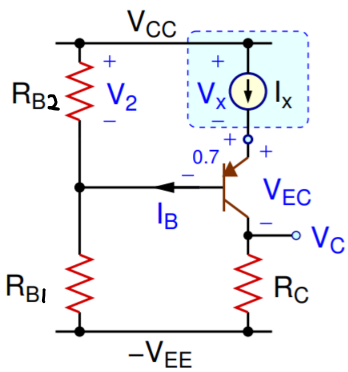
$$V_y = 0.5 + 0.7 = 1.2V$$

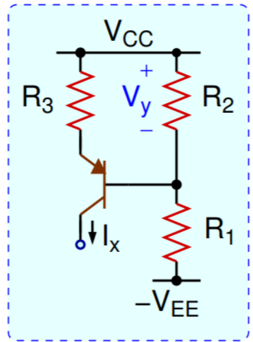
$$R_3 = \frac{0.5}{2m} = 250\Omega$$

$$R_2 = \frac{1.2}{1m} = 1.2k\Omega$$

$$R_1 = \frac{5-1.2}{1m} = 3.8k\Omega$$

PNP DC Biasing Circuit





PNP

I_C	$2mA$
V_C	$1.5V$
V_{EC}	$\geq 1V$
V_x	$\geq 1.5V$
V_{CC}	$5V$
V_{EE}	0
β	100
V_T	$25mV$
I_{supply}	$\leq 5mA$

All the values are the same as the previous part. It is just flip.

Simulations

(1)

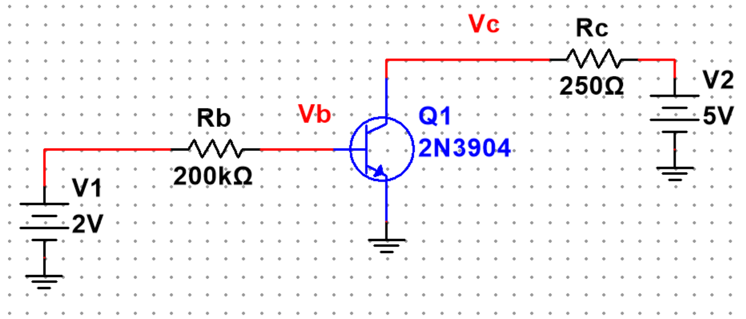


Figure 1: Schematic of NPN BJT characterization circuit for Fig. 2 ▲

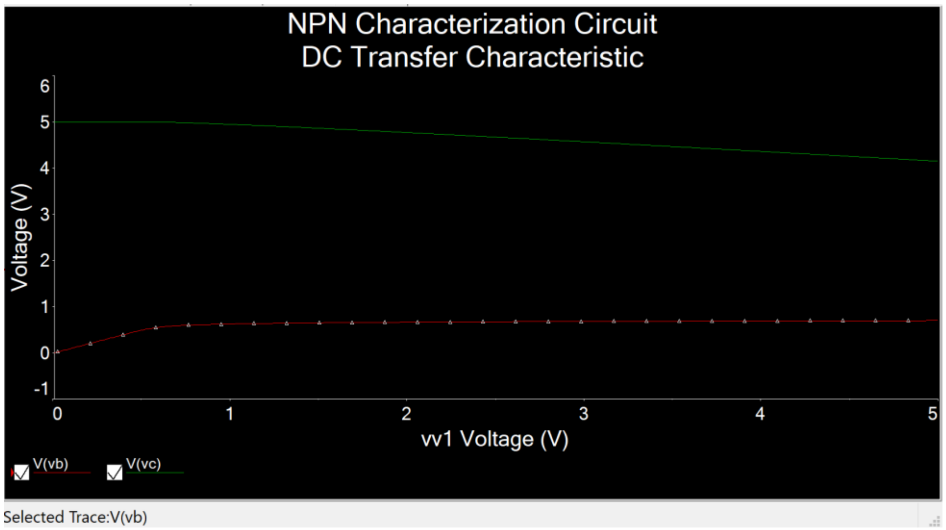


Figure 2: Simulation plot of NPN BJT characterization circuit using DC sweep of V1 from 0 to 5V, while V2 = 5V ▲

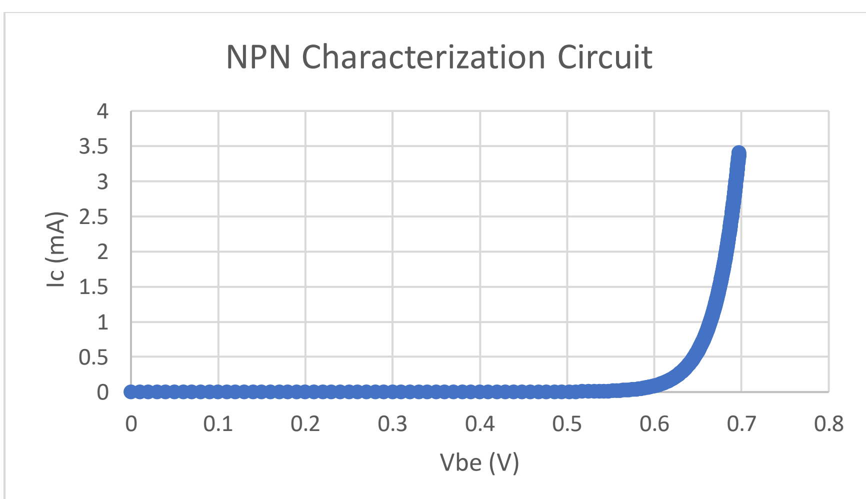


Figure 3: Excel plot for collector current (IC) of an NPN BJT as a function of Vbe ▲

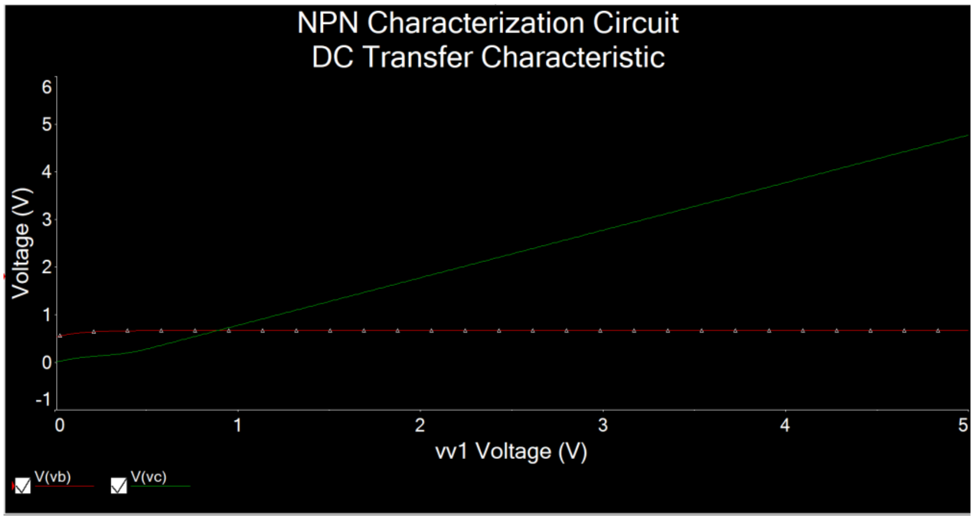


Figure 4: Simulation plot of NPN BJT characterization circuit using DC sweep of V2 from 0 to 5V, while V1 = 2V ▲

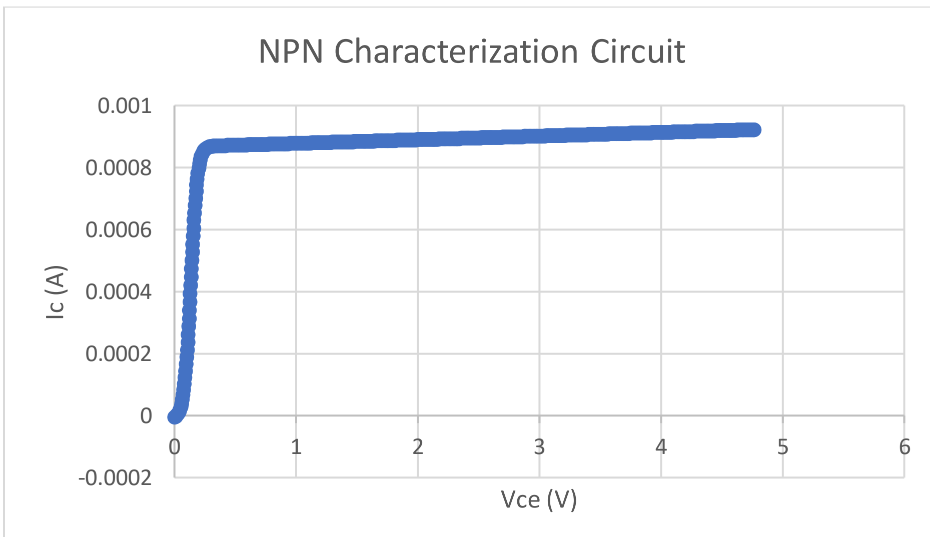


Figure 5: Excel plot for collector current (IC) of an NPN BJT as a function of Vce ▲

(2)

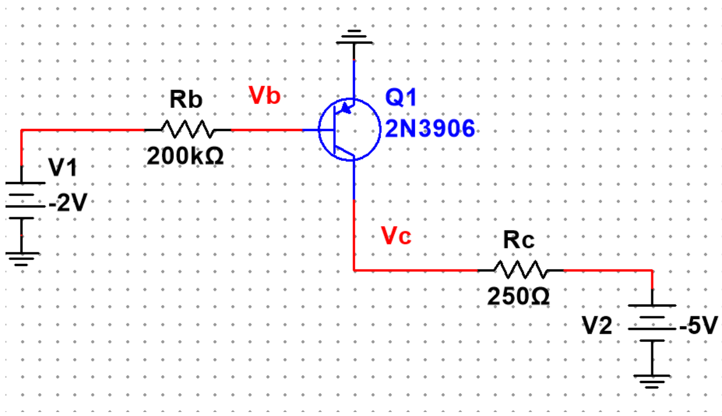


Figure 6: Schematic of NPN BJT characterization circuit for Fig. 4 ▲

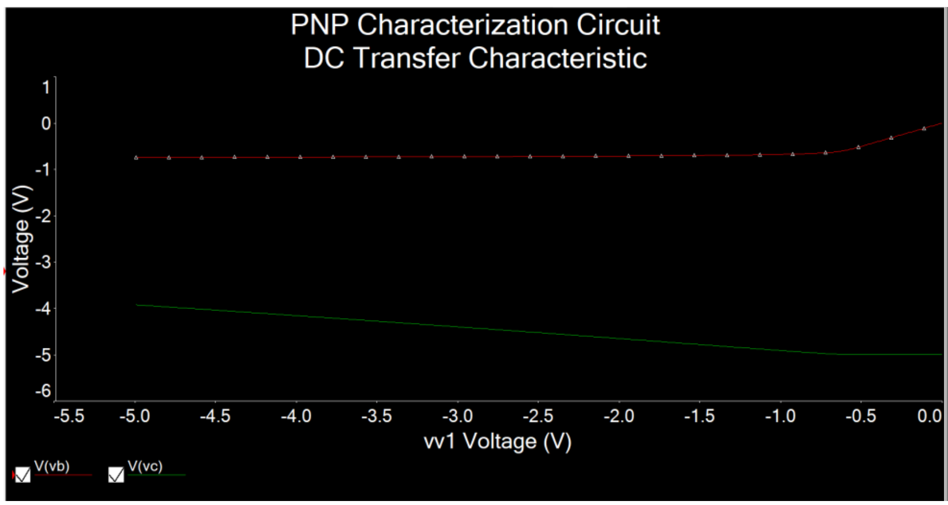


Figure 7: Simulation plot of PNP BJT characterization circuit using DC sweep of V1 from -5 to 0V, while V2 = -5V ▲

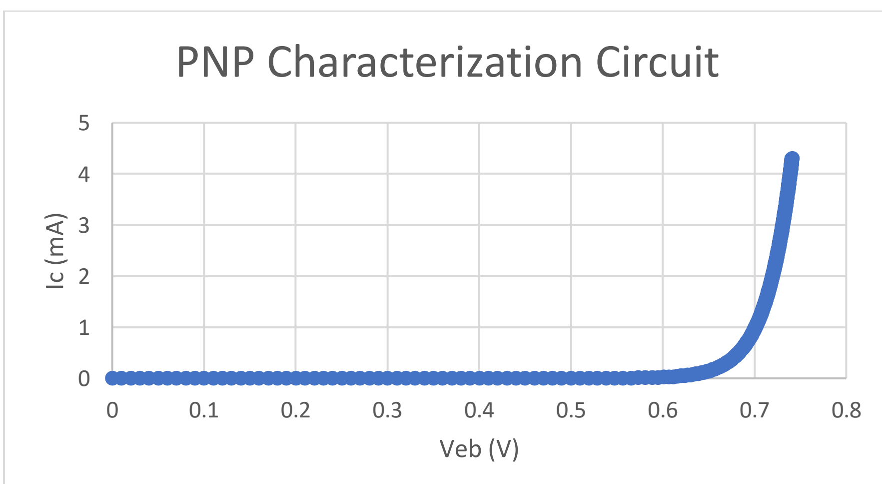


Figure 8: Excel plot for collector current (IC) of an PNP BJT as a function of Veb ▲

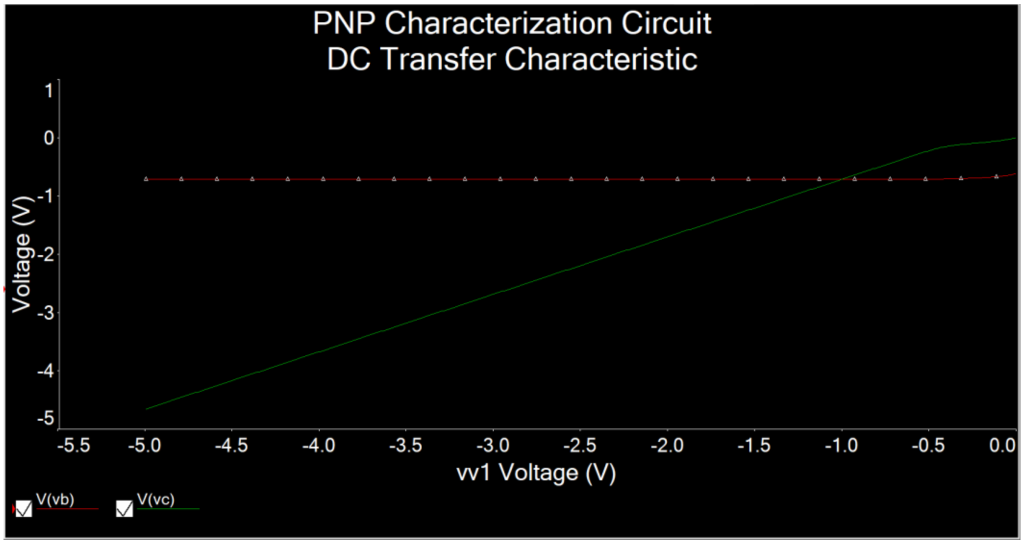


Figure 9: Simulation plot of PNP BJT characterization circuit using DC sweep of V2 from -5 to 0V, while V1 = -2V ▲

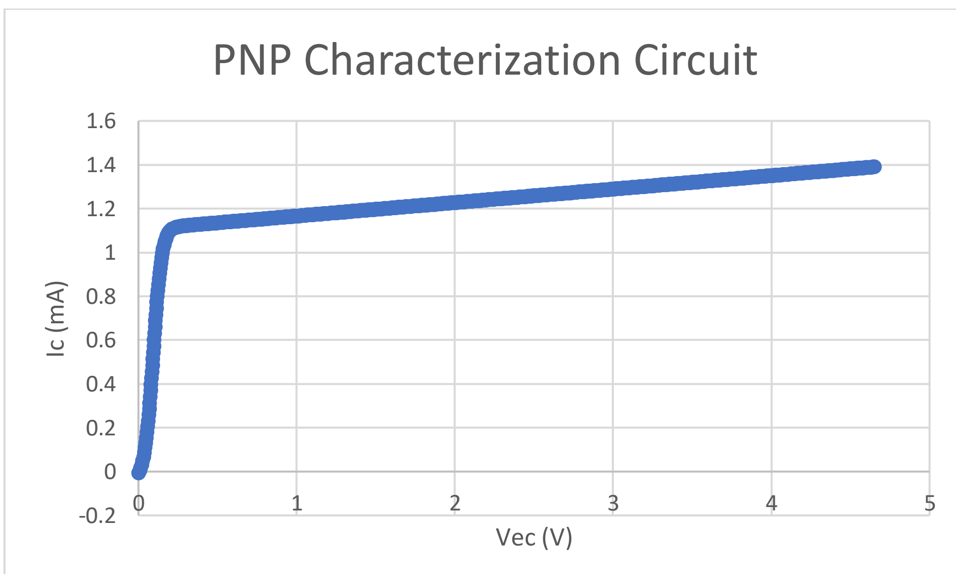


Figure 10: Excel plot for collector current (IC) of an PNP BJT as a function of Vec ▲

(3)

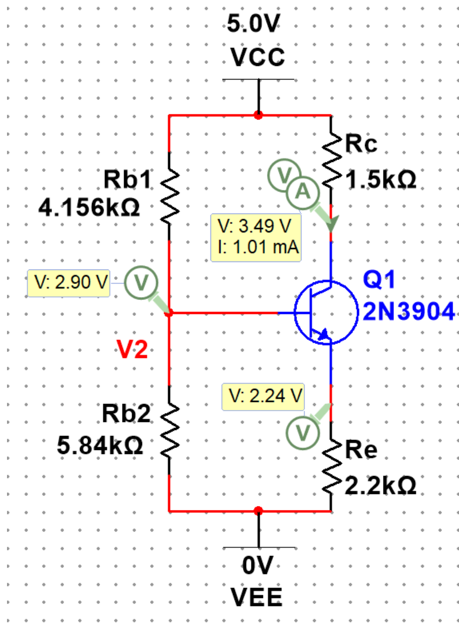


Figure 11: Schematic and interactive simulation for I_C, V_C, V_{RE}, and V_2 for NPN Resistive DC biasing circuit in Fig. 6(a) ▲

$I_C = 1.01mA$, $V_C = 3.49V$, $V_{RE} = 2.24V$, $V_2 = 2.90V$

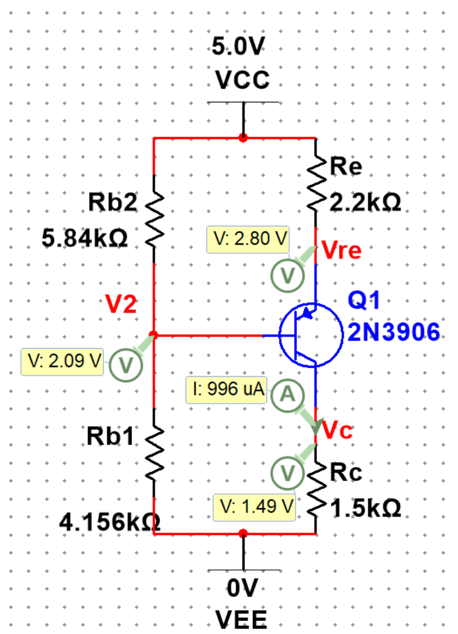


Figure 12: Schematic and interactive simulation for I_C, V_C, V_{RE}, and V_2 for PNP Resistive DC biasing circuit in Fig. 6(b) ▲

$I_C = 0.996mA$, $V_C = 1.49\ V$, $V_{RE} = 5 - 2.8 = 2.2V$, $V_2 = 5 – 2.09 = 2.91V$

(4)

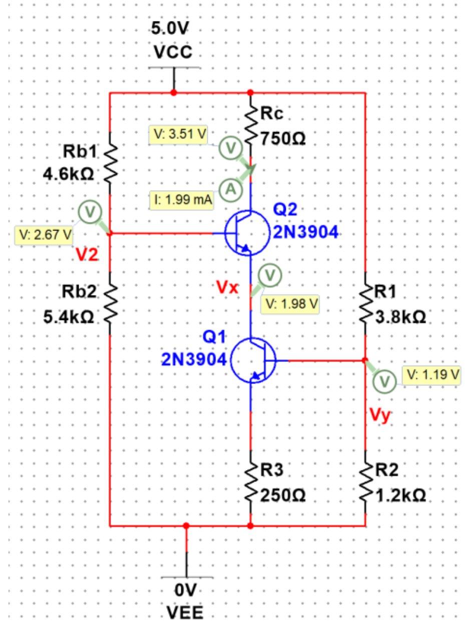


Figure 13: Schematic and interactive simulation for I_C, V_C, V_2, V_x, and V_y for NPN DC biasing circuit using current source in Fig. 7(a) and Fig. 7(b) ▲

$I_C = 1.99mA$, $V_C = 3.51V$, $V_2 = 2.67V$, $V_x = 1.98V$, $V_y = 1.19V$

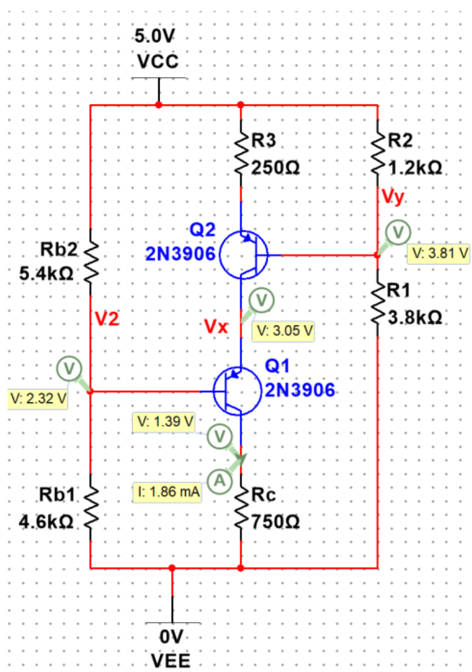


Figure 14: Schematic and interactive simulation for I_C, V_C, V_2, V_x, and V_y for NPN DC biasing circuit using current source in Fig. 8(a) and Fig. 8(b) ▲

$I_C = 1.86mA$, $V_C = 1.39V$, $V_2 = 5 – 2.32 = 2.68V$, $V_x = 5 – 3.05 = 1.95V$, $V_y = 5 – 3.81 = 1.19V$

Measurements

(1)

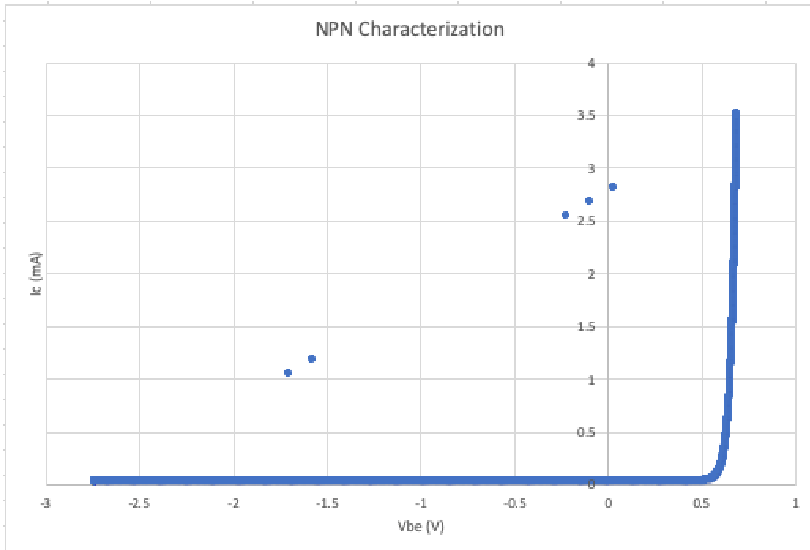


Figure 11: Excel plot for collector current (IC) of an NPN BJT as a function of Vbe ▲

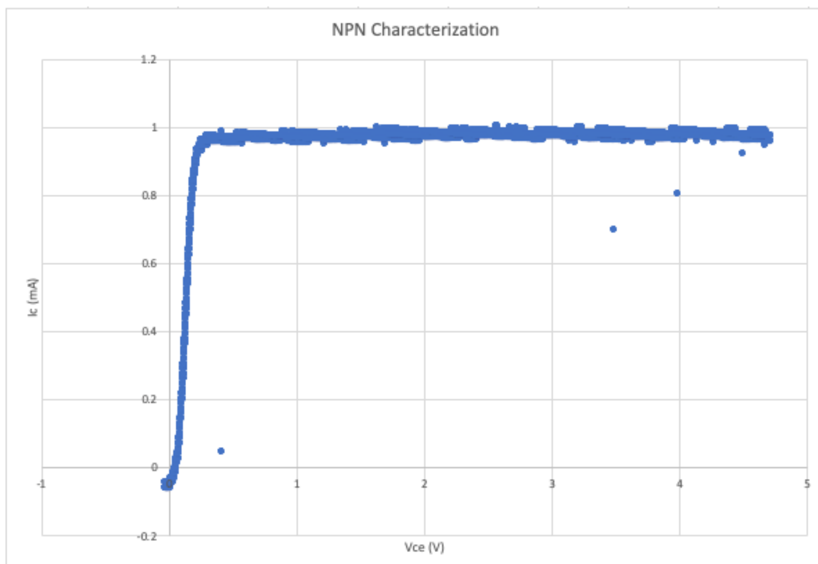


Figure 12: Excel plot for collector current (IC) of an NPN BJT as a function of Vce ▲

(2)

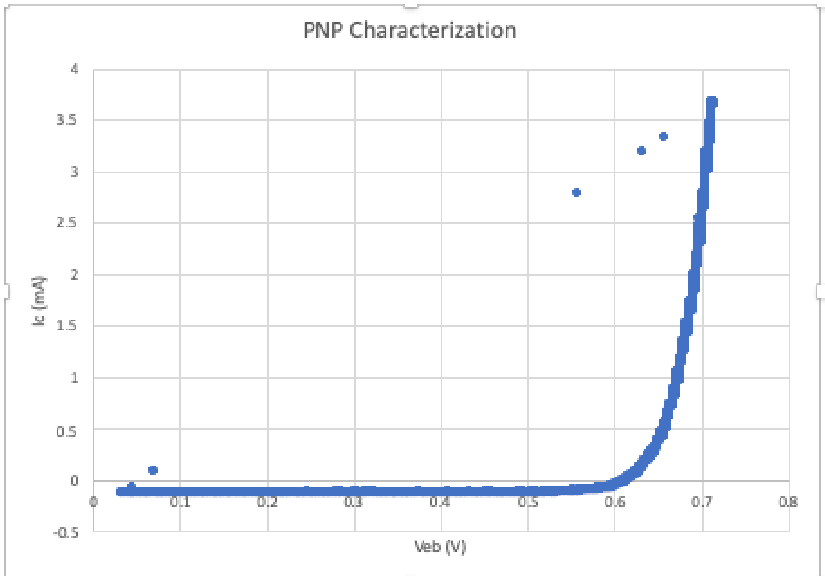


Figure 13: Excel plot for collector current (IC) of an PNP BJT as a function of Veb ▲

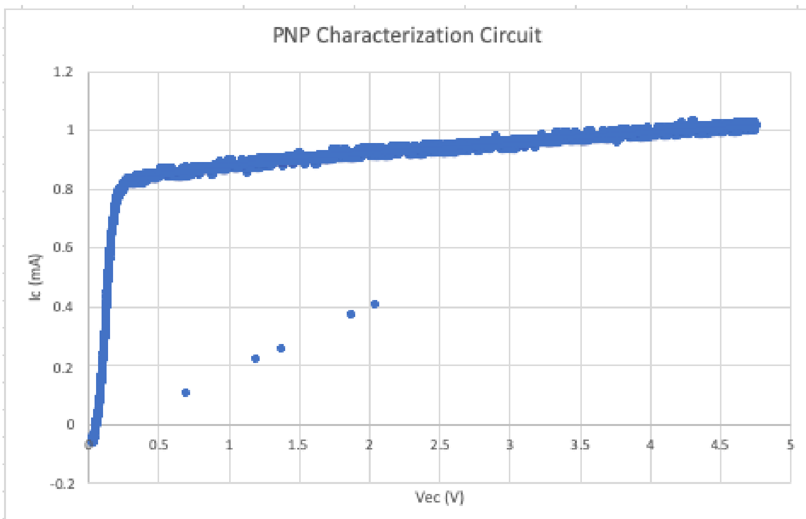


Figure 14: Excel plot for collector current (IC) of an PNP BJT as a function of Vec ▲

(3)

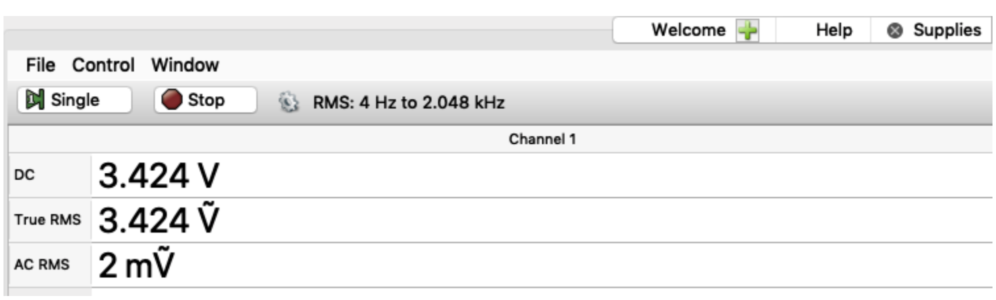


Figure 15: V_C for NPN Resistive DC biasing ▲

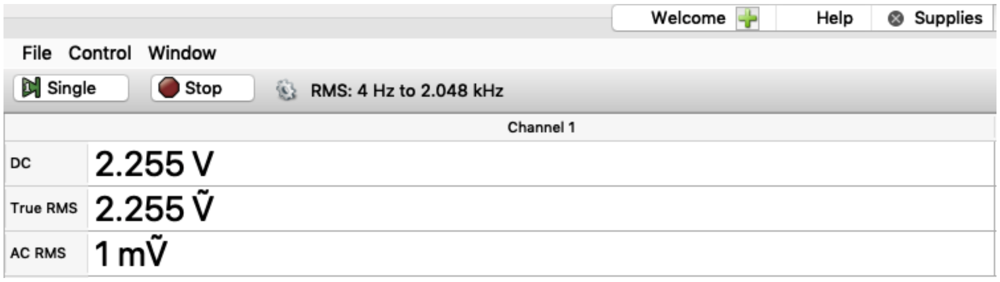


Figure 16: V_{RE} for NPN Resistive DC biasing ▲

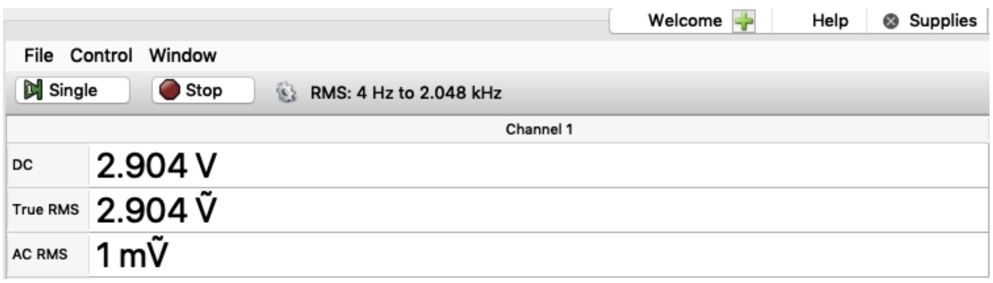


Figure 17: V_2 for NPN Resistive DC biasing ▲

$Ic = (5-3.424)/1500 = 1.05mA$

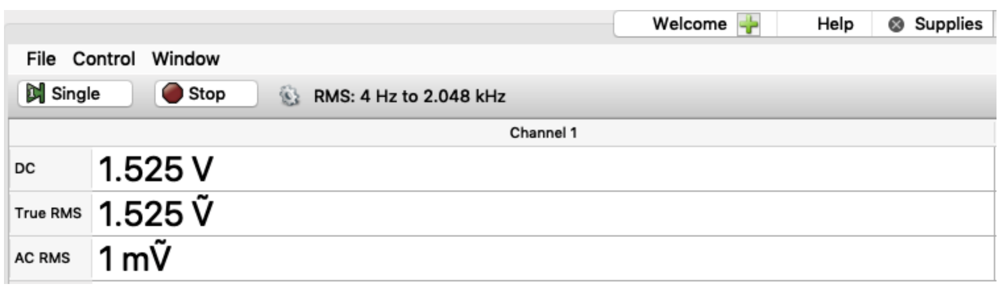


Figure 18: V_C for PNP Resistive DC biasing ▲

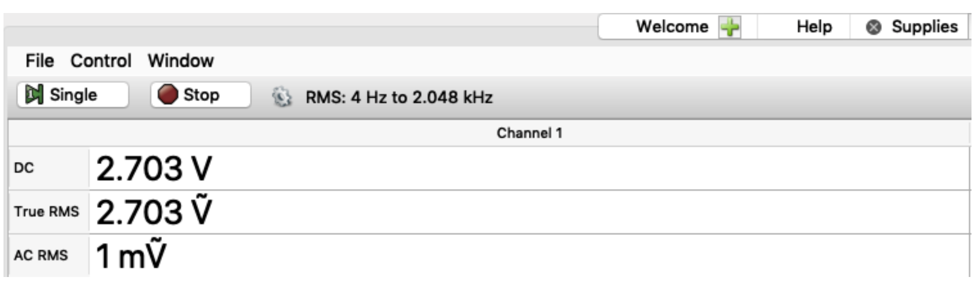


Figure 19: $V_{RE} = 5 – 2.703 = 2.297V$ for PNP Resistive DC biasing ▲

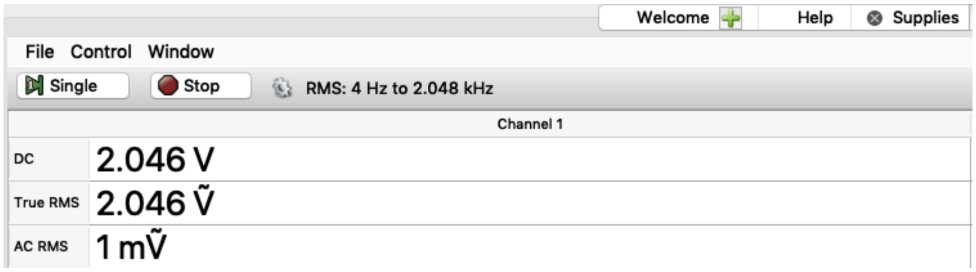


Figure 20: $V_2 = 5 - 2.046 = 2.954V$ for PNP Resistive DC biasing ▲

Ic = 1.525/1500 = 1.01mA

(4)

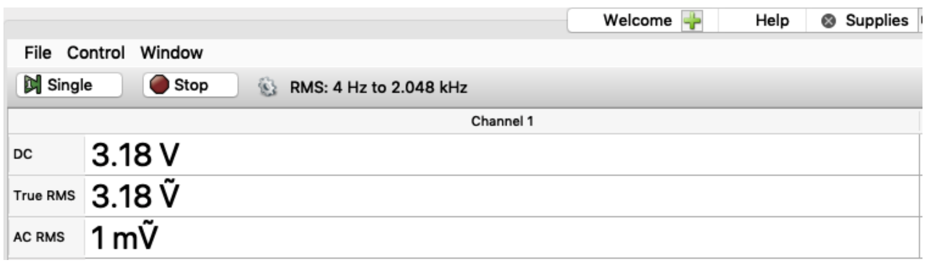


Figure 21: V_C for NPN DC biasing circuit ▲

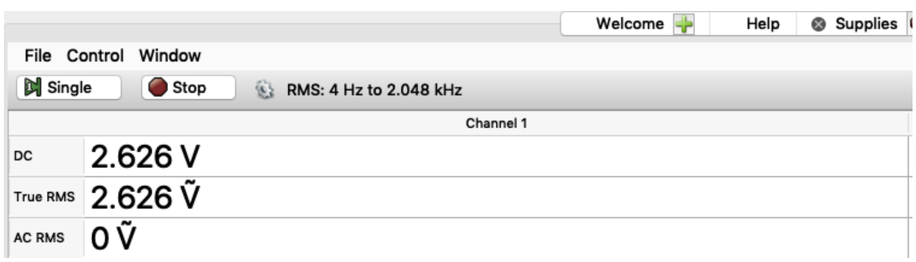


Figure 22: V_2 for NPN DC biasing circuit ▲

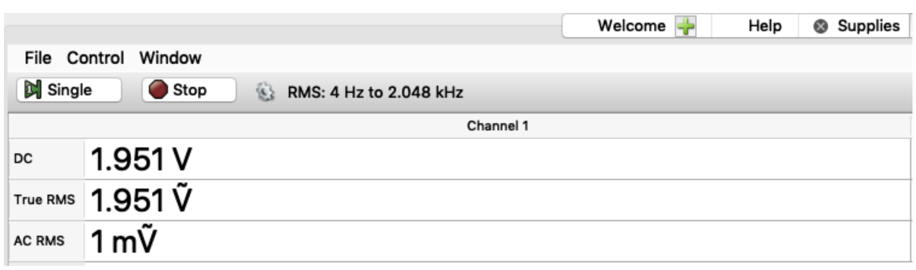


Figure 23: V_x for NPN DC biasing circuit ▲

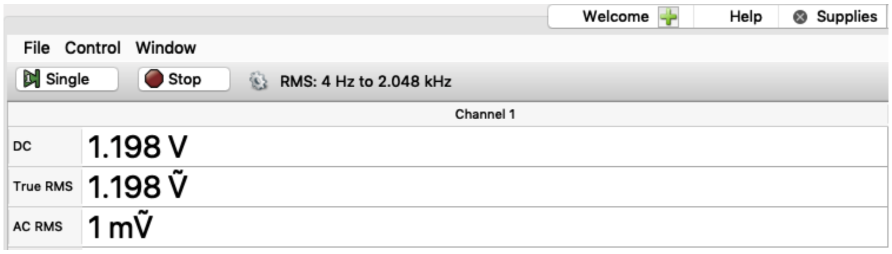


Figure 24: V_y for NPN DC biasing circuit ▲

Ic = (5 - 3.18) / 750 = 2.427mA

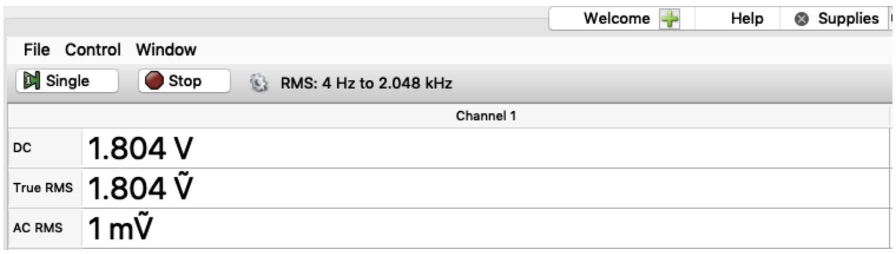


Figure 25: V_C for PNP DC biasing circuit ▲

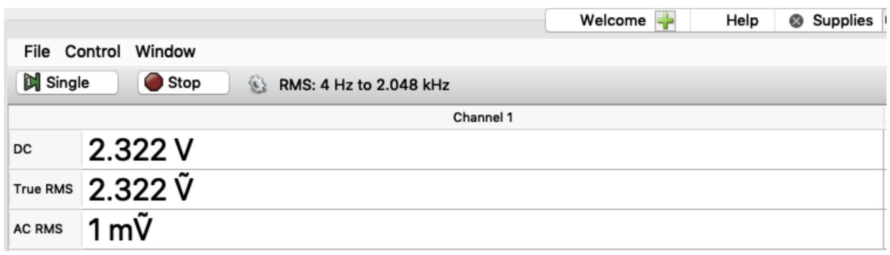


Figure 26: V_2 = 5 – 2.322 = 2.678V for PNP DC biasing circuit ▲

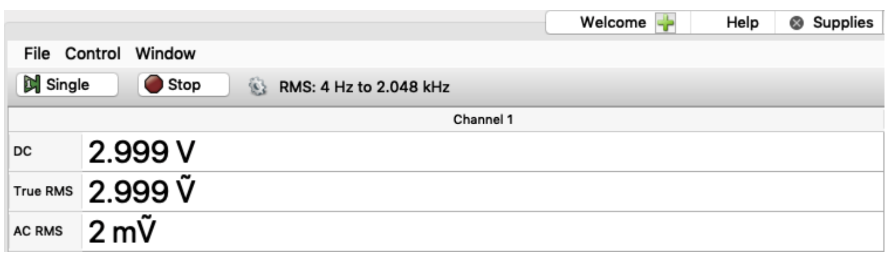


Figure 27: V_x = 5 – 2.999 = 2.001V for PNP DC biasing circuit ▲

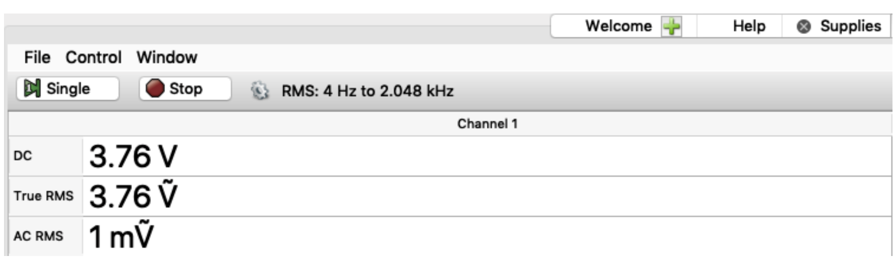


Figure 28: V_y = 5 – 3.76 = 1.24V for PNP DC biasing circuit ▲

Ic = 1.804 / 750 = 2.405mA

Tables

NPN Resistive DC Biasing Circuit

	Calculation	Simulation	Measurement
V_C (V)	3.5	3.49	3.424
V_2 (V)	2.922	2.90	2.904
V_{RE} (V)	2.222	2.24	2.255
I_C (mA)	1	1.01	1.05

PNP Resistive DC Biasing Circuit

	Calculation	Simulation	Measurement
V_C (V)	1.5	1.49	1.525
V_2 (V)	2.922	2.91	2.954
V_{RE} (V)	2.222	2.2	2.297
I_C (mA)	1	0.996	1.01

NPN DC Biasing Circuit

	Calculation	Simulation	Measurement
V_C (V)	3.5	3.51	3.18
V_2 (V)	2.7	2.67	2.626
V_x (V)	2	1.98	1.951
V_y (V)	1.2	1.19	1.198
I_C (mA)	2	1.99	2.427

PNP DC Biasing Circuit

	Calculation	Simulation	Measurement
V_C (V)	1.5	1.39	1.804
V_2 (V)	2.7	2.68	2.678
V_x (V)	2	1.95	2.001
V_y (V)	1.2	1.19	1.24
I_C (mA)	2	1.86	2.405

Comment

The calculation, simulation, and measurement values are all very close. However, measurement values are a bit off from the calculation and simulation values and this is because I used approximate resistor values but not exact resistor values.

For NPN and PNP characterization plot, both Ic vs. Vbe plots go up at around 0.6V which means that the transistor turns on at about 0.6V. And both Ic vs. Vce plots go up basically immediately that means Ic and Vce are going constantly.