Lab 7: Characterization and DC Biasing of the BJT

ECEN 325 - 511

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Date Performed: October 26, 2021

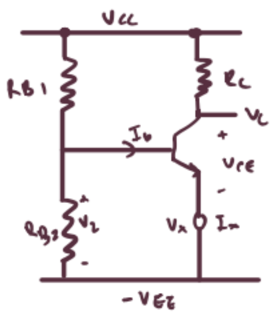
Due Date: November 2, 2021

Purpose

The objective of this lab is to be able to charaterize NPN and PNP BJTs and to analyze DC biasing circuits.

Calculations

1) NPN



$V_{cc} = 5V$

$V_c = 3.5V$

$I_c = 1mA$

$V_c = I_c R_c - V_{cc}$

$R_c = \frac{V_{cc} - V_c}{I_c} = \frac{5 - 3.5}{1mA} = \underline{1.5k\Omega}$

$R_E = \frac{V_{RE}}{I_E} \rightarrow I_E = (1+\beta) I_B = (1+\beta)(I_c/\beta)$

$I_E = (101)\frac{1mA}{100} = \underline{1.01mA}$

$I_B = I_E - I_c = \underline{0.01mA}$ $\qquad V_c = V_{RE} + V_{RC} = \underline{3.5V}$

$V_{RC} = R_c(I_c) = 1.5k(1m) = 1.5V$ $\qquad V_{RC} = \underline{1.5V} \rightarrow V_{RE} = \underline{2V}$

$R_E = \frac{V_{RE}}{I_E} = \frac{2V}{1.01mA}$ $\qquad R_E = \underline{1.98k\Omega} \approx 2k\Omega$

$I_{supply} = 2mA = I + I_c$ $\qquad I = 1mA$

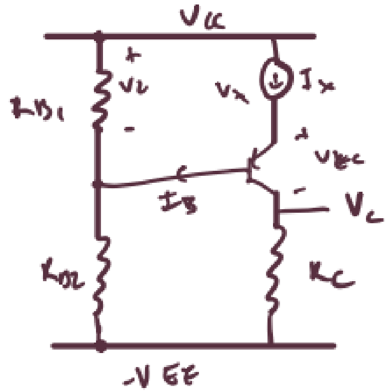
$V_{B1} + V_{B2} = V_{cc} \rightarrow V_{B2} = 0.7 + V_{RE} = 2.7V$

$V_{B1} = 5 - 2.7 = 2.3V$

$V_{B1} = I R_{B1} = 2.3 = 1mA(R_{B1}) \rightarrow \underline{R_{B1} = 2.3k\Omega}$

$V_{B2} = (I - I_B) R_{B2} = (2.7)(.99mA) = \underline{R_{B2} = 2.7k\Omega}$

1) PNP



$V_{EE} = 0V$

$V_c = 1.5V$

$I_c = 1mA$

$R_c = \frac{V_c - V_{EE}}{I_c} = \frac{1.5V}{1mA} = 1.5k\Omega$

$I_B = I_c / \beta = \frac{1mA}{100} = 0.01mA$

$I_E = I_B + I_C = \underline{1.01mA}$

$V_{RE} = V_{cc} - V_{Rc} - V_c = 5 - 1.5 - 1.5 = 2V$

$R_E = \frac{V_{RE}}{I_E} = \frac{2V}{1.01mA} = 1.98k\Omega = 2k\Omega$

$V_{R1} + V_{R2} = V_{cc} \rightarrow V_{R2} = .7 + 2 = 2.7V$

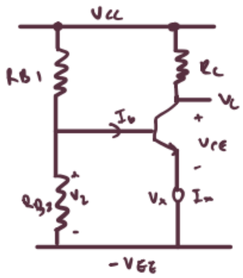
$V_{R1} = 2.3V$

$I_{supply} = I + I_E = 2mA \qquad I = 2mA - 1.01mA = 0.99mA$

$R_{B2} = \frac{V_{R2}}{I} = \frac{2.7V}{.99mA} = \underline{2.72k\Omega}$

$R_{B1} = \frac{V_{R1}}{I + I_B} = \frac{2.3}{1mA} = \underline{2.3k\Omega}$

2) NPN



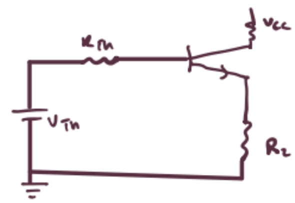
$I_c = 2mA$

$V_c = 3.5V$

$V_{CE} \geq 1V$

$V_X \geq 1.5V$, $V_{cc} = 5$, $V_{EE} = 0$

$\beta = 100$, $V_T = 25mV$, $I_{supply} \leq 5mA$



$V_{Th} = V_{cc}\left(\frac{R_2}{R_{B1}+R_{B2}}\right)$ $R_{Th} = \frac{R_{B1}R_{B2}}{R_{B1}+R_{B2}}$

$V_{cc} = I_cR_c + V_c \rightarrow R_c = \frac{V_{cc}-V_c}{I_{cc}} = \frac{5-3.5}{2\times10^{-3}} = 0.75k\Omega = \underline{750\Omega}$

$V_{Th} = V_{BE} + I_B R_{Th} + V_{CE} = .7 + 20\times10^{-6}(R_{Th}) + 1.5 = \underline{2.2V}$

$V_2 \geq 1.5V$

$I_B = \beta / I_c = 2/100 = 20\mu A$

$I_c \approx I_E = 2mA$

$V_{th} = V_{CE}\left(R_2/R_{B1}+R_{B2}\right)$

$2.2 = 5\left(R_2/R_1+R_2\right)$

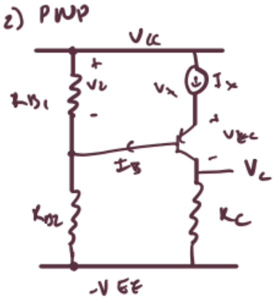
$2.2(R_1+R_2) = 5R_2$

$R_1 = 1.27R_2$

$R_{B2} = 1k\Omega$ $R_{B1} = 1.27k\Omega$

$R_1 = R_2 = R_3 = 500\Omega$

2) PNP



$I_C = 2mA$ $\quad \beta = 100$

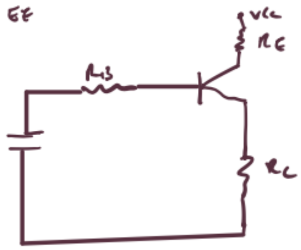
$V_C = 1.5V$ $\quad V_T = 25mV$

$V_{EC} \geq 1V$

$V_{2E} \geq 1V$

$V_{cc} = 5V$

$V_{EE} = 0V$



$V_2 = V_{cc} - V_{EC} - V_C = 5 - 1.5 - 1 = 2.5V$

$\underline{V_2 = 2.5V}$

$I_E \approx I_C = 2mA$

$R_E = \frac{V_2}{I_E} = \frac{2.5}{2\times10^{-3}}$ $\quad \underline{R_E = 1.25k\Omega}$

$R_C = \frac{V_C}{I_C} = \frac{1.5}{2\times10^{-3}}$ $\quad \underline{R_C = 0.75k\Omega}$

$V_2 = V_2 + 0.7 \rightarrow 2.5 + 0.7$ $\quad \underline{V_2 = 3.2V}$

$V_2 = \left(\frac{R_1}{R_1 + R_2}\right) V_{cc} \rightarrow 3.2 = \left(\frac{R_1}{R_1 + R_2}\right) 5$

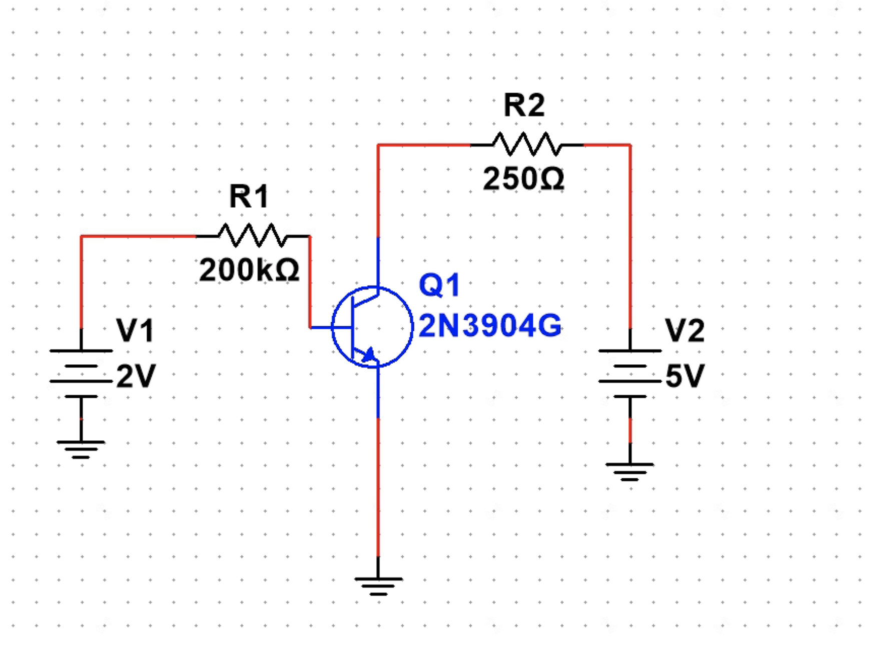
$R_1 = 1.77 R_2$ $\quad \underline{R_2 = 1k\Omega}$

$\underline{R_1 = 1.77k\Omega}$

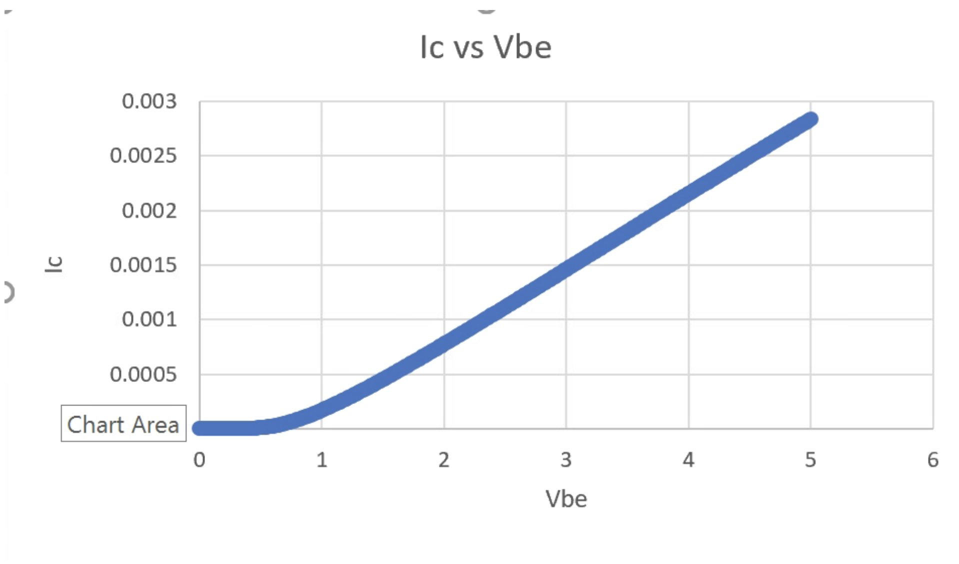
$R_1 = R_2 + R_3 = 500\Omega$

Simulations (on Multisim)

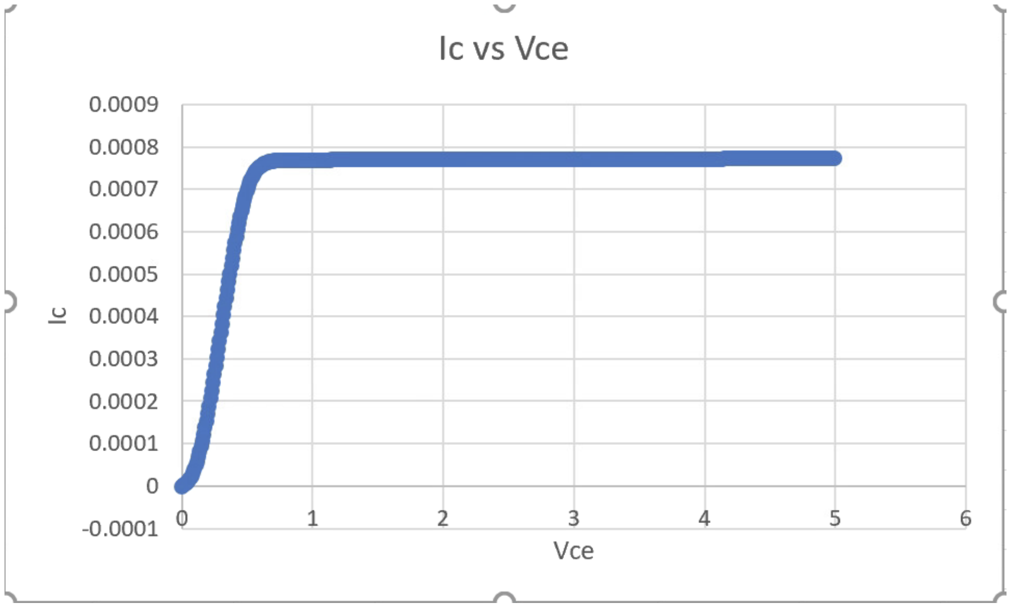
Schematic NPN



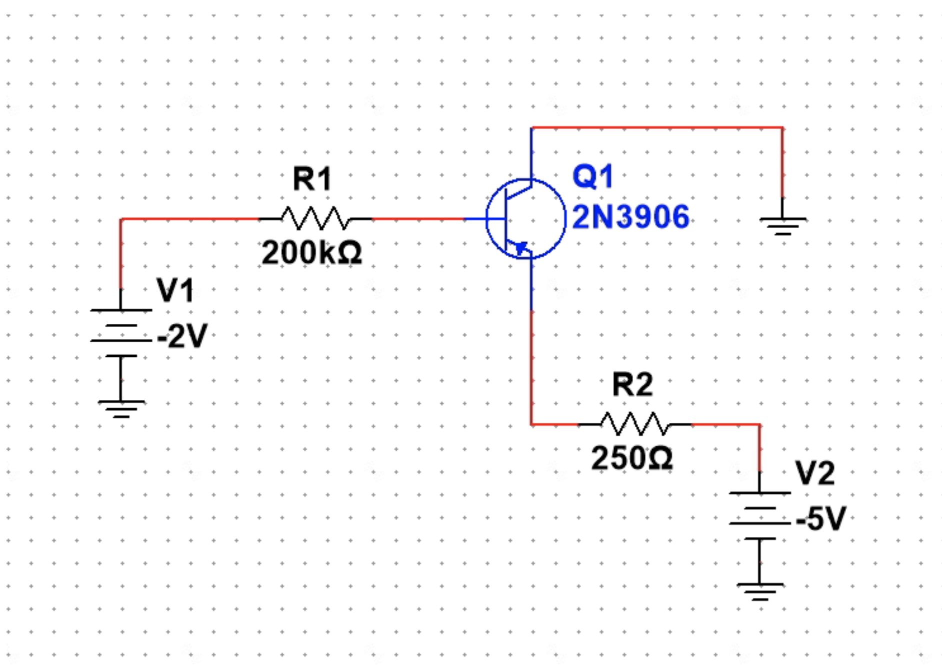
I_c vs V_{BE}



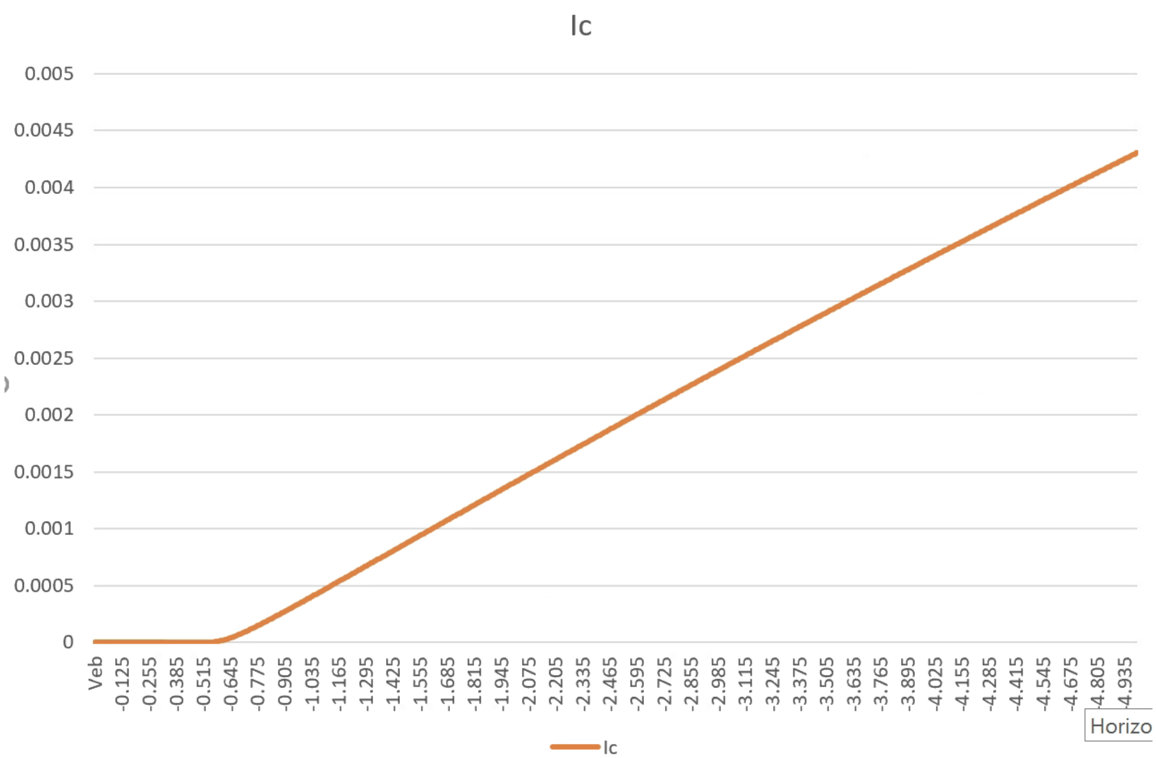
I_c vs V_{CE}



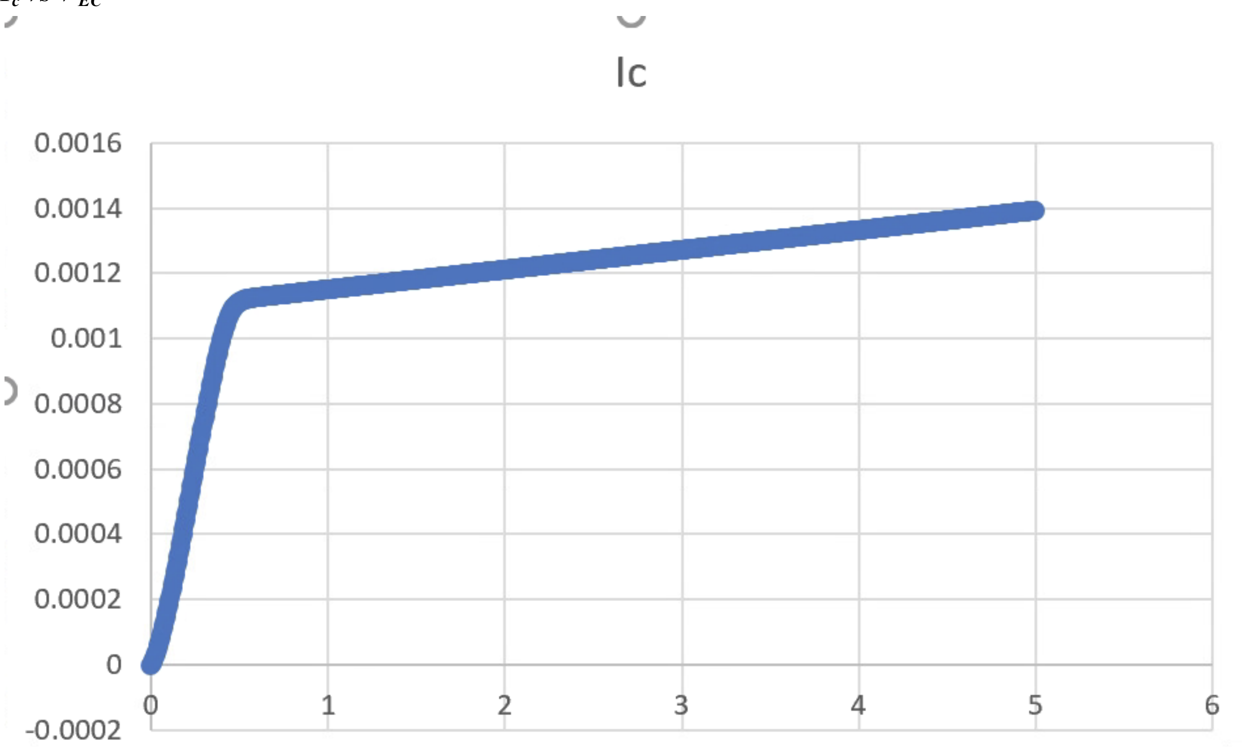
Schematic PNP



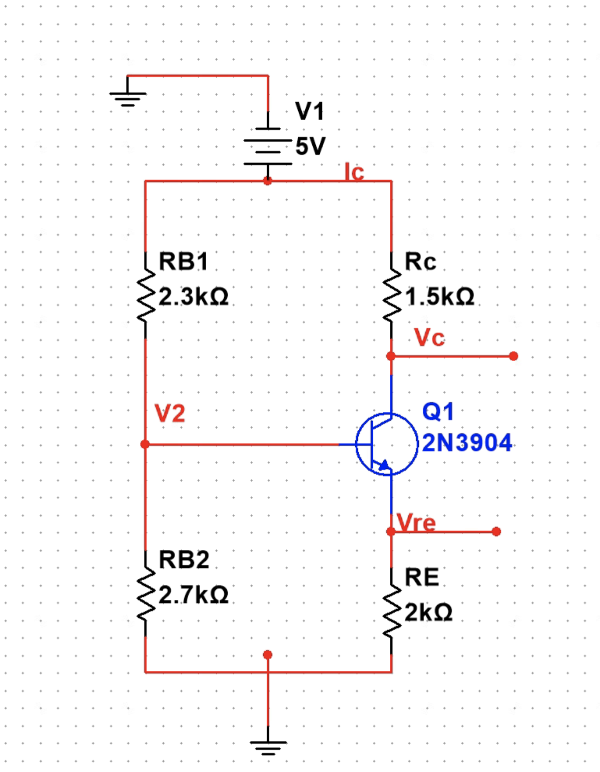
I_c *vs* V_{EB}



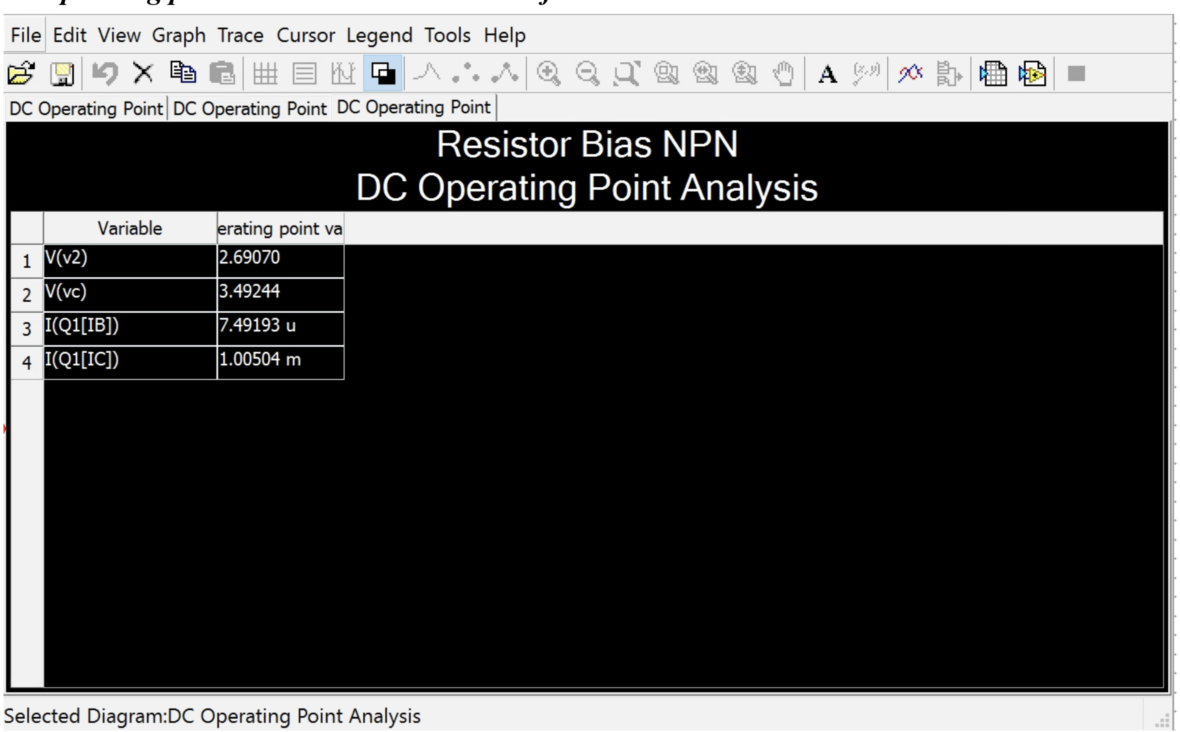
I_c *vs* V_{EC}



Schematic 6a

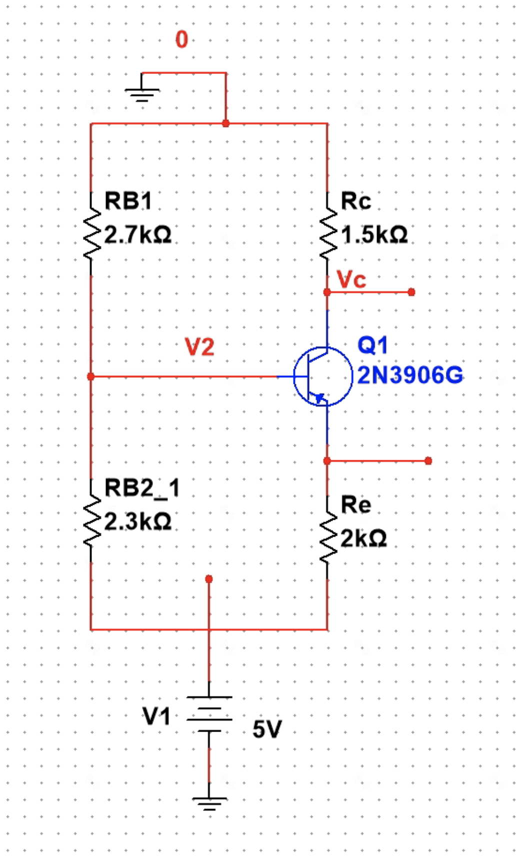


DC operating point or interactive simulation for 6a

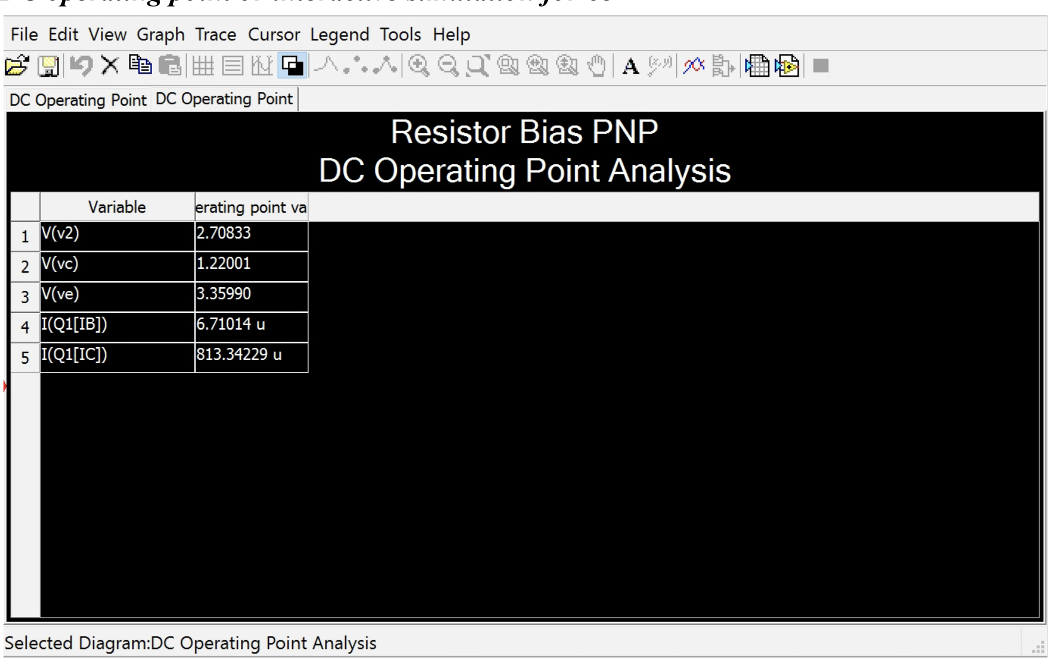


	Variable	erating point va
1	V(v2)	2.69070
2	V(vc)	3.49244
3	I(Q1[IB])	7.49193 u
4	I(Q1[IC])	1.00504 m

Schematic 6b



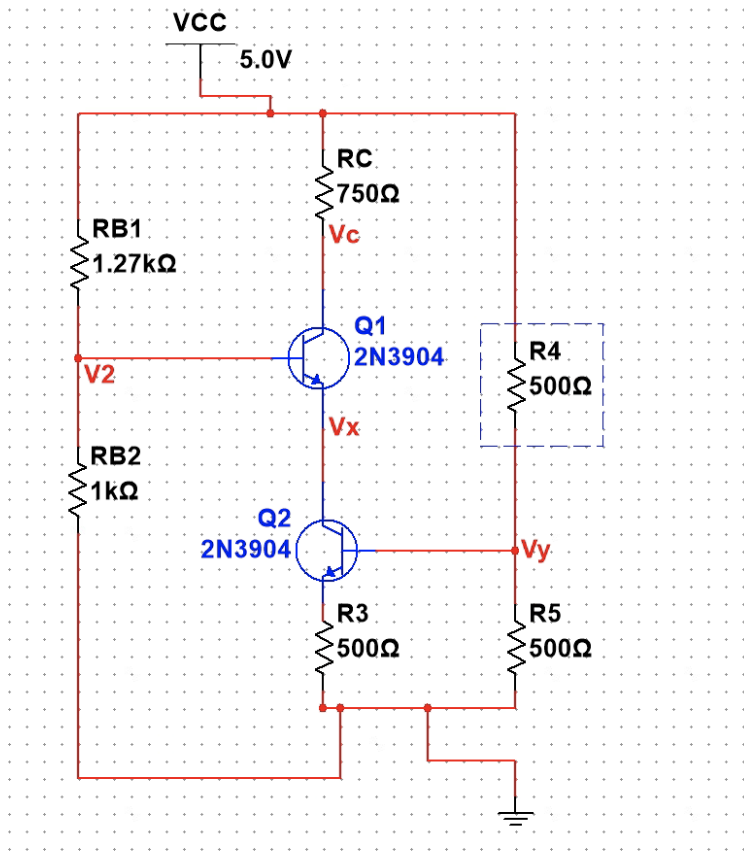
DC operating point or interactive simulation for 6b



Resistor Bias PNP
DC Operating Point Analysis

	Variable	erating point va
1	V(v2)	2.70833
2	V(vc)	1.22001
3	V(ve)	3.35990
4	I(Q1[IB])	6.71014 u
5	I(Q1[IC])	813.34229 u

Schematic 7a



DC operating point or interactive simulation for 7a

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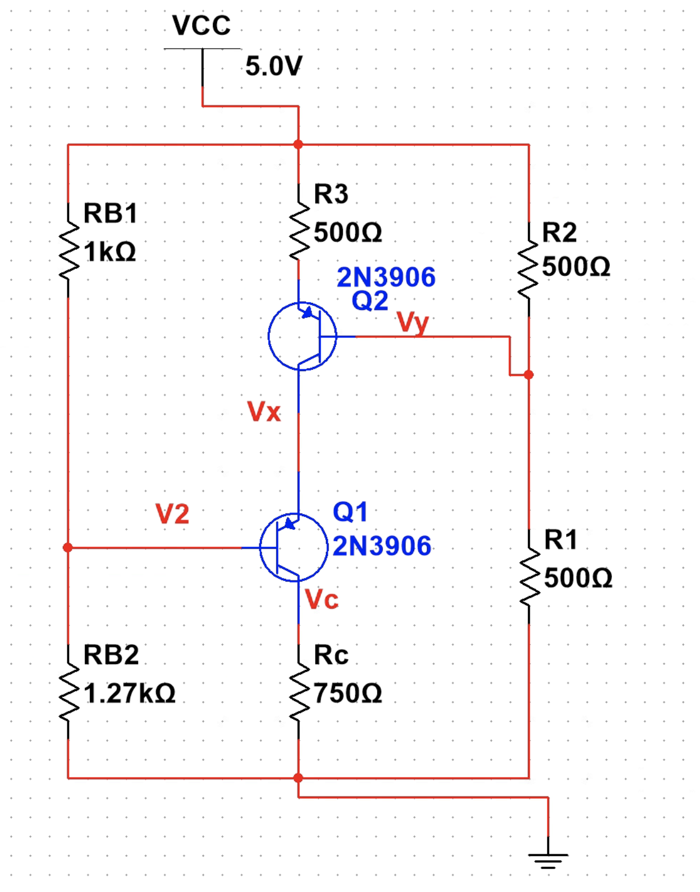
DC Operating Point | DC Operating Point | DC Operating Point

Current Source Bias NPN
DC Operating Point Analysis

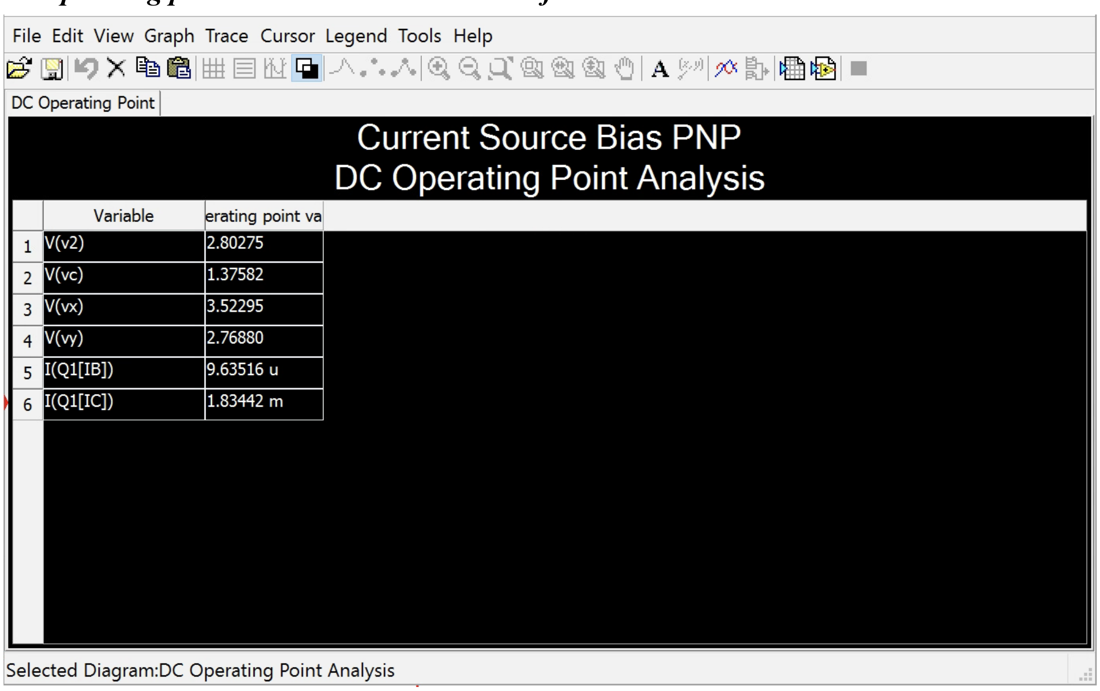
	Variable	erating point va
1	V(v2)	2.19604
2	V(vc)	3.72471
3	V(vx)	1.51676
4	V(vy)	2.18993
5	I(Q1[IB])	11.79822 u
6	I(Q1[IC])	1.70039 m

Selected Diagram:DC Operating Point Analysis

Schematic 8a



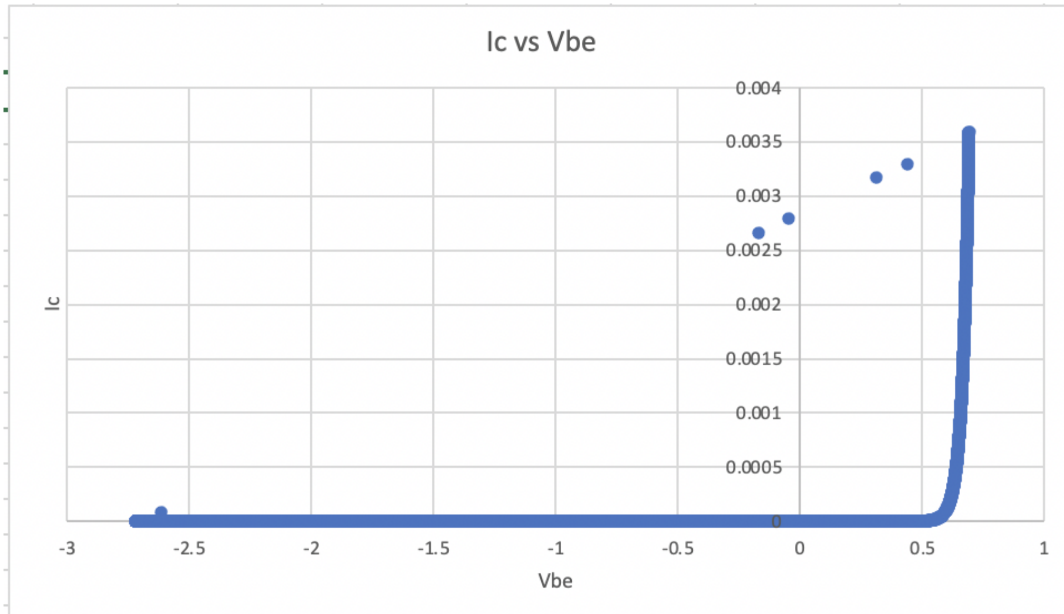
DC operating point or interactive simulation for 8a



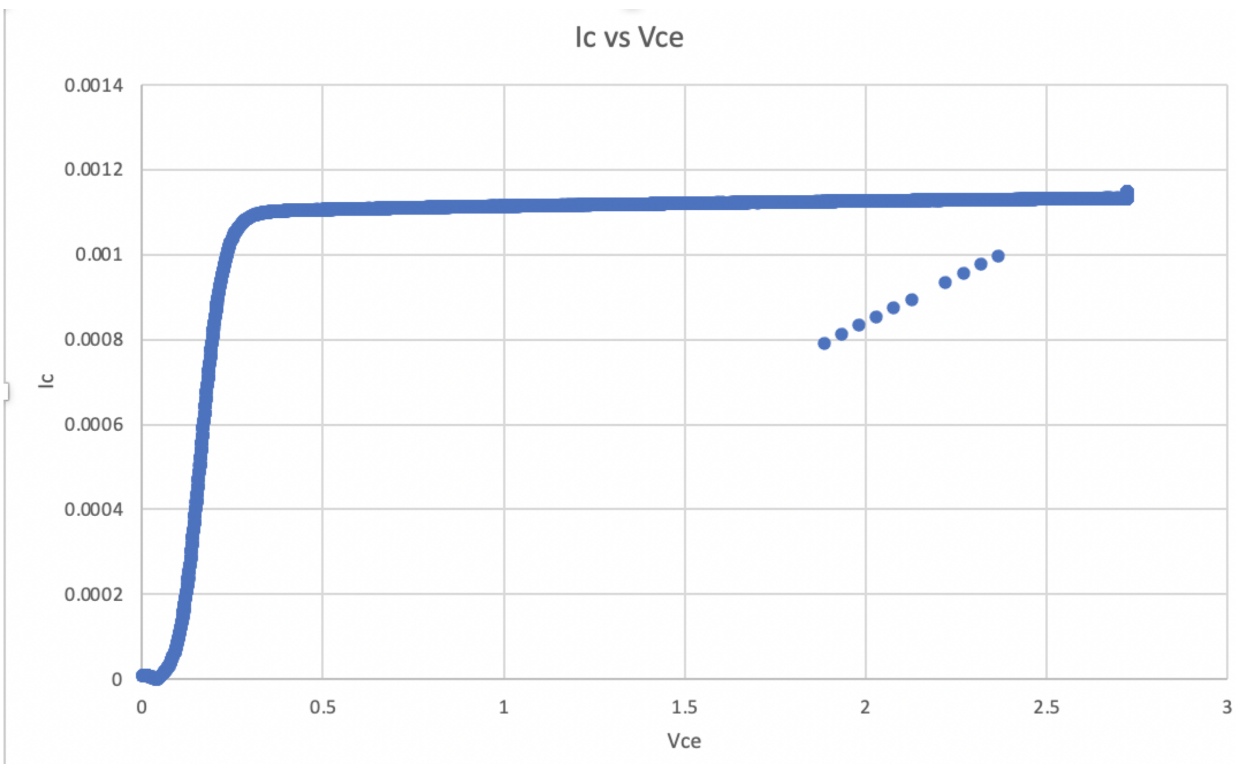
	Variable	erating point va
1	V(v2)	2.80275
2	V(vc)	1.37582
3	V(vx)	3.52295
4	V(vy)	2.76880
5	I(Q1[IB])	9.63516 u
6	I(Q1[IC])	1.83442 m

Measurements

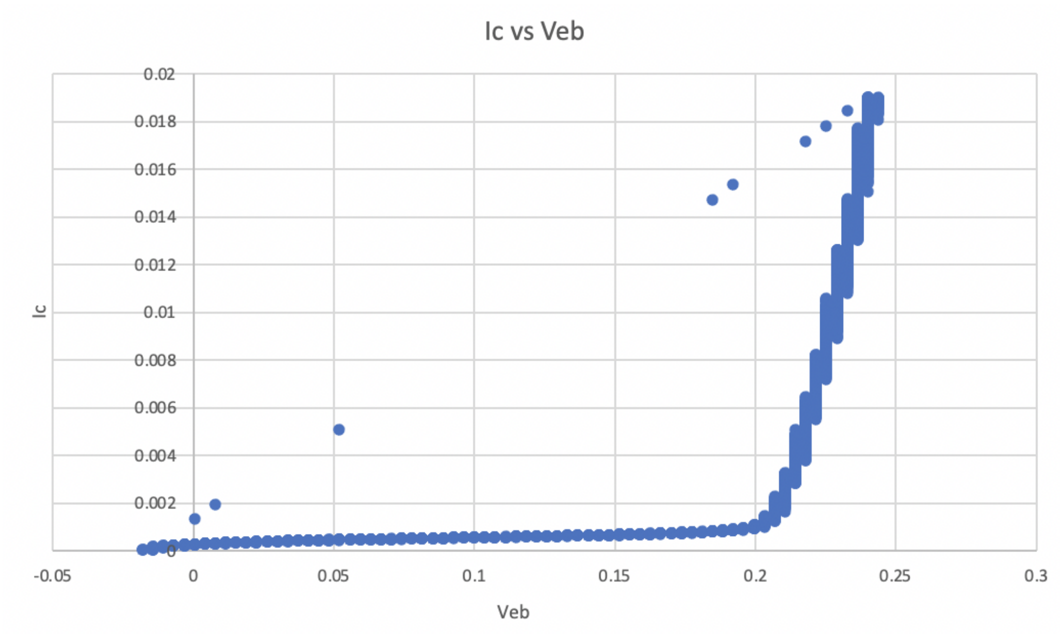
NPN: I_c vs V_{BE}



NPN: I_c vs V_{CE}



PNP: I_c vs V_{EB}



PNP: I_c vs V_{EC}

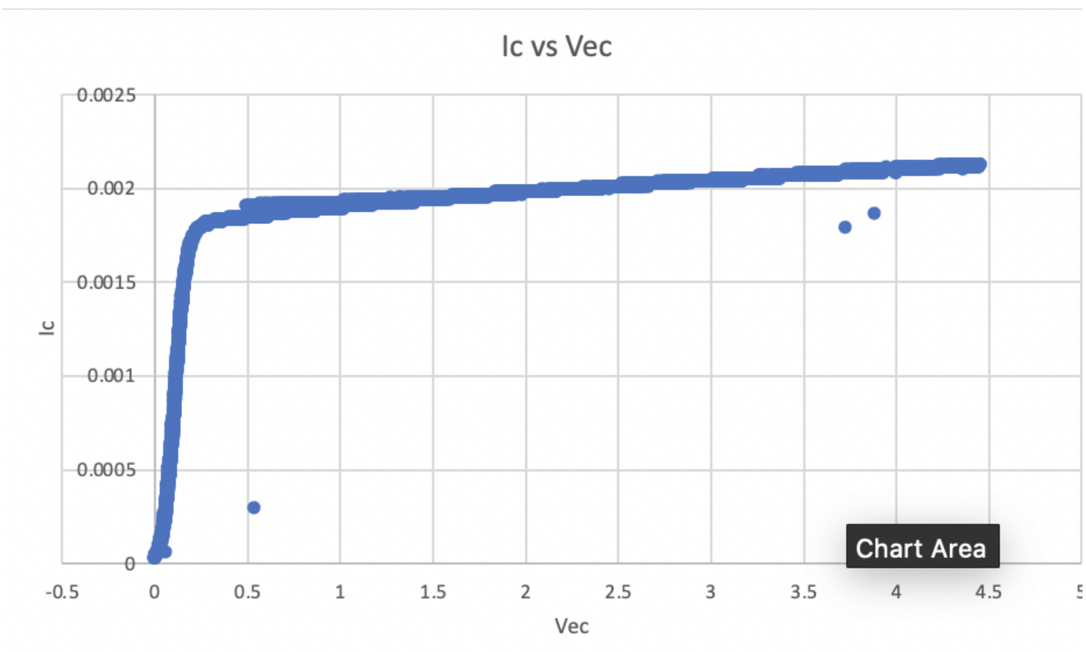


Figure 6 in Data Tables
Figure 7 in Data Tables
Figure 8 in Data Tables

Data Tables

Figure 6a

	I_C	V_B	V_C	V_E	V_2
Simulations	1.00504 mA	1.95601	3.49244	1.80342	2.69070
Measurements	1.17 mA	1.76	3.321	1.611	2.114

Figure 6b

	I_C	V_B	V_C	V_E	V_2
Simulations	813.34229 uA	1.43678	1.22001	3.35990	2.70833
Measurements	8.966 uA	1.345	1.258	3.41	2.711

Figure 7

	I_C	V_C	V_2	V_X	V_Y
Simulations	1.70039 mA	3.72471	2.19604	1.51676	2.18993
Measurements	1.836 mA	3.541	2.314	1.211	2.241

Figure 8

	I_C	V_C	V_2	V_X	V_Y
Simulations	1.83442 mA	1.37582	2.80275	3.52295	2.7688
Measurements	1.932 mA	1.455	2.731	3.431	2.873

Discussion

For lab 7, students learned about DC biasing and characterization of NPN and PNP BJTs. Most of the values between the simulations and measurements were pretty consistent for the circuits. If there were any minor differences, that's probably because of component differences, old breadboards, or loose wires.