

BJT IV Characteristics

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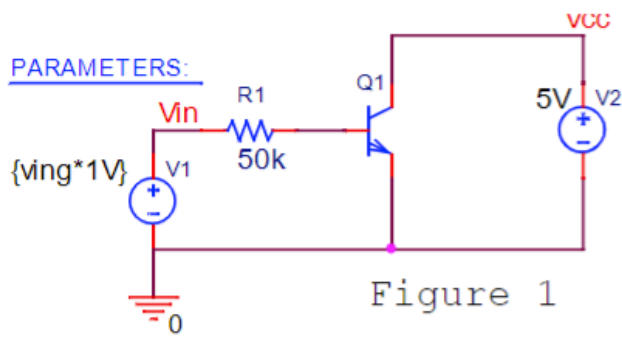
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Executive Summary: This experiment validates the function of a bipolar junction transistor and its different terminals.

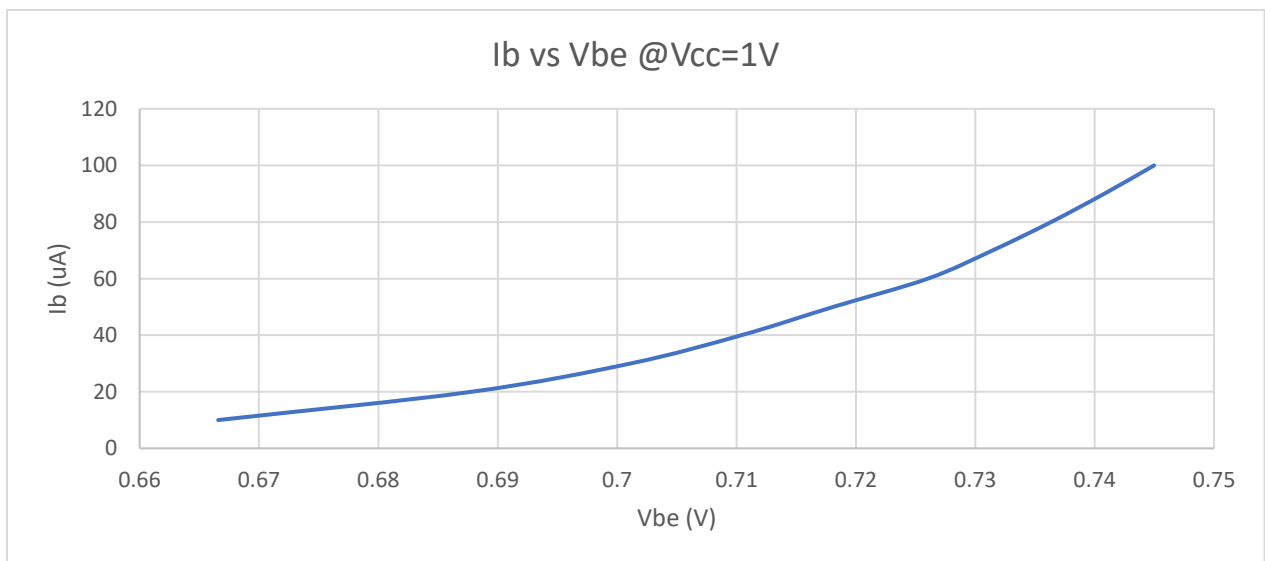
Objective: To study the current voltage relationship of bipolar junction transistors in both a laboratory and simulation setting.

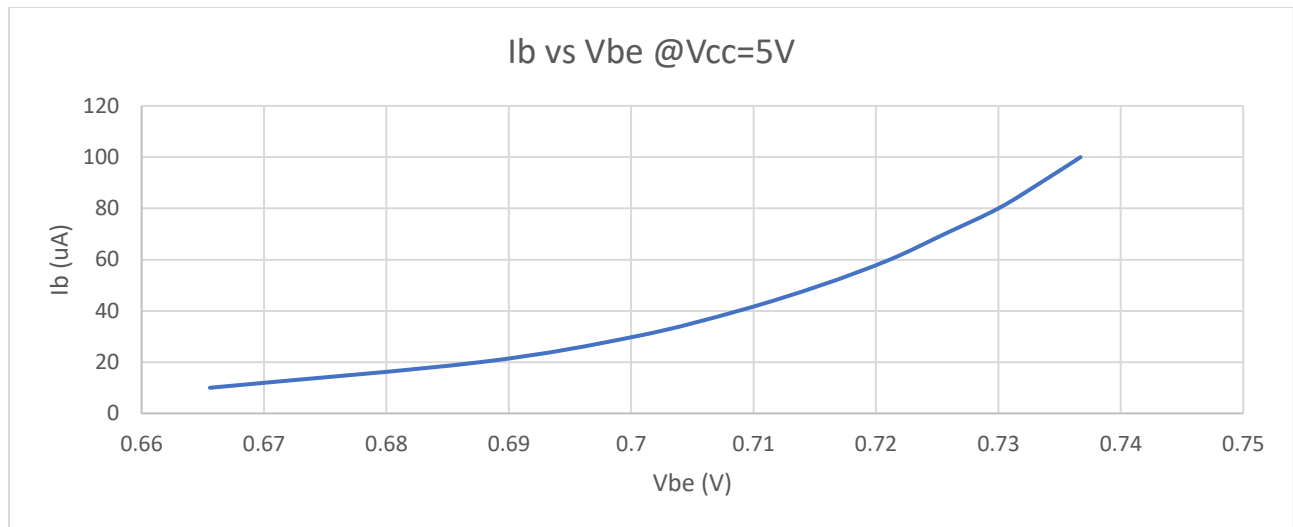
Figure 1 (LAB)

Schematic



Excel Generated Plot

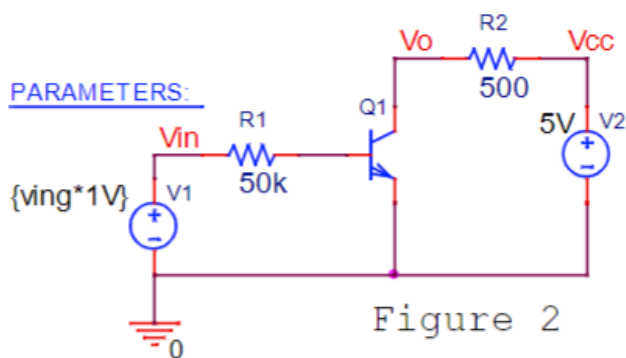




This is the input configuration curve. So between $V_{cc} = 1V$ and $5V$ (which is close to output voltage V_{ce}), there is a small change in input voltage V_{be} while input current I_b is more or less constant, indicating that V_{be} is dependent on V_{cc} or I_c . This aligns with theory: $I_c = I_s \exp(V_{be}/V_t)$ shows that collector (output) current is voltage controlled via V_{be} .

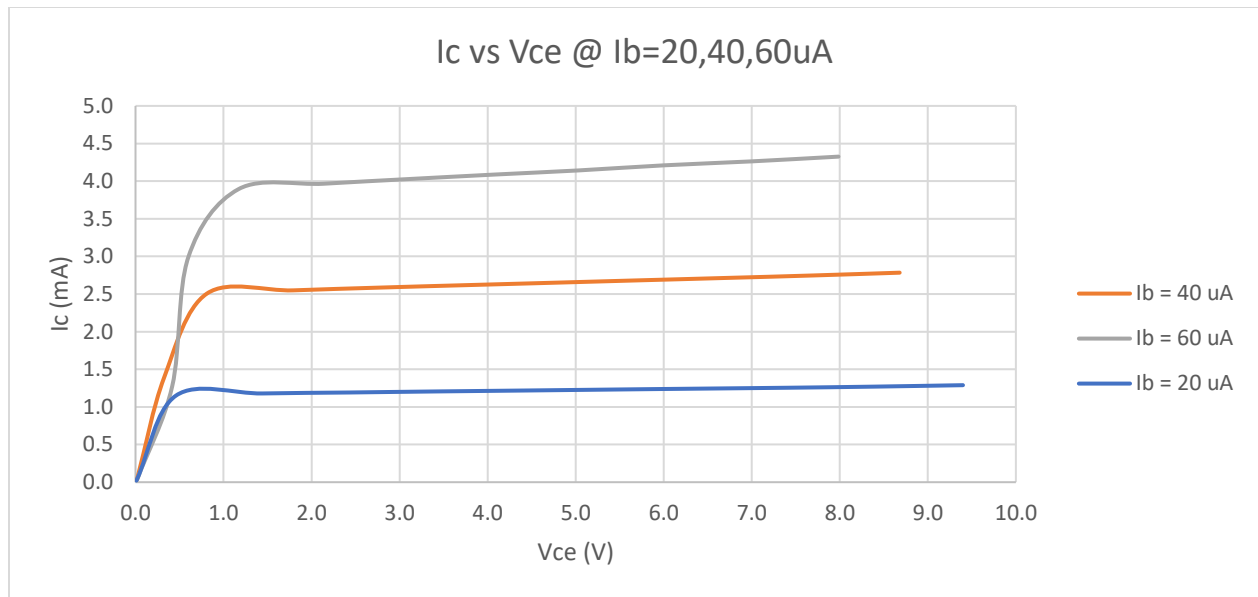
Figure 2 (LAB)

Schematic



Excel Generated Plot

This is the output configuration curve.



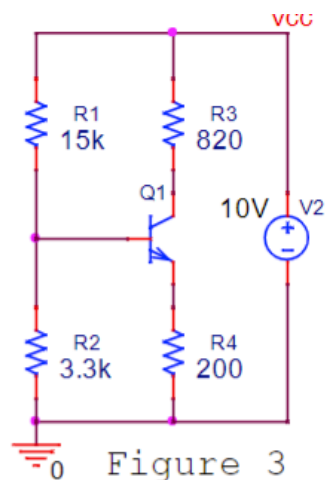
BETA Calculation

At $V_{ce} = 5V$, $I_b = 40\mu A$, $I_c = 2.6mA$, so by $I_c = \beta I_b$, β will be

$\beta = 65$.

Figure 3 (LAB)

Schematic



R differences	Vc	Ve	Vce [V]	Ib [mA]	Ic [mA]	gain (beta)
R1=14.7k	7	1.2	5.8	0.06481	4.684	72.2728
R3=680						

Betas for figures 2 and 3 are similar in magnitude 65 vs 72.

Figure 1 (SIM)

Schematic same as in lab portion of this report.

Simulation Profile

General
Analysis
Configuration Files
Options
Data Collection
Probe Window

Analysis Type:
DC Sweep

Options:

- ☒ Primary Sweep
- ☐ Secondary Sweep
- ☐ Monte Carlo/Worst Case
- ☒ Parametric Sweep
- ☐ Temperature (Sweep)
- ☐ Save Bias Point
- ☐ Load Bias Point

Sweep Variable

- ☐ Voltage source Name: V2
- ☐ Current source Model type:
- ☒ Global parameter Model name:
- ☐ Model parameter Parameter name:
- ☐ Temperature

Sweep Type

- ☒ Linear Start Value: 1 End Value: 5
- ☐ Logarithmic Decade Increment: 1
- ☐ Value List

General Analysis Configuration Files Options Data Collection Probe Window

Analysis Type:
DC Sweep

Options:

- ☒ Primary Sweep
- ☐ Secondary Sweep
- ☐ Monte Carlo/Worst Case
- ☒ Parametric Sweep
- ☐ Temperature (Sweep)
- ☐ Save Bias Point
- ☐ Load Bias Point

Sweep Variable

- ☐ Voltage source Name:
- ☐ Current source Model type:
- ☒ Global parameter Model name:
- ☐ Model parameter Parameter name:
- ☐ Temperature

Sweep Type

- ☒ Linear Start Value: End Value: Increment:
- ☐ Logarithmic Decade Increment:
- ☐ Value List

Excel Generated Plot

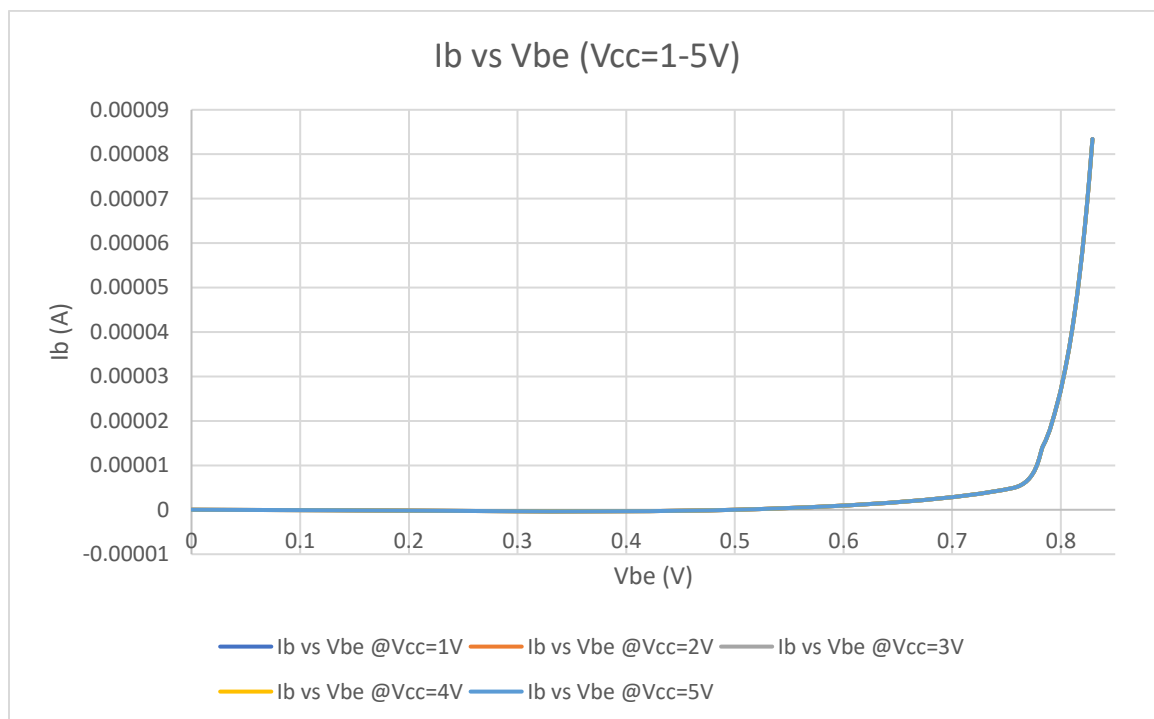


Figure 2 (SIM)

Schematic same as in lab portion of this report.

Simulation Profile

General

Analysis

Configuration Files

Options

Data Collection

Probe Window

Analysis Type:

DC Sweep

Options:

☒ Primary Sweep

☐ Secondary Sweep

☐ Monte Carlo/Worst Case

☒ Parametric Sweep

☐ Temperature (Sweep)

☐ Save Bias Point

☐ Load Bias Point

Sweep Variable

☐ Voltage source

Name:

☐ Current source

Model type:

☒ Global parameter

Model name:

☐ Model parameter

Parameter name:

vinb

☐ Temperature

Sweep Type

☒ Linear

Start Value:

1

☐ Logarithmic

Decade

End Value:

5

☐ Value List

Increment:

0.5

General

Analysis

Configuration Files

Options

Data Collection

Probe Window

Analysis Type:

DC Sweep

Options:

☒ Primary Sweep

☐ Secondary Sweep

☐ Monte Carlo/Worst Case

☒ Parametric Sweep

☐ Temperature (Sweep)

☐ Save Bias Point

☐ Load Bias Point

Sweep Variable

☒ Voltage source

Name:

V2

☐ Current source

Model type:

☐ Global parameter

Model name:

☐ Model parameter

Parameter name:

☐ Temperature

Sweep Type

☒ Linear

Start Value:

0

☐ Logarithmic

Decade

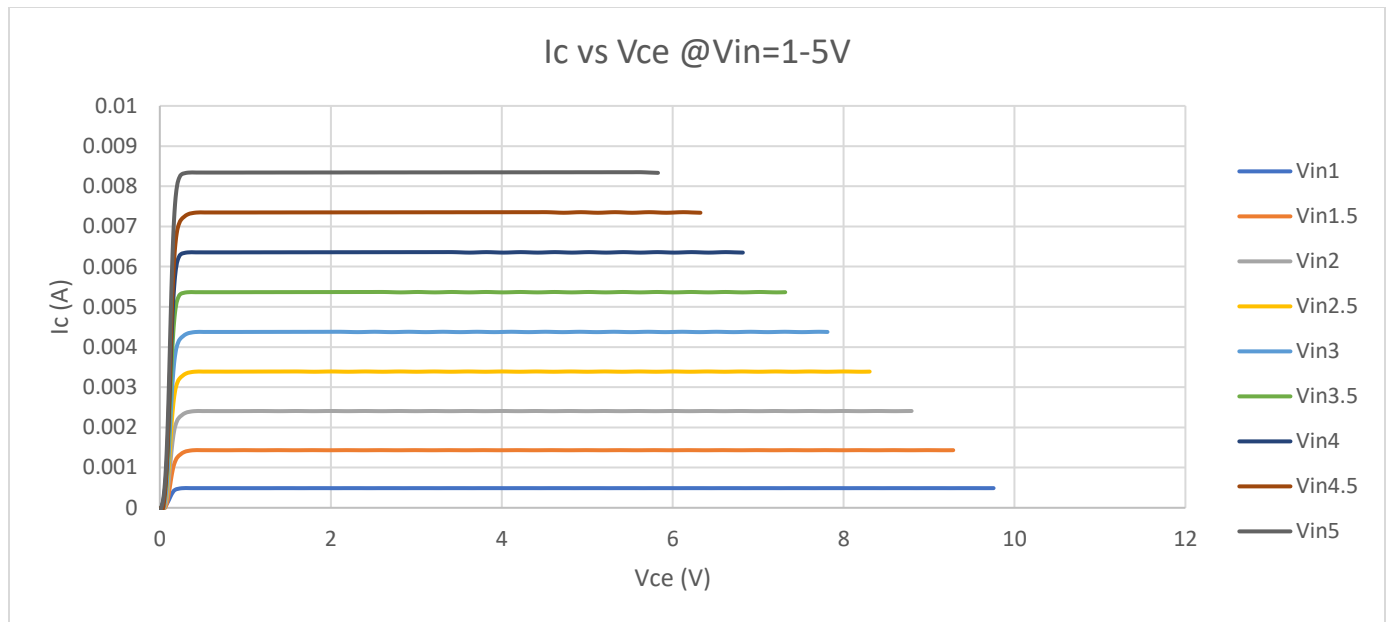
End Value:

10

Increment:

0.1

Excel Generated Plot

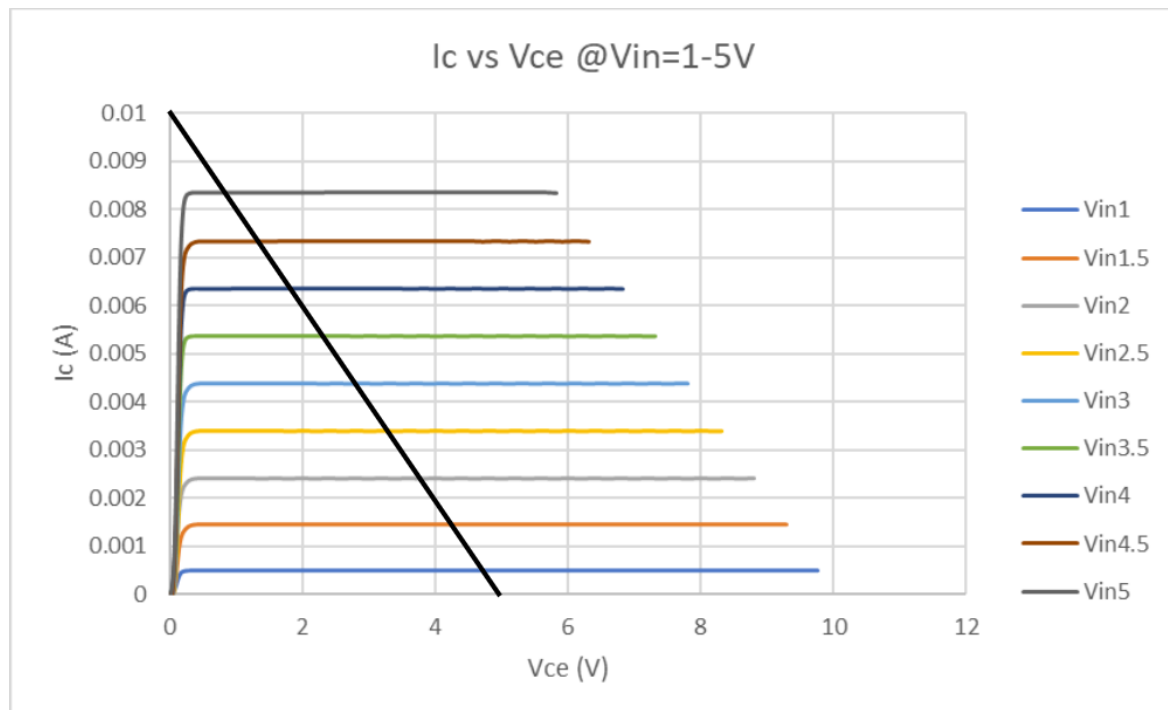


As V_{in} (and therefore input voltage V_b) increases, I_c increases and V_{ce} decreases. V_b 's increase corresponds to V_{be} 's increase, so the $I_c = I_s \exp(V_{be}/V_t)$ relationship is maintained.

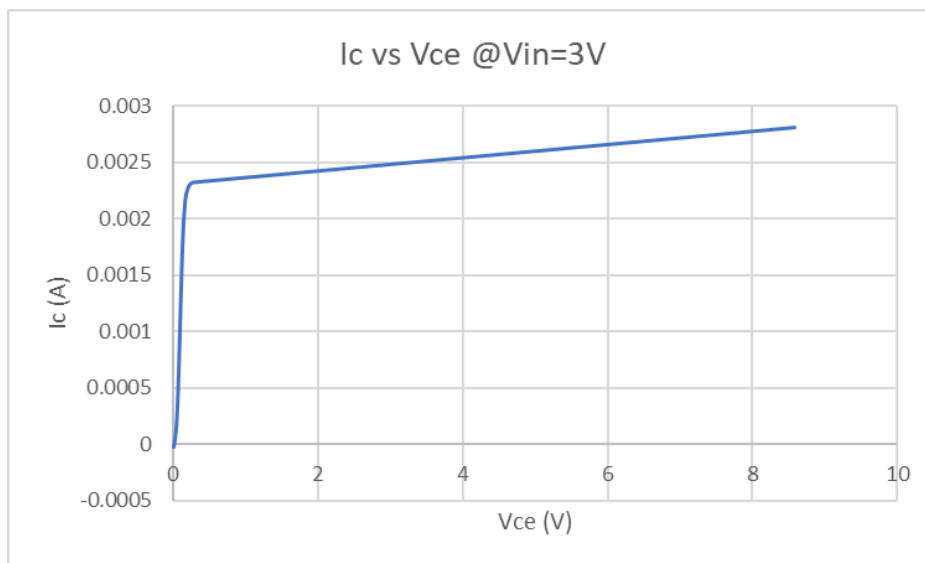
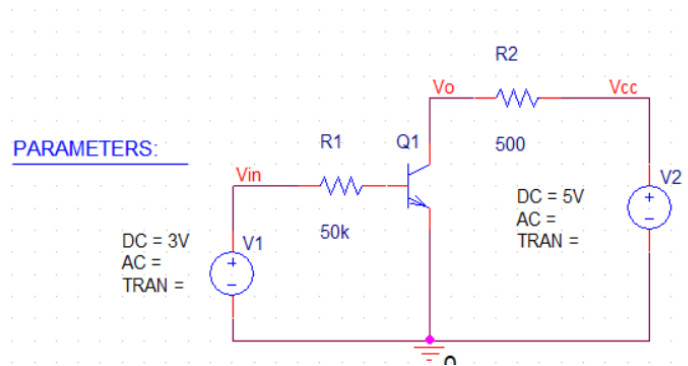
1. Load Line

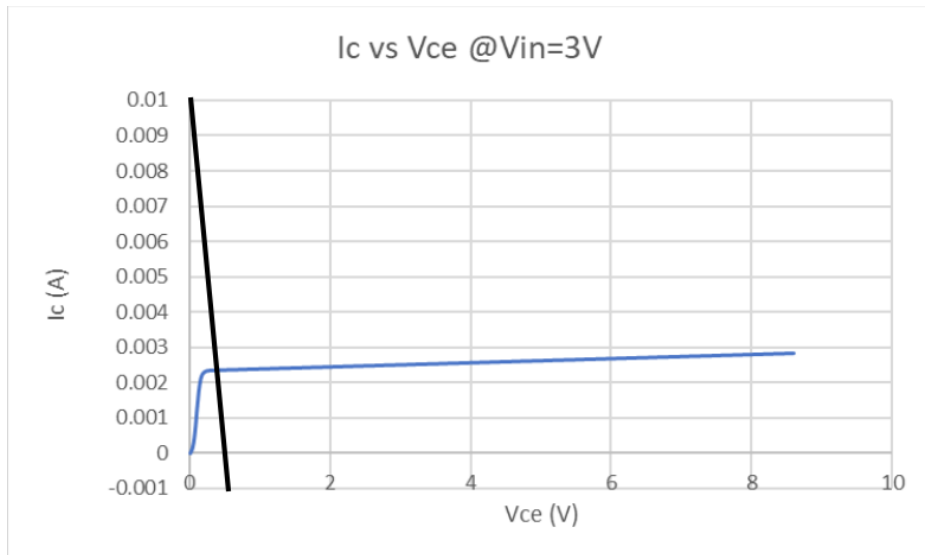
Y intercept is $V_{cc}/R = 5V/500\Omega = 10mA$.

X intercept is $V_{ce} (V_o) = 5V$ /// slope = $-1/500\Omega$



2. At $V_{in}=3V$, $V_o (V_{ce}) = 2.9V$ & $I_c = 4.4 \text{ mA}$. This is the operating point (Qpoint).
3. If $V_{be} = 0.812V$ @ the Qpoint ($V_{ce} = 2.9V$, $I_c = 4.4mA$, $V_{in} = 3V$), then what is Beta?
 $V_b = V_{be}$ because emitter is grounded, so $I_b = V_b/R_1 = 0.812/50k = 16.24\mu A$.
 Now $I_c = \beta I_b$ gives $\beta = 270.94$.
4. If $V_{in} = 3V$, $V_a = 50V$ (aka $-50V$), then $V_o (V_{ce}) = 2.9V$, $I_c = I_{c0}(1+V_{ce}/V_a) = 46.552mA$. Transistor is in forward active.
5. Schematic (@ Beta = 50)



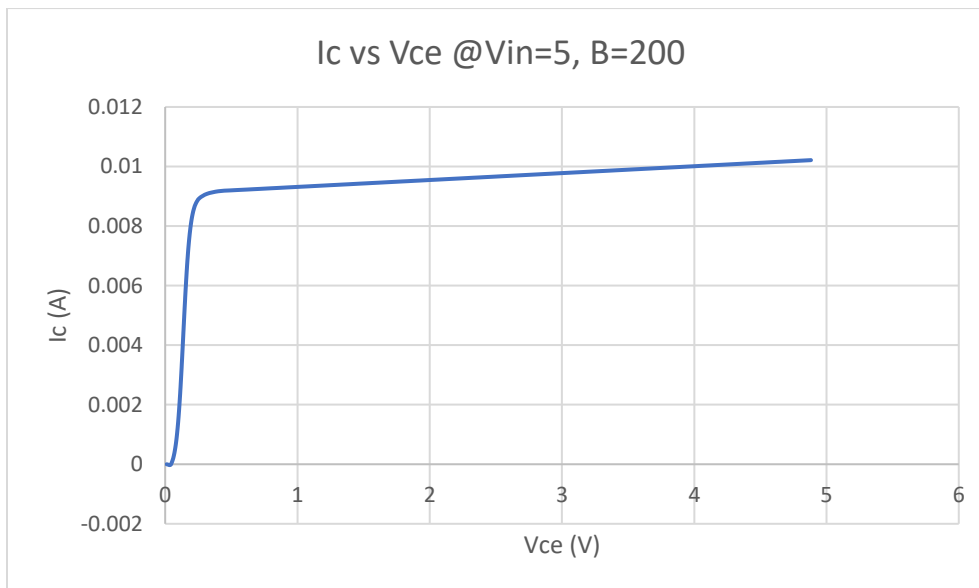


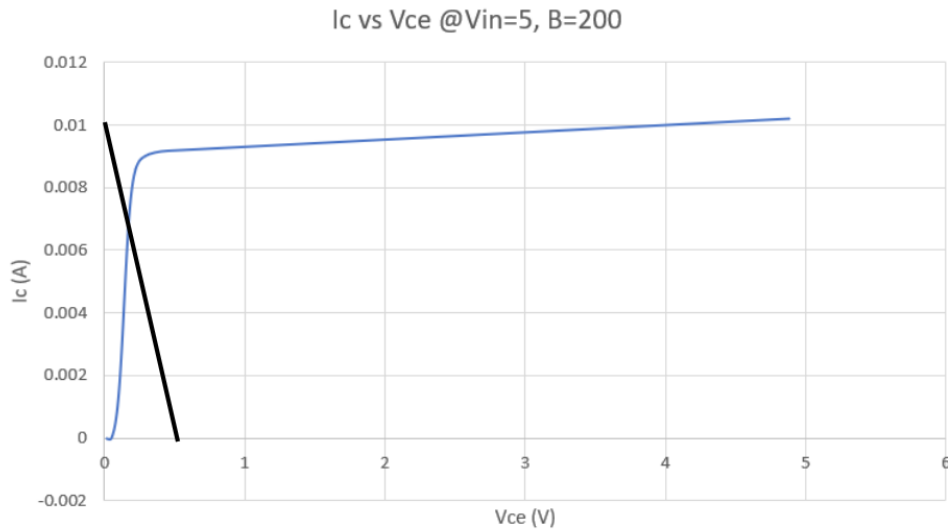
Qpoint is at $V_{ce} = 0.4V$, $I_c = 2.5mA$, transistor is in forward active mode.

Y intercept = $V_{cc}/R = 10mA$.

X intercept = $I_c = -V_{ce}/500 + 10mA$, solving for V_{ce} when $I_c = 0$ gives $0.55V$.

Now @ Beta=200





1. Qpoint is at $V_o (V_{ce}) = 0.25V$, $I_c = 7mA$, transistor is in saturation mode.

Y intercept = $V_{cc}/R = 10mA$.

X intercept = $I_c = -V_{ce}/500 + 10mA$, solving for V_{ce} when $I_c = 0$ gives 0.55V.

2. Now, (still in $B=200$ case) if $V_o = 4V$, what is the new value of R_2 @ $V_{in}=3V$?

$I_c = 10mA$, $R_2 = (V_{cc}-V_o)/I_c = (5-4)/10mA = 100 \text{ ohm}$

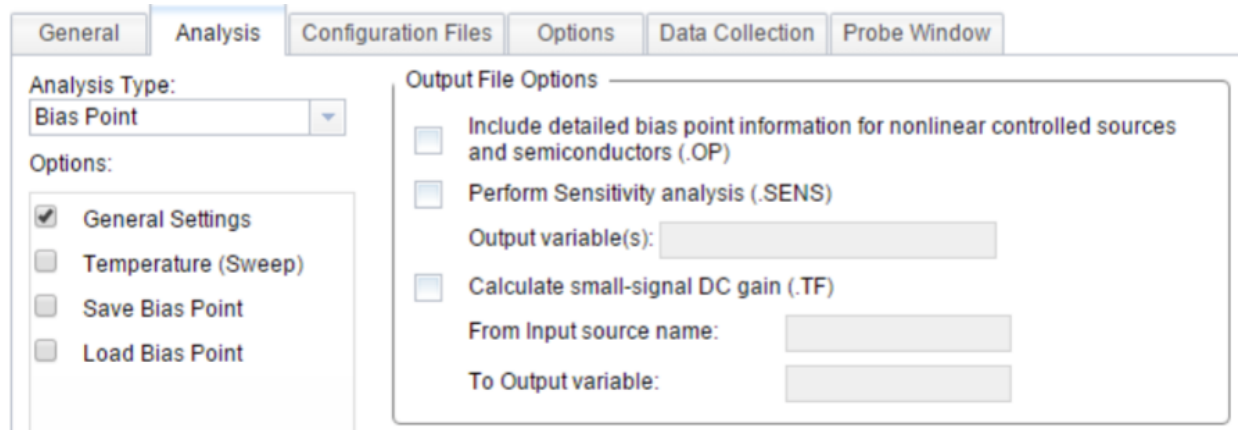
3. Now if $V_o = 4V$, $R_2 = 500 \text{ ohm}$, what is V_{cc} ?

$I_c = 10mA$, $10mA = (V_{cc}-4V)/500ohm$, $V_{cc} = 5-4 = 1V$

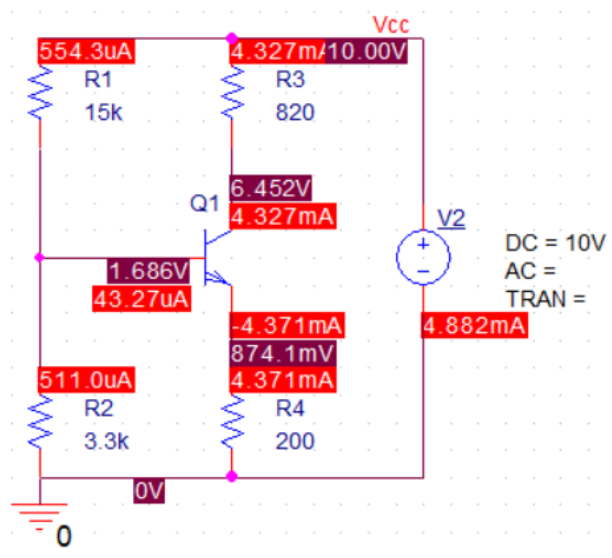
Figure 3 (SIM)

Schematic same as in lab portion of this report.

Simulation Profile



PSpice Generated Bias Point Simulation



$$\text{Beta} = I_c / I_b = 4.327\text{mA} / 43.27\text{uA} = 100$$

Analysis

Addendum or Reference

Excel Generated Data (some datasets may be linked if too large)

Figure 1 (LAB)

	Vcc (V)	Vce [V]	Ic [mA]
Ib = 20uA	0	0.01007	0.02073
Vbe = 1.8V	1	0.459	1.15
R = 51K, 470	2	1.443	1.179
Vs=1.69V	3	2.43	1.192
	4	3.43	1.21E+00
	5	4.415	1.22E+00
	6	5.405	1.23E+00
	7	6.39	1.24E+00
	8	7.408	1.26E+00
	9	8.393	1.27E+00
	10	9.399	1.29E+00

Figure 2 (LAB)

	Vcc (V)	Vce [V]	Ic [mA]
Ib = 40uA	0	1.64E-02	3.40E-02
Vbe = 2.8V	1	0.326	1.39E+00
R = 51K, 470	2	0.811	2.51E+00
Vs=2.73V	3	1.792	2.55E+00
	4	2.78	2.59E+00
	5	3.75	2.62E+00
	6	4.74	2.65E+00
	7	5.712	2.68E+00
	8	6.712	2.71E+00
	9	7.7	2.75E+00
	10	8.68	2.78E+00

	Vcc (V)	Vce [V]	Ic [mA]
Ib = 60uA	0	2.03E-02	0.0395

Vbe = 3.8V	1	0.417	1.276
R = 51K, 470	2	0.6	2.99
Vs=3.76V	3	1.172	3.895
	4	2.14	3.966
	5	3.103	4.028
	6	4.08	4.088
	7	5.035	4.143
	8	6	4.21
	9	7	4.263
	10	7.985	4.326

Figure 3 (LAB)

	Vc	Ve	Vce [V]	Ib [mA]	Ic [mA]	gain (beta)
R1=14.7k	7	1.2	5.8	0.06481	4.684	72.2728
R3=680						

Figure 1 (SIM)

[2200L-L5model1.xlsx](#)

Figure 2 (SIM)

[2200L-L5model2.xlsx](#)

[2200L-L5model2.1.xlsx](#)

[2200L-5model2.2.xlsx](#)

