THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2115: ENGINEERING ELECTRONICS LABORATORY

Tutorial #3:
Parametric Sweep Simulation of a BJT

INTRODUCTION

In this tutorial, we will discuss how to generate a typical I-V curve for a Bipolar Junction Transistor (BJT) in Multisim. To do this, a DC Sweep simulation will be combined with a parametric simulation.

BACKGROUND

Bipolar Junction Transistors

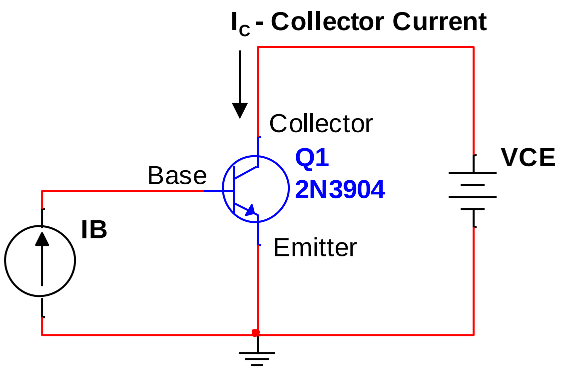

Figure 1 – BJT Test Circuit

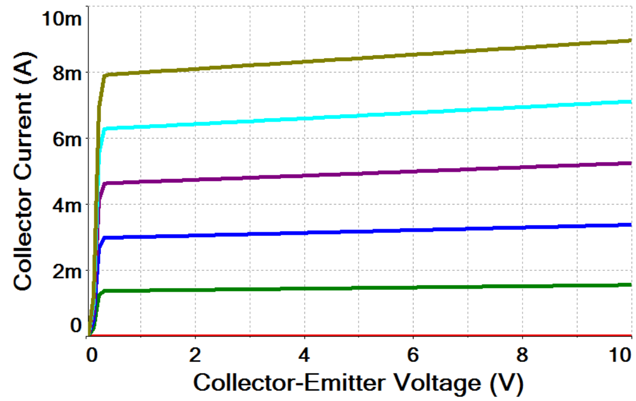

Figure 2 – BJT I-V Curve

A **Bipolar Junction Transistor** (BJT) is a three-terminal non-linear device. Current applied to the base of the transistor (I_B) controls the amount of current that will flow from the collector to the emitter (I_C). In theory, this is a "Current Controlled Current Source" (CCCS). I_B is the "control," and the Collector-Emitter terminals act like those of a "current source," where the current is I_C.

In order to "turn on" the BJT device, we follow a two-step process:

1. **Apply voltage** across the **Collector-Emitter** terminals (V_{CE}).
2. **Apply current** to the **base** terminal (I_B). Then current (I_C) will flow from the collector to the emitter, behaving as a current source.

To **characterize** the full range of operation of the device, we vary both $\mathbf{V_{CE}}$ and $\mathbf{I_B}$ to see the variation in $\mathbf{I_C}$. The test circuit used to characterize a BJT device is shown in **Figure 1** above. The typical I-V curve that this test circuit will produce is shown in **Figure 2** above. This tutorial will explain how to produce the I-V curve using Multisim.

INSTRUCTIONS

Part I – Plotting a Single I-V Curve for a BJT

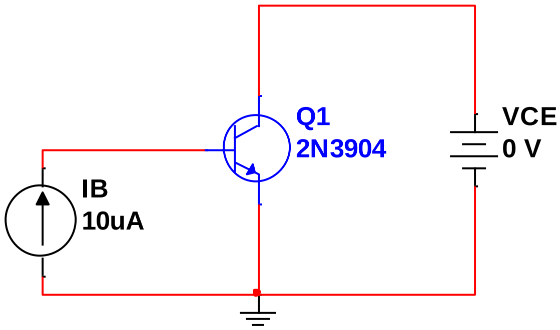

Figure 3 – BJT Characterization Circuit

1. **Build** the circuit in **Figure 3** in Multisim.
    a. By default, the current source (I_{DC}) and voltage source (V_{DC}) will be named I1 and V1, respectively. **Rename** them to I_B and V_{CE} as you see in the schematic above.
    b. Make certain that the current source is upwards so current goes "into" the base.
    c. **Set V_{CE} = 0V** and **I_B = 10μA**.
2. **Run** a **DC Sweep Analysis** to "sweep" V_{CE} from 0V to 10V while I_B pushes 10μA into the base of the transistor and observe its effect on I_C.
    a. **Set** the **Source** to be V_{CE}
    b. **Start value:** 0V
    c. **Stop value:** 10V
    d. **Increment:** 0.1V
    e. **Select** I_C of the transistor as the output
3. **Press Simulate** and you should see the following graph.

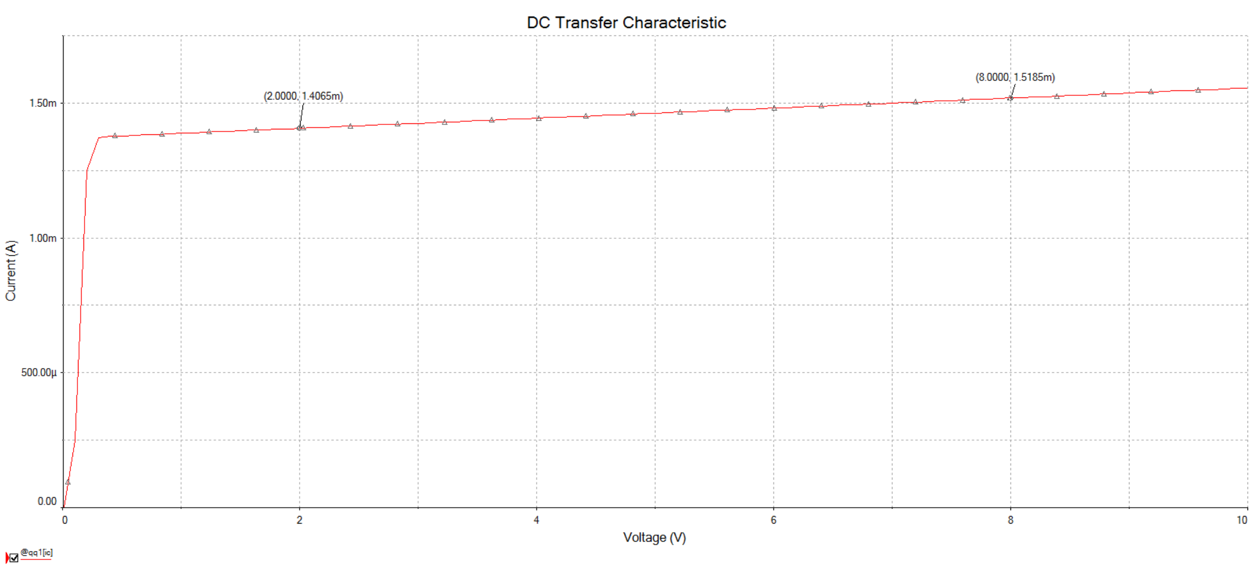

Figure 4 – I-V Curve for 2N3904 BJT (I_B = 10μA)

Note: *This is a single I-V curve for a BJT. The x-axis is the "swept" variable (V_{CE}) and the y-axis is the collector current. From the markers on the graph, we see that for I_B = 10μA and V_{CE} = 2V, I_C = 1.4065mA. When I_B = 10μA and V_{CE} = 8V, I_C = 1.5185mA.*

Part II – Plotting a Family of I-V Curves for a BJT

In the simulation above, I_B was fixed at 10µA while V_{CE} was swept. Now we would like to see how the BJT behaves if both V_{CE} *and* I_B are swept. This is known as a DC Sweep combined with a Parametric Sweep, often called a "**parametric simulation**." In our case, I_B is the "parameter"' we wish to vary while V_{CE} is swept.

1. **Using** the **same circuit** from the previous simulation, reopen the **DC Sweep Analysis** settings.
2. **Click** the box next to **Use source 2** to enable the second parameter I_B and enter these settings.
    a. **Set** the **Source** to be I_B
    b. **Start value:** 0A
    c. **Stop value:** 50µA (50e-6)
    d. **Increment:** 10µA (10e-6)
3. **Run** the simulation and the following graph should appear.

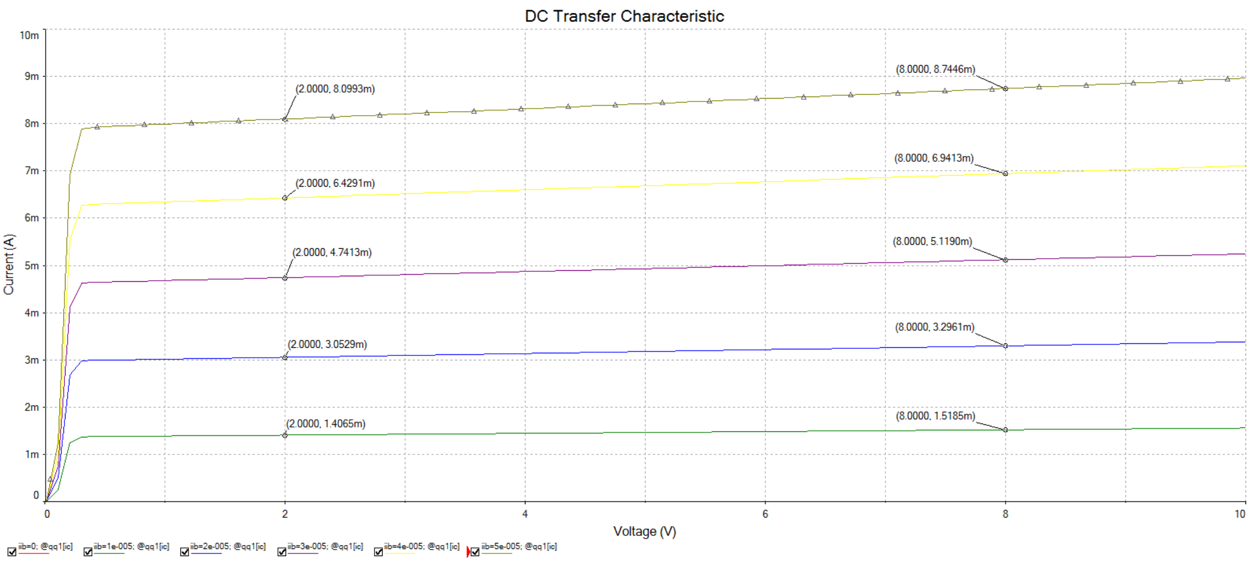

Figure 5 – Family of I-V Curves for 2N3904 BJT (0µA ≤ I_B ≤ 50µA)

Note: *This is called a family of I-V curves for a BJT. The x-axis is still the "swept" variable (V_{CE}) and the y-axis is still the collector current. However, now there is one I-V curve for each value of I_B that we specified: 0µA, 10µA, 20µA, 30µA, 40µA, and 50µA.*

From the markers on the blue graph, we can interpret the following:

- *When I_B = 10µA and V_{CE} = 2V, I_C = 1.4065mA.*
- *When I_B = 10µA and V_{CE} = 8V, I_C = 1.5185mA.*

From the markers on the top green graph, we can interpret the following:

- *When I_B = 50µA and V_{CE} = 2V, I_C = 8.0993mA.*
- *When I_B = 50µA and V_{CE} = 8V, I_C = 8.7446mA.*

What is incredibly important to take away from the second graph is the effect of I_B on the transistor. Notice that I_C (collector current) is small (~1.5mA) when I_B is small (10µA) for the given values of V_{CE}. But when we increase I_B to 50µA, I_C is much, much higher (~8.5mA) for the same values of V_{CE}! In effect, I_B has "controlled" the value of I_C, showing how this device behaves as a "current controlled current source." It can be confusing, but if you look at the graph and ask questions in lab, this will be clearer.