THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

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

Experiment #5:
Characterization of an NPN Bipolar Junction Transistor (BJT)

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	1kΩ	R_B	Basic/Resistor	---
Resistor	100kΩ	R_C	Basic/Resistor	---
Transistor	2N3904	Q_1	Transistors/BJT_NPN/2N3904	NPN BJT

Table 1 – Component List

OBJECTIVES

· To characterize a BJT using a DC power supply and DMM
· To compare measured characterization results to manufacturer specifications

PRELAB

Part I – Generate Equipment List

1. Read through the lab manual and generate an equipment list.

Part II – Parametric Sweep Simulation of a BJT

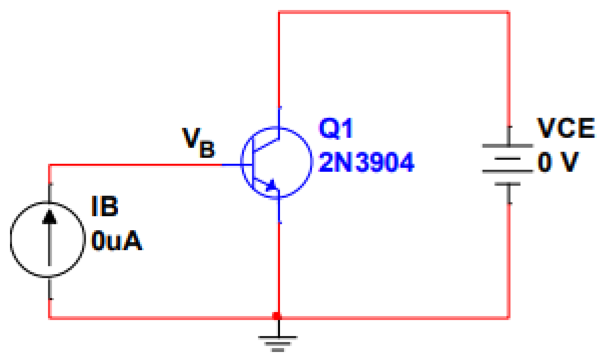


Figure P.1 – BJT Test Circuit

1. **Build** and **simulate** the circuit in **Figure P.1** using Multisim.
   a. **Use** the "**Parametric Sweep Simulation of a BJT**" tutorial on the lab website to generate an I-V curve (I_C vs. V_{CE}) for the 2N3904 BJT.
   b. **Sweep** V_{CE} from **0V** to **10V** in **0.2V** increments.
   c. **Sweep** I_B from **10μA** to **50μA** in **20μA** increments.
   d. **Plot** the collector current to generate three different I-V curves.
   e. **Place** markers at **V_{CE} = 2V** on each curve.
   f. **Record** the values for **V_{CE}**, **I_C**, and **I_B** from the markers in **Table P.1**.
   g. **Re-run** the simulation, plotting the voltage at node **V_B** instead of the collector current and again place markers at **V_{CE} = 2V.**
   h. **Record** the values for **V_{BE}** from the markers in **Table P.1**.

I_B	Value	Calculated	Simulated	Measured
10μA	I_B			
	V_{CE}			
	I_C			
	V_{BE}			
	β			
30μA	I_B			
	V_{CE}			
	I_C			
	V_{BE}			
	β			
50μA	I_B			
	V_{CE}			
	I_C			
	V_{BE}			
	β			

Table P.1 – BJT Values

Part III – BJT Calculations

1. **Use Equation P.1** to calculate IC and record the values in the calculated section of **Table P.1**.
    a. **Calculate** I_C for each value of V_{BE} collected in the simulations in **Part II**.
    b. **Assume I_S = 6.734fA** and the typical value for **V_T = 26mV** (thermal voltage).
    c. **Calculate** the value of the DC current gain (**$\beta = I_C / I_B$**) for each value of I_B in **Table P.1**.

$$I_C \cong I_S\left(e^{\frac{V_{BE}}{V_T}}\right)$$

Equation P.1 – Collector Current of NPN BJT in the Active Region of Operation (Assumes $V_A >> V_{CE}$ and n = 1)

Part IV – Specification Sheet Values

1. In the simulation above, we have swept V_{CE} from 0V to 10V and I_B from 10µA to 50µA. However, the 2N3904 BJT can handle a significantly higher set of values.
    a. From the specification sheet for the 2N3904 BJT, gather the following specifications:

Parameter	***Value***
Maximum Collector-Emitter Voltage (V_{CEO})	
Maximum Emitter-Base Voltage (V_{EBO})	
Maximum Continuous Collector Current (I_C)	
Maximum Collector-Base Voltage (V_{CBO})	
Maximum DC Current Gain (β or h_{FE})	
Base-Emitter ON Voltage (V_{BE}) when V_{CE}=5V and I_C=10mA at room temperature	

Table P.2 – 2N3904 BJT Spec Sheet Values

LAB

Part I – Transistor Characterization Using a Test Circuit

In this part of the lab, you will generate only three I-V curves (I_C vs. V_{CE}) as you did in the prelab. I_B will be the parameter whose value will step from 10µA to 50µA in 20µA steps.

In the prelab, you generated an I-V curve for the 2N3904 transistor using the schematic in **Figure P.1**. You were able to generate base current I_B in the range of 0µA to 50µA. In the lab, the power supply can behave as a current source, but it **cannot** produce a current as small as 50µA. To create the same family of I-V curves in the lab, we must use the circuit in **Figure 2.1**. The voltage source combined with the 100kΩ resistor at the base will behave as the 0µA to 50µA current source from **Figure P.1**.

The data collected during this part of the lab is to be recorded under the ***Measured*** column of **Table**

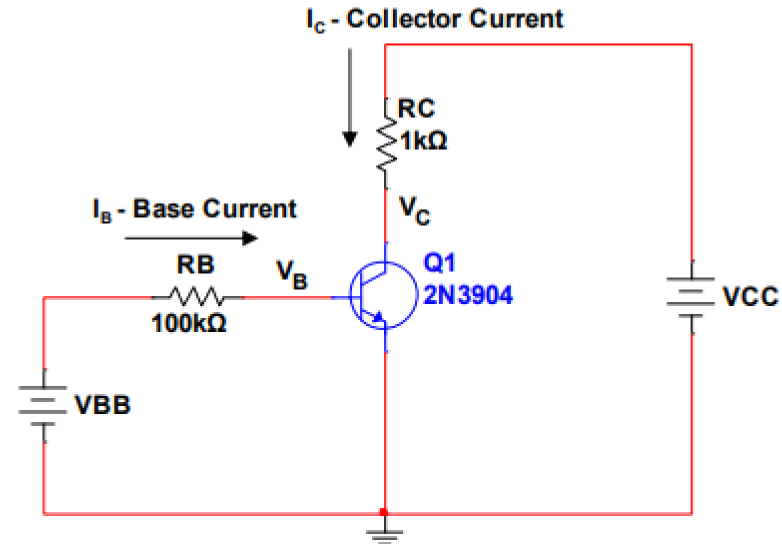
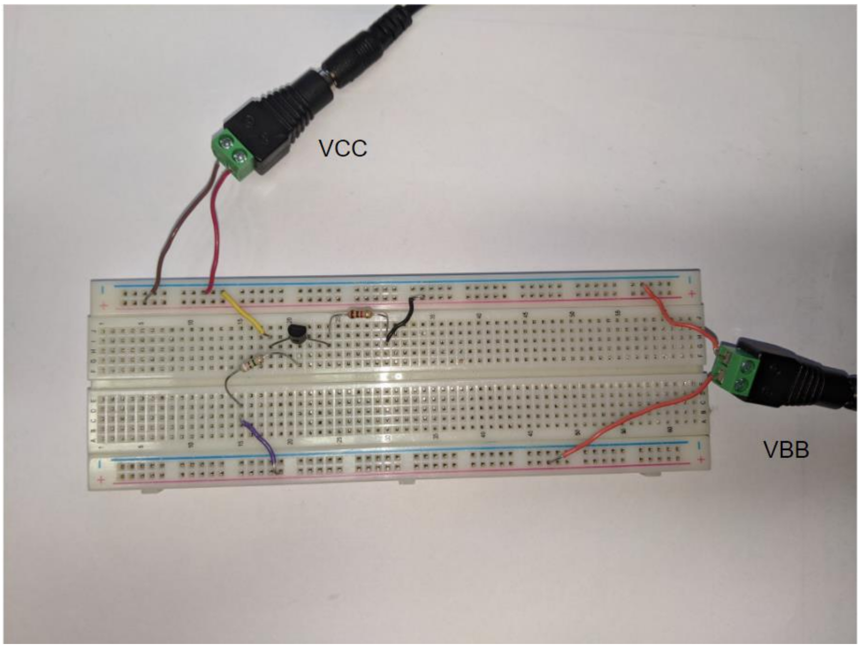


Figure 2.1 – BJT Test Circuit to Generate Family of I-V Curves



1. **Measure** the **I_B = 10μA** curve.
    a. **Build** the circuit depicted in **Figure 2.1** using the 2N3904 BJT.
    b. **Measure** the exact resistances of R_B and R_C using the DMM and record these values.
    c. **Use** a DMM to measure the voltage at node **V_B** in the circuit. This is **V_{BE}**.
    d. **Use** a DMM to measure the voltage at node **V_C** in the circuit. This is **V_{CE}**.
    e. **Adjust** V_{CC} until V_{CE} equals 2V.
    f. **Adjust** V_{BB} until V_{BE} equals the value found in the prelab when **I_B = 10μA** and **V_{CE} = 2V**.
    g. **Readjust** V_{CC} until V_{CE} equals 0V.
    h. **Record** V_{CC}, V_{CE}, V_{BB}, and V_{BE} in **Table P.1**.
    i. **Calculate** the voltage across R_B to **calculate** and **record** the current I_B in **Table P.1**.
    j. **Calculate** the voltage across R_C to **calculate** and **record** the current I_C in **Table P.1**.
    k. **Adjust** V_{CE} from 0V to 2V in 0.2V increments, repeating steps h-j at each step.
    l. **Adjust** V_{CE} from 2V to 10V in 1V increments, repeating steps h-j at each step.
    m. **Calculate** β for each recorded value of I_C and IB.

Note: Remember, you can do voltages from -5 to 5 Volts using the AD2. If you need voltages higher than this, you will need to use the 3-24V power sources.

2. **Measure** the **I_B = 30μA** curve.
    a. **Repeat** steps a-m above, but in step f, adjust V_{BB} until I_B = 30μA. You will need to calculate the current I_B from the voltage across R_B.
3. **Measure** the **I_B = 50μA** curve.
    a. **Repeat** steps a-m above, but in step f, adjust V_{BB} until I_B = 50μA. You will need to calculate the current I_B from the voltage across R_B.

POST-LAB ANALYSIS

1. **Plot** a family of I-V curves for the **calculated** and **measured** data collected in **Table P.1**.

2. **Compare** the **Calculated**, **Simulated**, and **Measured** (DMM) results via graphs (overlaying them where possible) and percentage error in all cases.