University of Maryland Baltimore County
Department of Computer Science and Electrical Engineering

CMPE 314 Lab 4
Transistor Characteristics

I. Objective

Construct transistor circuit and measure basic transistor characteristics.

II. Introduction

A bipolar junction transistor (BJT) is a three-terminal electronic device constructed of doped semiconductor material and may be used in amplifying or switching applications. The BJT consists of two very closely spaced pn junctions, the base-emitter junction and the base-collector junction. Under typical operating conditions (forward active mode), the base-emitter junction is forward biased while the base-collector junction is reverse biased. A BJT in the forward active mode can be thought of as a current controlled current source.

III. Equipment and Parts

DC power supply, oscilloscope, breadboard, resistors, digital multimeters, NPN transistor, cables and wires.

IV. Experiments and Procedures

Part (A). Forward Active Mode I-V Characteristics

(1) Construct circuit shown in Figure 1, where R_B=200 kΩ, R_C=2 kΩ, transistor: 2N3904 NPN. A DC equivalent circuit is shown in Figure 4 in the end of this lab manual.

(2) Increase the DC voltage V_{BB} from 0 V to 3 V with step of 0.5 V. For each V_{BB} step, increase V_{CC} from 0 V to 10 V with step of 0.25 V for $V_{CC} \leq 2$ V and with step of 1 V for $V_{CC} > 2$V. Record down the corresponding voltage V_{CE} and V_{BE} for each V_{CC} input. Calculate corresponding I_B and I_C, as shown in the figure. (Note, for a given V_{BB}, I_B is fixed. While for different V_{CC}, I_C is varying.)

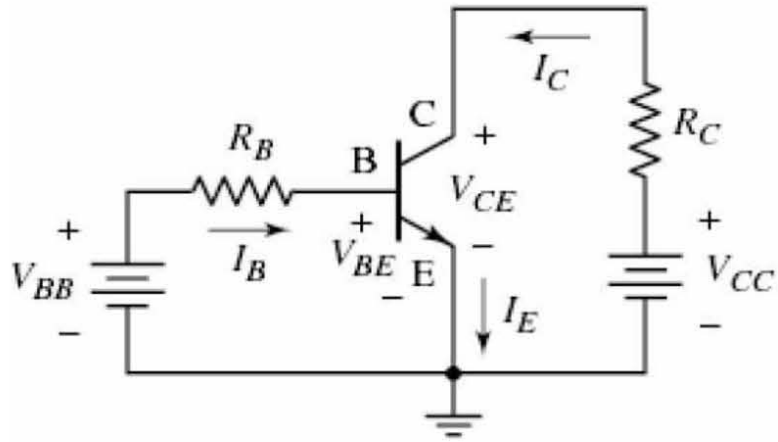

Figure 1: Common emitter circuit with NPN transistor

(3) Plot all the I_C vs V_{CE} curves for a given I_B (meaning for a given V_{BB}) on the same plot, which is called collector characteristic curves. Find the DC forward current gain β_F. Your plots should look like something as below in Figure 2. (Note, the curves are done using PSPICE and MATLAB; in PISPICE, BJT model 2N3904 is used. There are 7 curves on the same plots, two overlaying at I_C=0. Your measurements don't have to be exactly the same as the numbers shown on the plots, while your curves should be close to the plots shown.)   Determine the early voltage from the measured curves (read the textbook for the concept of the early voltage.)

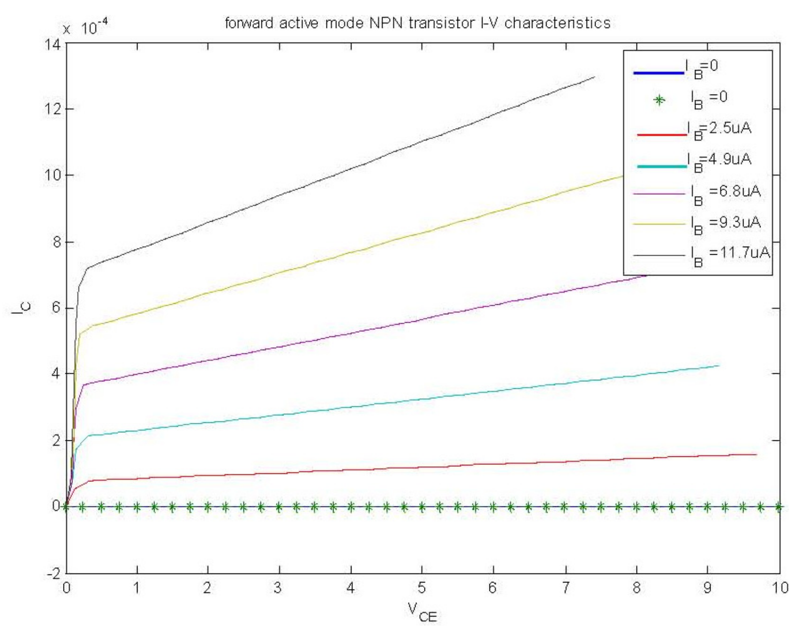

Figure 2: Transistor I-V characteristics for NPN common emitter circuit

(4) For your reference, another set of I-V curves is shown as in Figure 3. This one uses an ideal BJT model QbreakN. Think about the difference between Figure 2 and Figure 3.

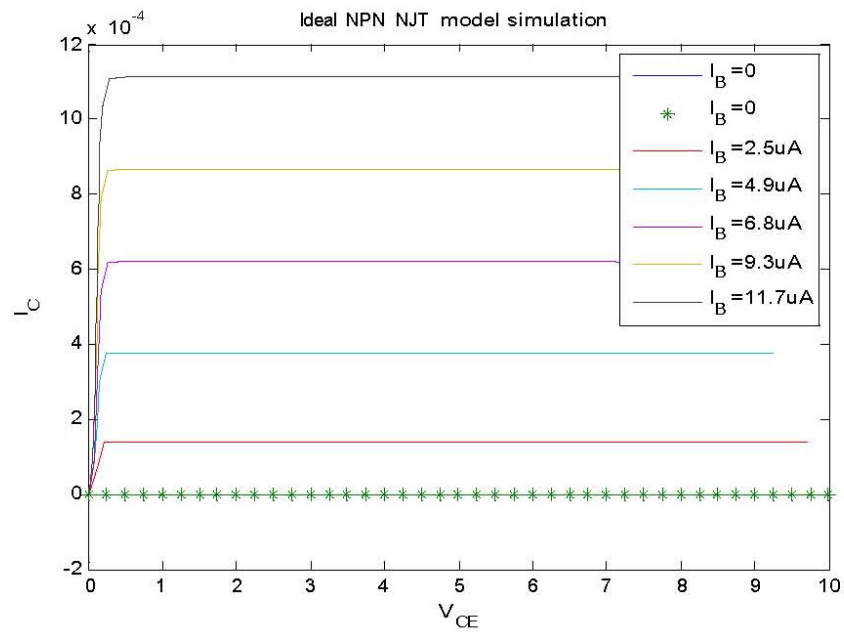

Figure 3: Transistor I-V characteristics simulation using ideal BJT model

Part (B) DC Analysis

(1) Set V_{CC}=10 V, and vary V_{BB} from 1 V to 4 V, with step of 0.5 V. Measure I_C and V_{CE}. For this step the measurements should be obtained by using multimeter and hand recording.

(2) Plot I_C vs V_{CE} loadline on the same plot with the I-V characteristics curves got in Part (A). Also plot the theoretical I_C vs V_{CE} loadline on the same plot. Identify the cutoff, saturation, and forward active regions on your plots.

Part (C) PSPICE simulation

Use PSPICE to simulate Part (A) and Part (B). Use Q2N3904 model in the bipolar junction transistor library. You need to add this library in PSPICE. Set up the DC sweep with primary and secondary sweeps. For simplicity in Part A, keep the step size for V_{CC} as 0.25 V. Measure V_{CE} and V_{BE} separately and export these values to MATLAB. Perform the calculations for the values of V_{CE} and I_C. In this way you will be able to plot the curves in MATLAB. Save your data and plot all curves in MATLAB. Compare simulation results and your experimental results. You do not need to plot simulation and experimental curves on same plots.

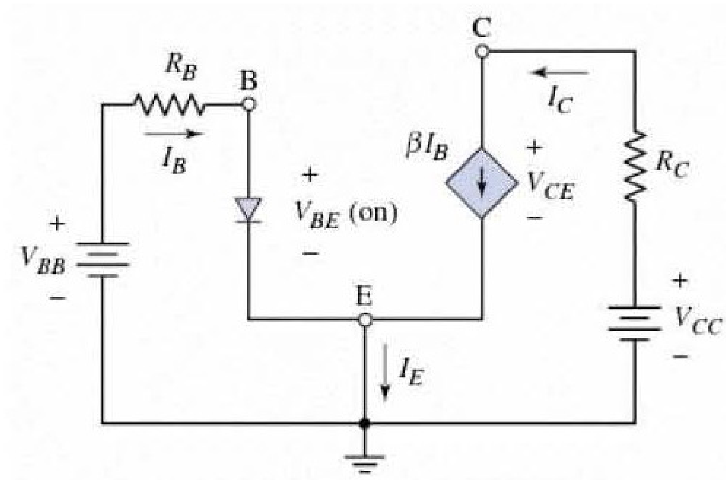

Figure 4: DC equivalent circuit of common emitter circuit