ECET 380-Numerical Methods-Project 3

Table of Contents

Introduction

This project concerns itself with the bipolar junction transistor (BJT) arranged in a common emitter amplifier design, shown below in Figure 1:

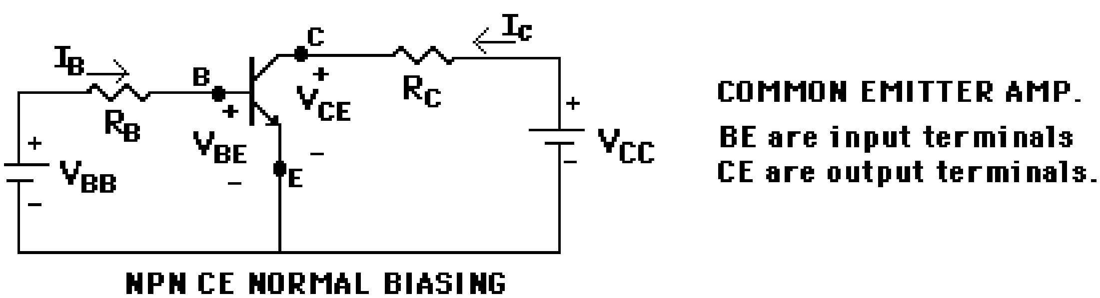


Figure 1 BJT in common emitter amplifier configuration

The BJT acts as a switch: When the voltage between the base and emitter, V_{BE}, is less than the turn-on voltage (usually about 0.7 V) the BJT is an open switch, preventing current from travelling from the collector (C) to the emitter (E). When V_{BE} is greater than the turn-on voltage, the BJT becomes a closed switch, allowing current to flow from the collector to the emitter. A mechanical analogy of the BJT is a check valve that requires a minimum differential pressure before forward flow can occur.

Using Kirchoff's Voltage Law, we observe two fundamental equations:

$$V_{BB} - I_B R_B - V_{BE} = 0$$

$$V_{CC} - I_C R_C - V_{CE} = 0$$

The common emitter amplifier configuration is used when there needs to be a current gain, that is, the collector current is greater than the base current. We define the gain β as the ratio of the collector current to that of the base current:

$$\beta = \frac{I_C}{I_B}$$

To determine where the operating point of the common emitter BJT, we first place the BJT in a curve tracer, which plots the collector current of the BJT based on the base current. Figure 2 displays a typical curve tracer results. These are the lines that rapidly jump up and then increase as V_{CE} is increased. Note these lines characterize the BJT only.

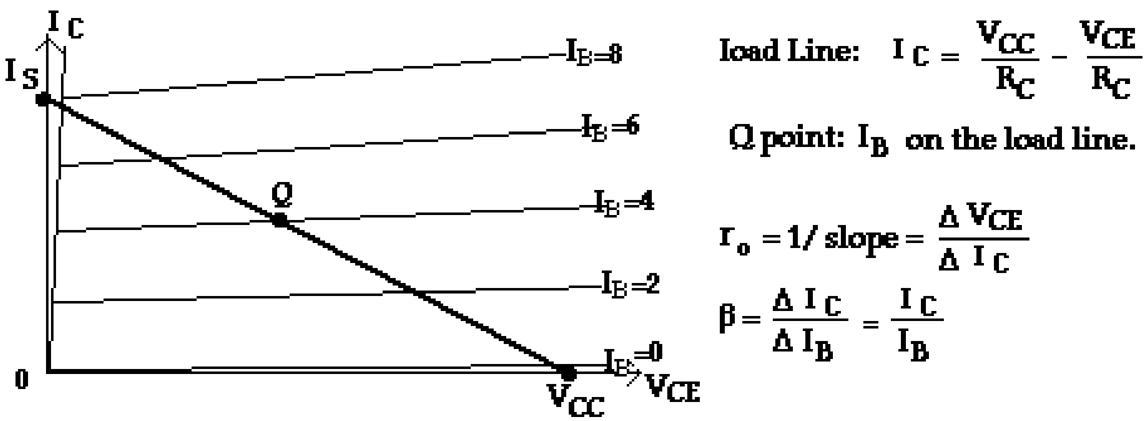


Figure 2 Curve tracer and load line curves

Now that the BJT is characterized, the system load needs to be analyzed. Recall the following equation:

$$V_{CC} - I_C R_C - V_{CE} = 0$$

Rearranging the equation, we have

$$I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{V_{CC}}{R_C} - \frac{1}{R_C} V_{CE}$$

This form of the collector current is called the *load line*, where the collector current is a function of the collector to emitter voltage V_{CE}. Observation of the load line yields two important points for analysis:

a. When $V_{CE}=0$, the maximum collector current is achieved. This is called the *saturation current*, I_s. Thus, it should be easy to see the saturation current is

$$I_s = \frac{V_{CC}}{R_C}$$

b. When $V_{CE}=V_{CC}$, there is no voltage difference across the collector resistor R_C. This means there is no collector current when $V_{CE}=V_{CC}$. This is called the *cutoff condition*.

To determine the operating point Q, the user draws a line on the BJT characteristic curves, starting from the saturation current at V_{CE}=0 until to 0 current (the cutoff condition) at V_{CE}=V_{CC}, shown in Figure 2. The intersection of this line with the BJT characteristic lines from the curve tracer yields the operating points at various base currents I_B. Each of these points are the points for each base current for which Kirchoff's Voltage Law is satisfied.

Project

The goal of this project is to determine the operating point, given the BJT curve tracer data and the common emitter amplifier configuration, at various base currents I_B.

BJT data and system configuration

The BJT data is provided in the Excel file 'Curve Tracer Data.xls'. Note there are some parts of the data that needs to be addressed:

a. DO NOT use the first two columns (or a base current of zero), but only the cases or nonzero base currents
b. DO NOT consider the data where the collector to emitter voltage, V_{CE}, is negative.
c. DO NOT consider the data where both V_{CE} and I_C are zero.
d. Typically, the system does not operate in the rapidly increasing area. Thus, when you are doing your analysis, only consider the region of interest. However, make sure you do plot the rapidly rising region in addition to the data after it

System configuration

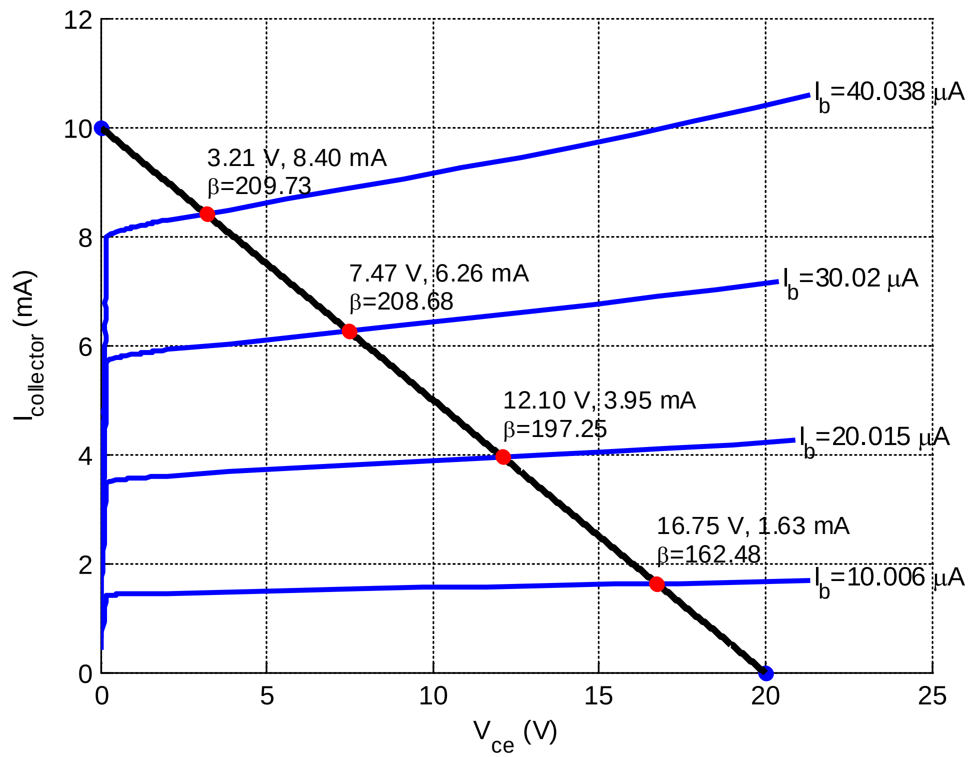
Base resistor resistance: R_B=100 kΩ

Collector resistor resistance: R_C=2 kΩ

Collector supply voltage: $V_{CC} = 20\ V$

Results

You should produce a plot similar to the one shown below. Note: Don't copy and paste this in your report. Your programs will be executed to ensure proper operation/calculation.



Tips and hints

a. Get the BJT characteristic curves to plot as above first. Note you do not plot where V_{CE} is negative
b. Create a load line and plot it next. Write down the approximate intersections of the load line with the BJT curves. Use these values for verification of your algorithm
c. If you approach the problem properly, you do not have to use any functions you developed in the previous weeks to solve for the operating points
d. Use the *text* command (if using MATLAB) to provide the operating point values
e. Conduct a web search to determine how to provide formatted values in the display of your operating point values if using MATLAB