Department of Electrical and Computer Engineering
University of California, Santa Barbara
ECE 2B, Lab 2

BIPOLAR JUNCTION TRANSISTOR BIASING

OBJECTIVE

Proper biasing of a bipolar junction transistor is essential to ensure correct operation. In this lab you will be learning about proper DC bias conditions for two different BJT circuits and will be studying their respective sensitivity to changes in the value of β.

INTRODUCTION

The correct operation of any transistor depends on providing proper DC bias conditions. For the bipolar junction transistors that we will be using, the normal or forward-biased active region of operation is utilized for amplifiers with linear transfer characteristics. This region is defined by $V_{CC} > V_{CE} > 0.3V$ for an NPN device.

The design of a bias circuit for the BJT must account for significant variations in the forward DC current gain, β, where $\beta = I_C / I_B$. Transistor data sheets generally refer to h_{FE} instead of β, but these can be considered the same quantity. Not all transistors have the same β value. It is common for randomly selected transistors to have betas differing by a factor of two or three. The current gain also varies significantly with temperature at a rate of 0.7% per degree Celsius. Thus, if you are designing a circuit which must be capable of using any transistor which the supplier may provide and still operate over a significant temperature range, you must *create a circuit whose operating point is not a strong function of current gain.*

The BJT DC model shown below in Figure 1 is often used to represent the BJT for DC biasing. Remember that in the active region, the base-emitter junction is forward-biased and the collector-base junction is reverse biased. Thus, in the active region, current will flow through the collector (βI_B).

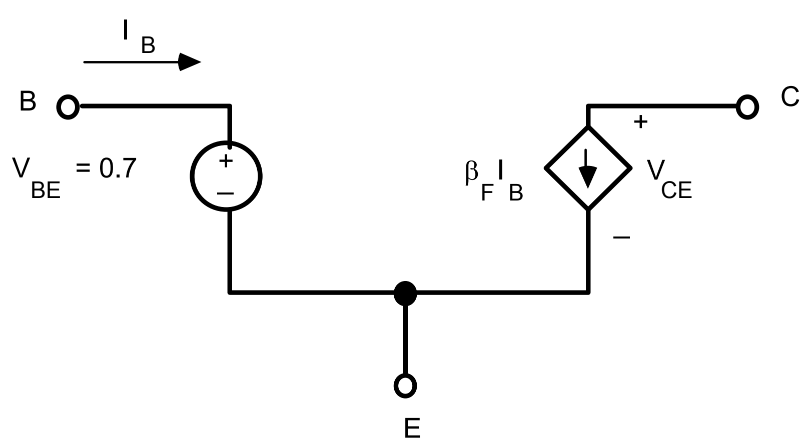


Figure 1: DC Model for a BJT in the Forward-Active Region

In this lab you will be using both NPN and PNP bipolar junction transistors. PNP devices are very similar to NPN devices except the polarities of bias voltages are opposite. A way to keep the polarities straight between the two is to remember that the base-emitter junction must be forward biased and the base-collector junction must be reverse biased for either type of BJT. As can be seen in Figure 2, by looking at the direction of the arrow on the BJT and remembering the correct biasing polarity for a diode, one can easily determine the correct biasing polarity for the BJT.

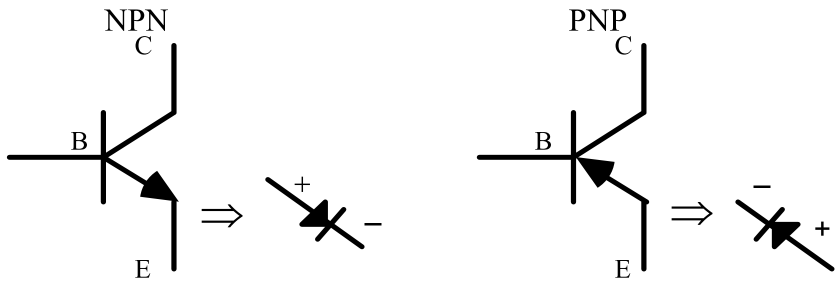


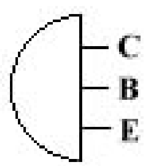
Figure 2: NPN and PNP Bipolar Junction Transistors

PROCEDURE

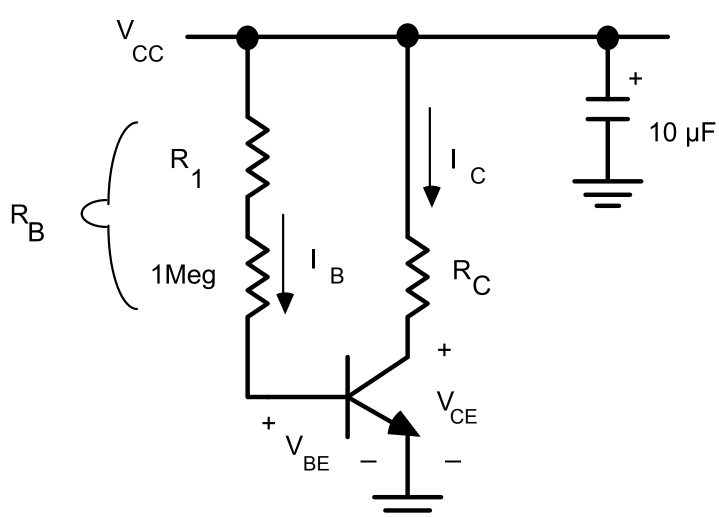
1. Two Resistor Bias Circuit

Materials Required: one 1MΩ resistor, two resistors of value to be determined, one 10μF capacitor, one (or two if possible) 2N3904 NPN BJTs.

(a) Measure the β values for your transistor on the curve tracer. If you look at the top of your BJT, you can determine the collector, base and emitter of the BJT from the following diagram.



(b) Assuming $V_{CC} = 12V$, $V_{CE} = 5V$, $I_C = 1mA$, calculate the value of $R_B(R_1)$ and R_C for the circuit shown below. Show all your calculations in your lab notebook.



(c) Build the above circuit using your calculated resistance values and your BJT.

(d) Measure the operating point (V_{CE}, I_B, and I_C) and determine β from your measurements. How does this value compare to the one found using the curve tracer?
(e) Did you reach the desired operating point? If not, why not? Modify your circuit if necessary to come within 10% of the given specifications.
(f) If possible, replace your BJT with another NPN BJT that has a β value at least 20% different than your first BJT. Repeat steps (c)-(e).
(g) Calculate the sensitivity of V_{CE} to changes in β (i.e. $\Delta V_{CE} / \Delta\beta$).

2. Four Resistor Bias Circuit

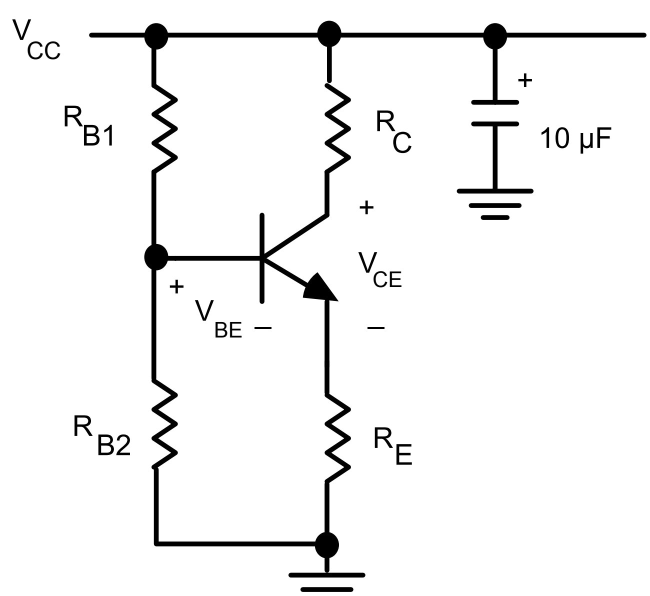
Materials Required: four resistors of value to be calculated, one 10µF capacitor, same BJT's as in the previous section.

(a) Assuming $V_{CC} = 12V$, $V_{CE} = 5V$, $I_C = 1mA$, calculate the value of R_{B1}, R_{B2}, R_C and R_E for the circuit shown below. (The β value is the same as in the last section.) Show all your calculations in your lab notebook.

This circuit analysis requires you to use some design judgment. You have to choose 4 resistors to make the bias circuit work, and there isn't a unique mathematical solution to this problem. What this means is that there may be many combinations of R_{B1}, R_{B2}, R_C and R_E *that will satisfy your circuit analysis, but only a few solutions that will also allow your bias circuit to operate in the best way (our electronics shop may not have the exact value of resistor you need, so use the best approximation of values in your actual circuit).*

In addition to using the values of V_{CC},, V_{CE} *and* I_C *listed above, calculate the values of resistors and construct the corresponding circuits assuming:*

(1) $V_E = V_{CC}/10$,
(2) $V_E = V_{CC}/2$, *and* $\beta R_E > R_{B2}$



(b) Build the above circuit using your calculated resistance values and your BJT.

(c) Measure the operating point (V_{CE}, I_B, and I_C) and determine β from your measurements. How does this value compare to the one found using the curve tracer?
(d) Did you reach the desired operating point? If not, why not? Modify your circuit if necessary to come within 10% of the given specifications.
(e) If possible, replace your BJT with another NPN BJT that has a β value at least 20% different than your first BJT. Repeat steps (c)-(e).
(f) Calculate the sensitivity of V_{CE} to changes in β (i.e. $\Delta V_{CE} / \Delta\beta$).
(g) How does the sensitivity of the four resistor bias circuit compare to the sensitivity of the two resistor bias circuit?

3. **Four Resistor PNP Bias Circuit**

Materials Required: four resistors of value to be determined, one 10µF capacitor, one PNP BJT.

(a) Repeat parts (a)-(c) of section 2 using a 2N3906 PNP BJT, *and using the same analysis for $V_E = V_{CC}/10$ or $V_{CC}/2$, as you did for the NPN circuits.*
(b) How is the wiring for the circuits for the NPN and PNP BJT's different?