

Lab 8

BJT Biasing and Q-Point

Purpose

In this lab, the characteristics of BJT's will be investigated. These include the characteristic curves for the BJT, as well as β . Also, methods for biasing the BJT will be studied.

Material and Equipment

Oscilloscope	Power Supply
Curve Tracer	Multimeter
2N3904	Assorted Resistors

Prelab

Show all your calculations. Don't just run simulations

- 1) Read the background section for Lab 7.
- 2) Use data sheets to look up the three junction breakdown voltages, the maximum collector current, and estimates for β and the V_{BE} , (forward bias voltage) at an I_C of 10mA.
- 3) Calculate the necessary biasing resistor (R_b) to achieve a V_{CEQ} of 8V for Figure 7-3. Assume that $R_c = 1.33$ kohms (this will give $I_c = 9$ mA) and that $\beta = 100$. Repeat calculations for $\beta = 300$. Simulate this circuit in PSPICE. From PSPICE, determine through trial and error, the exact R_b that achieves the necessary Q-point. You must run a DC bias point analysis and enable all the bias current and bias voltage displays. This schematic must be included in your prelab. From the R_b determined through PSPICE, determine the value of β that PSPICE is using in its calculations. Also verify that the R_b obtained through PSPICE lies between the two R_b 's that you had calculated for the extreme β s of 100 and 300.
- 4) Calculate the necessary biasing resistors for Figure 7-4 to achieve the same Q point ($V_{CEQ} = 8$ V and $I_{cq} = 9$ mA) as in part 3. Assume that β is 100, $V_e = 3$ V and $R_b = .1\beta R_e$. (Hint: From these constraints you can calculate R_e , R_c , R_b , V_{bb} , and finally R_1 and R_2). Repeat calculations with $\beta = 300$. Simulate both these circuits in PSPICE. Run a DC bias point analysis and enable all the bias current and bias voltage displays. Notice how close the two results are. What does this tell you about β stability of this design?

Background

The bipolar junction transistor (BJT) can be modeled as a current controlled current source. The circuit symbol and the pin out for the actual device can be seen in Figure 7-1.

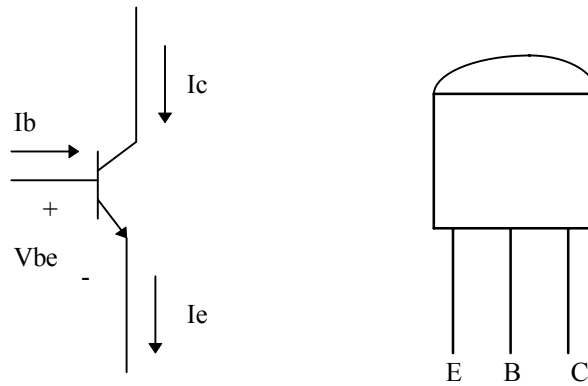


Figure 7-1: The bipolar junction transistor.

In order to analyze a BJT circuit the following simplified equations can be used:

$$I_c \approx I_e \approx \beta I_b$$

$$V_{be} \approx .7V$$

These equations assume the device is operating in the active region (typical for amplifier applications). From these equations we see that the current through the collector of the device is controlled by the input current to the base. Thus if we change the current into the base, we get a proportional change in the collector current. The constant of proportionality is called β , or sometimes h_{fe} . β is typically on the order of 20 - 500.

In order to characterize the operation of a particular transistor, a complete set of characteristic equations is needed. Typically, these curves look like those in Figure 7-2. These curves show that in the active region of operation, the collector current is constant and depends on the base current.

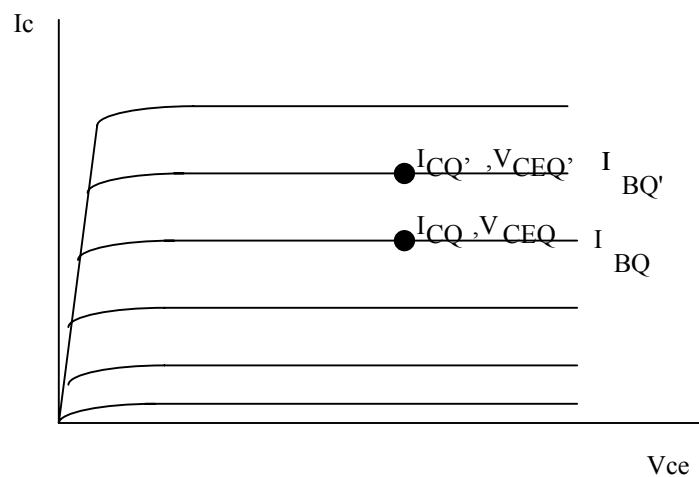


Figure 7-2: Characteristic curves for the BJT transistor.

These curves can be used to calculate the large signal current gain, β_{DC} (or h_{FE}) and the small signal current gain, β_{AC} (or h_{fe}). These values are in general calculated for a given bias point I_{CQ} , V_{CEQ} using the following equations:

$$\beta_{DC} = \frac{I_{CQ}}{I_{BQ}}$$

$$\beta_{AC} = \left| \frac{I_{CQ} - I_{CQ'}}{I_{BQ} - I_{BQ'}} \right|$$

From this, one can see that the large signal gain depends only on the Q point and the small signal gain depends only on small deviations around the Q point.

In order to use a transistor in an amplifying circuit it has to be biased. In other words, a Q point has to be set in order to place the device in the active region of operation. There are several methods which can be used bias a transistor. Figures 7-3 and 7-4 demonstrate two possibilities.

The first scheme (Figure 7-3) is called a fixed bias scheme. In a fixed biasing the base current is set through a base resistor and the emitter of the transistor is grounded. This scheme is not used in practice since the Q point depends very strongly on β .

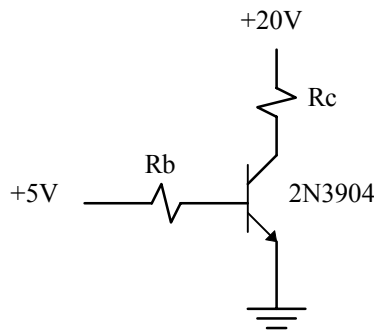


Figure 7-3: Fixed biasing scheme.

A second possibility, which is commonly used, is the self biasing scheme. Here the base voltage is set through a voltage divider and the emitter is tied to ground through a resistor. If designed correctly, this scheme is relatively independent of β .

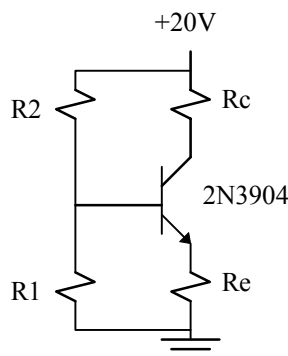


Figure 7-4: Self-biasing voltage divider scheme.

In the procedure below, one will investigate the characteristics of the BJT and some of the different methods which can be used for biasing.

Procedure

This lab will require interactive participation from all of the groups. In part 3 of the procedure, the groups will investigate the biasing scheme in Figure 7-3 and Figure 7-4. Each group will record on the board the β of their transistor, the resistor values, and the Q points obtained for each of the two biasing schemes. This data should be copied at the end of the lab by everyone for use in writing the lab report.

1) Transistor Curve Tracer

- a) For the 2N3904 transistor in the parts kit, use the curve tracer to obtain traces of the characteristic curves. The TA will show you how to use the curve tracer. Obtain the characteristic I_C Vs V_{CE} curves for 5 different values of I_B . From these curves, fill up the table given below. Note that all measurements must be taken at the same value of V_{CE} . The value of V_{CE} should be chosen that the transistor is operating in the reverse active mode, but quite near to the saturation mode.

Curve #	I_C	I_B	B_{DC}	B_{AC}
1				
2				
3				
4				
5				

- b) Now fill up the same table, but this time all measurements must be taken at a higher value of V_{CE} . The value of V_{CE} must be high enough that the transistor is operating strongly in the reverse active mode.
- c) For each of the tables above, calculate the mean β_{ac} and mean β_{dc} as well as the standard deviation in their values.
- c) Carefully label the transistor using masking tape. The value of β for these devices will be needed in this and in following labs. Compare these values to the speced values for the 2N3904.

2) BJT Biasing Schemes

For each of the biasing schemes, TA verification is absolutely essential. The TA needs to verify that you have indeed biased the transistor as specified.

a) Fixed Biasing scheme

Build the fixed biasing scheme. Through trial, error and logical reasoning determine the exact R_B required to bias your circuit. The design used in your prelab may be a good starting point.

- 1) Measure the following parameters: I_c , I_e , I_b , V_{ce} , V_b , V_c , V_e , V_{be} , β . (Use a DMM to make your measurements).
- 2) Get the TA to sign off on your observations and record your measurements on the white board.

b) Self Biasing scheme

Use any one of the two designs from the prelab, depending on your judgement as to which design would be more accurate. There is no need to adjust any values or tinker with the circuit

- 1) Measure the following parameters: I_c , I_e , I_b , V_{ce} , V_b , V_c , V_e , V_{be} , β . (Use a DMM to make your measurements).
- 2) Get the TA to sign off on your observations and record your measurements on the white board.

Finally, use the values of betas (only β_{DC}) from the other groups to estimate the mean and standard deviations in β_{DC} .

Questions and Requirements for Lab Report

Use all of the data obtained in class to answer the following questions:

- 1) What is the average value of β_{DC} and β_{AC} for the 2N3904 transistor that you used (results from part 1)? Compare these with the values in the spec sheets. Do they lie within the range mentioned in the spec sheets? Does V_{CE} have a role in the variation of β ?
- 2) How much variation is there in β across the transistors used by the various groups? Quantify this with standard deviation tolerance values? Compare with the spec sheets as in question 1?
- 3) Discuss qualitatively (in words) and quantitatively (with percent differences), how the Q point varies with β using a self bias scheme versus a fixed bias scheme. Which scheme is more stable?
- 4) Qualitatively, What is the reason that the self biasing scheme is more beta stable than the fixed biasing scheme? Is it the presence of the emitter resistor or is it the voltage divider? Either way specify the role of both the emitter resistor as well as the voltage divider.