Experiment 4
The BJT in the Common-Base Configuration

Introduction

The purpose of this experiment is to explore the behavior of the bipolar junction transistor (BJT) in the common-base configuration. The loop containing the emitter junction is considered the "controlling" loop; the loop containing the collector junction is considered the "controlled" loop. Considered separately, each junction appears to be a diode, but considered together, the two junctions are found to strongly interact.

Equipment Needed

- Digital Storage Oscilloscope (DSO)
- Function Generator (FG) with floating output (HP 33120A)
- PN2222A npn Bipolar Junction Transistor (BJT)
- Lab Power Supply
- Ohmmeter

Procedure

Use an ohmmeter to perform six tests on the PN2222A npn transistor: Measure the conductivity between two leads, using each of the three possible combinations, and checking each lead pair with both forward and reverse polarity. The test results can be recorded on a table like that below.

Lead Pair Used	Forward Conductivity?	Reverse Conductivity?
E-B (Forward, connect E=-, B=+)	yes or no	yes or no
C-B (Forward, connect C=-, B=+)	yes or no	yes or no
E-C (Forward, connect E=-, C=+)	yes or no	yes or no

In making these connections, you might assume that the red lead of the ohmmeter is positive, and the black lead is negative.[1] The important outcome of the test is not a number, but simply whether there is, or is not, significant conductance. Note that if you use a meter having a range marked "diode" or "junction," the meter may indicate the junction voltage drop for a small test current, rather than a resistance. (This is the case with the HP 34401A.) Decide what the expected results of each of these six tests should be for an npn transistor, and compare with your actual results. If they don't agree, your transistor may be bad. This is a quick method for finding a bad BJT which works most of the time. One other caution: some digital multimeters use a test

[1] This is true for most digital meters, and a few analog ohmmeters. However, you may find that an older analog ohmmeter has reversed polarity, such that on its resistance scales black becomes positive! This is not a well-known fact, but it is important to find out if you are using such a meter to check a transistor.

voltage on their ohmmeter ranges so small that it cannot forward bias a pn junction. If this is the case, all six readings will be simply "no conductance." Such meters usually have a "diode" range which deliberately supplies enough open-circuit voltage to forward bias a pn junction.

Connect the circuit of Fig. 1. "NC" means "not connected." The PN2222A is supplied in the industry-standard package "TO-92," shown in the figure. Note that the inputs to channels 1 and 2 of the DSO are indicated, with the ground point shown. The FG must have a floating output because neither of its output connections is grounded. The FG output cable center conductor is "+", and its shield braid is "-" in Fig. 1. This is normally assumed, and will cause agreement with the signs given in this procedure for the FG offset voltage.

1. Set the FG for a 100-Hz 20-Vpp triangle wave with 0-V offset.

2. Connect scope channel 1 to display v_{BE} (this means that "invert" must be selected on the channel 1 input menu).

3. Connect scope channel 2 to display i_E by viewing the voltage drop on R_E . (The display will then be 1 V per 1 mA.)

4. Put both baselines at the center of the screen. The peak value of i_E should be about 9 mA (9 V), and the peak value of v_{BE} should be about -8 V.

5. Switch to the X-Y mode (on the Horizontal "Main/Delayed" menu). You should have an i-v characteristic for the emitter-base junction which shows a forward region, a reverse region, and a reverse-breakdown region.

6. Record the i-v characteristics of the emitter-base junction twice: once using X and Y scale factors optimized to display all of the curve, including the reverse-breakdown region, and then again using scale factors optimized to display the origin and forward region only. Estimate the values of the E-B junction reverse avalanche and forward

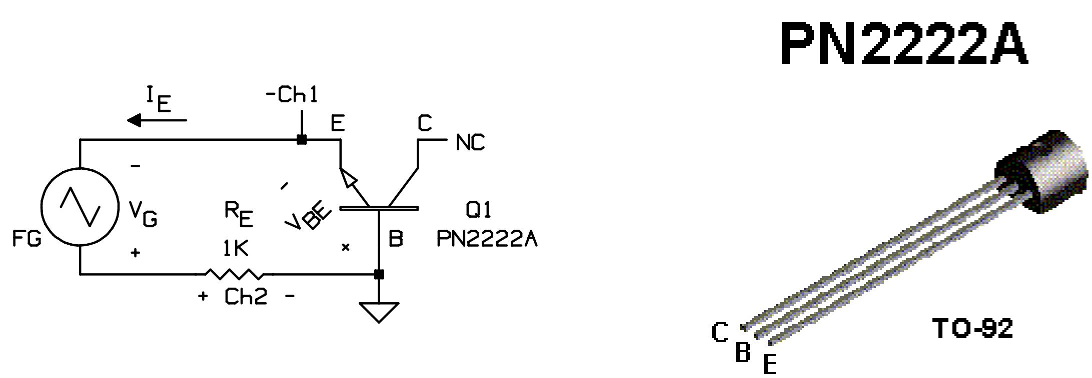

Fig. 1. Emitter junction characteristics of the PN2222A npn transistor.

voltage drops, and record these in your notes.

7. Set the DSO to display the forward portion of the emitter junction i-v characteristic. Connect the collector to ground,[2] and record the effect that this has on the emitter i-v characteristic (relative to leaving the collector open-circuited).

8. Continue to display the emitter forward i-v characteristic. Connect the collector to a +10 V power supply through a 1-KΩ series resistor,[3] and record the effect this has on the emitter i-v characteristic. The results of steps 7 and 8 can be concisely recorded in one screen image containing three traces, all on the same scales, recorded by using the waveform storage facility.

Connect the common-base circuit of Fig. 2.

1. Set the FG for a 100-Hz 2-Vpp triangle wave with -1 V of offset. Note that its output connections are reversed relative to Fig. 1.

2. Set the DSO to show v_G *vs.* time on channel 1, and v_{CB} *vs.* time on channel 2. Use appropriate vertical scale factors and baseline locations for each channel. You should see evidence of operation (at different points in the waveform) in the active, saturation and cutoff modes of the BJT. Record this set of waveforms.

3. Display v_G and v_{EB} together, and record the result. This set of waveforms should allow you to deduce at which points in the cycle the E-B junction is forward biased, and at which points it is reverse biased.

4. Set the DSO for the X-Y mode to display $v_{\mathbf{CB}}$ *vs.* v_G . (To place the origin at center screen, both channels 1 and 2 must have their baselines at center screen.) Record this X-Y plot.

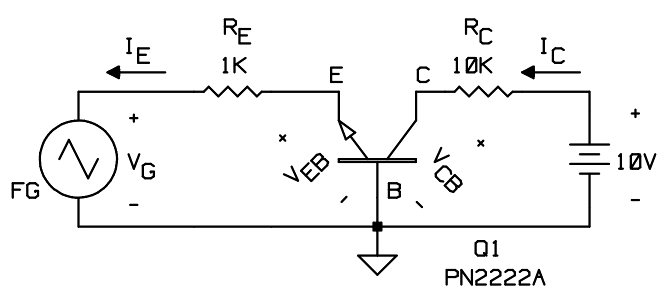

Fig. 2. Common-base circuit.

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[2] Connect the collector directly to the base with no more than a few inches of wire. A long, high-inductance connection can cause a parasitic oscillation (in the 200-MHz region) in this circuit.

[3] The series resistor prevents a parasitic oscillation due to the power supply lead inductance.

Report

1. The ohmmeter test is based on the fact that a good BJT has two pn junctions connected back-to-back. Discuss what the results of the six tests should be, and the implications for a BJT which does not agree with these predictions. Your discussion should include both pnp and npn types.

2. The procedure for Fig. 1 examined the forward and reverse characteristics for the E-B junction alone. Describe your results. Are the forward E-B characteristics completely independent of the reverse-bias conditions which may exist on the C-B junction?

3. Parts 1-3 of the procedure for Fig. 2 produced waveforms of v_G, v_{CB}, and v_{EB} *vs.* time. Define the terms "active," "saturation," and "cutoff" with regard to a BJT. Using your recorded waveforms, indicate which portions of the waveforms correspond to each of these modes of the BJT. Use the recorded waveforms to deduce approximately what the corresponding waveforms for i_E and i_C would be, and either sketch or describe these.

4. The amplitude of v_{CB} should be significantly different from that of v_G. Theoretically predict their relationships and compare with your experimental data. Assume that α is close to unity. Use the PN2222A data sheet supplied to determine what the manufacturer is saying about the value of α.

5. Predict the result of operating Fig. 2 with the emitter lead of Q1 disconnected, but the collector loop intact. What would be i_C and v_{CB}?