

Physics 120 Lab 8: Bipolar Junction Transistors

The bipolar junction transistor (BJT), conceived by William Shockley and first realized by Morry Tanenbaum (1955), predated the realization (although not the conception) of the FET and is one of the most profound technological achievements of the age of electronics. Let us study some basic BJT circuits. Compared with the FET, which functions as a voltage-controlled current source, the BJT, operates as a current amplifier or a current-controlled current source.

8-1 Transistor Junctions are Diodes

Here is a method for spot-checking a suspected bad transistor: the transistor must look like a pair of diodes when you test each junction separately. But do not take this as a description of the transistor's mechanism when it is operating: it does *not* behave like two back-to-back diodes when operating as the base is physically very thin and draws little current.

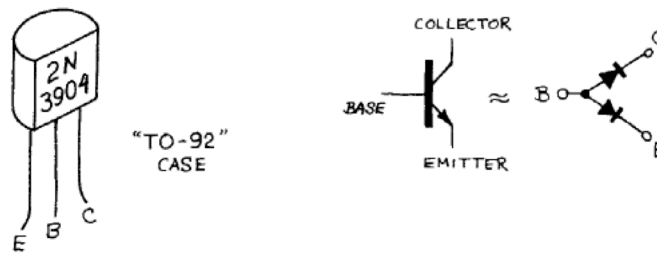


Figure 8.1: Transistor junctions (for testing, not to describe transistor operation).

Get a 2N3904 NPN transistor, identify its leads, and verify that it looks like the object back-to-back diodes shown above using a DVM's *diode test* function; most meters use a diode symbol to indicate this function. The diode test applies a small current, *i.e.*, a few milliamps, that flows from the Red to Black lead and the meter reads the junction voltage. What voltages do you read? Document this.

8-2 Emitter Follower

Wire up an NPN transistor as an emitter follower, as shown below.

Drive the follower with a sine wave of about 1 V amplitude and 1 kHz that is symmetrical about zero volts, *i.e.*, be sure the de “offset” of the function generator is set to zero, and look with a scope at the poor replica that comes out and show a SCREENSHOT. Explain exactly why this happens.

If you turn up the waveform amplitude you will begin to see bumps *below* ground. Show a SCREENSHOT. How do you explain these? (*Hint*: see V_{BE} breakdown specification in the data sheet for the 2N440 transistor: the ‘440 is very similar to the ‘3904, and in this characteristic is identical.)

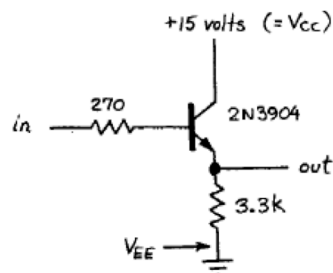


Figure 8.2: Emitter follower. The small base resistor is often necessary to prevent oscillations.

Now try connecting the emitter return, *i.e.*, the point marked V_{EE} , to -15 V instead of ground, and look at the output. Document with a SCREENSHOT and explain the improvement.

8-3 Input and Output Impedance of Follower

Measure R_{in} , the resistance looking into the base, and R_{out} , the resistance looking back into the emitter, for the follower below:

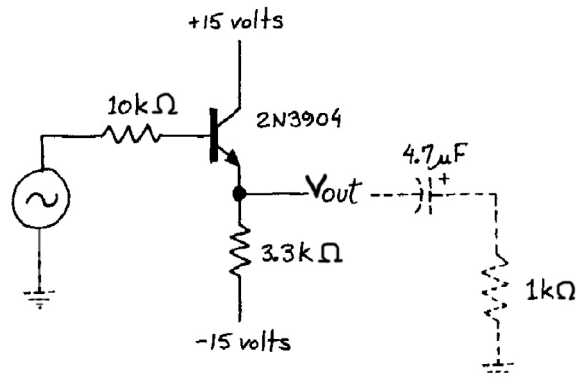


Figure 8.3: Follower: circuit for measuring R_{in} and R_{out}

Using the last circuit (8.2), replace the small base resistor with a 10 kΩ resistor in order to simulate a signal source of moderately high impedance, *i.e.*, low current capability (see figure above).

- a) Measure R_{out} , the output impedance of the follower, by connecting a 1 kΩ load to the output and observing the drop in output signal amplitude; for this use a small input signal, less than a volt. Document with a SCREENSHOT. Use a blocking capacitor – why? (*Hint*: in this case you could get away with omitting the blocking cap, but often you could not).

Suggestions for measurement of R_{out}

- If you view the emitter follower's output as a signal source in series with $R_{outThevenin}$, then the 1 kΩ resistive load forms a voltage divider at signal frequencies, where the impedance of the blocking capacitor is negligibly small.
- The attenuations are likely to be small. To measure them we suggest that you *AC couple* the signal to the scope, to ensure centering, then load the circuit and read the amplitude in percent.

- b) Remove the 1 kΩ load. Now measure R_{in} , which here is the impedance looking into the transistor's base, by looking alternately at both sides of the 10 kΩ input resistor. For this measurement the 3.3 kΩ emitter resistor is also the "load". Again, use a small signal. Document with a SCREENSHOT. Does the result make sense?

When you have measured R_{in} and R_{out} , infer your transistor's β (see textbook or class handout on Emitter Follower for help). You will next make a direct measurement of β .

8-4 Transistor Current Gain

You saw how the transistor's current gain, β , modified impedances in section 6.3. Now measure β directly at several values of I_C with the circuit shown below using the DMM as an Ammeter. The $4.7\text{ k}\Omega$ and $1\text{ k}\Omega$ resistors limit the currents. Which currents do they limit, and to what values?

Try various values for R , using the resistor substitution box. Try $1\text{ M}\Omega$, $500\text{ k}\Omega$, $200\text{ k}\Omega$, $100\text{ k}\Omega$, and $50\text{ k}\Omega$; note that when the resistor is too small the transistor will no longer be in the active state as I_C is too large. Estimate the collector current I_C for each different I_B . Don't bother to measure I_B directly; just assume $V_{BE} = 0.6\text{ V}$ and calculate I_B as $(5.0\text{ V} - 0.6\text{ V}) / (R + 4.7\text{ k}\Omega)$. Estimate β as an average across measurements; a plot of I_C versus I_B with a fitted line would be best.

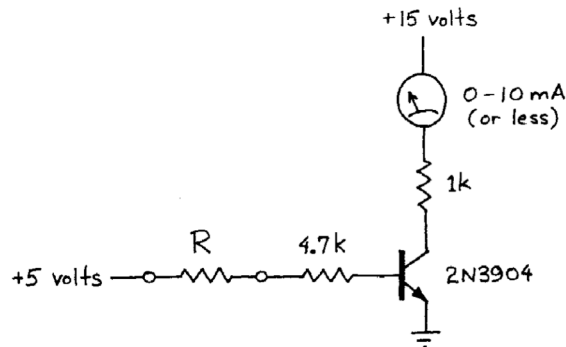


Figure 8.4: Circuit for measurement of β .

8-5 Common-Emitter Amplifier

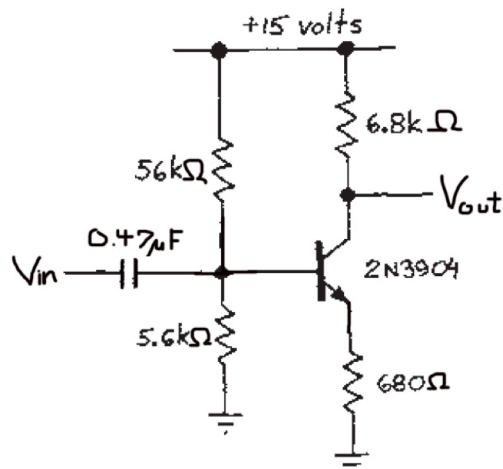


Figure 8.5: Common-emitter amplifier.

Wire up the common emitter amplifier as shown above and as discussed in lecture. What should its voltage gain (V_{out}/V_{in}) be? Check it out using an input at $\sim 1\text{ kHz}$ with an amplitude of a few hundred millivolts. Is the signal's phase inverted? Document your work with SCREENSHOTS emphasizing the AC part and the DC offsets.

Is the collector quiescent operating point at the expected values (see textbook or class handout on Emitter Follower for help)? What should the output impedance be? Check it by connecting a resistive load (as in part 8.3, but you will need to figure out a good value for the load) through a blocking capacitor; the capacitor lets you test impedance at signal frequencies without altering the biasing scheme. Describe your results and document with a SCREENSHOT.