I. DESCRIPTION AND OBJECTIVES
This laboratory presents a basic practical summary of bipolar junction transistors and will provide the opportunity to become familiar with some common transistor circuits.

II. Transistor Junctions are Diodes
Here is a method for a spot-checking a suspected bad transistor: the transistor must look like a pair of diodes when you test each junction separately. But, caution: 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 (the following circuit, made with a pair of diodes, would be a flop, indeed.)

![Figure 1: Transistor junctions (for testing, not to describe transistor operation)](image)

Get a NPN transistor, identify its leads, and verify that it looks like the object shown in Fig. 1, by measuring the voltage across the BC and BE junctions, using a DVM’s diode test function. (Most meters use a diode symbol to indicate this function.) The diode test applies a small current (a few milliamps: current flowing from Red to Black lead), and the meter reads the junction voltage. You can even distinguish BC from BE junction this way: the BC junction is the smaller of the two; the lower current density is revealed by a slightly lower voltage drop.
III. Emitter Follower

Wire up an NPN transistor as an emitter follower, as shown below. Drive the follower with a sine wave that is symmetrical about zero volts (be sure the dc “offset” of the function generator is set to zero), and look with a scope at the poor replica that comes out. Explain exactly why this happens. If you turn up the waveform amplitude you will begin to see bumps below ground. How do you explain these? (Hint see $V_{BE}$ breakdown specification in the data sheet for the NPN transistor)

Figure 2: Emitter follower. The small base resistor is often necessary to prevent oscillation

Now try connecting the emitter return ( the point marked $V_{EE}$) to $-15$ V instead of ground, and look at the output. Explain the improvement.

IV. Input and Output Impedance of Follower

Measure $Z_{in}$ and $Z_{out}$ for the follower below:

Figure 3: Follower Circuit for measuring $Z_{in}$ and $Z_{out}$. In the last circuit replace the small base resistor with a 10 k resistor, in order to simulate a signal source of moderately high impedance, i.e., low current capability (see figure above).
a) Measure $Z_{out}$, the output impedance of the follower, by connecting a 1k load to the output and observing the drop in output signal amplitude; for this use a small input signal, less than a volt. Use a blocking capacitor—why? (Hint: in this case you could get away with omitting the blocking cap, but often you could not). $Z_{out}$ should be “small”.

**Suggestions for measurements of $Z_{out}$**
- If you view the emitter follower’s output as a signal source in series with $Z_{out\text{Thevenin}}$, then the 1k load forms a divider at signal frequencies, where the impedance of the blocking capacitor is negligibly small. See fig. 4
- The attenuations are likely to be small.

![Figure 4](image)

*Figure 4:* this shows the Thevenin equivalent of the amplifier output with the 1K load

b) Remove the 1k load. Now measure $Z_{in}$, which here is the impedance looking into the transistor’s base, by looking alternately at both sides of the 10k input resistor. For this measurement the 3.3 k emitter resistor is also the “load”. Again, use a small signal. Does the result make sense? (see section 4.8 in the text or section 2.03 in the recommended text “Art of Electronics”). $Z_{in}$ should be “large.”

![Figure 5](image)

*Figure 5:* Equivalent circuit for the measurement of input impedance.
When you have measured $Z_{in}$ and $Z_{out}$ infer your transistor’s $\beta$. Derive the $\beta$ in terms of $Z_{in}$ and $Z_{out}$ in your lab report and check whether the amplitude of $\beta$ is reasonable and if it is compatible with the value you get from the next section.

**V Transistor Current Gain**

You saw the transistor’s current gain, $\beta$, at work in section III. Now measure $\beta$ (or $h_{FE}$) directly at several values of $I_C$ with the circuit shown below. To do this, measure the voltage across the 1k resistor. Explain why it is not a good idea to use a current meter. The 4.7k and 1k resistor limit the currents. Which currents do they limit, and to what values?

Try various values for $R$, e.g., 10M, 1M, 470k, 100k, 47k. Estimate the base current in each case (don’t bother to measure it, assume $V_{BE} = 0.6$ V), and from the measured $I_C$ calculate $\beta$ ($h_{FE}$).

![Figure 6: Circuit for measurement of $\beta$ or “$h_{FE}$”](image)
VI Current Source

Figure 7: Transistor current source

Construct the current source shown above (sometimes called, more exactly, a current “sink”). Slowly vary the 10k variable load, and look for changes in current measured by DMM. What happens at maximum resistance? Can you explain, in terms of voltage compliance of the current source?

Even within the compliance range, there are detectable variations in output current as the load is varied. What causes these variations? Can you verify your explanation, by making appropriate measurements? (Hint: Two important assumptions were made in the initial explanation of the current source circuit in the section 2.06 (Fig. 2.21) in the recommended text “Art of Electronics”.)

VII Common-emitter Amplifier

Figure 8: Common-emitter amplifier
Wire up the common emitter amplifier shown above. What should its voltage gain be? (use a small AC signal <10mV) Check it out. Is the signal’s phase inverted?

Is the collector quiescent operating point right (that is, its resting voltage)? How about the amplifier’s low frequency 3dB point (calculate it and measure)? What should the output impedance be? (Calculate it). Check it by connecting a resistive load, with blocking capacitor. (The blocking cap, again, lets you test impedance at signal frequencies without messing up the biasing scheme.)

**VIII. SPICE SIMULATION**

Problems 4.17 and 4.18 in the text.