Lab 3: Transistor Basics

Parts List
- Resistors: 33 Ω, 150 Ω, 1 kΩ, 4.7 kΩ, 10 kΩ, range from 47 kΩ to 4.7 MΩ
- Transistors: 2N3904 NPN (or equivalent), 2N2222
- Red LED
- Tactile switch

3.1 Goals of this Lab
Students should become familiar with the basic properties of bipolar junction transistors.

3.2 Transistor Junctions

Figure 1 indicates standard transistor terminal identification conventions. Find a 2N3904 transistor with the TO-92 style plastic case. This is a standard general-purpose silicon npn transistor. (Its matched pnp partner is the 2N3906.) Use a digital multimeter with special settings for testing diodes. (These settings supply an offset voltage of at least 0.6 V to bring the junction into conduction.) Check that the base-emitter and base-collector junctions qualitatively behave like diodes, at least as far as the DVM is concerned. Note that depending upon the DVM, not all transistors actually pass this test. Some of our DVMs have special transistor testers which is a much better way to test that a transistor is working properly. Try this as well, and note the DVM output.
3.3 Current Gain

We intend to measure transistor current gain, as expressed by the relationship \( I_C = \beta I_B \). Set up the circuit of Fig. 2. Measure the collector current \( I_C \) by measuring the voltage drop across the 1 kΩ resistor. \( I_B \) can be calculated using the known resistances, plus the forward “diode” voltage drop from base to emitter, i.e. \( V_{BE} \approx 0.6 \) V. (You should verify this value of \( V_{BE} \) with the DVM.) Use five different resistors for \( R \), from about 47 kΩ to about 4.7 MΩ. Calculate \( \beta \) for each case. Is it constant?

![Figure 2: Setup for measuring transistor current gain.](image)

3.4 Transistor Switch and Saturation

Connect the circuit shown below. The 2N2222A transistor comes in a TO-5 package; see Fig. 1 for the connections. The LED is a standard red light-emitting diode. Electrically, it is very similar to the standard diodes used in this lab. However, when biased forward, it emits red light. (The terminal adjacent to the notch is the anode.) We are using the LED here only to indicate current flowing to the transistor’s collector.

You can use a push-button ‘tactile’ switch, or just connect/disconnect a jumper wire to get the same effect. Start with \( R = 10 \) kΩ. With the switch closed, the diode should light. Calculate and measure \( I_B \) (just measure the voltage across \( R \)). Assuming \( \beta = 100 \), calculate \( I_C \). You should confirm that this is close to the actual value by measuring the voltage drop across the 33 Ω resistor. This is normal transistor operation, satisfying all of our design rules, and we are controlling (switching) a large current (\( I_C \)) by means of a small current (\( I_B \)).

3.4.1

Now make \( R = 1 \) kΩ. Try repeating the calculations above, and verify that we no longer can have \( I_C = \beta I_B \). The transistor is saturated. Measure this saturated value of the collector-emitter voltage \( V_{CE} \). This is as close to the emitter potential as the collector can get for this \( I_B \). However, for larger values of \( I_B \), it may be possible to achieve lower values of \( V_{CE}^{sat} \). Try replacing \( R \) with 150 Ω and measure \( V_{CE} \) again. How does the saturated \( V_{CE} \) depend on \( I_B \)?
Figure 3: A transistor switch. For values of $R$ less than a few kΩ, the transistor will be saturated. The LED is a standard red light-emitting diode.