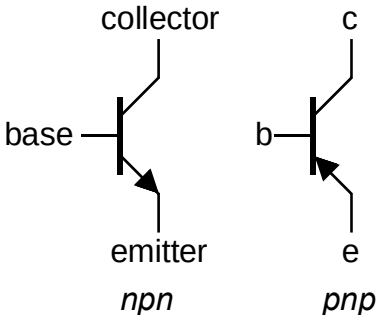
Transistors

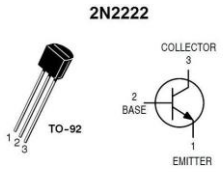
Goals

1. Understand basic transistor operation.
2. Measure current gain in a transistor.
3. Explore features of transistor circuits.

Background



A transistor is our first "active" element. It is a three terminal device that is used to amplify signals. The three terminals are the collector, base, and emitter, as shown at right. Transistors come in two flavors: *npn* and *pnp*, where the *n* and *p* refer to *n*-type and *p*-type semiconductors used to make the three parts. Under normal operation, the base-emitter diode is forward biased (*i.e.* conducting) and the base-collector diode is reverse biased. The "magic" of a transistor is that even though the base-collector diode is reverse biased, there is a large current flow and the current into the collector is much larger than the current into the base. This "current gain" is the key aspect of the device and usually obeys the equation $I_c = \beta I_b$, where β is the transistor gain (sometimes called h_{FE}).



Download a copy of the data sheet for a 2N2222 *npn* transistor and find the specifications on gain. The pin diagrams may differ from what we have, which is shown at right.

Experimental Instructions

1. Transistor operation

The goal of this experiment is to determine what is required to turn on a transistor and to measure the current gain β.

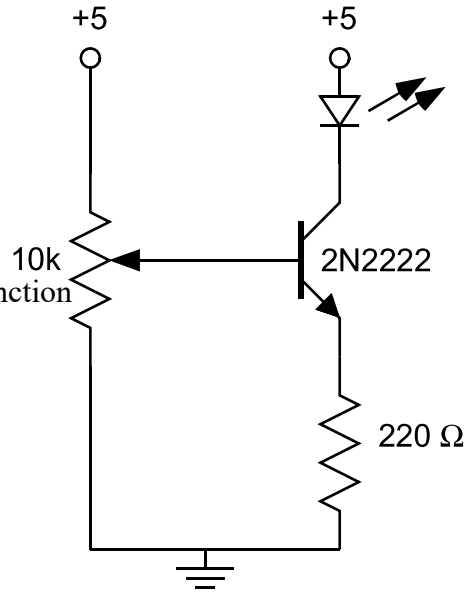
a. Diode drops: Measure the diode drop voltage across all possible pairs of transistor terminals of the transistor using the DMM (diode setting).

b. Transistor gain: Build the circuit shown at right. Adjust the potentiometer to the end that makes the base voltage 0 V. Then increase the voltage at the base until the LED just barely lights up. Now go back about 2 turns of the potentiometer into the off region to start the experiment. For every turn of the potentiometer back into the on region, measure:

i. the current into the base of the transistor as a function of current through the LED (collector current, I_C)

ii. the voltage between the base and the emitter, V_{BE}.

Make measurements until the LED current, I_C stops increasing.



Plot the following.

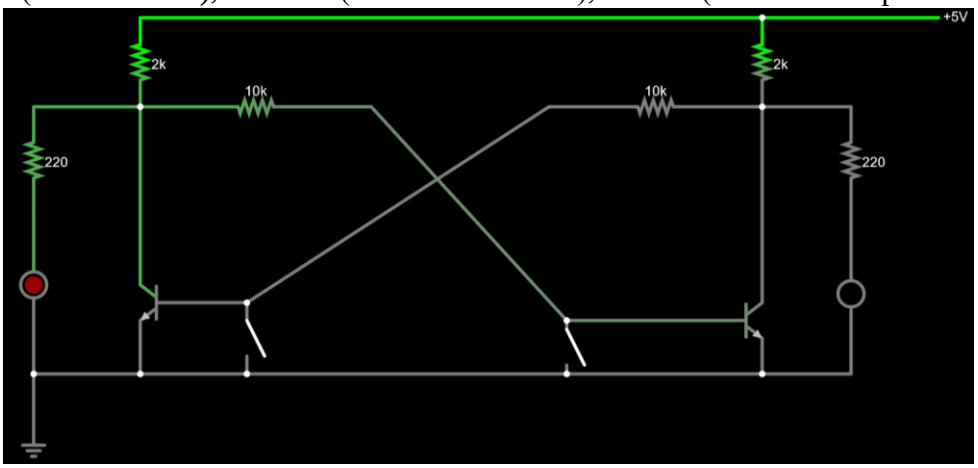
→Plot the LED current (*i.e.* the collector current) vs. the base current and determine the transistor gain b.

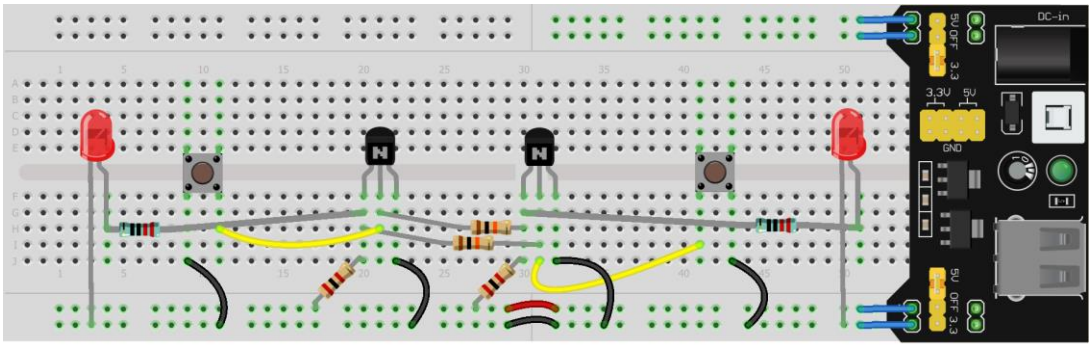
→Plot the LED current vs. the base-emitter voltage.

2. Let's build something cool and challenging with transistors!

a. The SR- Latch or Flip-Flop Circuit [1 bit of RAM memory]

For a change, we'll give you the circuit and breadboad view below. Do not copy it, find the best layout for you! In addition to 2 transistors and LEDs, you'll need 6 resistors shown below, 2x220 Ω (for red LEDs), 2x10kΩ (connected to base), 2x2kΩ (connected to power rails).





Construct the truth table for your circuit, the switches are your input bits, pressing the right switch is an input bit of "1", and the left switch input bit "0". Likewise, right LED ON is output bit "1" and the left is output "0".

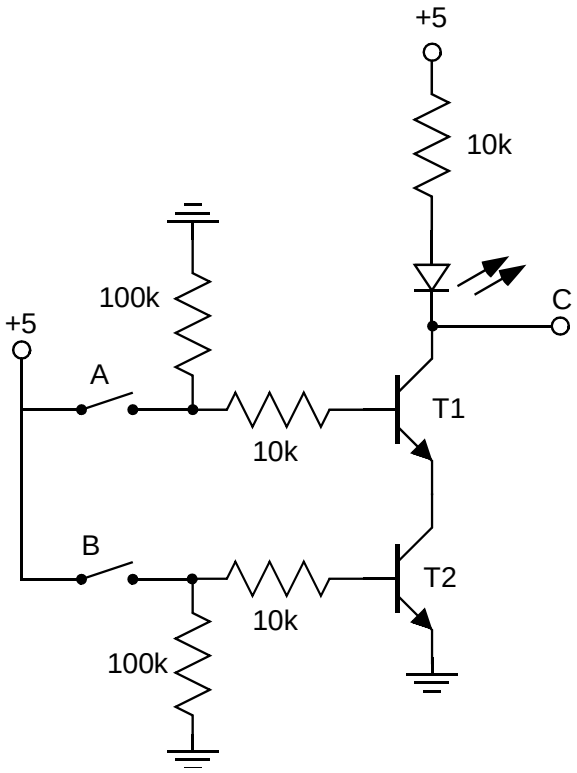
→Take a picture of your circuit in operation. *Get the instructor or TA to grade your circuit by demonstrating the above flip-flop function.*

→What happens when the power is turned off? Discuss in the report why this circuit functions as 1 bit of random-access computer memory.

➔ How does this circuit remember your input after you let go of the switch?

b. Computer Logic Gates with Transistors

The goal of this experiment is to learn about logic gates and build an example. Transistor-transistor logic (TTL) is the basis of much of integrated circuit technology. TTL is often used to do binary arithmetic. In that case, a value of 0 (FALSE) is represented by a low voltage of ground or 0 V and a value of 1 (TRUE) is represented by a high voltage of nominally +5 V. To accommodate noise and other circuit issues, a voltage of 0-0.4 V is considered low and a voltage of 2.4-5 V is considered high. For a given logic gate, the output as a function of the inputs is given by the truth table for the gate. Typical gates used in TTL logic are AND, OR, NOT, NAND (not AND), and XOR (exclusive OR).



AND gate: Build the circuit at right for an AND gate. The switches at A and B control the inputs and the two transistors T1 and T2 are both 2N2222 transistors. For this circuit, an open switch is 0 and a closed switch is 1. The 100k resistors are called pull-down resistors and ensure that the inputs are grounded when the switches are open. The LED is the indicator for the output. If the LED is on, that indicates a value of 1 or TRUE; if it is off, that is 0 or FALSE.

➔Take a picture of your circuit in operation.

Get the instructor or TA to grade your circuit by demonstrating the above logic gate function.

➔ Construct the truth table for your circuit. Discuss briefly why an AND gate is of practical use.