Transistors I

Physics 251

Fall 2022

In this lab, you will investigate some of the characteristics of a bipolar transistor, and then make and evaluate a transistor switch.

Part 1: Transistor behavior, finding β

In this part of the experiment, you will make some voltage measurements that may give you an idea of how the base of a transistor acts as a control element. Start by setting up the circuit shown on your breadboard. Use a 2N3904 or a 2N4401 or other similar small signal transistor. The resistor R_4 is called a potentiometer (or a pot). By turning the control, you can vary the voltage at A from zero up to Vcc. The terminal marked 2 on the bottom of the pot must be connected in the circuit at A for proper operation. Terminals 1 and 3 are interchangeable. Use the built in fixed power supply in your protoboard for the +15 Volt terminal and ground (0 Volt) terminal.

You can find the data sheet on these transistors by searching for, for instance "2n2904 datasheet".

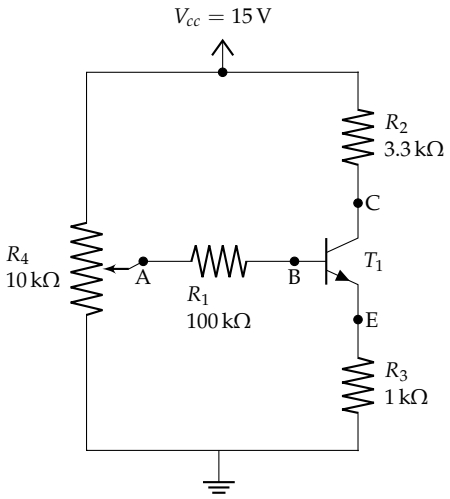

Figure 1: Circuit for Part 1 used to determine the transistor's β. The transistor T_1 should be either a 2N3904 or a 2N4401 npn transistor.

After checking the circuit, you are ready to measure voltages. Use your DMM for voltage measurements, and make all voltage measurements relative to ground. First, measure V_{cc}. This should be about 15 volts and it should not change. Next, adjust the pot for the minimum voltage at A (V_A). Make measurements of V_A, V_B, V_C, and V_E as you adjust R_4 through its range. Not much will happen for V_A below about 0.6 volts.

Then you will come to a range where V_C is quite sensitive to V_A. This is the "active" region where our simple transistor model is approximately valid. Take plenty of data in this range. For V_A values above the active region, the transistor will be saturated ($V_{CE} \approx 0$) and V_C will probably not change much. Make the following plots with all axes labelled:

1. V_C, V_E, and V_B vs V_A,
2. $(V_B - V_E)$ vs V_A, and
3. Collector current I_C as a function of the base current I_B. You will need to use ohm's law to get currents from your voltage values. For example, the current into the collector, I_C, is

$$I_C = \frac{V_{CC} - V_C}{R_2}.$$

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From your results, you should be able to see several things. In the active region, the emitter voltage should follow about 0.6 volts below the base voltage, and the collector current should be proportional to the base current. You should be able to find the value of β for your transistor as the slope on the current graph. Record the

value of β for your transistor. What is the approximate saturation voltage for your transistor?

Part 2: Transistor switch

In this part of the lab, you will make and evaluate a transistor switch. If you did not design a switch yet, take time now to do so. The specifications are as follows: The switch should turn on an LED (Light Emitting Diode) with a current of roughly 10 ma. The power supply voltage is 5 volts and the input voltage is 0 for "LED off" and 2 volts for "LED on".

Before connecting a switch circuit, it will be worthwhile to connect the circuit shown at the right to see how a LED works. CAUTION - LED's do not like to have their leads bent too much. Since LED's have 1.5 to 2 volts of forward drop, this circuit puts about 10 ma through the diode. Try the diode both ways to determine the forward direction. (Note - one lead is longer so you can tell which way you have it connected.) Use the 5 volt terminals on your powered protoboard for this circuit.

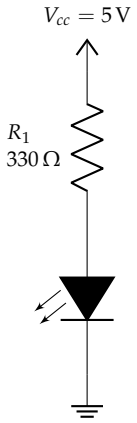

Figure 2: Simple circuit to light an LED

Now set up the switch. To provide the necessary 2 volt input signal, set your variable power supply to 2 volts. Does the LED go on when a 2 volt input is applied and go off when the input is removed? If there is time, you can make the LED flash by using your function generator for the input signal. Proceed as follows: Connect your function generator to the scope using a frequency of 1 to 5 kHz so it's easy to view the signal on the scope. Set the scope input for DC, the function generator output for a square wave, and adjust the function generator offset and amplitude knobs for a 0 to 2 volt square wave. Reduce the function generator frequency to 3 or 4 Hz, and connect it to the switch. You should have a flashing light.