

Lab 2: Diodes and Transistors

2.1 Goals of this Lab

Students should become familiar with the basic properties of diodes and transistors.

2.2 Diode V-I Characteristics

Figure 1 below indicates the directionality of diode connections. For a forward-biased diode, the direction of current flow I_F is indicated.

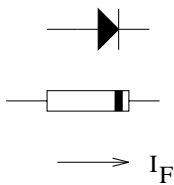


Figure 1: Top: diode symbol used in circuit schematics. Middle: A diode in the lab will look like this, with the bar indicating the device polarity, as shown. Bottom: Direction of current for a forward-biased diode.

Build the diode test circuit shown below in Fig. 2. Use a 1N4001 diode, which is a standard general-purpose device. We wish to determine its V-I response. We will vary R in order to vary the circuit's current. You can use the variable $10\text{ k}\Omega$ on your prototype board for R . (The neighboring potentiometer on the prototype board can be used as the $1\text{ k}\Omega$ resistor, if you wish.) The digital voltmeter, DVM-1, is used to measure the current passing through the diode by measuring the voltage drop across the $1\text{ k}\Omega$ resistor.

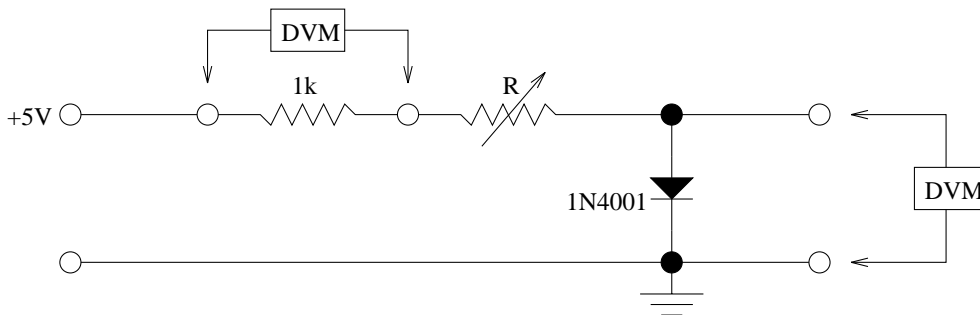


Figure 2: Diode test circuit.

Make a plot of the diode voltage versus \log_{10} of its current by varying R from zero to $10\text{ k}\Omega$. Make as many measurements as you need to determine a smooth curve. You may need to switch from the $+5\text{ V}$ power supply to $+10\text{ V}$ to see the V - I curve flatten out at high current. (Or alternatively, measure the voltage across a resistance smaller than $1\text{ k}\Omega$, like $100\ \Omega$.)

2.2.1

Now reverse the diode and repeat the procedure above. It may be difficult to obtain more than one or two data points for this reverse-biased case.

2.3 Diode Clamp

Build the circuit shown in Fig. 3. Use the oscilloscope with $\times 10$ probe to measure input and output. Input sine, triangle, and square waves of frequency $\sim 10\text{ kHz}$ and amplitude $\sim 300\text{ mV}$. Look at input and output. Now, increase the amplitude of the input. What happens as the input exceeds $\sim 0.6\text{ V}$? Sketch the input and output for inputs with amplitudes of about 2 V . Why might this diode arrangement be useful in instrumentation?

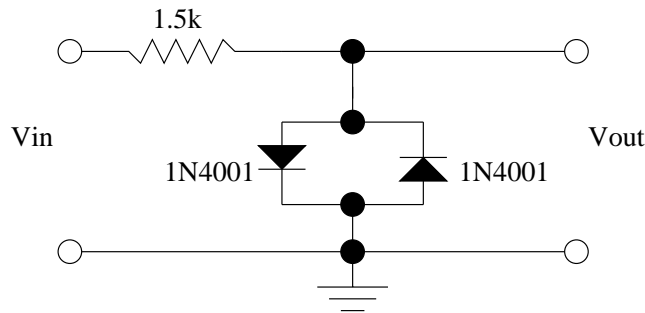


Figure 3: Diode clamping circuit.

2.4 Transistor Junctions

Figure 4 indicates standard transistor terminal identification conventions. Find a 2N3904 transistor with the T0-92 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.) Measure resistance across the base-emitter and base-collector junctions in order to confirm *qualitatively* that these junctions both behave like diodes. (For a non-linear device, resistance can be defined as a function of current: $R(I) = V(I)/I$. Here, one wishes only to demonstrate that resistance for forward bias is much smaller than reverse bias. A quantitative measurement would involve a setup like that of Figure 1.)

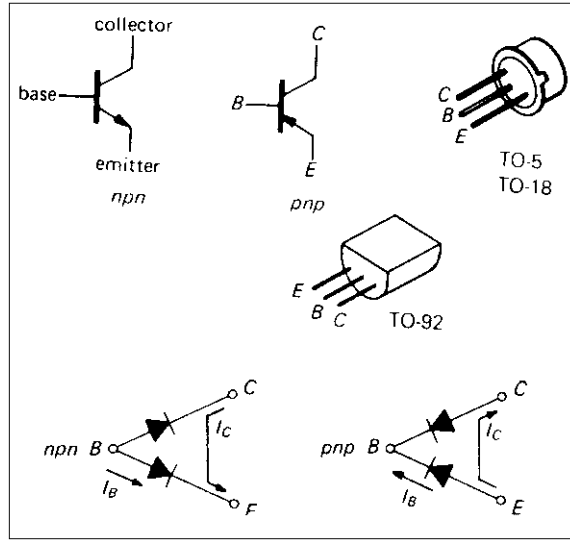


Figure 4: Transistor connections.

2.4.1

Repeat these measurements for a 2N3906 pnp transistor.

2.5 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. 5. Measure the collector current I_C by measuring the voltage drop across the 1 k Ω 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 k Ω to about 4.7 M Ω . Calculate β for each case.

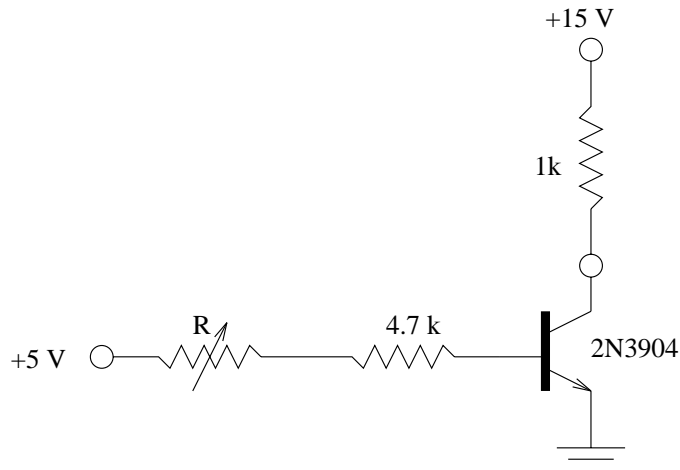


Figure 5: Setup for measuring transistor current gain.

2.6 Transistor Switch and Saturation

Connect the circuit shown below. The 2N2222A transistor comes in a TO-5 package; see Fig. 4 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.

Start with $R = 10 \text{ k}\Omega$. With the switch closed, the diode should light. Calculate and measure I_B . Assuming $\beta = 100$, calculate I_C . You should confirm that this is close to the actual value by measuring the voltage drop across the $33 \text{ }\Omega$ resistor. This is normal transistor operation, and we are controlling (switching) a large current (I_C) by means of a small current (I_B).

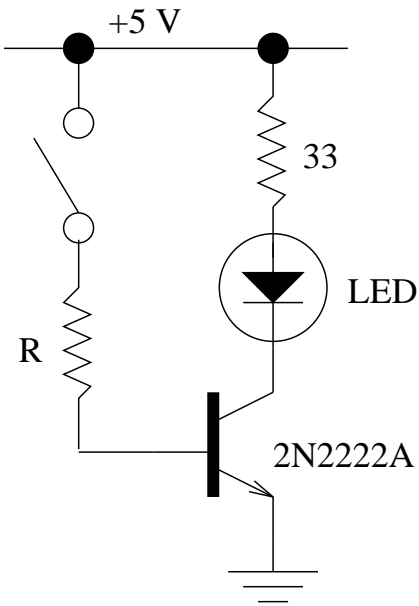


Figure 6: A transistor switch. For values of R less than a few $\text{k}\Omega$, the transistor will be saturated. The LED is a standard red light-emitting diode.

2.6.1

Now make $R = 1 \text{ k}\Omega$. 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 $150 \text{ }\Omega$ to see if this works.