Mixed Electronics Lab 4
Diodes

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1 Introduction

As an introduction to semiconductor devices, students will characterize the behavior of LEDs, photo diodes, schottky diodes, and zener diodes. Students will be able to discuss how they expect each to behave and to model that behavior mathematically in MATLAB. This will serve as an introduction to analog electronics which will be continued in their first design project.

1.1 Background

Diodes are semiconductor devices, meaning that they are less conductive than metals, but still pass a current. They are passive circuit elements that do not require an independent power supply. Physically, diodes are made by combining Silicon based materials. A diode is represented with an arrow, indicating the direction in which it passes current. Because Diodes conduct current in a single direction they are ideally nonlinear devices. However, in reality their behavior is more accurately modeled using the diode equation, as shown in eq 1.1. There are many types of diodes one may use, photo diodes are optical sensors, which emit current in the presence of light. Light Emitting Diodes work in the opposite way, where they emit light when current is passed.

$$I_D = I_S(e^{qV_D/NkT} - 1) \tag{1}$$

I_D = Diode Current in Amps I_S = Saturation Current in Amps (assume 10^{-12})
q = 1.6 x 10^{19} coulombs V_D = Diode Voltage N = Emission Coefficient
k = 1.38 x 10^{-23} T = Temperature in Kelvin

Diodes have an anode and a cathode, where current only flows from the anode to the cathode, and never in the opposite direction. The anode of a diode is associated with p-type semiconductor layer, and the cathode is associated with the N-type semiconductor layer. Between the layers is the depletion region, which breaks down when a voltage is applied, and allows current to flow. Diodes are labeled with a stripe on the cathode, so that they may be oriented correctly.

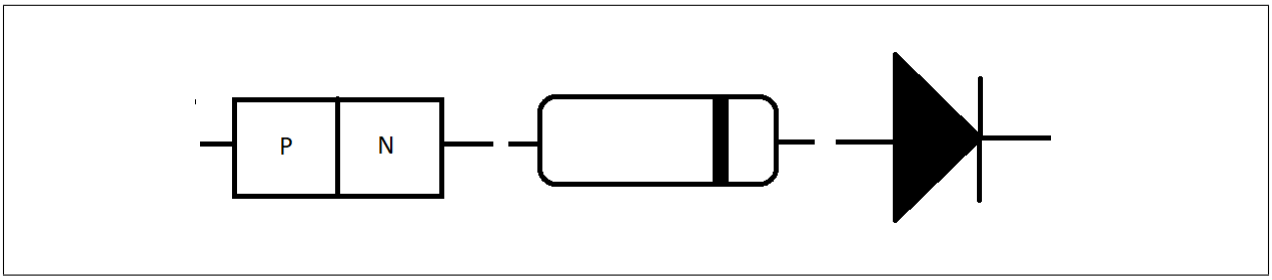

Figure 1: From left to right the figure shows a model on the semiconductor layers, an illustration of a physical diode, and the circuit symbol for a basic diode. Each illustration has obvious directionality, and are depicted with the anode on the left, and the cathode on the right.

1.2 Analysis

1. Based on your understanding of the diode equation, and any data sheets available, develop test circuits and procedure to confirm the behavior of a schottky diode, a Zener diode, an LED, and a photo diode.
2. Create and fill in a data table predicting the behavior of the diodes with different DC inputs, based on their data sheets and your understanding of diode properties.
3. Build the circuit, taking care to consider the orientation of each diode.
4. Characterize the behavior of the diode at various DC voltages, paying careful attention to the point of saturation.
5. Create a plot based on your measurements, and be able to explain how different regions of the response differ from one another.
6. Diodes are an important part of transforming AC signals to DC, because they only pass current in one direction and therefore exclusively maintain a positive voltage. A set of diodes can be arranged in a rectifying bridge, which reorients current to flow in a single direction, and output the absolute value of the input. Design a rectifying bridge and characterize its behavior.
7. Build the rectifying bridge and confirm it behaves as expected.

1.3 Questions to be considered

1. There are different methods of smoothing a rectified signal. Low pass filters and logic gates can be used independently or in combination in order to transform a sine wave into a digital high or low voltage. Discuss what steps are necessary to perform an analog-to-digital conversion.

2. Design an ADC for a 1 kHz, 1 V_{pp} sine wave. Show that the output of your system is a 3.3 V square wave, when the source is switched on and off.