ECEN 325 Lab 6: Diodes

Objectives

The purpose of this laboratory exercise is to investigate the basic properties and characteristics of semiconductor diodes. I-V characteristics, switching behavior, and rectification properties are examined, leading to the construction of a DC power supply.

Introduction

Diode I-V Characteristics

The diode allows current to flow in one direction only, similar to a one-way water valve. A semiconductor diode consists of a junction formed by contact between p-type and n-type semiconductor material. The terminal connected to the p-type material is called the anode, and the terminal connected to the n-type is called the cathode, as in Fig. 1. On most diodes, the cathode is marked by a band on the body of the device.

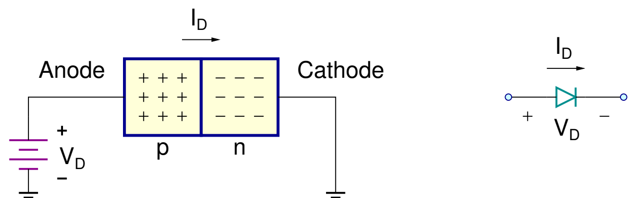
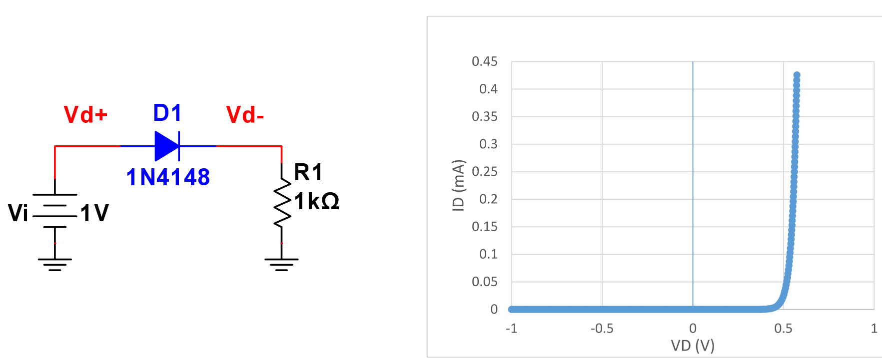


Figure 1: Semiconductor Diode

When the anode is at a higher voltage than the cathode, the diode is forward biased, and current will flow through the diode from the anode to the cathode. When the anode is at a lower voltage than the cathode, the diode is reverse biased, and very little current will flow. The current flowing through the diode can be expressed as

$$I_D = I_S \left(\exp\left(\frac{V_D}{nV_T}\right) - 1 \right) \approx I_S \exp\left(\frac{V_D}{nV_T}\right) \tag{1}$$

where I_D and V_D are the current through the diode and voltage drop across the diode, respectively, as shown in Fig. 1, $V_T = kT/q$ is the thermal voltage, which is around 25 mV at room temperature, I_S is the saturation diffusion current, which is a constant dependent on the diode's geometry and material, and n is a device constant between 1 and 2. To examine the I-V characteristics of a diode, a test circuit as shown in Fig. 2(a) can be used. Measuring the voltage drop V_D across the diode and the current through the resistor R for different values of V_i results in the exponential I-V characteristics shown in Fig. 2(b).



(a) (b)

Figure 2: (a) Diode Test Circuit for I-V Characteristic (b) Resulting $I_D - V_D$ plot

DC Power Supply

One of the most commonly used applications of diodes is DC power supply, which converts the AC line voltage into a regulated DC voltage. Figure 3 shows the block diagram of a typical DC power supply. The AC voltage is first passed through a transformer to step it down to a lower voltage, then rectified using diodes. The resulting DC voltage is pulsating and hence is then filtered to remove or reduce the ripples, producing a constant DC voltage. Additional circuitry may be added to provide voltage regulation so that the desired voltage is maintained, independent of the load current drawn.

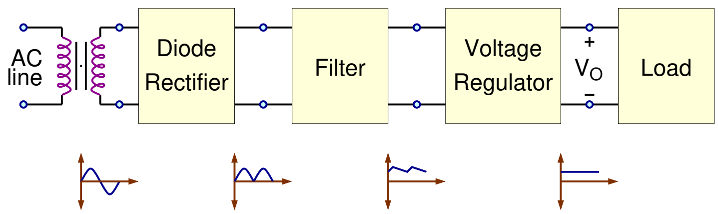


Figure 3: Block diagram of a typical DC power supply

Figures 4(a) and (b) show two power supply circuits using full-wave rectification. If the transformer available is single-ended, the bridge rectifier composed of four diodes can be used to obtain full-wave rectified signal as in Fig. 4(a). If a center-tap transformer is available, full-wave rectification can be realized using two diodes as in Fig. 4(b). In both circuits, R_L represents the load resistance, which is not a part of the power supply circuit. The filter is implemented using a single capacitor.

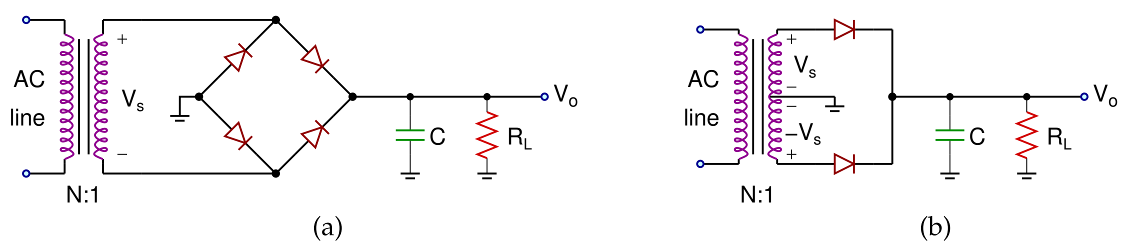


Figure 4: (a) Bridge rectifier with a single-ended transformer (b) Full-wave rectifier with a center-tap transformer

Table 1: Power Supply Design Specifications

Output Voltage	V_o
Maximum Output Current	$I_{o,max}$
Maximum Ripple	% of V_o
Transformer Type	Center-tap or Single

Typical specifications for a power supply are given in Table 1. Since the maximum ripple is observed at the maximum load current, the worst-case load resistance can be calculated as

$$R_L = \frac{V_o}{I_{o,max}} \tag{2}$$

Based on the maximum ripple and load specifications, value of the capacitor can be calculated as

$$C = \frac{1}{2f_i R_L K_r} \tag{3}$$

where f_i is the frequency of the AC line (60 Hz in the US), K_r is the ratio of the maximum ripple to the peak output voltage (for example, if the maximum ripple specification is 10%, then $K_r = 0.1$).

For the bridge rectifier in Fig. 4(a), 0-to-peak voltage of V_s should be designed as

$$\hat{V}_s \approx V_o + 1.4 \tag{4}$$

whereas the peak V_s voltage in Fig. 4(b) should be designed as

$$\hat{V}_s \approx V_o + 0.7 \tag{5}$$

Note that in Fig. 4(b), the total voltage at the secondary winding is $2V_s$.

Calculations

Design the power supply in Fig. 5 to have 3V output voltage (V_o) with a maximum load current of 3mA and 10% maximum ripple, where V_s is a 250-Hz sine wave. Determine the peak amplitude of V_s and the value of C.

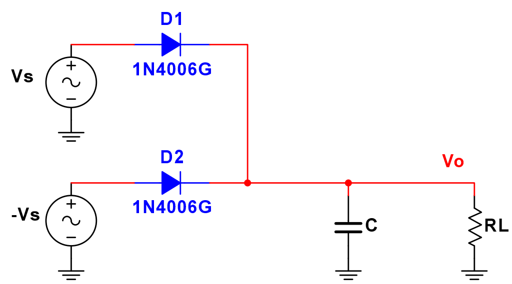


Figure 5: Power supply circuit

Simulations

For all simulations, provide screenshots showing the schematics and the plots with the simulated values properly labeled.

1. Draw the schematics for the diode characterization circuit in Fig. 2(a) and perform a **DC sweep** of V_i from -1V to 1V. Export the simulation data to Excel, and plot I_D as a function of V_D.
2. Draw the schematics for the power supply circuit in Fig. 5 with the calculated values, and obtain the **time-domain waveform** for the output voltage using **transient simulation**. Measure the peak output voltage, maximum ripple, and the peak current on the diodes and the load resistor.

Measurements

For all measurements, provide screenshots showing the plots with the measured values properly labeled.

1. Build the diode characterization circuit in Fig. 2(a) and apply a ramp signal from -1V to 1V at 1Hz as the input (V_i). Export the voltage measurements from the **scope** to Excel, and plot I_D as a function of V_D.
2. Build the power supply circuit in Fig. 5 with the simulated component values, and obtain the **time-domain waveform** for the output voltage using the **scope**. Measure the peak output voltage and the maximum ripple.

Report

1. Include all measurement plots.
2. Prepare a table showing calculated, simulated and measured results.
3. Compare the results and comment on the differences.

Demonstration

1. Calculations and simulations must be submitted on Canvas as a single pdf file **before** the lab session. All simulation plots must include a timestamp.

2. Your name and UIN must be written on the side of your breadboard.

3. For the diode characterization circuit in Fig. 2(a):

   - Apply a ramp signal from -2V to 2V at 1Hz for V_i, and export V_{d+} and V_{d-} measurements to Excel.
   - Plot I_D vs. V_D in Excel.

4. For the DC power supply in Fig. 5:

   - Show the time-domain output (V_o) using the **scope** and measure the output peak voltage.
   - Measure the maximum voltage ripple on the output waveform.