Diodes I – Introduction to Nonlinearity

1 Objectives

1.1 Understand the difference between linear and nonlinear circuits.
1.2 Gain basic understanding of diode characteristics.
1.3 Build and observe operation of half-wave rectifier and full-wave rectifier.

2 Background

2.1 Diodes

This background section has been slightly modified from [1]. If you are taking (or have taken) ECEN 3313, this section will presumably serve as a review. If you are taking ECEN 3021, this section will provide a brief description of the most basic properties of diodes. All the background material needed for this lab is covered in this background section. There is no need for you to study electronics or solid-state texts.

A diode is a two-terminal device, the schematic symbol for which is shown in Figure 2.1.

Fig. 2.1 A diode.

The diode will usually have a band on one end, indicating the cathode. Referring to Figure 2.1, the way to remember the polarity convention is that the stripe on the diode is the bar in the schematic symbol (the cathode), so the arrow part (the anode) of the schematic points towards the band.

An ideal diode basically acts as a switch, allowing current to flow from the anode (A) to the cathode (K) when the diode is forward-biased \( V_d > 0 \). When the diode is reverse-
biased $V_d < 0$, $I_d$ is zero. Thus current normally flows in the direction of the arrow in the schematic symbol.

In a real diode, life is not so simple. First of all, the amount of current a diode will conduct depends on the diode voltage $V_d$. The actual dependence is exponential, as you will learn when you take ECEN 3313. For the amounts of current $I_d$ you are likely to encounter in this lab, the diode voltage drop $V_d$ will be between 0.6 and 0.8 V. There is also an internal resistance in the diode, although this is unlikely to be noticed under most practical conditions.

There is also a reverse leakage current, $I_d < 0$ which flows through the diode when it is reverse-biased. This current is typically negligible. Diodes also experience reverse breakdown, in which the application of a large negative $V_d$ results in a large (negative) $I_d$.

A fact about any real switching element is that, when they are turned off, a finite amount of time must pass before current flow ceases. This applies to real diodes as well: if they are conducting current in a forward direction, and the applied voltage polarity is suddenly switched, the diode will not immediately shut off --- some reverse current will flow for a short time (called the reverse recovery time of the diode). This recovery time is often abbreviated as $T_{RR}$. Some diodes have much shorter reverse recovery times than others. The $T_{RR}$ also depends on the amount of current flowing through the diode: the higher the current, the longer the recovery time. Diodes with large values of $T_{RR}$ (such as the 1N4007) are often referred to as rectifiers, since they are primarily used to convert low frequency AC (such as 60 Hz) into DC. Diodes with small values of $T_{RR}$ (such as the 1N914 or 1N4148) are often referred to as switching diodes, signal diodes, or simply fast diodes.

### 2.2 Rectifiers

Rectifiers are used when a DC voltage has to be obtained from an AC source. Let us assume that $V_s$ is a sinusoidal voltage source $v_s(t) = A \sin(\omega t)$. The current in Figure 3.1 will flow during the positive half cycles of $v_s(t)$. During the negative cycles of $v_s(t)$ no current will flow. Notice the current $i(t)$ is a periodic signal with the same frequency of $v_s(t)$. Also, the voltage across $R1$ is not symmetric about the horizontal axis; therefore it has a nonzero DC value. The DC value of $v_s(t)$ is given by $V_{DC} = A/\pi$. You can confirm this from your PSpice simulation and experiment.

In the circuit in Figure 3.2, two of the diodes are always forward biased and two are reverse biased. This causes the current through the resistor to always flow in the clockwise direction (for the circuit in Figure 3.2). The current $i(t)$ (and the voltage across $R1$) is a periodic signal with a frequency twice the frequency of $v_s(t)$. As before, the voltage across $R1$ exhibits a nonzero DC component.
3 Pre-Lab

3.1 Read carefully Section 2: Background.

Simulate the circuit given in Figure 3.1 using PSpice. Use sinusoidal voltage source for input. Use the D1N4007 diode model (or similar e.g., D1N4002).

![Half-wave rectifier circuit](image)

**Fig. 3.1** Half-wave rectifier.

(i) In Probe, use cursors to identify the peak of \( V_{out} \).
(ii) Why does \( V_{out} \) have a lower peak voltage than \( V_s \)?
(iii) What is the DC average voltage of \( V_s \) (Use PSpice)?
(iv) What is the DC average voltage of \( V_{out} \) (Use PSpice)?
(v) Connect a capacitor of value 0.1 \( \mu \)F in parallel with \( R_1 \). Have you observed any change in the response? Increase frequency in steps of 500 Hz and observe the change in response. Explain the changes.
(vi) What is the definition of a linear system? Is the circuit from (v), with the capacitor in parallel with \( R_1 \), linear? For that circuit, can you determine a transfer function between \( V_s \) and \( V_{out} \)? Explain your answers carefully.
(vii) Repeat (i), (ii), (iii) and (iv) for modified circuit.

3.2 Simulate the circuit given in Figure 3.2 using PSpice.

For the simulation output to make sense, you need to use \( V_{out}^- \) as the reference for \( V_{out}^+ \).

(i) In Probe, use cursors to identify the peak of \( V_{out} \).
(ii) Why does \( V_{out} \) have a lower peak voltage than \( V_s \)?
(iii) What is the DC average voltage of \( V_s \) (Use PSpice)?
(iv) What is the DC average voltage of \( V_{out} \) (Use PSpice)?
(v) Connect a capacitor of value 0.1 \( \mu \)F in parallel with \( R_1 \). Have you observed any change in the response? Increase frequency in steps of 500 Hz and observe the change in response.
(vi) Repeat (i), (ii), (iii) and (iv) for modified circuit.
4 Procedure

**Be sure** to measure the **exact** values of all components you use in your circuits, and record them in your lab notebook.

4.1 Half-Wave rectifier

a) Build the circuit in Figure 3.1 using a 1N4007 rectifying diode for D1.

b) What do you observe on the scope? Verify the results obtained in pre-lab. Can you determine the forward voltage drop of the 1N4007? If yes, what is the value of it?

c) Compare all responses (obtained in lab experiments and pre lab) and explain any discrepancies.
4.2 Full-wave Bridge Rectifier

a) Build the circuit in Figure 3.2 using 1N4007 rectifying diodes for $D_1$–$D_4$. When connecting the scope probes do not connect the ground clips. Instead connect Ch. 1 to $V_{out}^+$ and Ch. 2 to $V_{out}^-$. Make sure the subtract function is selected on the scope.

b) What do you observe on the scope? Verify the results obtained in pre-lab.

References


