# ELEG 309 Laboratory 3

JUNCTION-DIODE BASICS

March 21, 2000

## 1 Objectives

The overall objective of this Experiment is to familiarize you with the basic properties of junction diodes and, as well, provide an overview of some important but simple applications. The main concentration, however, will be on the devices themselves, with most emphasis on their forward-conduction properties.

## 2 Components and Instrumentation

While many of the Explorations to follow could be done with a single diode of a single type, there is much to be learned about different diode types, and the myriad applications of multiple diodes. Thus you are provided with two 1N4148, (a small-signal diode), two 1N4001, (a low-power rectifier diode) and one 1N4733 (5.1 V Zener diode). On each, the band indicates the cathode end for normal forward conduction. As well, you have a supply of (standard) resistors, an oscilloscope, a function generator, a multifunction DMM (including ohmmeter ranges), and a dual power supply.

## 3 Reading

The Explorations to follow, and the corresponding Preparation are based primarily on Sections 3.4, 3.5, 3.6, and 3.7 of the Text. Read these relatively thoroughly.

## 4 Preparation

The items of Preparation are keyed directly to Sections of Explorations, with tasks related to the Figures located there.

### 4.1 Diode action

#### 4.1.1 Ideal Rectification

- For a rectifier circuit consisting of an ideal diode whose cathode is connected to a grounded 1 kΩ load, all fed by a 10 V peak triangle wave at 100 Hz, sketch the input and output waveforms.
- Now, augment your sketch with another waveform showing the output with diodes for which the forward drop is constant at 0.7 V, for all currents.

#### 4.1.2 Rectififer Filtering

- For a circuit resembling that in Figure 2, consisting of an ideal rectifier diode, a 0.1 $\mu$F capacitor, and a 100 kΩ load, fed by a 10 V peak triangle wave at 100 Hz, sketch the output waveform.
- Augment the above sketch with the waveform corresponding to a diode with a constant drop of 0.7 V.

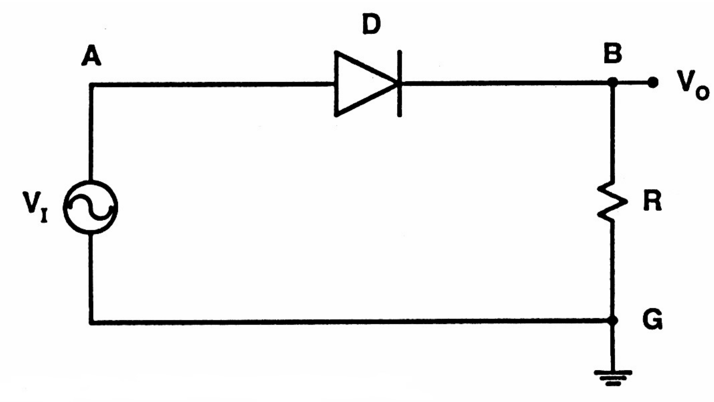


Figure 1: The Basic Rectifier Circuit.

## 4.2 Diode conduction

### 4.2.1 Basic Measurements

- A particular diode with grounded cathode, fed via a 1 kΩ resistor from a 10 V supply, has a voltage drop of 0.62 V. What is the corresponding diode current?
- When the diode operating in the circuit described above is shunted by a 1 kΩ resistor, the diode drop changes by 3.0 mV. What are the coordinates of a second point on the diode characteristic? Estimate $n$ for this diode.

### 4.2.2 Diode Measurement with an Ohmmeter

- On a particular digital ohmmeter, having a 1.99 kΩ maximum range, diode (a) reads 14.0 kΩ, while diode (b) reads 12.0 kΩ. Which is the larger junction?
- If during the measurements above, the voltages across the diode are measured (using a second DVM) to be 0.70 V and 0.60 V, respectively, what diode currents are flowing?

### 4.2.3 Forward-Conduction Modelling - Finding a Large-Signal Model

Use the information provided by the diode characteristic of Fig. 3.20 of the Text, to estimate $V_{D0}$ and $r_D$ for a diode model which matches operation at 0.5 mA and 5 mA.

### 4.2.4 Forward-Conduction Modelling - Finding a Small-Signal Model

- A silicon diode for which $n = 2$ operates at 5 mA with a drop of 0.69 V from a high-resistance source. What is its incremental resistance $r_d$?
- If the junction above is shunted by a 1 kΩ resistor, what new junction voltage would you expect? What shunt resistor would produce a 10 mV junction drop?

# 5 Explorations

## 5.1 Diode action

To set the stage, we will jump directly into an important application of diodes, the one called rectification, the conversion of a bipolar (ac) signal into a unipolar (dc) one.

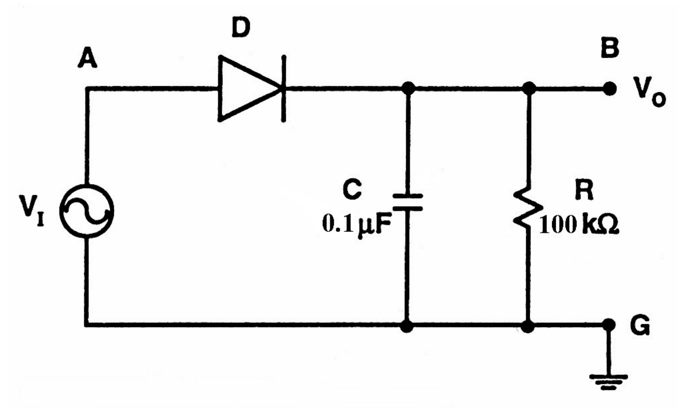


Figure 2: A Rectifier Circuit with Capacitor Filter.

### 5.1.1 Ideal Rectification

- **Goal:** To explore the detailed behavior of the diode in performing the rectifier function.
- **Setup:**
  - Assemble the circuit shown in Fig. 1, using a 1N4001 diode and 1 kΩ resistor.
  - Set the generator to provide a sine wave at 100 Hz with 10 V peak amplitude.
  - Use your two-channel oscilloscope to display waveforms at nodes A and B.
- **Measurement:**
  - Measure the voltages at nodes A and B, using an oscilloscope.
  - Estimate the diode voltage drop at the peak of the output, and at an output voltage which is one-tenth of the peak value.
  - Examine the relationship between $v_A$ and $v_B$ near where $v_B$ begins to go positive. Estimate the time (and corresponding phase angle) at which the output voltage is 1/2 the diode drop at the peak; find the corresponding voltage drop across the diode.
  - Switch the generator to provide a square-wave output. Notice the direct effect of the diode drop.
- **Tabulation:** $v_A, v_B, v_{Dpeak/10}, t_{d/2}, \Phi_{D/2}, v_{D/2}, v_D$.
- **Analysis:** Consider the fact that while this circuit demonstrates the overall behavior of the rectifier quite well, detailed measurements of the diode itself are awkward and inherently imprecise. Various solutions exist for the problem of differential measurement. The most convenient approach to use is an oscilloscope with a broad-band differential measurement capability to measure the diode drop directly, but this is difficult in practice; Generally speaking, what is needed is more basic knowledge of diodes themselves before we launch into the details of applications. Such is the motive of the Explorations following. But first, we will consider one more important system application of diodes where we might gain additional insight into our modelling need.

### 5.1.2 Rectifier Filtering

- **Goal:** To explore the use of a capacitor to store energy from a rectifier between intervals of diode conduction, and thereby to smooth or filter the rectifier output voltage.
- **Setup:** Assemble the circuit shown in Fig. 2. Use a 10 V peak 100 Hz sinewave input.
- **Measurement:**

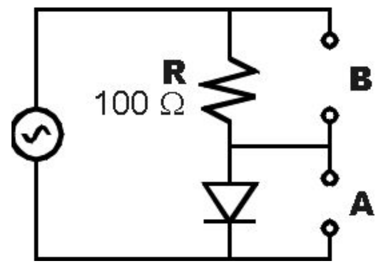


Figure 3: Diode curve tracing circuit.

- Display the waveforms at nodes A and B with an oscilloscope. Estimate the diode drop during conduction. Sketch and carefully label both waveforms. Estimate the time interval for which the diode is forward conducting.
- Shunt $C$ by a capacitor $C_2 = 0.1\,\mu$F. Measure $v_A$ and $v_B$ as above.
- Disconnect $C_2$. Shunt $R$ with a resistor $R_2 = 100$ kΩ.
- Switch the generator to provide a square wave. Repeat the measurements listed above.

- **Tabulation:** Input type, $v_{Apeak}, v_{Bpeak}, v_{Bvalley}$.
- **Analysis:** Consider the advantages of a very large filter capacitor. Calculate the ripple voltage as $v_r = v_{peak} - v_{valley}$ in all cases. Estimate the fraction of a cycle for which the diode conducts in each case? What is the average output voltage? What is the average diode current?

## 5.2 Diode Conduction

Now, having seen the diode in action, so to speak, we will explore some basic properties of the most important characteristic of a junction diode.

### 5.2.1 Diode $IV$ Curve

- **Goal:** To explore the nonliearity of the current-voltage characteristic of a diode.
- **Setup:** Assemble the circuit as shown in Fig. 3 with 1N4001 diode, a 100 Ω resistor. Use frequency of 100 Hz. Set up your oscilloscope to XY mode.
- **Measurement**
  - Slowly increase the input amplitude observing the IV curve of a diode being traced on the oscilloscope screen. Adjust the oscilloscope inputs (sensitivity and polarity) as necessary. Notice how the forward voltage across the diode is limited despite increasing the input.
  - Repeat the above observations with the zener diode 1N4733. Note the sudden increase in the reverse crurrent as the reverse voltage exceeds some 5 V.
  - If time permits, repeat the above observations with the signal diode 1N4148. **Be careful here!** The diode is rated for 10 mA. Before starting to increase the input, calculate what the diode will tolerate.
- **Tabulation:** The maximum forward voltage in each case. Zener voltage for zener diode.
- **Analysis:** Consider the significance of the nonlinearity of the diode characteristic. Note also how the characteristic changes as we replace the rectifying diode with a signal diode, or a zener diode.

### 5.2.2 Diode Measurement with an Ohmmeter

An ohmmeter is quite useful for rapid analysis of diode junctions. Here we will use it in only a first-order way to reinforce some basic ideas about diodes. Later, we can use it to evaluate transistors. Note that the "resistance" reading has no direct significance relative to the diode characteristic, but makes relative magnitude comparison possible directly, and quantification possible indirectly.

- Insert some of your diodes into sockets on your prototyping board for convenience of probing with your meter leads. The arrangement is noncritical (as long as they are not shorted), but for convenience and reduction of experimental error, orient their cathodes the same way. A common cathode (or anode) connection (but not both!) is OK. With an ohms scale, measure across one diode. Reverse the meter leads and do it again. What do you conclude about rectification? about the ohmmeter polarity (and its internal battery) and the direction of current flow?

- Try another diode type. Note the relative resistance of a large (-area) rectifier diode and a small (-area) signal diode.

- **Analysis:** Consider the quick study of a diode that an ohmmeter makes possible: You can find its polarity, whether it is open or shorted, and its relative junction size.

# THE END