University of Pennsylvania
Department of Electrical and Systems Engineering

ESE 206: Electrical Circuits and Systems II - Lab

JUNCTION DIODE BASICS

I. Purpose:

The overall objective of this Experiment is to familiarize the student with the basic properties of the junction diode and, as well, provide an overview of some important but simple applications. The main concentration, however, will be on the device itself, with most emphasis on the diode's forward-conduction properties.

II. Components and Equipment:

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

1 - oscilloscope
1 - function generator
1 - Multifunction DMM (with ohmeter ranges)
1 - dual power supply.
2 - 1N914 diodes (or equivalent 1N4148) - a small-signal diode
2 - 1N4004 diodes - a low-power rectifier diode
1 - 100 μF polarized capacitor
1 - 1 kΩ, 10 kΩ resistors

Please note that on each diode, the band indicates the cathode end for normal forward conducting operation.

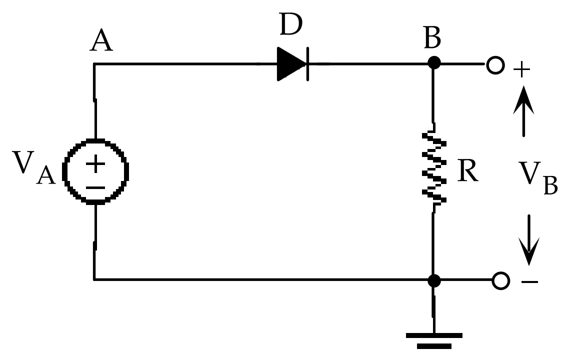

Figure 1 Basic Rectifier Circuit

III. Prelab Assignment:

1. Read Sections 3.1, 3.3 and 3.5 of the Sedra & Smith Text (5th Edition).

2. Ideal Rectification:

(a) Consider the rectifier circuit in Fig. 1 with load resistance R = 1 kΩ load. Let the input V_A be a 10 V peak triangle wave at 100 Hz, sketch the input and output waveforms, V_A and V_B, respectively.

(b) Redraw the sketch of the output waveform V_B made in (a) above to take into account a diode which has a constant voltage drop of $V_D = 0.7$ V for all currents.

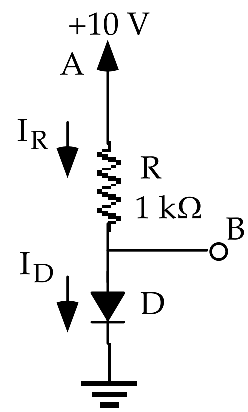

Figure 3 Diode Forward-Drop Test Circuit #1

4. Diode Forward Drop Measurement:

(a) Consider the circuit in Fig. 3, consisting of some particular diode with its cathode connected to ground and anode connected to a 1 kΩ resistor that is fed from a 10 V supply. If the diode voltage drop is 0.62 V measured at node B, what is the corresponding diode current I_D?

(b) Let the diode operating in Fig. 3 be shunted by a 1 kΩ resistor as shown in Fig. 4. With the shunting of the diode by the 1 kΩ resistor, the diode drop decreases by 3.0 mV. Determine the new value for the diode current I_D.

(c) Use the voltages and currents in (a) and (b) to compute an estimate for the value of parameter n for this diode.

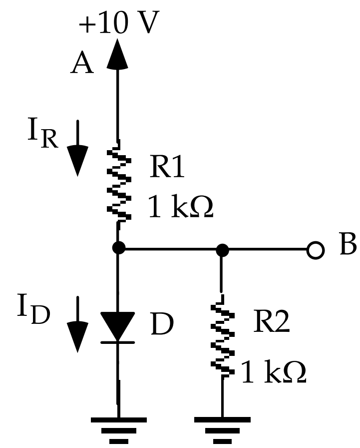

Figure 4 Diode Forward-Drop Test Circuit #2

5. Forward-Conduction Modeling - Finding A Large and Small Signal Model

(a) Using the diode I-V characteristic in Fig. 3.12 on page 156 of the Sedra & Smith text (5th Edition), estimate the values of V_{D0} and r_D for a piece-wise linear diode model which matches this characteristic exactly at $I_D = 0.5$ mA and 5 mA.

(b) Let a diode for which n = 2 operate at 5 mA with a drop of 0.69 V. Determine the incremental resistance r_d for this diode.

IV. Experimental Procedure:

1. Ideal Rectification:

Goal: To explore the detailed behavior of the diode in performing the rectifier function.

a) Assemble the circuit shown in Fig. 1, using a 1N4004 diode and 1 kΩ resistor.

b) Set the generator to provide a sine wave at 100 Hz with 10 V peak amplitude.

c) Use a two-channel oscilloscope, externally triggered, to display waveforms at nodes A and B.

d) Using the waveforms in (c), estimate the diode voltage drop V_D at the peak of the output, and at an output voltage which is one-tenth of the peak value. Hing: You can display the difference between the two signals on the scope by going to the +/- menu and selecting the proper function.

e) Switch the generator to provide a square-wave output. Note the direct effect of the diode drop.

Record the waveforms observed and the estimated values for V_D.

2. Rectifier with Capacitor Filter:

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 rectified output voltage.

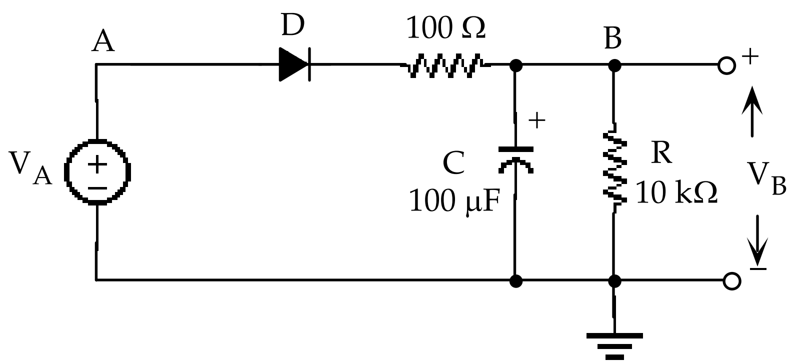

Figure 5 Rectifier Circuit #2 With Capacitor Filter

a) Assemble the circuit shown in Fig. 5 using an 1N4004 diode. Use a 10 V peak 10 Hz sinewave as input. Note that 100 μF capacitor is polarized thus, its + terminal must be connected as indicated in Fig. 5. The 100 Ω resistor is added to limit the current in the diode. You can assume that it has a minimal effect on the operation of the circuit.

b) 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. Note that there is a 50 Ω source resistance (internal to the function generator) in between node A and the actual voltage source.

Record the waveforms, and for each input waveform record the peak values for v_{Amax} and v_{Bmax}, and the minimum value for v_{Bmin}.

c) Replace 10 kΩ R in Fig. 5 with a 1 kΩ resistor. Measure the waveforms at nodes A and B as in a). Record the waveforms as you did above.

3. Diode Forward Drop Measurement:

Goal: To explore a simple means of characterizing diode forward drop.

a) Assemble the circuit shown in Fig. 3 using a 1N4004 diode.

b) Use your DMM to monitor as you adjust the supply voltage to 10 V. Measure $V_B = V_D$ and determine I_D.

c) Shunt R with another 1 kΩ resistor (i.e. put a 1 kΩ resistor in parallel with R). Measure $V_B = V_D$ and determine I_D.

d) With two 1 kΩ resistors connected, shunt diode D with a second IN4004 diode (assumed to be matched). What does V_D become? Estimate the current I_D in each diode.

Record your measurements in table with headings # of Diodes (i.e. 1 or 2 diodes), R, V_D, and I_D.

In your report use your measurements in b) - d) above to determine values of the parameters I_S and n (see Eqs. 3-3 to 3-5 of the Sedra & Smith text) for the your 1N4004 diodes.

4. Forward-Conduction Modeling - Finding A Large & Small Signal Model:

Goal: To explore a relatively simple but effective way to characterize a diode over a wide current.

a) Using the circuit in Fig. 3, connect the anode of the diode to one of the leads for each of four resistors, with values 1 kΩ, 10 kΩ, 100 kΩ, and 1 MΩ. The second leads for each of the resistors are to be left open circuit for the time being. As measurements are taken (see section b below), each of these open terminal will be connected to the 10 V supply alone in sequence. That is first connect the 1 kΩ resistor and take your measurements. Next disconnect the 1 kΩ resistor from the circuit , then connect the 10 kΩ resistor and take your measurements, and so on until you have used all four resistors. [Please note, from a safety point of view, to limit currents which might flow as a result of accidental misconnection, use the power-supply current-limit feature and/or a small series resistor connected to the supply, say 10 Ω to 100 Ω.]

b) For a supply voltage of 10 V, measure V_D as each resistor is connected to the supply in sequence. Estimate the diode current I_D for each value of R. Please note that if the supply voltage is raised slightly, to 10.7 V or so, the values of current become somewhat easier to estimate (or calculate) and to plot.

c) Repeat the measurements in a) and b) for the 1N914 (or 1N4148) diode.

Record your data for each diode in a table with headings R, V_D, and I_D.

In your report consider the following:

a) Using these data as four points, make sketches of the forward-drop I-V characteristic for your diodes on a linear current scale, and on a log current scale. From the log scale sketch, estimate the value of n.

b) For the 1N4004 diode: If 10 mA is the "normal" operating current, determine the diode junction voltage V_{D0} at 1% of normal (i.e. 0.1 mA) and at 0.1% of normal (i.e. 10 μA). For these values used as V_{D0} (See Fig. 3.12 of the Sedra & Smith text), determine values for r_D.

c) For the 1N4004 diode: Determine estimates of incremental resistance at about 5 mA, 0.5 mA, and 50 μA.

Kenneth R. Laker
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