Laboratory #2

Zener Diodes and Diode Rectification

I. Pre-Laboratory Assignments

1. Sketch the approximate characteristic curve you expect to record for the Zener diode in part 1 of the Laboratory Experiments.
2. With R = 750 Ω, simulate the circuit shown in Fig. 1 with *Advanced Design System*. Plot the diode voltage and current over the complete region of operation extending from well into breakdown, through the reverse bias region, and well into the forward bias region.
3. What would happen to the output voltage of the bridge rectifier in Fig. 2 if one diode burned out (becomes an open circuit)? Sketch the input and output voltages together on the same graph if D_3 was burned out. Repeat if D_1 burned out.
4. Notice in the circuit of Fig. 2 that we have connected the load resistance in a "balanced" manner. Do you expect that the circuit would or would no longer behave as a bridge rectifier if node A were grounded? Explain.
5. Obtain a datasheet for a red LED as shown in the figure below. What is the forward voltage drop when the diode is "on"?

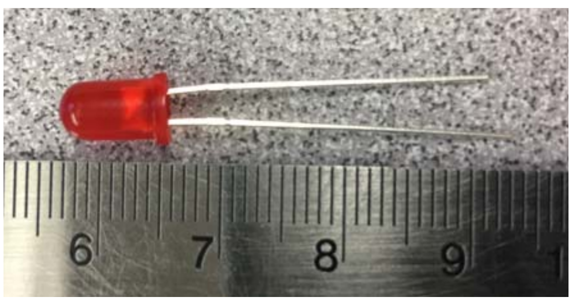

Figure A Photograph of the red LED used in the lab. The ruler units are mm.

6. For a 100-Hz sinusoidal input voltage of 10-V peak amplitude, compute the diode conduction time and the ripple voltage for the half-cycle peak rectifier circuit in Fig. 3. Repeat these calculations for a triangle input voltage waveform.

II. Laboratory Experiments

Zener Diode

1. The Zener diode you will characterize in this lab is part number 1N4736. This diode is specified to have V_Z (at I_{ZT}) = 6.8 V and I_{ZT} = 37 mA. It is a 1-W diode with a maximum Zener resistance r_{zT} = 3.5 Ω (at I_{ZK} =1 mA).
   (a) Choose a resistor R in the range of 500 Ω to 1,000 Ω and measure its resistance as accurately as you can. Construct the circuit shown in Fig. 1. Measure the diode voltage and current over the complete region of operation extending from well into breakdown,

through the reverse bias region, and well into the forward bias region. Plot this characteristic curve. Include a measurement at I_{ZT} and compare with the rated V_Z.

(b) From your plot in part 1(a) of the characteristic curve in the breakdown region, estimate V_{Z0} and r_Z.

(c) From your plot in part 1(a) of the characteristic curve in the forward bias region, estimate V_{D0} and r_D.

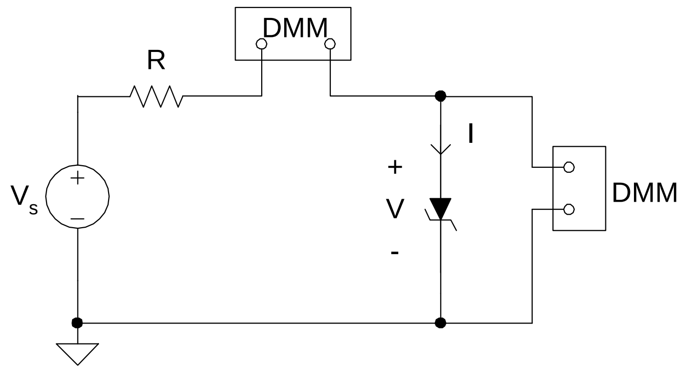

Figure 1 Zener diode characterization circuit.

Full-Cycle Bridge Rectifier†

2. The bridge rectifier you will be building in this part is shown in Fig. 2. Note that the diodes in this circuit are light emitting diodes (LEDs). Do not construct the circuit yet.
   (a) Set a power supply to zero volts and connect it to the leads of one LED. The positive voltage should be connected to the anode of the LED (the longer lead). As you very gradually increase the voltage the LED should illuminate. What voltage is needed to attain full illumination of the LED? Compare this to the forward voltage from the datasheet you collected in part 5 of the pre-lab. Compare both of these values to the forward voltage drop of a 1N4148. Note that if the voltage is set too high (and the current becomes too large) you may burn out the LED. What is the value of this current according to the datasheet?
   (b) Construct the bridge rectifier shown in Fig. 2. The function generator should be set to a square wave voltage with zero average value at a frequency near 1 Hz or less. Increase the amplitude of the square wave until the LEDs fully illuminate. Since the frequency is so low, you need to adjust the time scale to large values (perhaps 20 ms/div or so).
   (c) Sketch the input voltage waveform and indicate at which times you observe each LED on and off. Based on these visual observations, sketch the current paths in the bridge rectifier for each half cycle of the input square wave voltage. Show that this coincides with your theoretical expectations for this circuit.
   (d) Connect a lead wire from node A to the circuit ground. Explain why the circuit no longer behaves as a bridge rectifier. In contrast, why does the circuit in Fig. 4.25(a) of the text behave as a bridge rectifier with node A grounded?

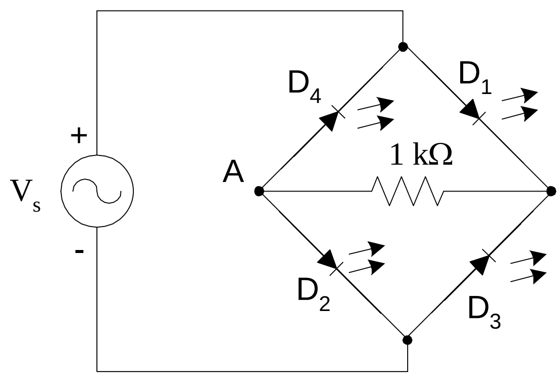

Figure 2 Full-cycle bridge rectification circuit using four LEDs.

Half-Cycle Peak Rectification††

3. The capacitor *C* in the half-cycle peak rectifier in Fig. 3 is an electrolytic capacitor and is polarized. That is, it must be connected to the circuit so that DC current is directed into the "+" terminal as indicated in the circuit. The "-" terminal of electrolytic capacitors is labeled on the package.
   (a) Construct the half-cycle peak rectification circuit shown in Fig. 3 with R = 10 kΩ. Use a 1N4148 small signal silicon diode for *D*.
   (b) For a sinusoidal voltage of 10 V peak and a frequency of 100 Hz, display the waveforms at nodes A and B simultaneously on the oscilloscope. Both channels should have the same average level on the display and set to the same vertical scale. Sketch and carefully label both of these waveforms. Now change the time scale for the voltage measurement at node B to make the ripple readily apparent. Measure the time interval Δt for which the diode is forward conducting and compare with your predictions. Measure the ripple voltage and compare with your predications from the prelab.
   (c) Replace *R* with a 1-kΩ resistor. Repeat the measurements and sketches in part 3(b).
   (d) Set the function generator to a triangle waveform. Repeat part 3(b) with R = 10 kΩ and part 3(c) with R = 1 kΩ.

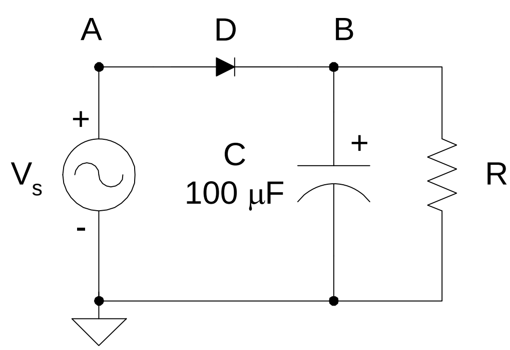

Figure 3 Half-cycle peak rectification circuit.

Note: In the Δt measurements in part 3(b), you should expect to see some differences between your measurements and predictions. The primary reason for this is the 50-Ω internal source resistance, R_s, of the function generator, as shown in Fig. 4.

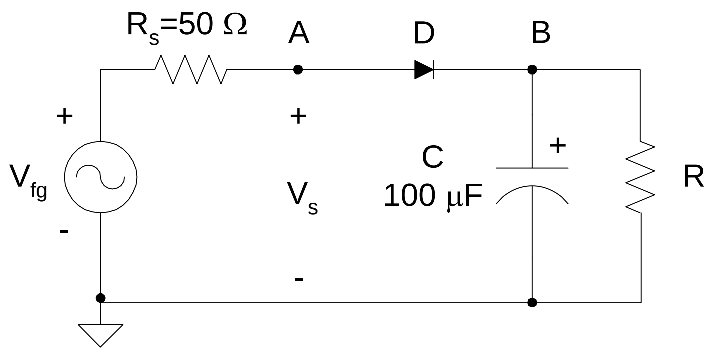

Figure 4 Half-cycle peak rectification circuit with the internal source resistance of the function generator included.

During the time period Δt when the diode conducts, current is drawn from the function generator through R_s and D to C. Consequently, there is a charging time constant $\tau = (R_s \parallel R)C \approx R_s C$ (which is approximately 5 ms ignoring the diode resistance) that limits how fast the output voltage can increase. Therefore, in your measurements you will notice that the output voltage seems "clipped," which is nothing more than the slowed down charging of C during times Δt primarily due to the internal source resistance of the function generator. However, in your pre-lab predictions of Δt you probably assumed an instantaneous charging of C. Therefore, the predictions for Δt and the measurements will likely not have great agreement.

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† Special thanks to Messrs. Brian Glover and Jason Nemeth for suggesting the LEDs.

†† Adapted from Kenneth C. Smith, *Laboratory Explorations for Microelectronic Circuits*. New York: Oxford University Press, fourth edition, 1998.