

ECE 2201 – PRELAB 1

DIODE CHARACTERISTICS

P1. Lab Notebook Preparation:

- (1) Obtain an appropriate engineering lab notebook and write your NAME and ECE BOX# on the cover, so that your notebook can be returned to you.
- (2) Reserve the first two pages of your lab notebook for a Table of Contents (TOC). Always good practice for an engineering notebook.
- (3) Review this experiment IN ADVANCE and prepare Circuit Diagrams, Tables, and Graphs in your notebook, prior to coming to lab.

P2. Simulation:

- (4) Review the Camtasia Video, “Diode Characteristics” at: users.wpi.edu/~sjbitar/ece2201
- (5) Use Multisim to create the *V-I Diode Characteristic Curves* for both the 1N4148 (or 1N4149) signal diode and the 1N4004 rectifier diode. NOTE: If you are unfamiliar with the simulator, review some of the other videos as well. Bring copies of your simulation to lab.
- (6) Use Multisim to verify Parts II, III, and IV of this lab assignment. Bring copies of your simulations to lab.

P3. Hand Analysis or Simulation: (NOTE: For simulation, use the VIRTUAL diode model.)

- (7) For the diode circuits of Fig. (a) and (b), plot v_{OUT} and i_D as a function of time if v_{IN} is a 1kHz sine wave with peak amplitude of 5V.
- (8) For the diode circuits of Fig.(a) and (b), plot the voltage transfer characteristics (v_{OUT} as a function of v_{IN}) .

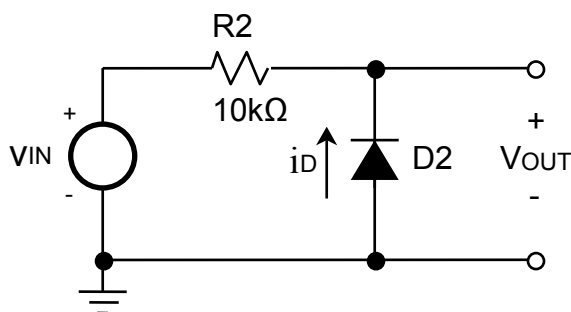


Fig. (a)

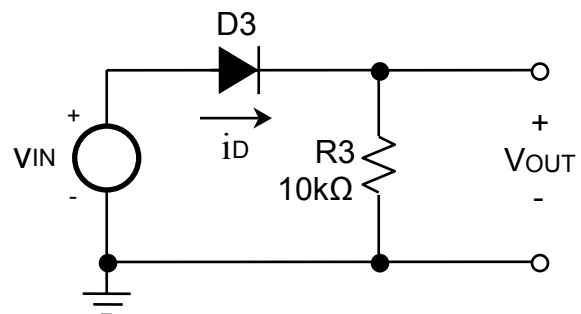


Fig. (b)

ECE 2201**LAB 1 - DIODE CHARACTERISTICS****PURPOSE:**

The purpose of this laboratory investigation is to determine the voltage and current characteristics of several P-N junction diodes including the 1N4148 signal diode, the 1N4004 rectifier diode and the 1N5231B zener diode. Diode signal processing applications are also introduced including signal clipping and rectification. Limitations of switching frequency are also investigated. Upon completion of this lab you should be able to:

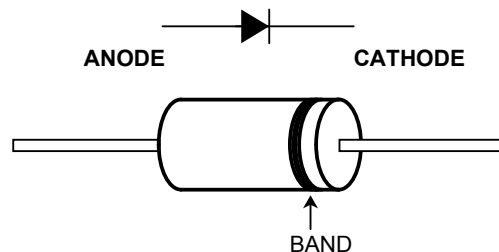
- Measure and plot the V-I terminal characteristics of P-N junction diodes.
- Configure an oscilloscope in X-Y mode to display the *V-I characteristics* of a diode (curve tracer).
- Determine exponential diode model parameters I_S and n from voltage and current data.
- Compare diode models including the constant-voltage-drop model, the piece-wise-linear model and the exponential model.
- Use an oscilloscope to display the *voltage transfer characteristic* of a diode signal processing circuit.
- Understand diode switching frequency limitations.

MATERIALS:

- ECE Lab Kit
- DC Power Supply
- 12VAC Transformer
- DVM
- Function Generator
- Oscilloscope

NOTE: Be sure to record ALL results in your laboratory notebook.

Diode pin designation reminder: Band on package indicates cathode:



PART I: DIODE V-I CHARACTERISTICS

Forward Bias Region

- 1.1. Build the circuit shown in Fig. 1-1 using the 1N4148 diode and a 1k Ω resistor. Vary V_1 from 0 to 10V in appropriate intervals to obtain enough data points to plot the *Forward Bias V-I Characteristic* of the diode.

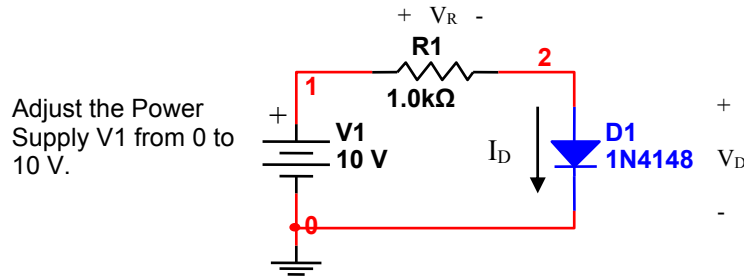


Figure 1-1.

- 1.2. Measure and record the voltages across the diode (V_D) and resistor (V_R), and calculate the current (I_D) for each data point. Create a table in your lab notebook of this data, as shown.

V_1 (Measured)	V_R (Measured)	V_D (Measured)	I_D (Calculated)
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮

NOTES:

- Take more data points at diode voltages between 0.4V and 0.7V volts for greater accuracy.
- Measure the actual resistance used. The resistors in your kit have a tolerance of $\pm 5\%$, so using the nominal value of 1k Ω for R_1 would give an uncertainty in I_D of $\pm 5\%$.
- When making measurements, use the appropriate scale on the DVM to display as many significant figures as possible for greater accuracy.
- For these measurements, the meter current can be assumed to be negligible if the input impedance of the meter is at least 10M Ω . Check this and make a note of it.

Reverse Bias Region

- 1.3. In order to measure the *Reverse Bias V-I Characteristic* of the diode, swap the direction or polarity of the diode and replace R_1 with a 1M Ω resistor as shown in Fig. 1-2. Sweep the power supply from 0 to 20V in increments of 2V. Record the voltage drops across D_1 and R_1 , and calculate the current (I_D) for each data point. Use these measurements to plot the *Reverse Bias V-I Characteristic* of the diode. NOTE: V_D and I_D values should be indicated as negative values for reverse bias.

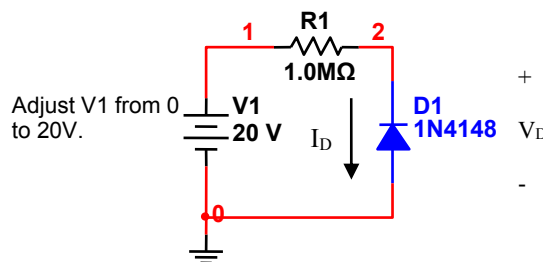


Figure 1-2.

PART II: DIODE V-I CHARACTERISTICS (SWEEP METHOD)

The *sweep method* can be used to easily display the V-I characteristic of a diode using an oscilloscope. Specialized instruments of this type are known as *Curve Tracers*. If a curve tracer is available, you most certainly can use one for this part of the experiment.

- 2.1 Set up the circuit in Figure 1-3 using the 12 V transformer that you will be given in the lab. The transformer needs to be plugged into on your bench and turned on. A light on the switch should indicate that power is on.

NOTE: The only ground reference point in the circuit is the scope probe ground. DO NOT connect any of the transformer leads to ground in this circuit.

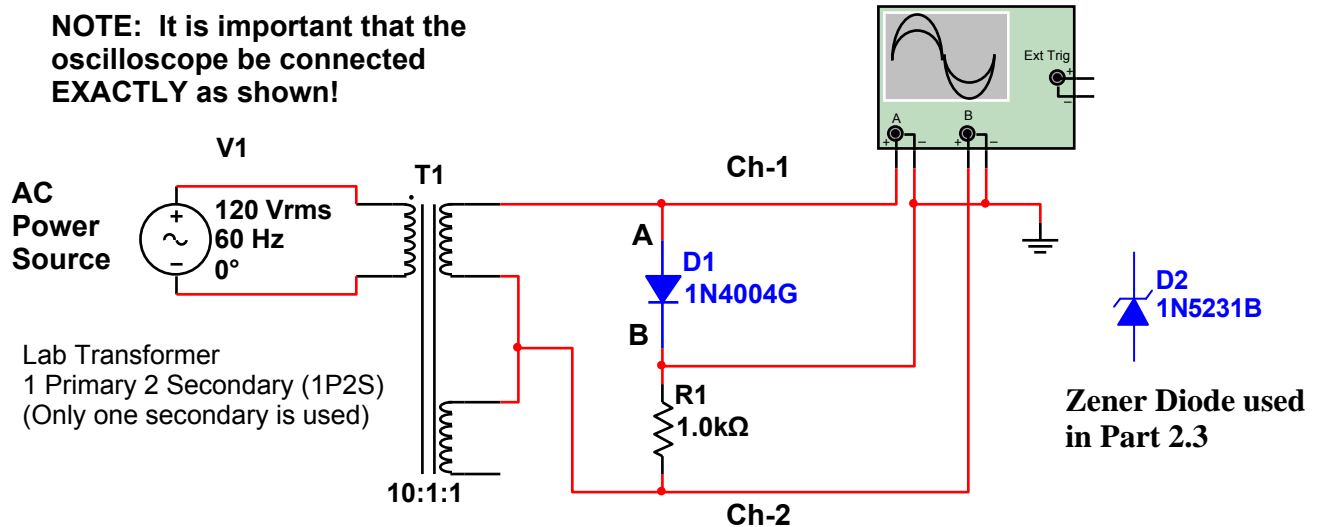


Figure 1-3

- 2.2 Next, press the “DISPLAY” key on the Oscilloscope and then select “XY Format” on the screen menu. Set Ch-1 to 200 mV/div and Ch-2 to 2 V/div so you will obtain an appropriate characteristic curve of the 1N4004 diode. Press the Ch-2 menu button, then press the screen “Invert” menu button to “ON”. Turn on the transformer switch. The waveform should sweep both the forward and reverse characteristic of the diode. The upper right quadrant should be the forward characteristic and the lower left, the reverse. Record this waveform then turn off the transformer switch.
- 2.3 In the circuit of Figure 1-3, remove the 1N4004 diode and replace it with the 1N5231B, Zener diode. Connect the cathode to point “A” and the anode to point “B”. Turn on the transformer switch and repeat the above steps in Part 2.2 above, making oscilloscope adjustments if necessary to obtain an appropriate Zener characteristic curve. Record this waveform, then turn off the transformer switch.
- 2.4 How are the V-I characteristics for the 1N4004 and 1N5231B similar? How do they differ? Can you explain why?

PART III: DIODE SIGNAL PROCESSING

Clipping Circuit

Often, an input signal may contain large voltage spikes that are too large for sensitive circuitry to process (eg. during a thunderstorm). In these cases, a signal *clipping* circuit can be employed to prevent the input signal voltage from exceeding a particular value.

- 3.1 Build the diode circuit shown in Fig. 1-4. Use the function generator to set up the input signal source (V1) to be a 5Vpk sine wave at a frequency of 1kHz. Adjust the DC power supply (V2) for an output of 2V.

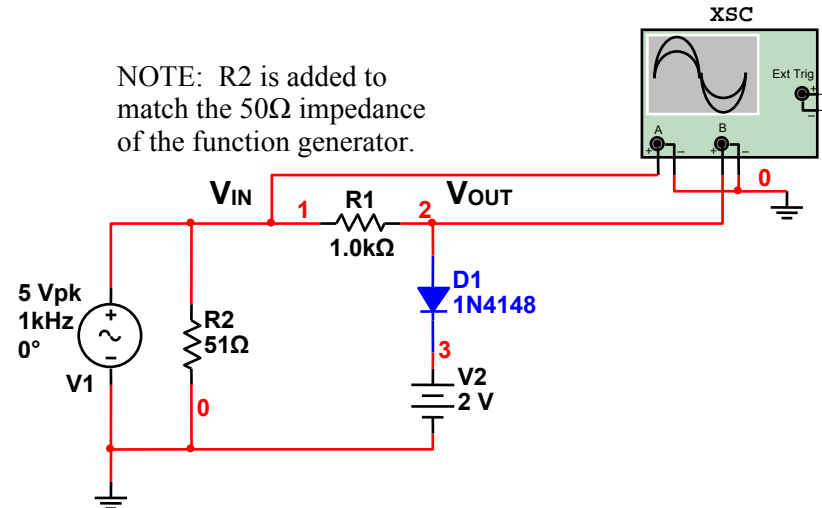


Figure 1-4.

Input and Output Waveforms

- 3.2 Set up the oscilloscope to view V_{IN} on Channel 1 (A) and V_{OUT} on Channel 2 (B). Set the vertical scale to 2V/div for each channel. Adjust the vertical position of each trace so that both are centered vertically. Once the vertical position is adjusted correctly, view the voltage waveforms. Also, be sure that both channels are on DC coupling and set up the time base of the scope to show at least one full cycle of the sine wave.
- 3.3 Sketch the input and output waveforms as shown on the oscilloscope. At what voltage does the output signal clip? Adjust the 2V DC supply between 1 and 3 Volts while viewing the waveform. Explain what you observe.

Voltage Transfer Characteristic

- 3.4 Change the display format of the oscilloscope to XY. This will display channel 1 (V_{IN}) on the horizontal axis, and channel 2 (V_{OUT}) on the vertical axis. The result will be a plot of V_{OUT} as a function of V_{IN} or the *Voltage Transfer Characteristic*. Sketch this characteristic in your notebook.

Design Challenge

- 3.5 Design a circuit to clip the signal at both +0.7Volts and -0.7Volts, using the parts in your kit. Is a DC power supply necessary for this design? Explain.

PART IV: DIODE SWITCHING FREQUENCY LIMITATIONS

Rectifying Circuit

Diodes are often used in circuits to convert *Alternating Current (AC)* into *Direct Current (DC)*. In these applications, the physical size (cross-sectional area) of the diode is increased to handle the higher current levels. Diodes used for these applications are called *rectifiers*. One trade-off for increasing the size of the diode is that maximum switching frequency of the diode is reduced. This part of the lab investigates the switching frequency limitation of a rectifier diode.

- 4.1 Build the diode circuit shown in Fig. 1-5. Use the function generator to set up the input signal source (V1) to be a 5Vpk sine wave at a frequency of 100Hz.

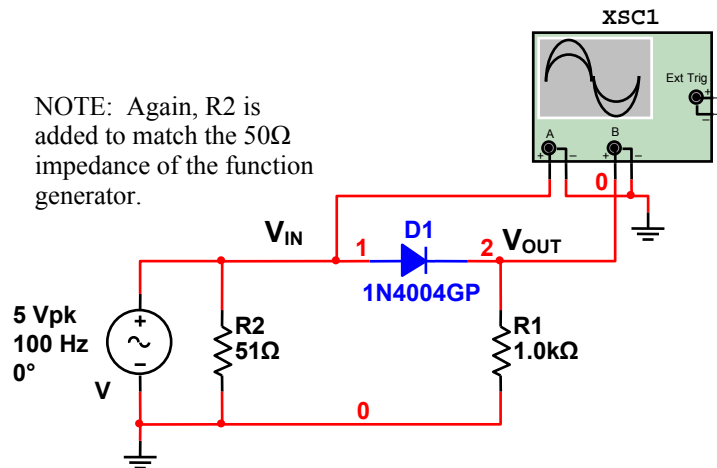


Figure 1-5

Input and Output Waveforms

- 4.2 Set up the oscilloscope to view V_{IN} on Channel 1 (A) and V_{OUT} on Channel 2 (B). Set the vertical scale to 2V/div for each channel. Adjust the vertical position of each trace so that both are centered vertically. Once the vertical position is adjusted correctly, view the voltage waveforms. Also, be sure that both channels are on DC coupling and set up the time base of the scope to show at least one full cycle of the sine wave. Sketch the resulting waveforms in your notebook. Is the diode performing the rectifying function? Explain.
- 4.3 Now increase the frequency of the signal from 100Hz to 1kHz, 10kHz, 100kHz, and 1MHz. Adjust the time base of the scope accordingly to constantly view at least two complete cycles of the wave. Sketch the waveforms at each frequency. What happens to the output voltage as frequency is increased? At what frequency does the 1N4004 diode cease to operate as a rectifier?
- 4.4 How do the waveforms compare to your simulations? Explain.

LAB WRITEUP

This lab assignment contains FOUR parts. Each section should include:

- (1) A brief statement describing the scope of each experiment.
- (2) Detailed schematics with all components labeled, values indicated and equipment used.
- (3) Explanations of each concept with key mathematical derivations that govern the behavior of the system.
- (4) Experimental results including tables, graphs, and oscillograms.
- (5) Pertinent simulations for comparison.
- (6) Overall conclusions and observations.

Additional details for each part of this lab are given below:

PART I: DIODE V-I CHARACTERISTICS

- W1. Graph the overall V-I characteristic for the 1N4148 diode based on your data, on linear axes with each region of the curve identified, using different voltage scales for the forward and reverse bias regions.
- W2. Derive the exponential model parameters I_s and n for your diode based on two or more of your data points and *Shockley's Diode Equation*, presented in class.
- W3. Graph Shockley's diode equation alongside your data using the parameters derived in part W4. Use a semi-log scale, $\log(I_D)$ vs. V_D , and plot the forward bias region only. NOTE: Exponential graphs should come out linear on a semi-log scale.
- W4. Compare the three diode models including, the constant voltage drop model, the piece-wise linear model, and the exponential model and answer the following questions.
- (1) Based on your data, what voltage would you use for a constant voltage drop model at a diode current of 5mA?
 - (2) For a piece-wise linear model, what values would you use for V_{D0} and r_D , at a current of 5mA?
 - (3) How well do these models predict the diode's V-I behavior?
 - (4) Are there any deviations from the model (e.g. at low currents or high currents)? What are the trade-offs involved with each model? Accuracy? Ease of use? Etc.

PART II: DIODE V-I CHARACTERISTICS (w/ Curve Tracer)

- W5. Include graphs from both lab and simulation.
- W6. Compare the V-I characteristics for the 1N4004 and 1N5231B. How are they similar? How do they differ? Explain.

PART III: DIODE SIGNAL PROCESSING

- W7. Include graphs of both the input and output waveforms as a function of time as well as the *Voltage Transfer Characteristic* of this circuit.
- W8. Include your circuit for the *Design Challenge* given, and the waveforms that result.

PART IV: DIODE SWITCHING FREQUENCY LIMITATIONS

- W9. Include graphs from both simulation and lab, for comparison.
- W10. Comment on the frequency limitation of diodes, based on your results.