Laboratory Goals

- Analyzing, simulating and building diode-based circuits.
- Taking measurements and applying transformations to obtain the diode I-V curve.
- Use the NI curve tracer to verify the IV curve

Pre-lab / lab reading

- NI ELVIS Quick Reference Guide
- Course Textbook
- Oscilloscope User's Guides (Copies of these reference books are available in the lab, or at the website)
- Read the pre-lab introduction below

Equipment needed

- Lab notebook, pencil
- NI ELVIS II
- Oscilloscope (Agilent or Tektronics)
- 2 oscilloscope probes (already attached to the oscilloscope)
- BNC/EZ Hook test leads
- Workstation PC, with PSICE application
- Rectifier Diodes
- Resistors and Capacitors
- Jumper Wires

Lab safety concerns

- Make sure before you apply an input signal to a circuit, that all connections are correct, and no shorted wires exist.
- Do not short the function generator signal and ground connections together .
- Do not touch the circuit wiring while power is applied to it .
- Ensure you connect devices using their correct polarity.

1. Pre-Lab Introduction

The diode is one of the oldest and most important electronic devices, although it is not as famous as its cousin, the transistor. It is used in all sorts of electrical and electronic systems, the diode functions as a one-way valve for electric current, it only allows current to flow in one direction. This is useful in converting AC to DC, processing high frequency signals, regulating voltages, and in other applications. There are two basic types of diodes. One is an electron tube like the triode and the other type uses semiconductors, like the transistor. Both were invented early in the 20th century.

The first diode was a modified light bulb. Thomas Edison discovered that including an extra electrode in a light bulb and connecting it to the positive side of a battery resulted in a current flowing from the filament through the empty space. Joseph J. Thomson (1856~1940) announced the discovery of the electron in April 1897 and explained the Edison effect where current travels just one way through a vacuum tube. Thompson received a Nobel prize in 1906. Others found another use for this device. In the early 1900s, John Ambrose Fleming used this one-way electrical "valve," to convert radio waves into a flow of current that could be measured by a galvanometer. The Fleming valve is remembered as the first true electronic device. It came into use for radio transmission and soon became the basis of Lee De Forest's Audion electron tube, which he invented in 1906.

Also, around 1906, American engineer Greenleaf W. Pickard invented a new type of diode. Pickard based his design on the earlier discovery that electricity can flow in only one direction through certain types of mineral crystals, such as silicon. By placing a silicon crystal between a metal base and a carefully placed fine wire, Pickard created a valve that could also be used to detect radio waves. This type of "cat's whisker" diode (so-named because of the fine wire used in it) became more popular after American H. C. Dunwoody patented a version of it that used a material called carborundum.

Today the variety of diodes and their uses have greatly expanded. Electron-tube diodes are rarely used, but silicon diodes are used in many types of equipment to detect high frequency electromagnetic waves, to convert sunlight into electricity, and many other purposes.

2. Pre-Lab Calculations

For the circuits below, plot the expected output waves

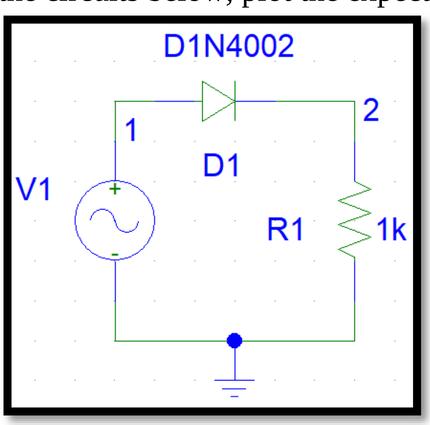

Figure 1: Half-wave rectifier

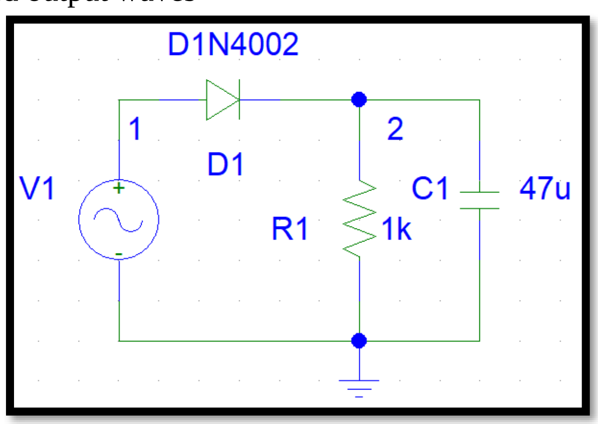

Figure2: Peak rectifier/detector

3. Diodes I-V Characteristics

Circuit Construction and Signal Measurement

- Build the circuit shown below using a diode and resistors provided by your TA

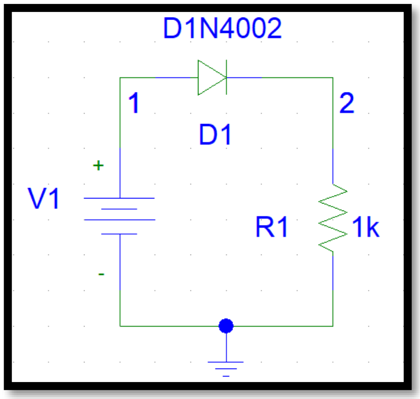

Figure 3: Diode-Based Circuit for DC transfer characteristics analysis

- Read the diode data sheet to identify which pins correspond to the anode (positive) and cathode (negative) terminals.
- Test the circuit by varying input voltage from -1.5 to +1.5 in increments of 0.1V. For measurement simplicity, use a DC Voltage Sweep in the Variable Power Supply.
- Using a digital multimeter measure the output voltage, the voltage across the diode, and the current consumption for each input.
- Plot I_D vs V_{in} , resistor voltage V_R vs V_{in}, and the diode's voltage V_D vs V_{in}.

Diode IV Curve

- Use the NI ELVIS two wire current-voltage analyzer to obtain the diode's IV curve.
- For this test, connect the diode's anode to the DUT+ terminal and the cathode to DUT-

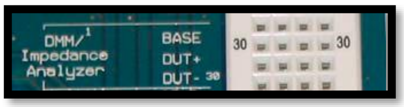

Figure 4: NI-ELVIS two wire current-voltage analyzer

- The Teaching Assistant will verify the produced curve and sign your lab notebook

4. Half Wave Rectifier Circuits using Junction Diodes

Circuit Construction and Signal Measurement

- Build a half wave rectifier circuit (shown in Figure 1), using a diode and a 1kΩ resistor.
- To test this half-wave rectifier, use a 10-$V_{pk\text{-}pk}$ 1-kHz sinusoid generated by the function generator, and use the oscilloscope to plot the output voltage V_o (measured across the resistor) vs. time. Compare it to the input voltage V_I from the function generator.
- Then plot the voltage across the diode V_D. What would happen with V_o and V_D if the diode is reversed? What would happen with V_o and V_D if the frequency changes?
- Now use the Tektronix XY mode to plot V_o vs V_I. Reverse the diode and repeat.

Peak rectifier/detector

- Consider now the peak rectifier shown in Figure2, where a capacitor is added at the output.
- Build the circuit using a 10$V_{pk\text{-}pk}$ 1-kHz input sinusoid a 1kΩ resistor and a 47μF capacitor.
- Provide a plot of V_I and V_o versus time using the oscilloscope. Write down the rectified peak voltage (V_p) and the ripple voltage (V_r) of the circuit. Plot also V_D versus time.
- Repeat the test, but now changing the resistor to 10kΩ. What happens to the ripple voltage (V_r) when the resistance changes? Why doesn't the peak voltage (V_p) change?
- Repeat the test again, but this time change the capacitor to 10μF What happens to the ripple voltage (V_r) when the capacitor changes? Did the peak voltage (V_p) change?
- Now test the circuit with a modified frequency. How does frequency affect the ripple voltage? Provide an equation for the ripple voltage as a function of *f*, *R* and *C*.
- Finally use the Tektronix XY mode to plot V_o vs V_I for each circuit tested.
- For all circuits tested, the required waveform should be applied using a function generator. **Remember to capture images of all the voltage waveforms obtained on the oscilloscope.** Also make sure to record the values of peak voltages (V_p) and ripple voltages (V_r) in your lab notebook and to get the notebook signed before leaving.

4. Full Wave Rectifier Circuits using Junction Diodes

Circuit Construction and Signal Measurement

- Build the circuit shown below using a 1kΩ resistor and four diodes provided by your TA.

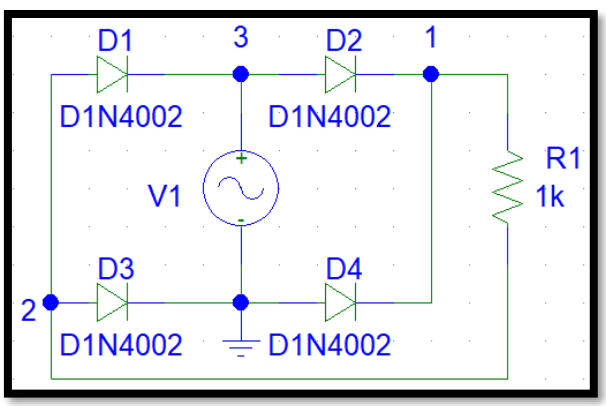

Figure 3: Diode Bridge

- Test the circuit using a 10-$V_{pk\text{-}pk}$, 1kHz sinusoid generated by the function generator.
- Provide a plot of V_I and V_o versus time and report the peak voltage V_p .
- Add a 47μF capacitor, in parallel with the resistor, provide a plot of V_I and V_o versus time, and write down the rectified peak voltage (V_p) and the ripple voltage (V_r) of the circuit.
- Now try changing the resistor, the capacitor, or the input frequency. How does it affect V_p and V_r? Provide an equation for the ripple voltage as a function of *f*, *R* and *C*. How is this different from the one for the half wave rectifier?
- Finally use the Tektronix XY mode to plot V_o vs V_I.

Further Exploration

- Can you reverse the output wave? What diode configuration would achieve this?
- How did changing the capacitor or resistor affect the output voltage?
- How does the frequency and period of the output voltage compare to that of the input?
- Compare the peak to peak voltages at the input and output. Why is the output peak to peak voltage less than the peak voltage at the input?

5. Simulations

In the last lab, you learned about the Multisim Simulation software. In class, you might have also already been introduced to PSPICE. Provide simulations with either simulation tool for the circuits tested today (preferably use PSPICE, as this will be used in your class final project). How do the simulations compare to the measurements?

6. Analysis

Write a summary report for the lab. Be sure to also include the following topics:

1. Draw a junction diode cross section diagram.
2. Identify and explain the operating regions of the IV curve generated for the diode.
3. Compare the results of the hand computation, physical experiment and curve tracer output graph. Do the values generally agree? Explain possible reasons for any differences.
4. How do your measured results compare to your simulations?
5. Explain any difficulties you had with these labs. (Please include any suggestions to improve them).