# Lab 6: Diodes (version 1.5)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Input-output relationship of a diode

An ideal diode will perfectly conduct when voltage is applied in one direction and completely block current flow when the voltage reverses sign. Real diodes have non-ideal characteristics caused by their physical construction, whether implemented as a vacuum tube or in the wide variety of semiconductor diode schemes.

A voltage sweep circuit displays the output current (I) vs voltage (V) applied to a diode. Construct the following circuit with a 1N4002 or equivalent diode. Unlike resistors and most capacitors, diodes cannot be placed into a circuit arbitrarily. Semiconductor diodes will be marked with an obvious band placed near the cathode. In the circuit below, the cathode of the diode is connected to R = 10 kΩ (value not critical).
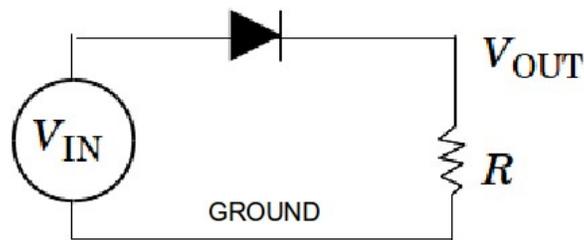

Voltage input and readout are accomplished here with NI-DAQmx. This provides an interface between LabView and a variety of NI devices including the Elvis II platform. The analog voltage needed to drive V_{IN} can be generated on pins 31 or 32 on the left side of the breadboard (ground is on pin 49 or 53). V_{OUT} can be read on any of the +/– terminal combinations found on pins 1—15. Tie V_{OUT} to a (+) pin and the corresponding (–) pin to ground. Ground is on pin 18 and should be connected to the other ground points. Note that V_{IN} is actually supplied by an *output* pin of the board; V_{OUT} is read by an analog *input* pin.

Open LabView and create a blank VI. Go to the Block Diagram, create a For Loop, and wire a control to the count terminal. This control will set the number of displayed data points in the experiment.

Turn on the main power switch of the Elvis board. Right-click on an open space in the block diagram, locate the Measurement I/O palette: NI-DAQmx--Data Acquisition. Use the thumbtack in the upper left corner of the window to hold it open. It is also recommended that the Context Help (Ctrl-H) of LabView be enabled to assist in wiring.

Two channels must be created: one to *write* the analog input voltage and a second to *read* the analog output voltage. The channels correspond to physical connections you have made on the Elvis board. Place two copies of DAQmx Create Virtual Channel.vi on the block diagram at the outside left of the For Loop. For the first channel, open its sub-menu and configure it for Analog Output: Voltage. Configure the second for Analog Input: Voltage. Right-click on the **physical channels** terminal and create controls for both of them.

LabView must be instructed to start the DAQmx interface you have just configured. To do this, go to the Data Acquisition palette and select the Start Task VI. Place it immediately to the right of each Create Virtual Channel VI, but outside the For Loop. Wire the Task-Out and Task-In lines together and create an input tunnel for each line on the For Loop. This portion of the Block Diagram should look as follows:
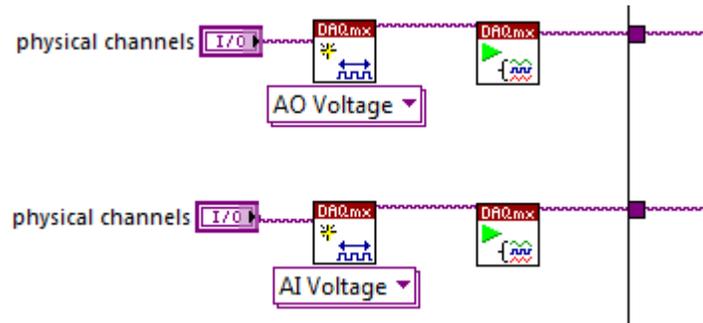
In the Data Acquisition palette, select the DAQmx Write VI and place it inside the For Loop. Connect the **task/channels in** terminal to the tunnel linked to AO Voltage. Configure it as Analog: Single Channel: Single Sample: DBL. Using the same procedure, place a DAQmx Read VI inside the For Loop and wire it to the AI Voltage task line. Configure it as Analog: Single Channel: Single Sample: DBL.

The DAQmx interface should be cleared just before the VI stops. This is accomplished with the Clear Task VI on the Data Acquisition palette. Place two of them on the outside right side of the For Loop and connect the task and error lines as shown below. Recall that the default operation of a For Loop will create an array at the output tunnel. Right-click on the tunnel and Disable Indexing.
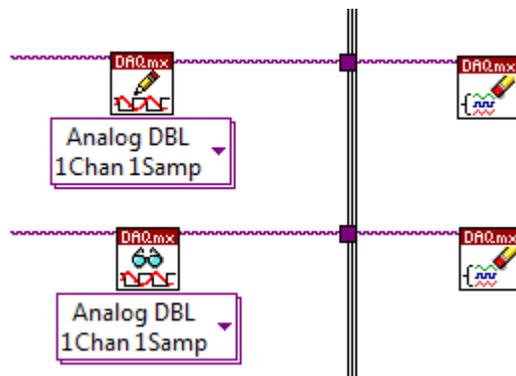
The purpose of this experiment is to sweep a voltage ramp across the diode in increments that are set in the For Loop and read the output voltage. Place a numeric control that defines the maximum ramp voltage on the Front Panel. Write suitable code to generate an incremental linear voltage ramp and wire this to the **data** terminal of the DAQmx Write VI. This terminal should also be brought to an output tunnel on the For Loop where it will generate a 1-D array that holds the values of the input voltage. The data terminal of the DAQmx Read VI with corresponding output voltages should also be wired to an output tunnel. Leave indexing enabled at both output tunnels. Add a 1 ms Wait delay inside the For Loop.

Insert some code to convert the 1-D output voltage array to current. The data should be displayed on an XY Graph plotting output current vs input voltage. Place an XY Graph on the Front Panel. Go to the Block Diagram, right-click and select Cluster, Class & Variant: Bundle and place it on the outside right of the For Loop. Wire the input voltage array to the top terminal and the output current array to the lower terminal. Wire the bundled output to the XY Graph.

The VI should operate at this point, but there is a problem: The For Loop does not know whether it should perform the read operation before or after the write. In its present configuration, this is ambiguous. There are a variety of ways to fix this, but the cleanest and most effective is to force data flow execution with the error cluster line. This cluster also provides troubleshooting information if there is a problem communicating with the Elvis board.

Create some space outside the For Loop by simultaneously holding the CTRL key and dragging the mouse. Wire the error cluster as shown below and merge the lines using Dialog & User Interface: Merge Errors. Connect its output to the For Loop to create an input tunnel.
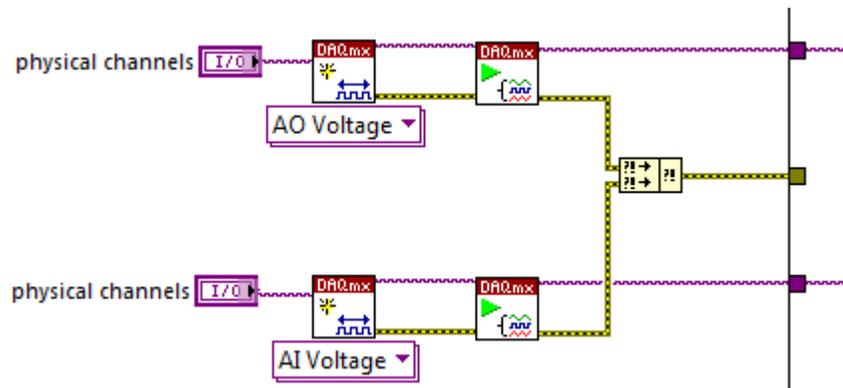
Inside the For Loop, wire the error cluster at the input tunnel to the error in terminal of DAQmx Write VI. Its error out terminal is then connected to the error in terminal of DAQmx Read VI. Data flow forces a voltage write immediately followed by a voltage read. The error line on the Read VI should then be brought out of the For Loop (disable indexing) and connected to the DAQmx Clear functions as shown below (the sequence here is arbitrary). The Simple Error Handler provides a user alert if an error occurs. This is an example of how LabView can be configured to gracefully handle errors and simultaneously enforce the execution order.
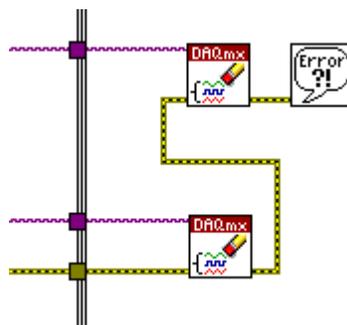

On the front panel, the physical channels must be selected to write and read the appropriate lines that are connected to the diode circuit on the Elvis board. Set the max voltage to 2V and operate the VI to verify expected diode operation. You should see an obvious threshold voltage where the diode turns on. Record this voltage to help interpret the next experiment. When your VI is working, save it and demonstrate for the instructor.

Troubleshooting: You can troubleshoot the circuit using an external oscilloscope and a probe. You may find it helpful to place your VI in a While Loop and letting it run continuously.

Half-wave rectifier

Wall-plug AC adapters use a diode-based circuit to rectify a sinusoidal AC voltage waveform to produce a DC voltage. The AC line (wall plug) voltage is 120 V rms must be sufficiently reduced with a step-down transformer (example shown in the photo) to provide a convenient secondary voltage as shown in the following circuit:
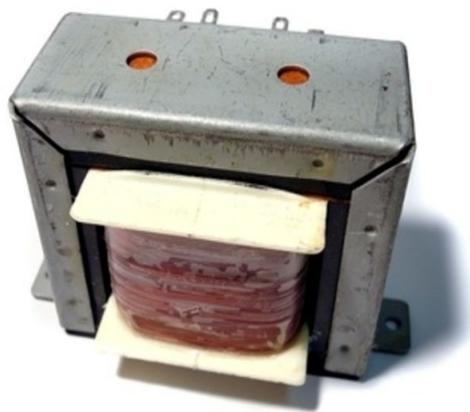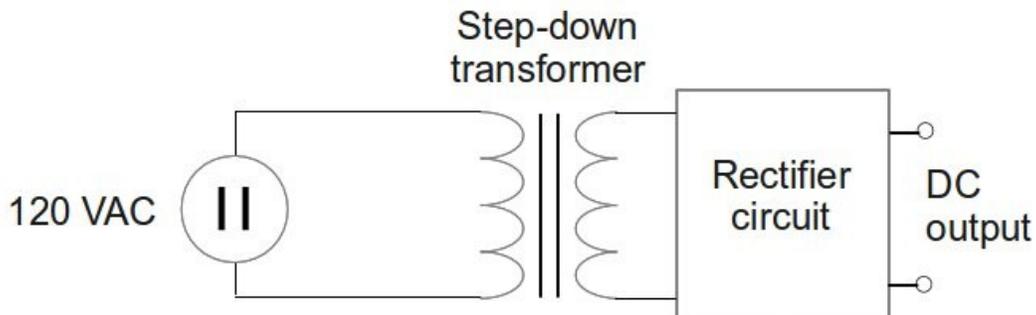
Note: The transformer turns ratio is determined by the ratio of primary windings-to-secondary windings. A transformer changes the AC voltage in direct proportion to the turns ratio; the current changes inversely proportional to the turns ratio.

In this lab, no step-down transformer is used; instead its action will be simulated. Because a diode passes current only when it is forward biased, it will modify a sinusoidal AC waveform. Change the circuit to add a second 10 kΩ resistor, but keep the input and output interface wiring the same. The output is read at the junction between the two resistors. The sinusoidal function generator and DC offset voltage are implemented in the LabView code described below.

1N4002
(or equivalent)

R1

V_{OUT}

3 V p-p

R2

V_{OFFSET}
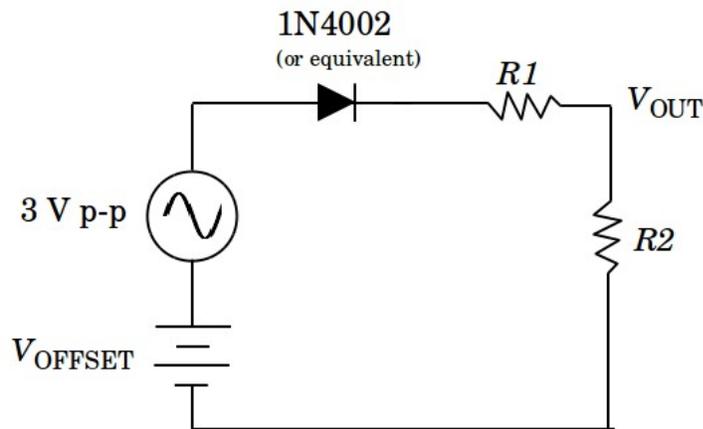
Save a copy of your working VI as a backup.   In the new copy, remove the XY Graph from the Front Panel; replace it with a Waveform Graph. Open the Block Diagram and replace the voltage ramp code with a sinusoidal function having a peak-to-peak voltage of 3 Volts and an adjustable offset: $V(t) = 1.5\sin(f\,i) + V_{OFFSET}$. The parameter i is the index of the For Loop and f will determine how many periods are displayed on the Waveform Graph (this requires $0 < f < 1$). Wire f as a control on the front panel and add a control for the DC offset voltage. Configure the output to display voltage, not current. On the Block Diagram connect the input and output 1-D arrays to a Build Array function and wire the resulting 2-D array to the Waveform Graph.

Set the offset voltage to zero and run the VI. Set f to display several periods and confirm half-wave rectification. Increase the positive voltage offset until rectification disappears. When you are convinced you understand what is happening, explain operation to the instructor.

Half-wave rectifier with filter

A capacitor placed across the output of the rectifier will smooth time-varying voltage fluctuations. Recall that a capacitor presents an infinite impedance to DC (ω=0) and decreasing impedance as the frequency increases ($Z_C = 1/j\omega C$). Electrolytic capacitors are useful in filtering applications because they provide a large amount of capacitance in a relatively small volume. The drawback is they are sensitive to voltage polarity; proper voltage orientation is achieved by observing the polarity labels (+ and −) on the case of the capacitor. If this polarity is not properly observed, the capacitor can fail catastrophically. Any capacitor will have a maximum voltage rating, so be sure this rating is not exceeded by the DC voltage present in the circuit.

1N4002
(or equivalent)

R1

V_{OUT}

3 V p-p
Sine
Wave

R2

C
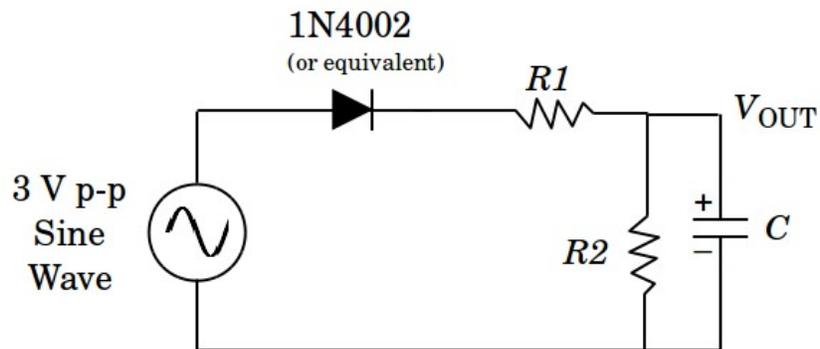
The goal here is to examine filtering action as the capacitor shown above is changed. We will define ripple as the maximum percentage voltage drop from peak that occurs each period. Set the offset to zero and experimentally determine a capacitor value that gives ~25% and ~10% ripple. Demonstrate for the instructor.

Note: When the ripple gets smaller, it will be difficult to measure on the Waveform Graph. An easy way to deal with this is by right-clicking on the graph and checking Visible Items: Graph Palette. This palette gives access to a variety of zooming features.

No writeup is required for this lab.