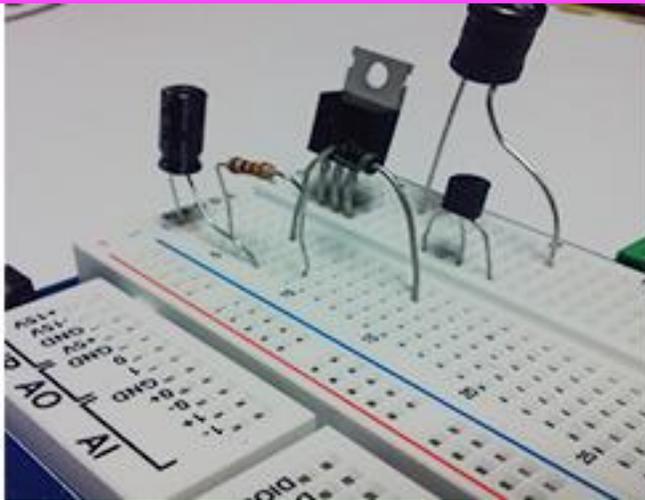# IV Analysis

Core Concept Instructor Set

nPoints
BY NTS PRESS

Light Emitting Diodes

Materials:

myDAQ

1 220 ohm resistor

3 LEDs (different colors)

3 Resistors (different values)

3 Capacitors (large value difference)

3 Inductors (large value difference)

"All circuits have resistance capacitance and inductance"

Learn It!

When building any electrical circuit, it is essential to understand the components you are using. All circuits have resistance capacitance and inductance and these components respond differently to voltage, current and how they change. Using this understanding it is possible to develop things like batteries, motors and rectifiers. To test the characteristics of a component you can create current vs voltage, current vs time or voltage vs time plots. In this module you will build a simple series test circuit and analyze the voltage and current characteristics of inductors capacitors resistors and diodes. You will gain an understanding of how reactive components store energy and see how that affects their response to a signal. You will also gain an understanding of an ideal current and voltage response versus a non ideal response.

Build It!

The ideal resistance of a circuit can be defined using ohms law for all voltages and currents as long as temperature remains the same. The limitation of a resistor is the amount of current it can withstand. The current and voltage characteristics of diodes can be defined using the Shockley ideal diode equation. Since diodes ideally act as an open or short circuit depending on the voltage being applied to them, they can easily become damaged if there is not a resistor in the circuit limiting the total current allowed to flow.

LED Electrical Characteristics

Step 1: Build the series circuit in Figure 1 using a 220 ohm and one of the three resistors of different values.

Step 2: Open the IV Analysis.vi and run it. Select the Resistors and Diodes tab which will perform a simple voltage sweep on the series circuit from 0-5V. Since resistors and diodes are not time dependant the current of the component can be determined incrementally depending on an individual voltage value applied. Set the Series Resistance control to 220 ohms. Click "Resistor IV", this will create a graph of the voltage versus current for the resistor you have in your circuit.

Figure 1 LED series circuit

Figure 2 IV Analysis Front Panel

The IV Analysis panel shows:
- Device Name: myDAQ1
- Series Resistance (ohms): 220
- Stop button
- Vcc circuit with AI0 Voltage Across Test Component and AI1 Voltage used to calculate current
- IV Curve graph with Current (y-axis, -0.2 to 2.4) vs Voltage (x-axis, -1 to 5)
- Diode IV and Resistor IV buttons
- Cursors table with X and Y columns: none 0.43080 0.07141; Cursor 1 none 2.98132 0.52307

$$V = IR$$

$$R = \frac{V_2 - V_1}{I_2 - I_1}$$

$$I = I_s(e^{V_D/(nV_T)} - 1)$$

Guiding Questions:

- Explain why the resistance value you read in LabVIEW does not match the color band value stated on your test resistors.
- What happens to a resistors value as it begins to heat up? What happens as it cools down?
- Using this test as a reference, explain how you think a digital multimeter reads a resistance value. How do you think it can increase the accuracy of its readings?
- What is the equation for calculating resistance based on its surface area and length? Can this equation be used to explain how other resistance based sensors work?
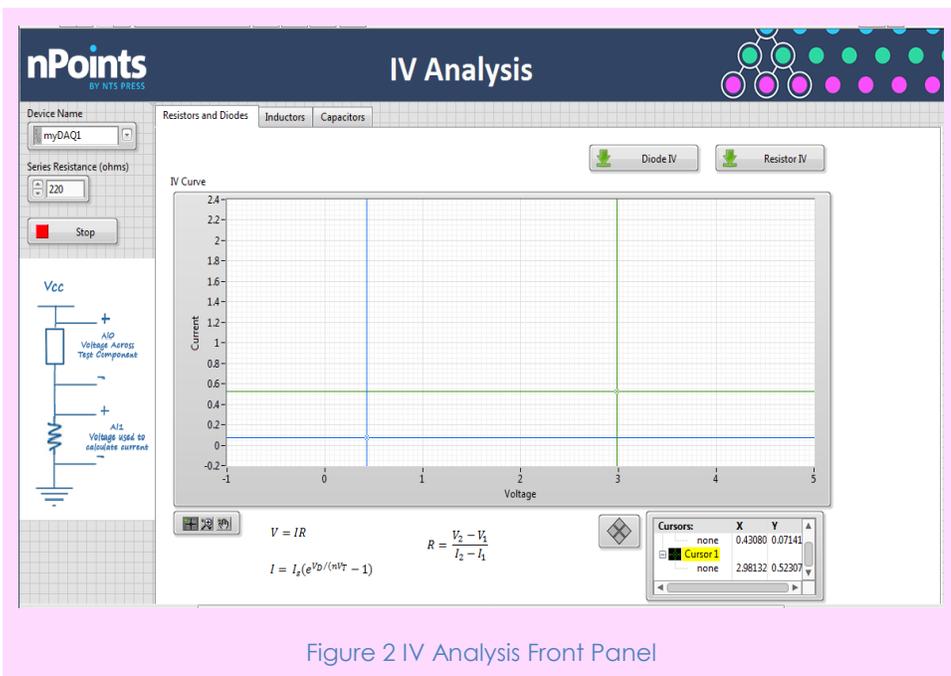
Step 3: Repeat this for the remaining 2 resistors you have. You may find other resistors and observe their respective curves. Since the current through a resistor is proportional to the voltage across it then we should be able to calculate the resistance you have in the series circuit by taking two points on one of the generated graphs, calculating the slope of the graph and inverting that number. Try calculating resistance by finding the inverted slope of the graph for one of your resistors. In order to use the provided cursors, click on the [icon] icon then hover over any of the two cursors on the graph, click and drag to your desired point. The numbers in the **Cursors** will update to show the X and Y points which correspond to voltage and current respectively.

Step 4: Replace the test resistor in the circuit with the first of your three colored LEDs. Remain on the Resistors and Diodes tab and click the Diode IV button. This will run through the same voltage step sequence done for the resistors.

Step 5: Repeat this with the remaining two LEDs and take note of how the graphs different with different colors.

Inductor and Capacitor Analysis

Inductors and capacitors resist change in either current or voltage respectfully due to the fact that they store energy in the form of magnetic and electrical fields. A capacitor "charges" when a voltage is applied to its terminals. In the charging state the capacitor acts like a short circuit, once it is charged it will act as an open circuit. An inductor creates a magnetic field from changing current, the magnetic field works to oppose the changing current. Figures 3 and 4 show the ideal current and voltage waveforms of a capacitor and inductor.

Step 6: Using the same series circuit you built in Step 1, replace the test component diode with one of your capacitors, click on the "Capacitors" tab and click "Capacitor IV". This will run a sequence that sends a 1Hz
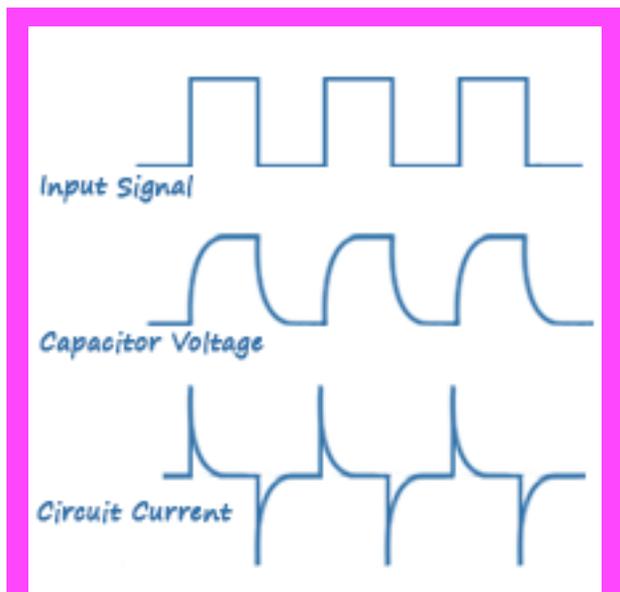

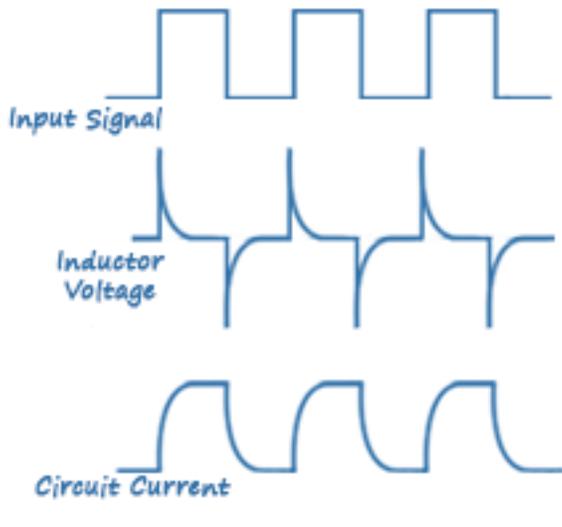Figure 3 Capacitor voltage and current waveforms

Figure 4 Inductor voltage and current waveforms

1Vpp square wave to your series circuit. The acquired signals are voltage and current from the circuit. Using the capacitor voltage waveform and the capacitor time constant equation

$$\tau = RC$$

We can estimate the value of the capacitor being used.

Step 7: Use the provided cursors on the capacitor voltage graph the same as you did from Step 3 and position one at the beginning of the rising edge of the voltage signal where the Y value of the cursor reads approximately 0V. Place the other at the point where Y is approximately 0.63V. You may need to use the zoom tool to zoom in on the graph to make finer movements with your cursor. Your graph should resemble Figure 5. The X values correspond to the nth sample where the cursor is located. The data was sampled at a rate of 100,000 Samples per second so if we take the difference between the two X values and divide by the sample rate we will get the time between the two voltage values which will be our estimate of the RC time constant τ.
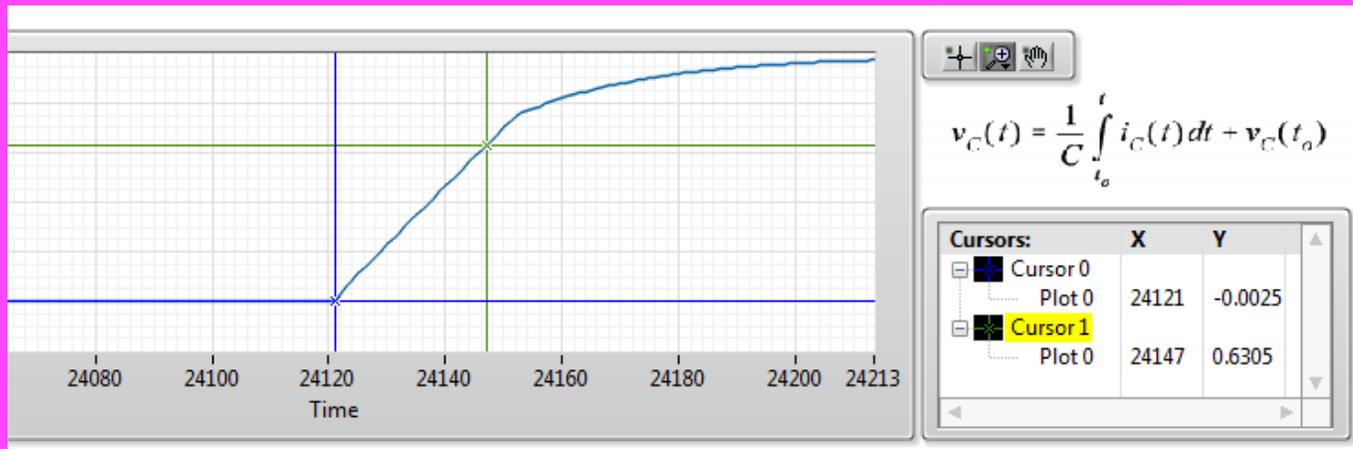

Figure 5 Cursors Used to measure time difference between voltage values

Using the time constant equation we can estimate the value of the capacitor in our series circuit.
Examine the voltage and current graphs, and note the similarities and differences between them and the ideal graphs.

Step 8: Repeat steps 6 and 7 with the remaining 2 capacitors.

Step 9: Replace the test capacitor in your circuit with one of your inductors, navigate to the Inductors tab and click on "Inductor IV". Observe the resulting voltage and current plots.

Step 10: Using the Current graph this time and the time constant equation for an inductor:

$$\tau = \frac{L}{R}$$

Guiding Questions:
- What do you see with the same duty cycle and frequency on different color LEDs? Why is this happening?
- Using what you observed in this portion of the module and your understanding of colors, explain how you would gain different colors using the Red Green and Blue LEDs. hrough each individual LED at a time to provide it with color data.

We will be able to follow the same steps as before to estimate the inductance in the circuit. In this case we will need to place the cursors at approximately 0V and at a point that is %63.2 of the max current.

Step 11: Repeat this process with the remaining two inductors.

Step 12: Explore the block diagram to gain an understanding of how this experiment was created.

Expand it!

- Research and calculate the values of your capacitors in series and parallel. Put your capacitors in a series or parallel configuration in your test circuit and acquire an IV curve. Calculate the capacitance of your combination using the charge time constant and see how the test value matches up to the ideal capacitance.

Research It!

How Light Emitting Diodes Work

http://www.howstuffworks.com/led.htm

How Capacitors Work

http://electronics.howstuffworks.com/capacitor.htm

Resistors

http://www.allaboutcircuits.com/vol_1/chpt_2/5.html

Inductors Info Please

http://www.infoplease.com/encyclopedia/science/inductor.html