

# UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE

## Department of Electrical and Computer Engineering

### EXPERIMENT 2 – BASIC CIRCUIT ELEMENTS

#### OBJECTIVES

The purpose of this experiment is to familiarize the student with basic circuit elements such as resistors, capacitors, and inductors. In addition, laboratory-controlled destruction will be used to evaluate the power ratings for selected components.

#### MATERIALS/EQUIPMENT NEEDED

14V Lamp

NI ELVIS II

Resistors: 68 $\Omega$ , 470 $\Omega$  (1/4 Watts), 1k $\Omega$ , 2k $\Omega$ , 56k $\Omega$ , 10M $\Omega$

Agilent U8031A DC Power Supply

Agilent 34461A Digital Multimeter

#### INTRODUCTION

Resistors, capacitors, and inductors are the most fundamental components used in electrical circuits. It is important that electrical engineers have a good understanding of the types and values available and how they should be used in various design applications.

#### Resistors

A resistor is a component that is designed to have a specific resistance and a maximum power rating. Resistance is the opposition a substance offers to current and the unit for resistance is *ohm*. Resistors can limit current, however, they produce heat while doing so. Therefore, the physical size of resistors is related to the ability to dissipate heat.

The maximum power rating of a resistor is generally specified at some rated temperature. Power ratings of resistors can range from 1/20 of a Watt to 1000 Watts depending on the type of resistor. A reduction factor must be applied to the power rating of a resistor if it is operated above its rated temperature. The maximum operating temperature of a resistor is somewhat higher than its power-rated temperature and is a function of the resistor's composition and construction.

Resistors could be either fixed (constant value) or variable. Fixed resistors are usually color coded with a four-band color code that indicates the specific resistance and tolerance. Each band that surrounds the body of the resistor helps identify the value (in ohms), the tolerance (in percent), and in some cases the reliability rating and/or the recommended solder. Most resistors

have a typical 5% - 10% tolerance value. In Figure 2-1 you will find how and where each band is located.

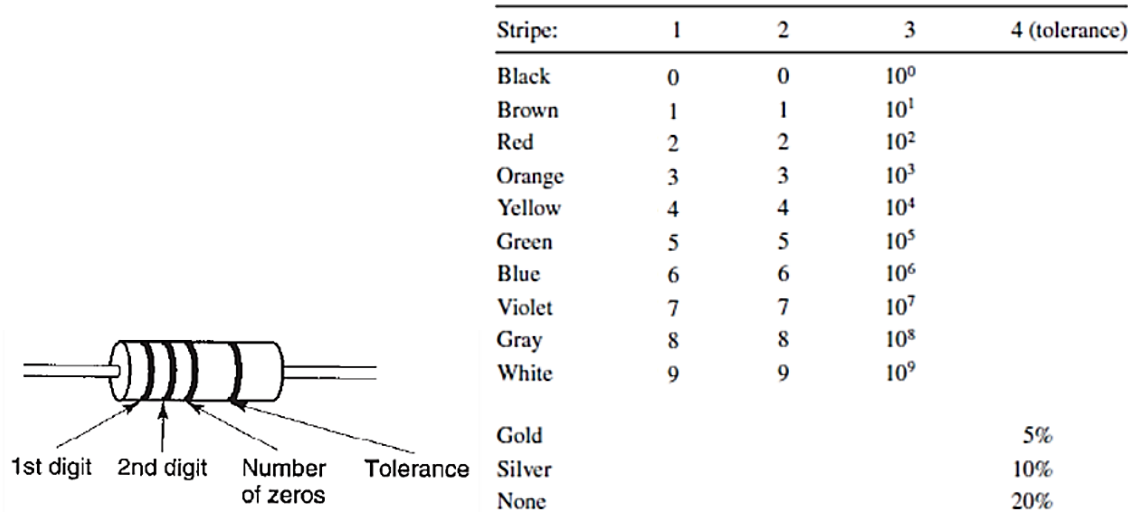


Figure 2-1 Resistor Color Code Layout (4 Bands)

Observe how the resistor bands are closer to one end than the other. The closest band to the end is generally the first or most significant digit (stripe 1), and the band on the opposite end (silver for 10% or gold for 5%) is the tolerance band. The absence of a silver or gold tolerance band indicates a tolerance of 20%. The first band will always be some color other than black with one rare exception, a “zero” Ohm resistor (i.e., a solid wire or jumper). In this case only one black band will exist.

If we have a resistor with the first band yellow, standing for the number 4, the second band violet, standing for the number 7, and the third band red, standing for the number 2, we place two zeros after the first two numbers (i.e., 47 + two zeros = 4700). The third band is often the most difficult band to decode; it represents the number of zeros or decimal places added to the previous two numbers. In this way we can describe a very large number of resistor values. For values less than 10 ohms the color gold or silver will be placed in the third color band.

When these colors appear we will move the decimal place of the first two digits to the left. As an example if we are looking for a 4.7 Ω resistor we should find a resistor with yellow (4), violet (7), and silver (10%) or gold (5%); the multiplier is 0.1. This becomes 47 X 0.1 or 4.7. It may take a little practice but with this method we are able to specify resistors that are less than ten ohms. For resistors of less than 5% tolerance there will generally be five bands. This is true because one additional significant figure is required to give the value.

### Capacitors

A capacitor is formed whenever two conductors are separated by an insulating material. Capacitors are made with flat conductors called plates. The plates are separated by an insulating

material called dielectric. There are many types of capacitors available with a wide variety of specifications for size, voltage rating, frequency range, and so forth. For general-purpose applications, small capacitors are constructed with paper, ceramic or other insulation material and are not polarized.

When a voltage exists between the plates, there will be an electric charge between the plates. The ability to store electric charge is a fundamental property of capacitors that affect both DC and AC circuits. The charge that flows is proportional to the size of the capacitor and the applied voltage, given by the equation

$$Q = CV$$

Where  $Q$  is the charge in Coulombs,  $C$  is the capacitance in Farads, and  $V$  is the applied voltage. The current through a capacitor is equal to the time rate of change of the voltage across the plates multiplied by the capacitance, or

$$i = C \frac{dv}{dt}$$

Two common methods for showing the value of a small capacitor are shown in Figure 2-2. In Figure 2-2(a) a coded number is stamped on the capacitor that is read in pF. The first two numbers represent the first two digits and the third number is a multiplier. For example the number 123 is a 12000 pF capacitor. Figure 2-2(b) shows the actual value stamped on the capacitor in  $\mu\text{F}$ . In the example shown, .012  $\mu\text{F}$  is the same as 12000 pF.

Larger electrolytic capacitors will generally have their value printed in uncoded form on the capacitor and a mark indicating either the positive or negative lead. They also have a maximum working voltage printed on them (which should not be exceeded). Electrolytic capacitors are always polarized, and it is very important to place them into a circuit in the correct direction based on the polarity shown on the capacitor.

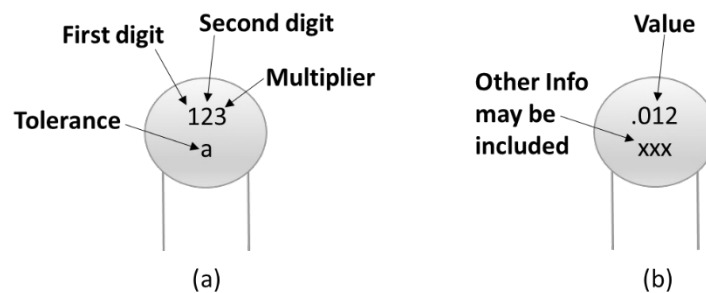


Figure 2-2 Capacitor Identification (a) Coded value (b) Stamped value

### Inductors

An inductor can be constructed simply by forming a coil of wire. When there is current through that coil of wire, a magnetic field is created around the wire. This electromagnetic field accompanies any moving electric charge and is proportional to the magnitude of the current. If the current changes, the electromagnetic field causes a voltage to be induced across the coil, which opposes the change. The voltage across the inductor is then equal to the time rate of change of current through the inductor multiplied by the inductance, or

$$v = L \frac{di}{dt}$$

Inductors are usually color coded with a four-band color code (see Figure 2-3) similar to the one for resistors. Each band helps identify the value (in  $\mu\text{H}$ ) and the tolerance (in percent). In Figure 2-3 you will find how and where each band is located.

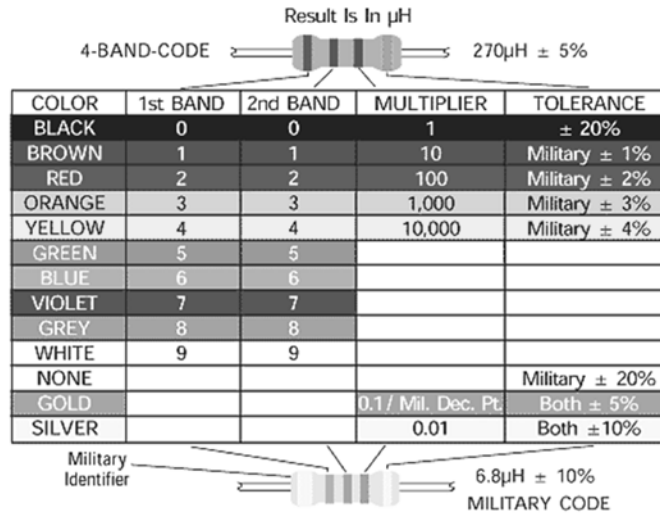


Figure 2-3 Inductor Color Code Layout (4 Bands)

### Ohm’s Law

As part of this experiment Ohm’s law will be verified with experimental data. When considering the validity of your results, it will be necessary to allow for such things as resistor tolerance and meter accuracy.

Ohms law states that the voltage in Volts is equal to the product of current in Amperes and the resistance in Ohms, or

$$V = IR$$

Different forms of this law are easily obtained with simple algebraic manipulations.

## NI ELVIS Introduction

ELVIS, which stands for Educational Laboratory Virtual Instrumentation Suite, is technology developed by National Instruments. It combines 12 of the most commonly used laboratory instruments into one streamlined circuit board. It offers precise measurements capabilities, eliminates the need for additional hardware and saves desk space for the user.

To use ELVIS hardware, all that is needed is the ELVIS board, a computer and the necessary cables to perform the given lab experiment. Figure 2-4 shows the windows that will appear when the NI ELVIS shortcut on the computer desktop is used to launch the ELVIS software.



Figure 2-4 ELVIS Instruments

These are all of the instruments that ELVIS has to offer. Not all of them will be used with every laboratory experiment. We will introduce the four most basic instruments during this lab including the digital multimeter (DMM), variable power supply (VPS), function generator (FGEN) and oscilloscope (Scope).

## Digital Multimeter (DMM)

The digital multimeter allows the user to measure resistance, voltage and current. For ELVIS, the multimeter is integrated inside so there is no need for an additional device. Two probes (red and black) are used to measure the quantities. It is standard practice that the black lead is connected to the negative terminal (common or ground) and the red lead is connected to the positive terminal. A picture of the DMM (Digital Multimeter) in ELVIS is shown in Figure 2-5.

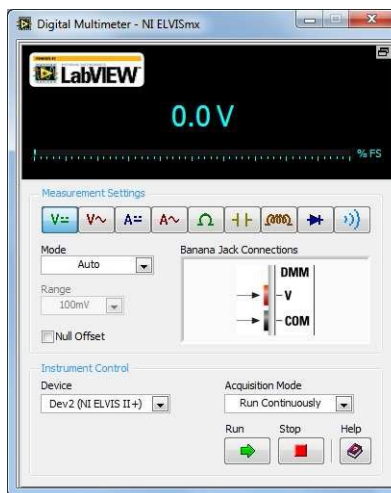


Figure 2-5 ELVIS Digital Multimeter

Note: All of the tools in ELVIS need to be running in order for them to function. The user must click 'Run' to activate the tool. If the user needs to stop using the tool, click 'stop'.

### Variable Power Supply (VPS)

The variable power supply (see Figure 2-6) is an adjustable voltage source. The user can specify a voltage or sweep a voltage (taught in future labs). The pins are labeled and located on the bottom left side of the ELVIS breadboard.

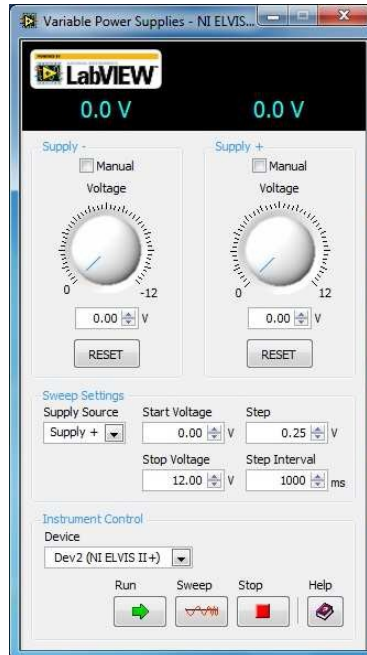


Figure 2-6 ELVIS Variable Power Supply

### Function Generator (FGEN)

The function generator (see Figure 2-7) is able to create a variety of waveforms including sine, triangle, square and ramp waveforms. All of these waveforms can be utilized at a variety of different frequencies. The user will use the function generator to provide a signal input to an electronic circuit. While using the function generator, the student must also use the oscilloscope which allows the user to visually see the signals.

Under the waveform settings, the user can select if they would like a sine, triangle or square wave. They can specify a frequency, amplitude and DC offset or use the manual mode.

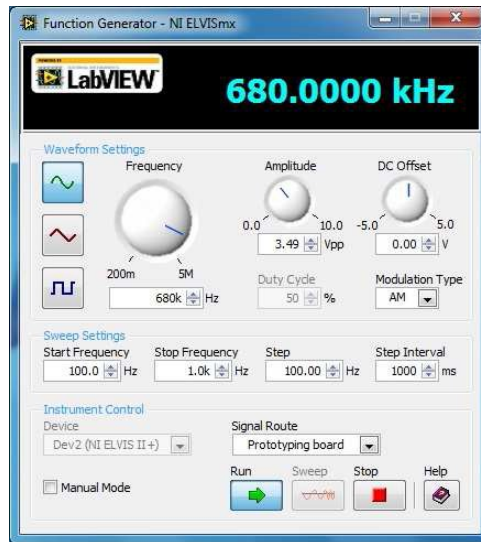


Figure 2-7 ELVIS Function Generator

### Oscilloscope (Scope)

The ELVIS oscilloscope includes two channels which represent two different inputs (see Figure 2-8). For example, the user can compare the input of a circuit to the output of the circuit. In order to use each channel, be sure that the channel is enabled by checking the “Enable” checkbox. For the Probe setting, just be sure that the switch on the probe cable matches the Probe setting in ELVIS.

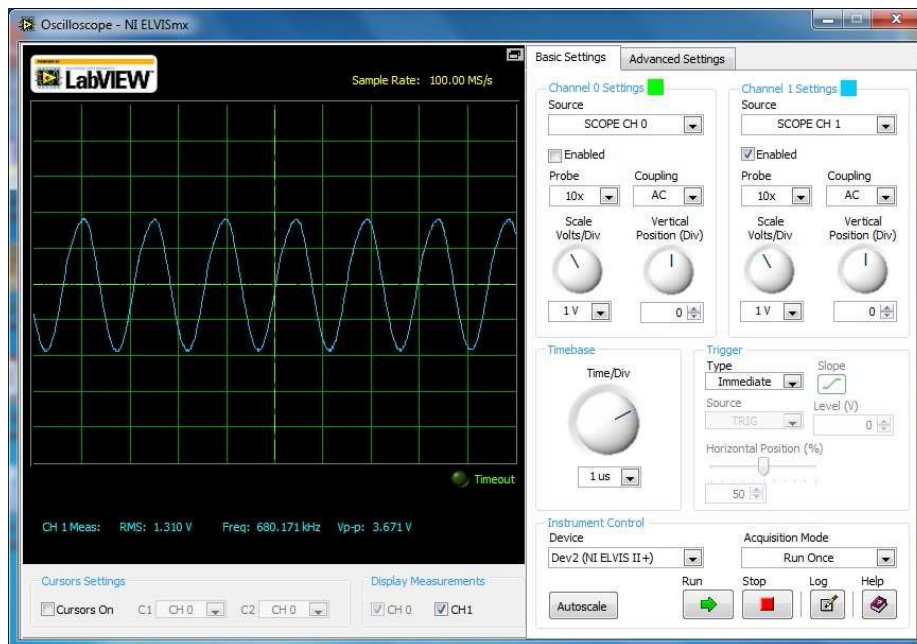


Figure 2-8 ELVIS Oscilloscope

### **ELVIS Set-Up**

1. Connect AC-DC power adapter to ELVIS at rear panel.
2. Use the USB cable to connect the PC to ELVIS via the rear panel connector.
3. Assure that ELVIS “Prototyping Board Power” switch (upper right corner) is off.
4. Turn on ELVIS main power switch (rear panel).
5. Power for the experimental circuit is obtained from the “Variable Power Supplies” connections at the lower left of the proto board.
6. Note that each ELVIS virtual instrument must be in “RUN” mode to function.



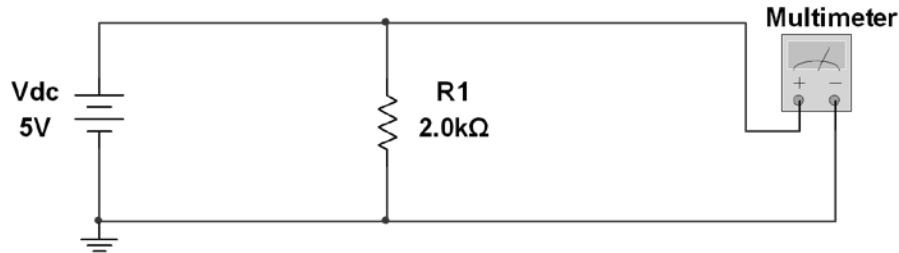
**PRELAB**

1. For resistors with the following colors bands give the resistance and tolerances:
  - a. Brown, Black, Red, Silver = \_\_\_\_\_
  - b. Blue, Gray, Black, None = \_\_\_\_\_
  - c. Green, Blue, Orange, Gold = \_\_\_\_\_
  - d. Brown, Black, Blue, None = \_\_\_\_\_
2. Determine the maximum current that a  $470\ \Omega$ ,  $\frac{1}{4}\ \text{W}$  resistor can have flowing through it without exceeding its power rating.
3. Determine the maximum voltage that a  $470\ \Omega$ ,  $\frac{1}{4}\ \text{W}$  resistor can have across it without exceeding its power rating.
4. A constant current source of 2 mA is placed across a fully discharged capacitor of  $100\ \mu\text{F}$ . In the time period before the capacitor reaches breakdown voltage, what is the time rate of change of voltage across the capacitor in V/s?

**PROCEDURE**

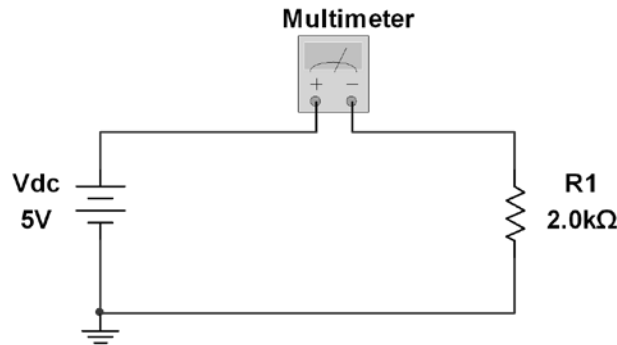
**Using the ELVIS DMM**

1. Connect the circuit of Figure 2-9. Use the multimeter to measure the voltage across the resistor (parallel connection in Fig. 2-9). Record the value in Table 2-1.



**Figure 2-9 Circuit for measuring the voltage across the resistor.**

2. Reconfigure the circuit and multimeter as shown in Figure 2-10 to measure the current through the circuit (series connection). Record the value in Table 2-1.



**Figure 2-10 Circuit for measuring the current across the resistor.**

3. Use the multimeter to measure the resistance of the resistor. Record the value in Table 2-1.
4. Obtain resistors having the values listed in part 1 of the Pre-lab and measure them with the multimeter. Record values in Table in Table 2-2.

**Power Rating Evaluation**

1. Use a 470-Ohm, 1/4-watt resistor and make the same connections as in Figure 2-10.
2. Increase the voltage in steps while taking voltage and current readings. The benchtop multimeter may be used to measure the voltage across the resistor to avoid having to reconfigure the circuit for every reading.
3. For each voltage increase, calculate resistor power, stopping when the power rating of the resistor has been reached. Let the current stabilize at each voltage setting before taking a reading. At each voltage setting, CAREFULLY touch the resistor to feel it getting warm. BE CAREFUL NOT TO GET BURNED! Record the results in Table 2-3.

4. Place a polarized, 16-volt capacitor in place of the resistor. Increase the voltage in steps while taking voltage and current readings up to 15 volt. Reduce the voltage to zero. Record the results in Table 2-4.
5. Replace the capacitor with the 14 V lamp. Increase the voltage in steps while taking voltage and current readings up to the rated voltage of the lamp. Do not exceed the rated voltage. Be careful the lamps will be very hot! Record the results in Table 2-5.

**DATA/OBSERVATIONS**

**Table 2-1 Meter readings for Figure 2-9 and Figure 2-10**

Voltage	Current	Resistance

**Table 2-2 Resistors measurement values**

Predicted Value (from Prelab)	Measured Value

INSTRUCTOR'S INITIALS:

DATE:



**Table 2-4 Readings for 16V polarized capacitor**

Voltage	Current

INSTRUCTOR'S INITIALS:

DATE:



### POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. Discuss how you measured the voltage, amperes, and resistance. Where did you take the measurement and why?
2. Perform a percentage error calculation for the resistors measured in Table 2-2 and the predicted color code values in the pre-lab. Why are these values, predicted and measured, different?
3. Plot current versus voltage for the 470-Ohm, 1/4-watt resistor.
4. Plot power versus voltage for the 470-Ohm, 1/4-watt resistor.
5. Plot the voltage and current data for the capacitor.
6. What type of relationship was found between the voltage and current for the resistor throughout the testing range?
7. How was the temperature of the resistor affected during the experiment?