

# NI ELVIS Has Entered the Lab

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## Abstract

Data acquisition systems (DAQ) are powerful tools that are essential components for solving a wide range of engineering problems. LabVIEW, a DAQ developed by National Instruments (NI), employs a graphical interface for signal acquisition, measurement analysis, and data presentation. The NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) provides a LabVIEW-based DAQ for science and engineering labs.

This paper describes four electrical engineering experiments that use NI ELVIS's virtual instruments to perform experiments in a sophomore instrumentation lab. NI ELVIS provides a low cost solution that provides a suite of virtual laboratory instruments, a PCI multifunctional DAQ, a workstation, and a prototype board. The combination of this suite of devices and a computer provide the instruments necessary for developing and implementing engineering laboratory experiments.

## 1. Introduction

The rapid advancement of computer software and DAQ technology affects the teaching style in electrical and computer engineering labs. In the 1990's engineering programs implemented digital multimeters and scopes that contained the capability to record data [1] [2] [3]. Today the emphasis in engineering labs is toward implementing devices that provide graphical computer interfaces, a range of input/output devices, the ability to record results, and feedback [4] [5]. These devices provide a set of virtual instruments that are not only applicable to laboratory work but industrial applications as well [6] [7] [8]. NI introduced NI ELVIS in 2003 with a cost to educational institutions of less than \$2000 [9]. NI ELVIS employs LabVIEW software, a PCI DAQ board, a prototype board, and a workstation to provide a suite of instruments as shown in Figure 1.

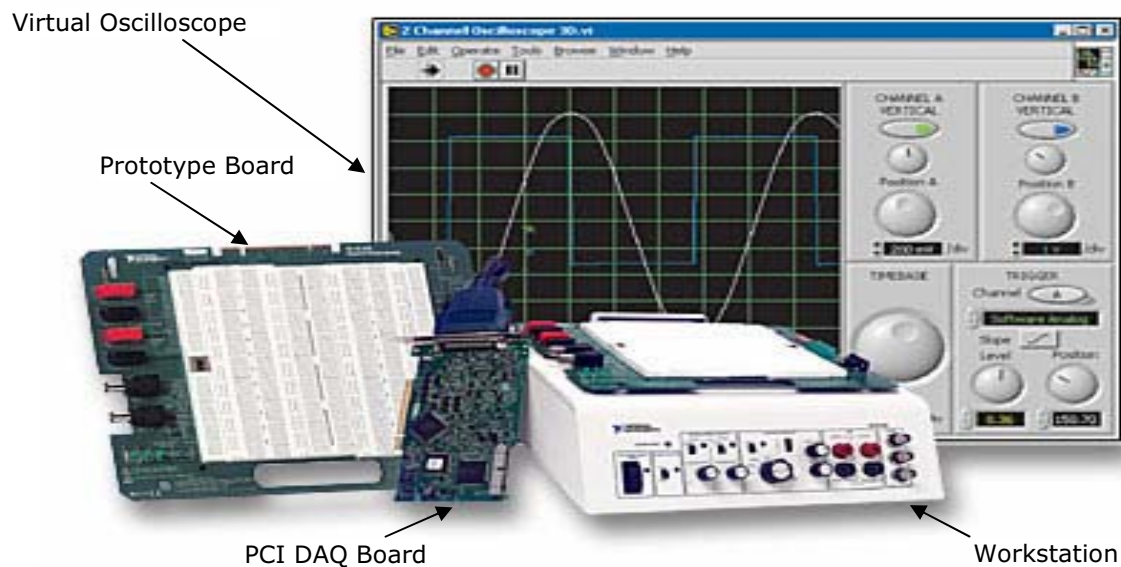


Figure 1. Ni ELVIS (Used with permission. Copyright 2004 NI)

This paper presents four electrical engineering experiments that employ NI ELVIS's virtual instruments and workstation in a sophomore instrumentation lab. Virtual instruments employed in this paper are the DC power supply, function generator, digital multimeter, oscilloscope, dynamic signal analyzer, and Bode analyzer. The NI ELVIS interface or the control panel on the workstation control the variable DC power supply and function generator. NI ELVIS instruments can be launched using the Instrument Launcher shown in Figure 2, and the

implementation of these virtual instruments does not require any programming. Figure 3 shows a workstation and prototype board with several experiments on the prototype board. The prototype board is removable, allowing students and instructors to assemble experiments and then insert the board into the workstation. The inputs and outputs to the DC power supply, function generator, digital multimeter, and oscilloscope are available on the workstation along with triggering signals for the oscilloscope.



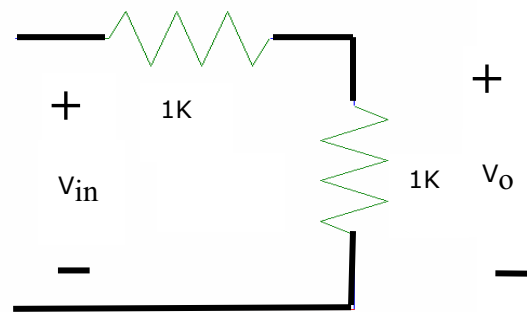
**Figure 2. Instrument launcher (Used with permission. Copyright 2004 NI)**



**Figure 3. NI ELVIS workstation (Used with permission. Copyright 2004 NI)**

## 2. Voltage Division

Voltage Division is the first experiment, and it allows the student to become familiar with NI ELVIS [4] [10]. The multimeter and oscilloscope measure the voltage across a resistor in a series resistive network using the function generator and DC power supply as sources as shown in Figure 4. An objective of the experiment is to determine the resistance of the multimeter using the data that is collected. Several sets of equal resistors are placed in series having nominal values of 1K  $\Omega$ , 10K  $\Omega$ , 100K  $\Omega$ , 1M  $\Omega$ , and 10M  $\Omega$ . The multimeter measures the resistance of the resistors, and the multimeter and oscilloscope measure the voltage across the resistors. The internal resistance of the NI multimeter is 1M  $\Omega$ .



**Figure 4. Series resistive network**

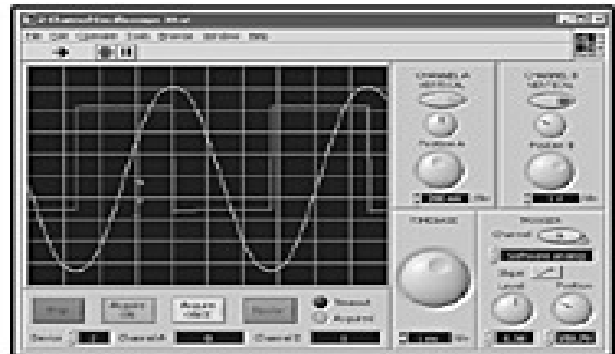
As the resistance values increase, the multimeter internal resistance affects the voltage measurements, thus illustrating that the multimeter can be an intrusive measuring device. Figure 5 shows the multimeter, function generator, variable power supply, and oscilloscope.

The function generator and the variable DC power supply are controlled via software by changing the values using the computer keyboard or mouse or by using the controls on the front of the workstation. Switches on the

front of the workstation control the software and manual modes. The multimeter and oscilloscope are controlled by data from the keyboard or using the mouse. Programming is not required, and all instruments are accessed via the instrument launcher showed in Figure 2. By employing an experiment from a physics lab with which students are familiar, the students can concentrate on becoming proficient with NI ELVIS.



(a) Multimeter



(b) Oscilloscope



(c) Function generator



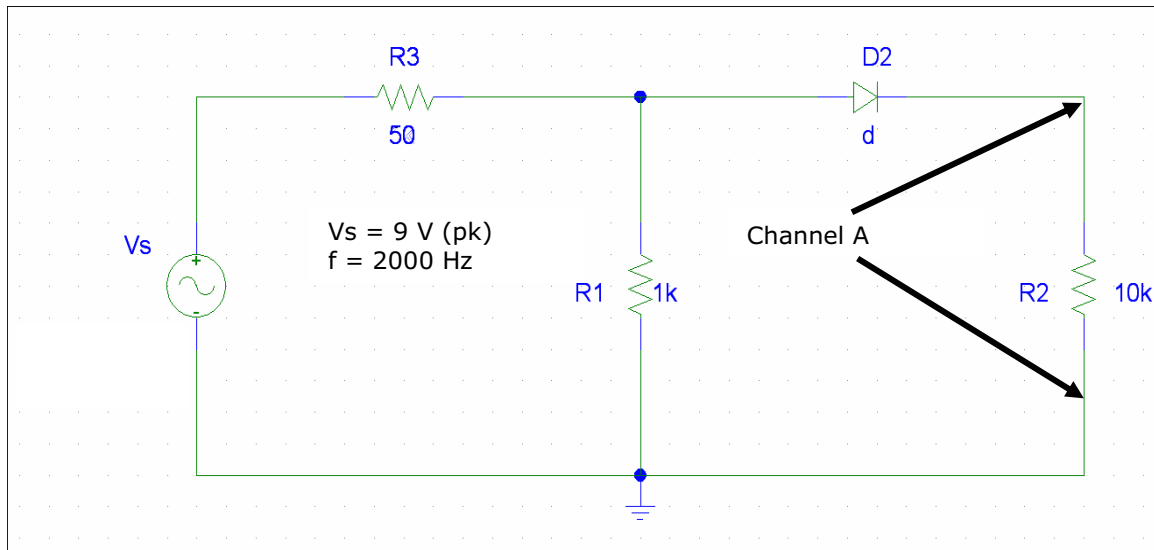
(d) Variable DC supply

**Figure 5. Multimeter, oscilloscope, function generator, and variable DC power supply (Used with permission. Copyright 2004 NI)**

Identical measurement are taken using a Tektronix PS 503A Dual Power Supply, Tektronix AFG 5101 Function Generator, Tektronix DM 5520 Digital Multimeter, and a Tektronix 2424L Digital Oscilloscope, all of which are traditional laboratory instruments. Students then compare and analyze the results measured by NI ELVIS and the traditional instruments highlighting the features, benefits, and shortcomings of each instrument [1] [2].

### 3. Measurements in a Rectifier Circuit

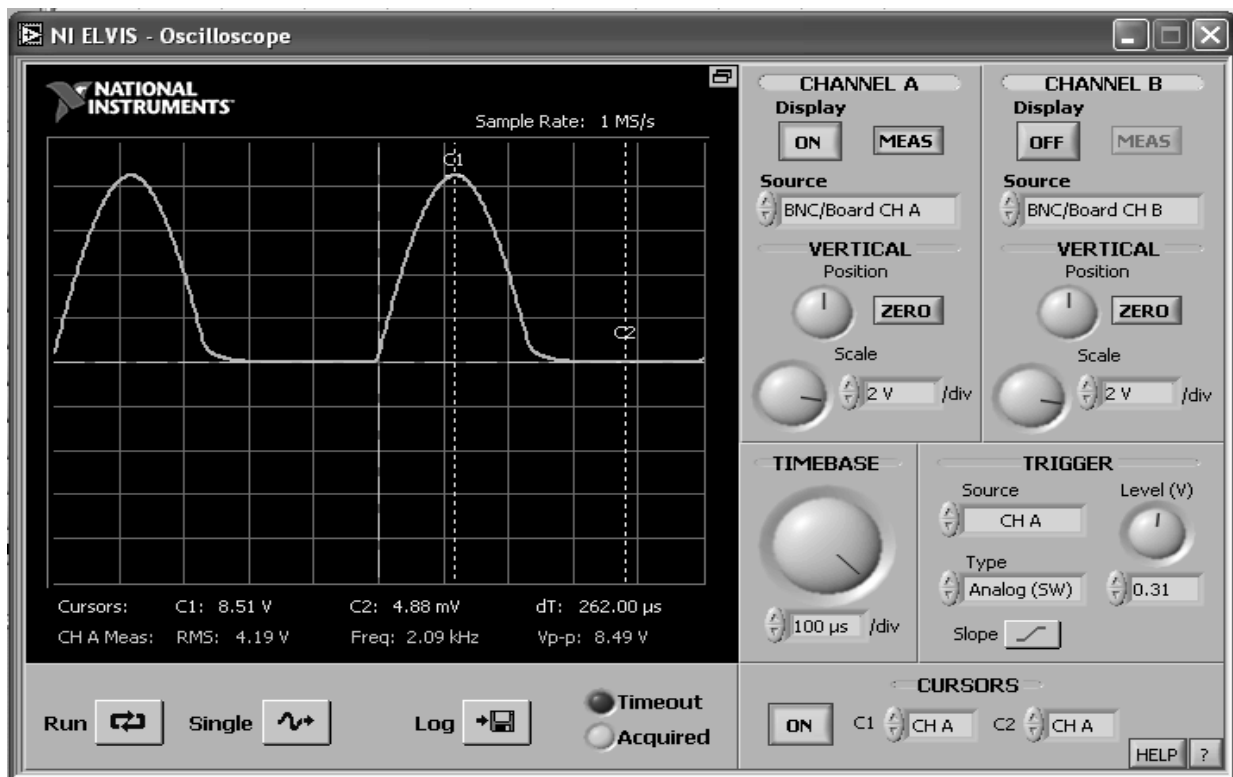
The second experiment is to study a rectified sinusoidal waveform in a resistor-diode network. A sinusoidal voltage source is applied to a series resistor-diode network, and voltage measurements are recorded across the 10KΩ resistor as shown in Figure 6.



**Figure 6. Resistor-diode circuit diagram**

Figure 7 shows the waveforms measured by the Channel A of oscilloscope. The function generator used in this experiment is the Tektronix AFG 5101 Function Generator rather than the NI ELVIS function generator.

The NI ELVIS has a maximum output of 5 volts peak-to-peak. The higher source 18 volts peak-to-peak of the AFG 5101 Function Generator provides a half-wave sinusoidal signal that is closer to the ideal.

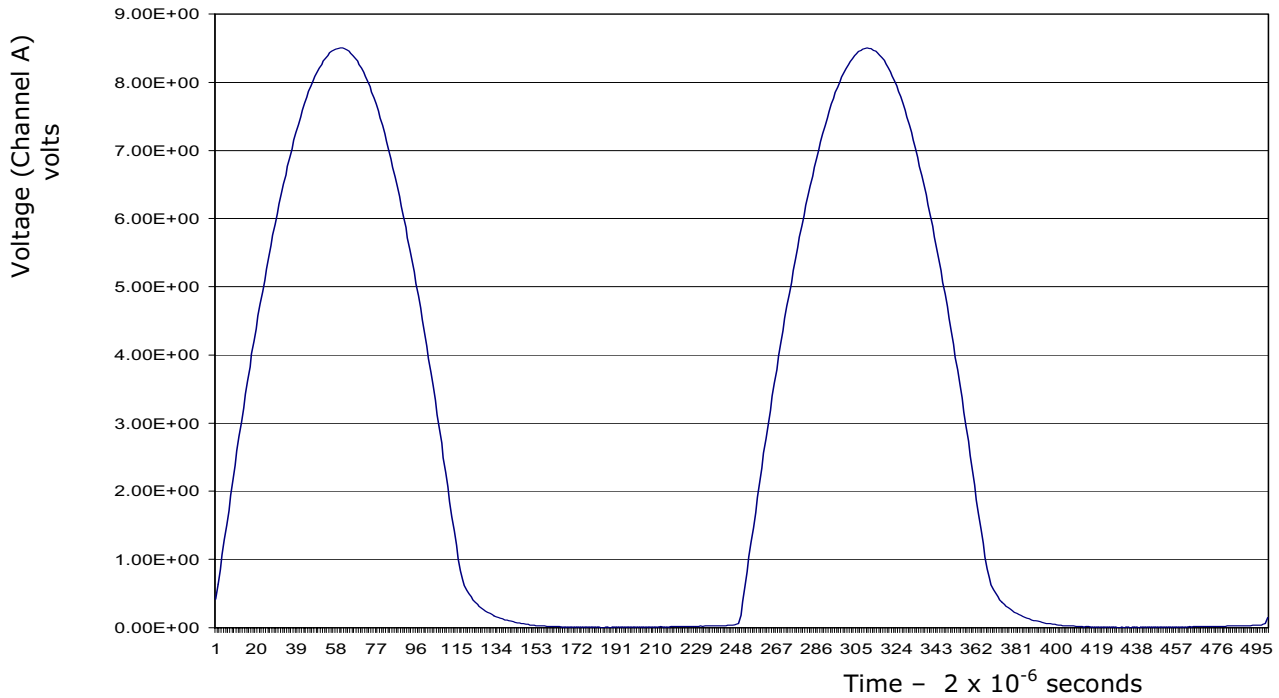


**Figure 7. Channel A for diode-resistor circuit (Used with permission. Copyright 2004 NI)**

NI ELVIS generates an output file that contains the voltages and time scale from Channel A of the oscilloscope. Table 1 is a three-point sample of this 505-point output file, and Figure 8 is a Microsoft Excel graph of the 505-point output file.

**Table 1. Output file of oscilloscope (Three-point sample)**

Time	Voltage – Channel A
10/06/2004 15:10:18.209792	-2.397461E+0
10/06/2004 15:10:18.209795	-2.260742E+0
10/06/2004 15:10:18.209799	-2.109375E+0



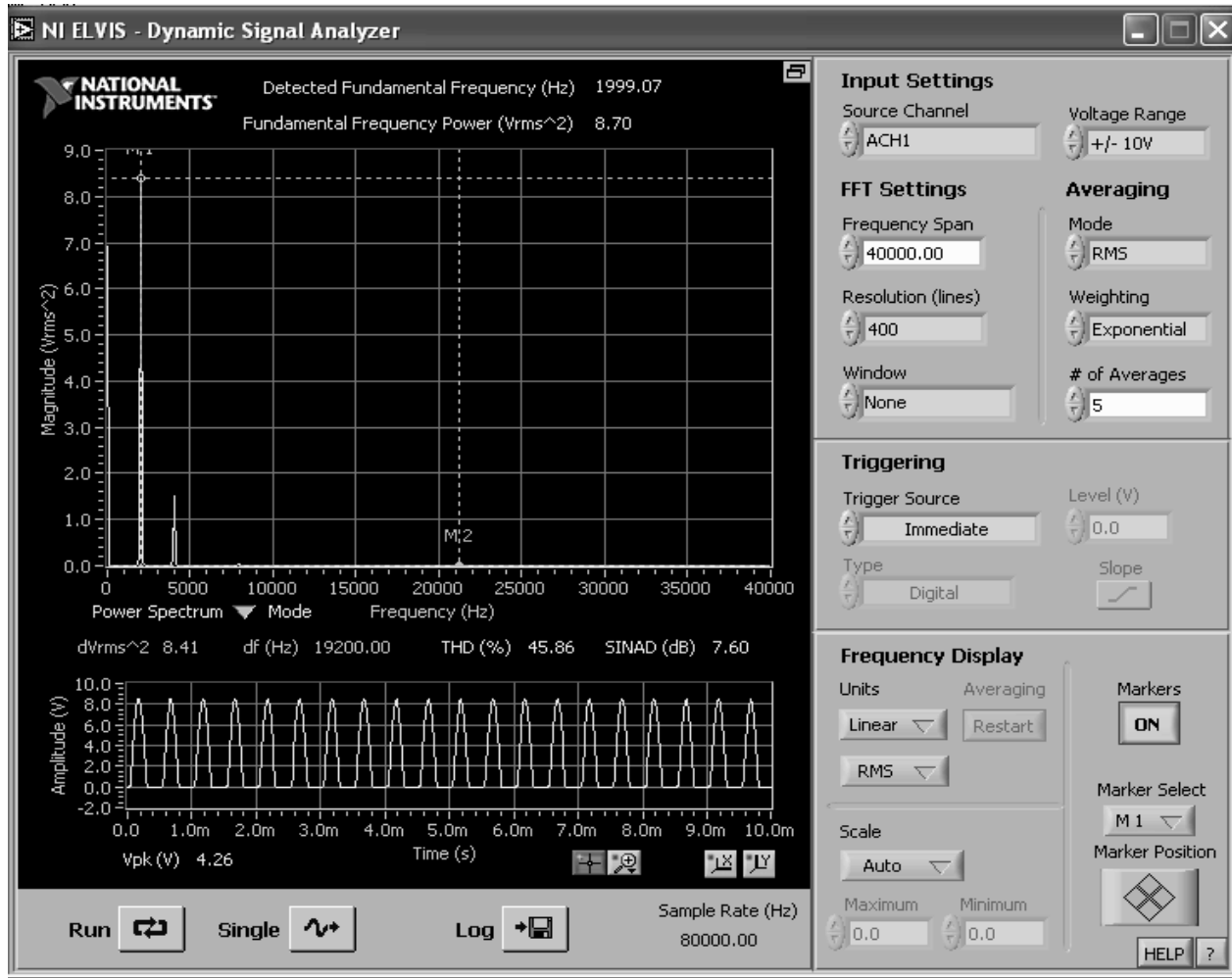
**Figure 8. Graph of output file for half-wave rectifier**

Identical measurements are taken using a Tektronix PS 503A Dual Power Supply, Tektronix AFG 5101 Function Generator, Tektronix DM 5520 Digital Multimeter, and a Tektronix 2424L Digital Oscilloscope, all of which are traditional laboratory instruments. Students then compare and analyze the results measured by NI ELVIS and the traditional instruments highlighting the features, benefits, and shortcomings of each instrument [1] [2].

#### 4. Dynamic Signal Analyzer

The purpose of the third experiment is to measure the Fourier coefficients of a half-wave rectified sinusoidal.

The circuit setup is the same as the second experiment, Electrical Measurements in a Rectifier Circuit Using a Digital Oscilloscope. The oscilloscope is initially employed to ensure that the circuit is set up properly. The Instrument Launcher is used to display the Dynamic Signal Analyzer (DSA). The oscilloscope and DSA cannot be employed simultaneously. A limitation of NI ELVIS is that not all resources can be used simultaneously. The input to the DSA is the same as used for Channel A in the second experiment, the voltage across the 10KΩ resistor. The DSA display is shown in Figure 9.



**Figure 9. Digital signal analyzer (Used with permission. Copyright 2004 NI)**

The DSA offers several filtering and averaging options, while also displaying the square of the RMS value of the Fourier coefficients. In addition, data is available from an output file. Students compare the measured values with the Fourier coefficients to an ideal half-wave rectified sinusoidal given by the following formula [11]:

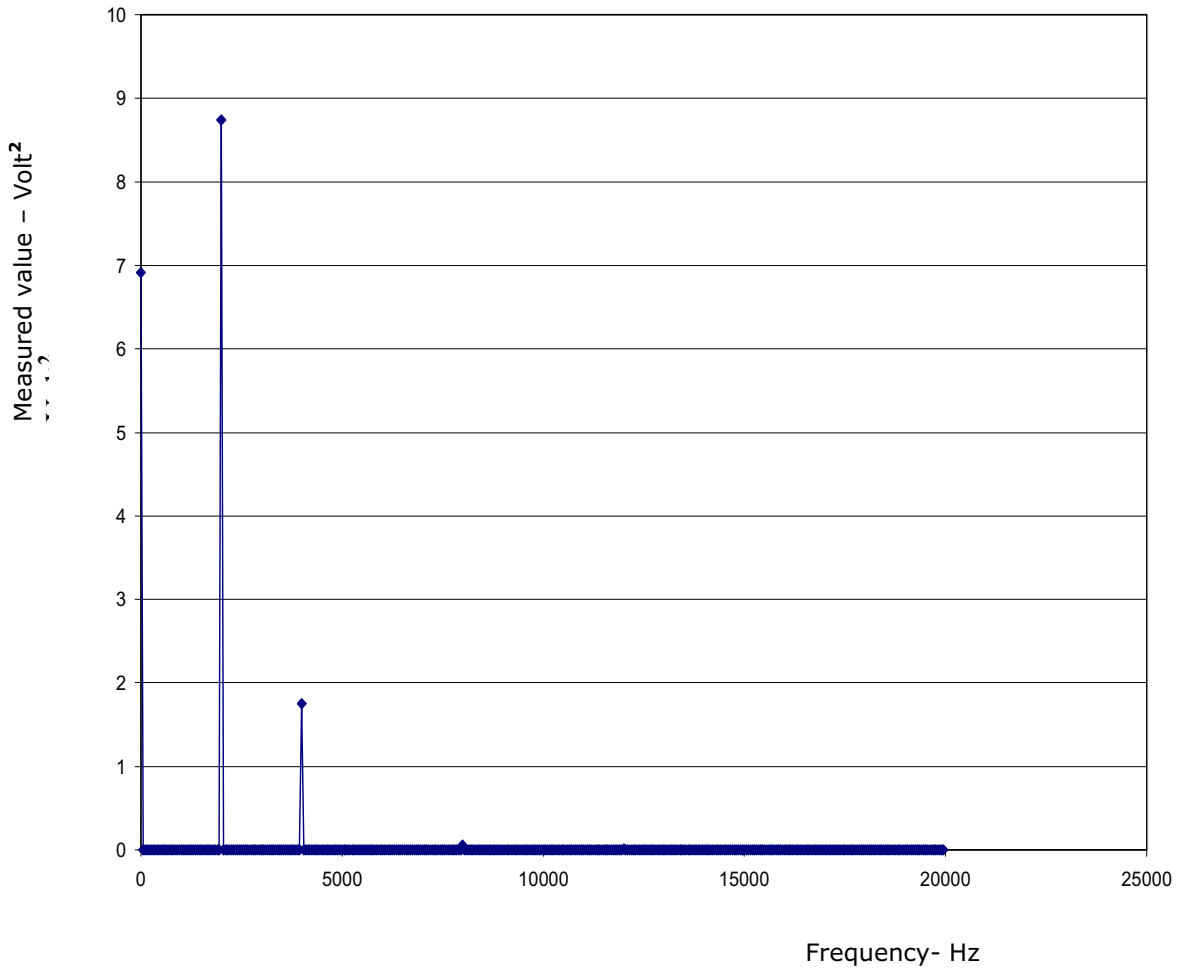
$$f(t) = \frac{A}{\pi} + \frac{A}{2} \sin \omega_0 t - \frac{2A}{\pi} \sum_{n=1}^{\infty} \frac{\cos 2n\omega_0 t}{4n^2 - 1}$$

where  $\omega_0 = 2\pi/T = 2\pi f_0$  and  $A$  is the peak value of the waveform.

Table 2 compares the Fourier coefficients of an ideal waveform with that obtained using NI ELVIS. Figure 10 is a Microsoft Excel graph displaying the output file from the DSA.

**Table 2. Comparison of Fourier coefficients of ideal half wave and laboratory results.**

	Fourier Coefficients – Volt	(Fourier Coefficients <sub>RMS</sub> – Volt) <sup>2</sup>	Measured value – Volt <sup>2</sup>	Percentage difference
DC	2.70	7.34	6.91	5.8
1 <sup>st</sup> Harmonic 2000 Hz	4.26	9.05	8.74	3.4
2 <sup>nd</sup> Harmonic 4000 Hz	1.81	1.63	1.75	7.4
3 <sup>rd</sup> Harmonic 6000 Hz	0.0	0.0	.005	–
4 <sup>th</sup> Harmonic 8000 Hz	0.36	0.065	0.062	4.6

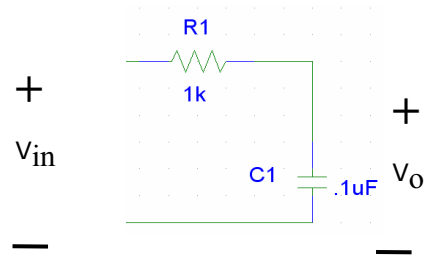


**Figure 10. Graph of output text file of DSA**

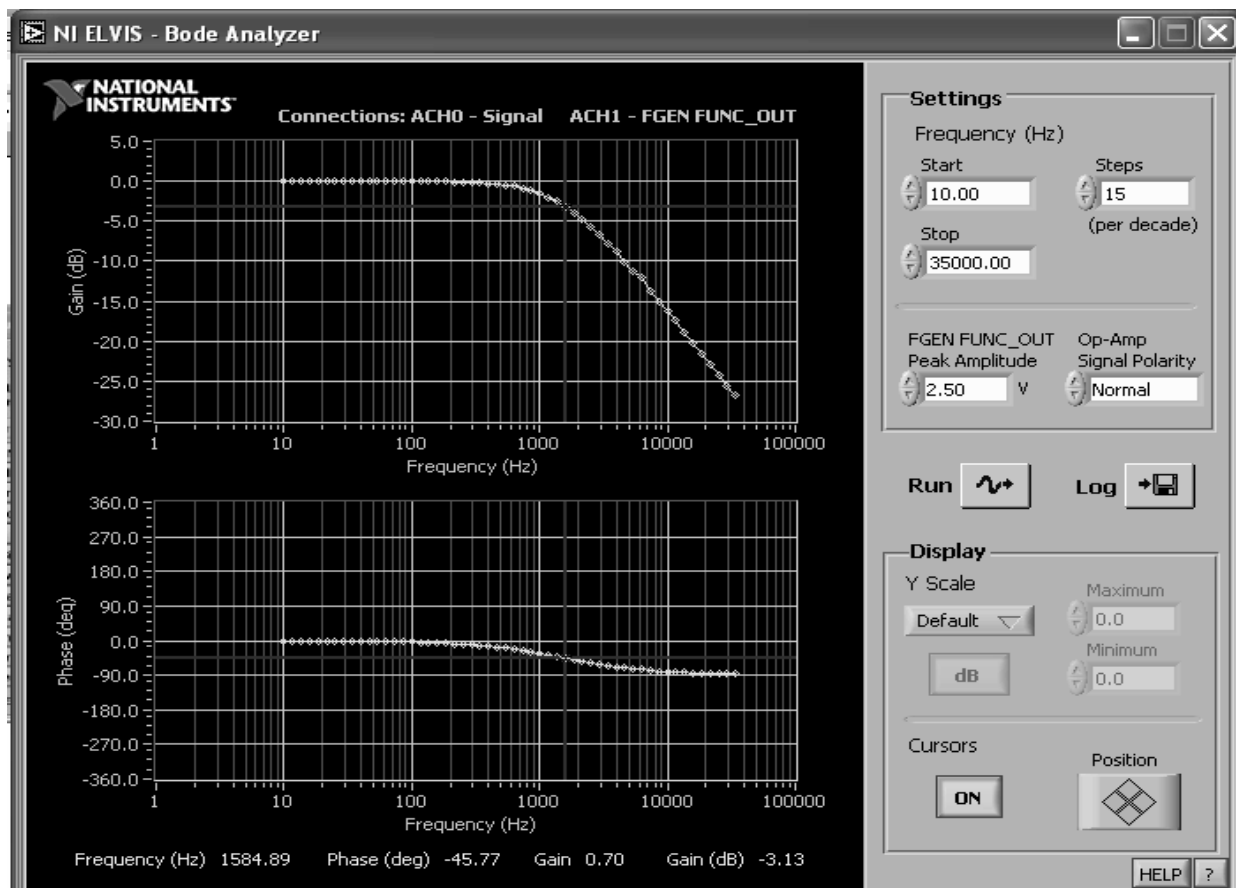
## 5. Bode Analyzer

The purpose of the fourth experiment is to display the Bode plot [12] of a low pass filter consisting of a capacitor and a resistor. The output voltage is measured across the capacitor as shown in Figure 11.

The Bode Analyzer employs the frequency sweep feature of the function generator and the analog input of the DAQ board to provide the Bode plots of magnitude vs. frequency and phase vs. frequency. Figure 12 shows the magnitude vs. frequency and phase vs. frequency plots.



**Figure 11. Low pass filter**



**Figure 12. Bode plot (Used with permission. Copyright 2004 NI)**

The start and stop frequency, number of steps per decade, and the magnitude of the input signal (limited to 2.5 volts peak) are available functions. Cursors are useful in determining values from the graph.

The absolute value of the transfer function [10] is

$$|H(j\omega)| = 1/((\omega RC)^2 + 1)^{1/2}$$

and for the phase

$$\text{Angle}(H(j\omega)) = -\text{Arctangent}(\omega RC).$$



For  $\omega = 1585$  Hz,  $R = 1$  K  $\Omega$ , and  $C = 0.1$   $\mu$  F then

$$|H(j\omega)| = 0.7078 \text{ and Angle } (H(j\omega)) = 44.9^\circ.$$

The values displayed with the use of a cursor of the DSA on the waveform are 0.70 and  $-45.77^\circ$  respectively. Both are within 2% of the calculated value. In addition, an output file is available for the waveforms.

## 6. Other NI Elvis instruments

Additional instruments available thru the Instrument Launcher include:

1. Arbitrary Waveform Generator – Source for a variety of signal types, such as periodic, harmonic, modulated, or other waveforms and provides the ability to load a data file to generate a stored waveform.
2. Two-Wire Current-Voltage Analyzer – A programmable power supply for conducting diode testing and viewing of I-V curves. The 2-wire instrument allows parameters settings such as voltage and current ranges, quadrant choice, and ability to save data to a file.
3. Three-Wire Current-Voltage Analyzer – A programmable power supply designed to function with NPN BJT transistors and familiarize students with curve analyzers. There is flexibility in parameter settings such as voltage and current ranges, base current increments, and ability to save data to a file.
4. Digital Writer – Provides TTL logic write access to the eight digital input channels on the prototype board and provides the ability to input values in binary, hexadecimal, decimal, and octal.
5. Digital Reader – Provides the ability to view the status of the digital input channels.

Specifications for NI ELVIS are available at <http://zone.ni.com/devzone/conceptd.nsf/webmain/164B9A4956FC274586256ED9005E926A?opendocument>.

## 7. Discussion

NI ELVIS provides a useful addition to existing traditional lab equipment such as digital multimeters, function generators, and digital oscilloscopes. Although NI ELVIS provides many of the same functions as traditional equipment, it is important to expose students to the operation of traditional instruments they will need in the practice of engineering such as digital multimeters, function generators, and digital oscilloscopes. It is for this reason that NI ELVIS is used in parallel with traditional equipment for all the experiments for which it is possible.

In comparing the traditional instruments and NI ELVIS, the students did not indicate a preference. While they were familiar with the traditional instruments from physics labs, they had not used these particular Tektronix instruments and became proficient with the traditional and NI ELVIS in about the same amount of time. The students did indicate a preference for the online help found in NI ELVIS over the traditional equipment's user manuals.

NI ELVIS enables the performing of DSA and Bode analysis, experiments that would not normally be performed in a sophomore instrument or electrical engineering lab. In addition, mechanical engineering students attend this lab course [13]. In the near future students will perform thermocouple and strain gauge experiments using NI ELVIS along with traditional methods. This is the first year that NI ELVIS has been used by the Chemistry department, and students in the future will enter the instrumentation lab with experience with NI ELVIS. Moreover, NI ELVIS has been adopted for use in the electronics lab this year [12], thus providing students a wide range of experience with virtual laboratory instruments and data acquisition techniques.

## 8. Conclusion

This paper reports on four experiments that use modern computer hardware and software to measure and analyze electrical networks. It has been demonstrated that the use of NI ELVIS provides an efficient method to obtain experimental results, add additional principles to experiments, and allows students to focus on the theory and practical aspects of the experiments [14]. Moreover, the parallel employment of NI ELVIS and traditional instruments broadens students' understanding of techniques necessary to design and test electrical devices. The comparison of measurements taken with NI ELVIS and traditional instruments resulted in small differences, thus affording confidence to students in their work and providing motivation to employ NI ELVIS in the future.

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