

# Virtual Laboratory for Electrical Circuit Course

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## Abstract

*A virtual laboratory for an introductory laboratory course in circuit analysis in Electrical Engineering Technology program is developed that can replace the traditional laboratory setup by an approach based on data acquisition (DAQ) instrumentation. The project utilizes LabVIEW software and DAQ board (Model PCI-6024E) both from National Instruments. The PCI-6024E is a multifunction I/O device having 8 digital I/O lines, 12 bit 16 single ended analog input lines, and two 12 bit analog output lines. The undergraduate laboratories have been poorly equipped due to the rising cost of laboratory instruments. This trend has created a strong market for laboratory instruments based on personal computers. LabVIEW provides a low-cost solution for laboratory instrumentation compared to its traditional counterpart since appropriate software, operating through a plug-in DAQ board, is readily available at a very low-cost. The LabVIEW can model standard laboratory instruments while offering more flexibility as it is software based. The combination of LabVIEW and available plug-in hardware enables the virtual instrument to be modified whenever needs change. This instrumentation system can be produced at a fraction of the cost of traditional instruments. Due to LabVIEW's graphical nature data can be easily presented in any forms such as charts, graphs, etc. The final product of this project will be used to teach the laboratory course in-class as well as via Internet so that students can take the course on the web which is the trend of education now.*

## 1. Introduction

LabVIEW, short for Laboratory Virtual Instrument Engineering Workbench, is a graphical programming system that has been adopted as the standard for data acquisition and instrument control software. LabVIEW is a

general-purpose programming system with extensive libraries of functions for data acquisition, instrument control, and data analysis. It is a program development application with graphical programming language, called "G", that features a graphical programming environment and all tools needed for data acquisition, analysis, and presentation. The programs in LabVIEW are called virtual instruments (vi) because of the way they imitate physical instruments. A vi consists of a user interface, a data flow diagram, and connections that allow each vi to be called from a higher-level vi. A vi has two main parts, the front panel and the block diagram. The front panel is the user interface to the vi and gets its name because it simulates the front panel of the physical devices. It can include displays, switches, buttons, and other controls. The block diagram is the vi's source code. This is designed using the G language. Components of the block diagram can include built-in functions, program control structures, and sub-vis. Each component in the block diagram must have an icon and a connector. The connectors enable data to flow from one element to another. Another powerful feature of LabVIEW is that it can be used to control or monitor devices over a network. In recent years, development of virtual laboratory has received considerable attention in the literature [1-4]. A virtual laboratory experiment on frequency modulation is developed in [1]. This system utilizes JavaScript and LabVIEW as the main vehicles for implementation and the data acquisition is accomplished with a GPIB card installed on a PC. Instantaneous power measurements in AC circuits using LabVIEW is reported in [2]. In this study, a LabVIEW vi is applied to an AC-to-DC power converter for a power range of 10  $\mu$ W – 100 W over a 1 Hz – 10 MHz frequency span. A MATLAB-based virtual laboratory is investigated in [3] where Cytec Switch Matrix and a dsp Siglab 20-22 are used to perform laboratory exercises. An architecture for a web-based data acquisition system to access instruments via RS-232C interface is presented by Kumar, et al. [4]. The system in [4] utilizes a PROTEK-506 digital multimeter, a PCLD-789D signal conditioning and channel multiplexing board,

and an A-to-D converter board named PCL-208. Basic signal generation, analysis, and data acquisition using LabVIEW are also available in [5-10]. In this project, we present a model for a virtual laboratory where circuits under test are built on a breadboard and the measuring tools are implemented by LabVIEW. This technique provides a low-cost solution for undergraduate laboratory experiments. Signals applied to the circuit, measurements taken from the tests and display of results are all accomplished by LabVIEW. Some simple examples are provided to illustrate effectiveness of the techniques.

## 2. Project Description

The project is focused on integrating LabVIEW software with an existing PC laboratory at the School of Engineering Technology and Sciences at South Carolina State University (SCSU). It demonstrates how LabVIEW and the associated hardware can be used to develop a virtual laboratory to perform laboratory experiments. Some examples are given in this section.

The following circuit in figure 1 is used to measure the voltage across a known resistor in a series connected circuit. The LabVIEW vi reads the input voltage entered by the user from the front panel via DAQ's analog output channel 0 and sends the voltage via the DAQ's analog output line to point A in the circuit under test. Then the vi takes samples of voltage signals at points B and C of the circuit via DAQ's input port channels 0 and 1 respectively. One single point analog output and two single point analog input icons of LabVIEW are used for sending signal to the circuit and reading the voltages from the circuit respectively. The numerical value of the voltage across and the current through resistor R1 are calculated by the block diagram of the vi using the linear voltage-current relationship of a resistor. This value is displayed on the front panel of the vi. The front panel and the block diagram of the vi used for this experiment are portrayed below in figures 2 and 3 respectively.

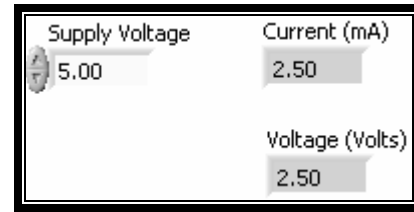


Figure 2. Front panel for voltage across & current in resistor

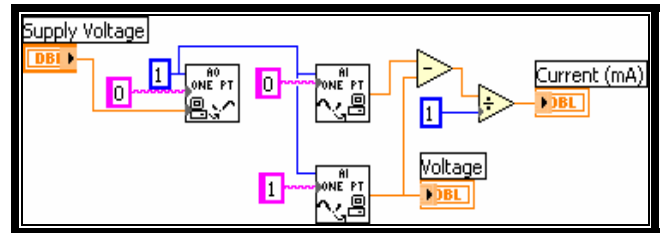


Figure 3. Block diagram for voltage across & current in resistor

The plot of voltage-current relationship (VI Curve) in R1 of the previous circuit is demonstrated in figures 4 and 5. The voltage from 0V to 8V is generated by the block diagram of the vi by operating in a loop. These voltages are then sequentially sent to the circuit as inputs and the corresponding voltage across the resistor is then sampled by the vi. These sampled voltages are used to compute the currents through the resistor using the linear mathematical relationship between the voltage and current in a resistor. The voltage-current data are converted into an array for display on the front panel in a graphical format. In this case, the front panel contains the graph only since the input signal for the circuit is generated by the block diagram of the vi.

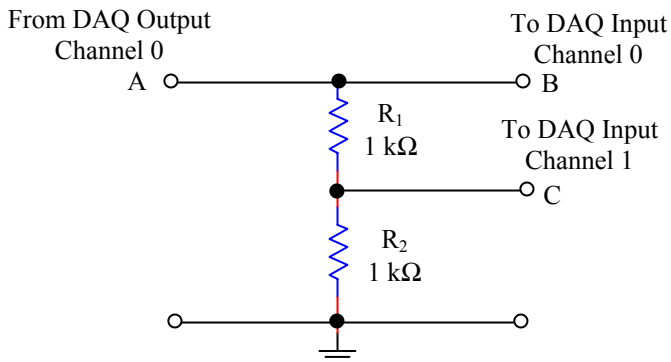


Figure 1. Circuit for voltage across & current in resistor

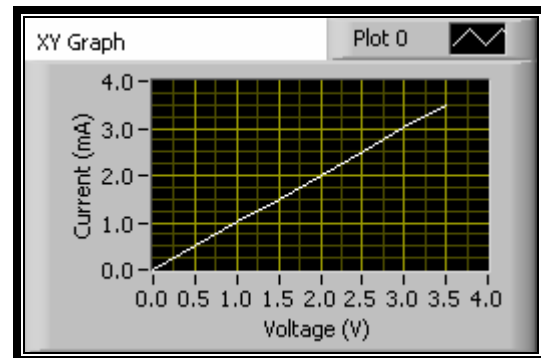


Figure 4. Front panel for VI graph

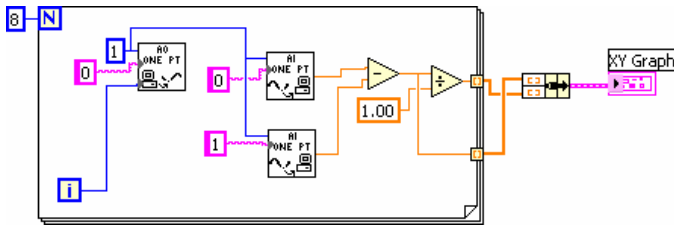


Figure 5. Block diagram for VI graph

Figures 6, 7, and 8 portray an RC series connected circuit built on a breadboard, the front panel and the block diagram of the LabVIEW vi respectively to demonstrate the capacitor charging experiment. User enters resistor and capacitor values, number of samples to be taken by the vi over 10 time constants of the capacitor charging, and the input voltage applied to the RC circuit under test all from the front panel of the vi. The front panel also displays the data in a graphical form after arranging them in an array.

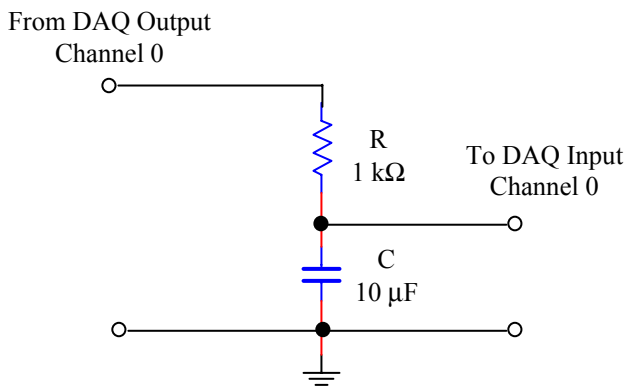


Figure 6. RC circuit for capacitor charging

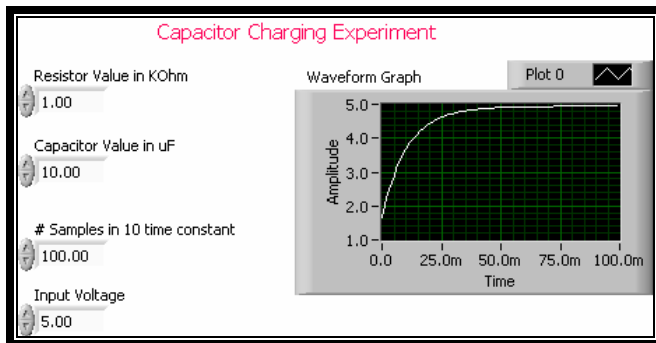


Figure 7. Front panel for capacitor charging experiment

The block diagram of the LabVIEW vi sends the input voltage to the RC circuit via channel 0 of the DAQ's analog output port, reads the resistor and capacitor values from the front panel, and calculates the time constant of the RC circuit. The time constant value of the RC circuit is in turn used to determine the total number of samples to be used for sampling the voltage across the capacitor. After the capacitor voltage is sampled, the data are stored in an array and displayed as a graph of capacitor voltage versus time. These functions of the block diagram are shown in figure 8 shown below.

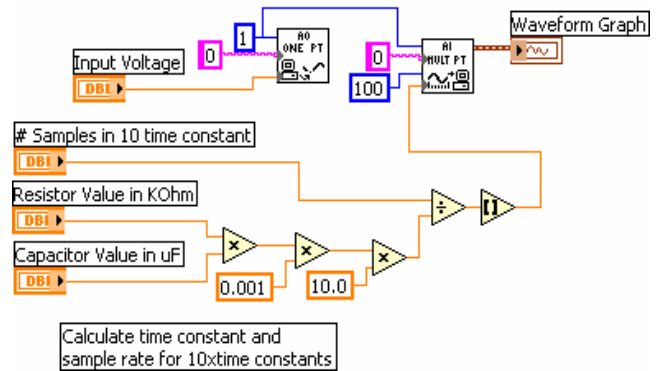


Figure 8. Block diagram for capacitor charging experiment

The following front panel and the block diagram displayed in figures 9 and 10 describe how to compute the capacitor voltage at each time constant using the circuit of figure 6.

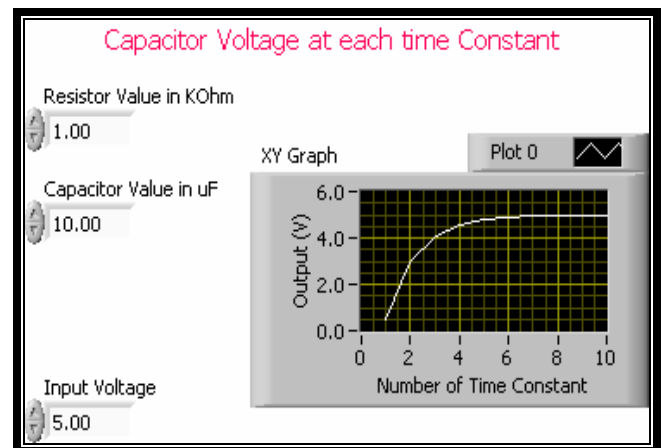
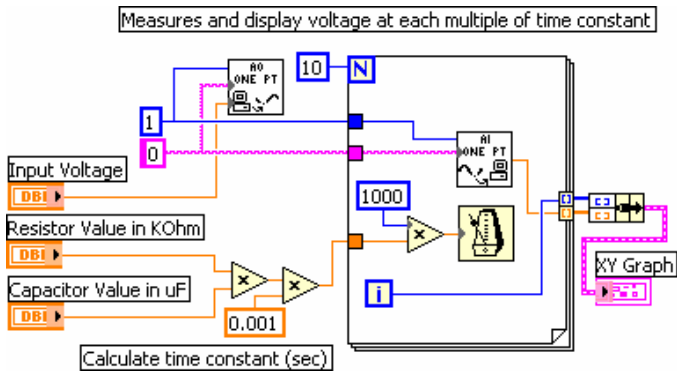


Figure 9. Front panel for capacitor voltage at each time constant



**Figure 10. Block diagram for capacitor voltage at each time constant**

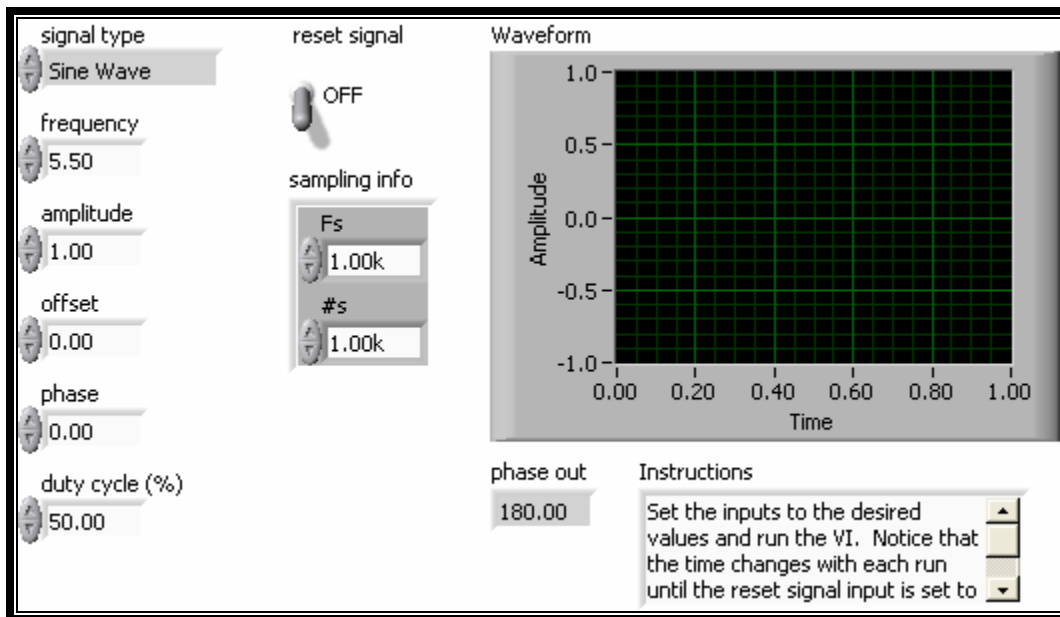
Ten laboratory experiments are developed for the circuit course. These experiments will be implemented in the virtual instrumentation laboratory and will replace the existing traditional experiments. The virtual instrumentation laboratory is equipped with 15 Pentium IV

PCs loaded with National Instrument's LabVIEW 6i software package and National Instrument's DAQ card (Model PXI-6024E) installed. Works are in progress to offer the experiments remotely.

Function generator and oscilloscope vis are distributed with the LabVIEW software package. Works are also in progress to include the oscilloscope and the function generator vis in our virtual laboratory experiments to enhance the capabilities of the experiment setup. The front panels of these two vis are depicted in figures 11 and 12 to show their features.

The function generator vi enables the user to produce different types of waveforms such as sine wave, triangular wave, and square wave. Controls are also provided for frequency, duty cycle, offset, and amplitude as appropriate.

The oscilloscope has two input channels with all basic controls including signal position, time base, and voltage per division to read values from the output display. It is also possible to turn each channel on and off.



**Figure 11. Front panel of function generator**

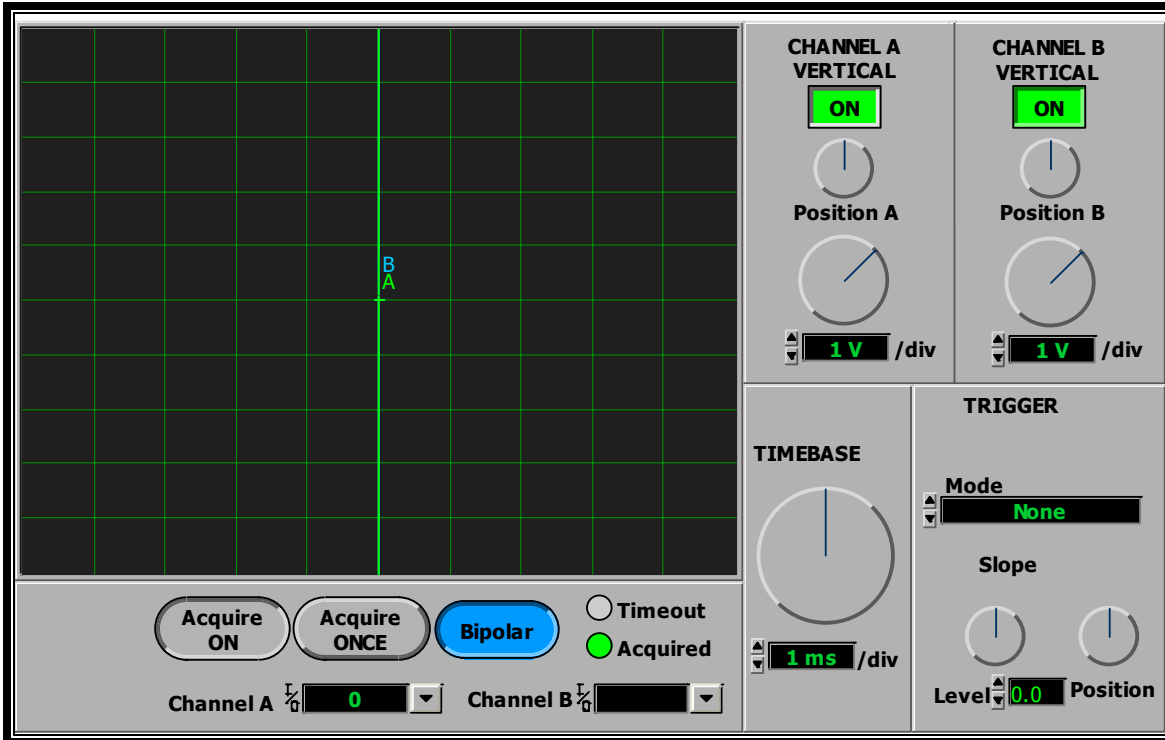


Figure 12. Front panel of oscilloscope

### 3. Conclusions

This initiative is undertaken to develop a virtual laboratory for undergraduate program in electrical engineering technology at SCSU which will provide real world relevant laboratory experimentation at a fraction of the cost of traditional instruments. These virtual instruments are rapidly replacing the traditional instruments in the industries. Since this type of instrumentation will soon be what the typical graduate will encounter on the job, undergraduate laboratory course like this needs to familiarize students with it. Systems for virtual instruments can be built with standard computers and cost-effective hardware. The laboratory experiments can be easily made ready for Internet delivery with the use of LabVIEW's Internet Developers Toolkit. This work will be extended to include virtual laboratory experiments for the control systems and the robotics courses.

### References

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