

On-campus and Online Virtual Laboratory Experiments with LabVIEW

Hasanul A. Basher and Saliman A. Isa
College of Science, Mathematics and Engineering Technology
South Carolina State University
zf_basher@scsu.edu

Abstract

Virtual Laboratory experiments for electronics course in undergraduate electrical engineering curriculum have been developed using data acquisition board (DAQ) and National Instruments LabVIEW™ software package. These applications are suitable for Internet delivery where students can conduct the experiments online. The undergraduate laboratories have been poorly equipped due to rising cost of laboratory instruments. This trend has created a strong market for software based (virtual) laboratory instruments. LabVIEW provides a low-cost solution for laboratory instrumentation compared to its traditional counterpart since appropriate software, operating through a plug-in DAQ board, are readily available at a very low cost. Since LabVIEW is software based, it can model standard laboratory instruments while providing more flexibility. These applications will be used to teach laboratory experiments in our basic electronics course either in-class and/ or remotely. Computer based learning has become an important part of education. The Internet further contributed greatly to long distance learning and remote laboratories. The lab is still under construction and some basic electronic experiments are briefly presented here.

1. Introduction

LabVIEW stands for Laboratory Virtual Instrument Engineering Workbench. It is a program development application with programming language, called “G”, that features a graphical programming environment. It has extensive libraries of functions for data acquisition, instrument control, and data analysis. It can model standard laboratory instruments while offering more flexibility. With virtual instrumentation, systems can be built with standard computers and cost-effective hardware. This enables the user to mix and match data acquisition and instrument control hardware to create virtual systems that meet one’s needs. Due to LabVIEW’s graphical nature, data can be presented in any forms such as charts, graphs, and user-defined graphics. LabVIEW interacts with the user in two separate forms of display such as block diagram and front panel. A program in LabVIEW is called a virtual

instrument (VI) because of the way it imitates a physical instrument. The front panel is the user interface to the VI and includes displays, switches, buttons, and other controls. The block diagram is the functional diagram of the system that includes 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 flow from one element to another.

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 application [1] utilizes JavaScript and LabVIEW as the main vehicles for implementation where the data acquisition is accomplished with a General Purpose Interface Bus (GPIB) card installed on a PC. Instantaneous power measurements in AC circuits using LabVIEW is reported in [2]. In this study [2], a LabVIEW VI is applied to an AC-to-DC power converter for a power range of 10 μ 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-5065 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 [5-11]. This project presents 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. This project utilizes LabVIEW software and DAQ board (Model PCI-6024E) and DAQ Signal Accessory board (Model SCB-68) all from National Instruments. Some simple examples are provided to illustrate the effectiveness of the techniques.

2. Project Description

The project is focused on integrating LabVIEW software with an existing PC laboratory at the College of

Science, Mathematics and Engineering Technology at South Carolina State University. Some examples of rectification of AC signals are provided in this section. LabVIEW is also used to control the experiments over the Internet. The Internet Developer Toolkit of LabVIEW enables us to publish each application and allows remote access to those.

2.1 On-campus Virtual Laboratory Experiment

The first example demonstrates the forward characteristics of a diode (1N004) connected in series with a 1 kΩ resistor as shown in Figure 1. Figures 2 and 3 show the front panel and block diagram of the LabVIEW VI respectively. Through the front panel, the user enters the range of input voltage (minimum and maximum) and the number of steps. These input data are used to compute the actual voltage that is applied to the circuit in steps. The block diagram which is the source code of the VI first checks if the maximum voltage entered by the user exceeds the permissible amount (10V). If the maximum voltage exceeds the limit, the VI displays a message “Value Exceeds Range” and stops the program from running. If the range is within the specified limit, the VI displays the message “Running”, and sends the voltage to the input of the circuit in steps via DAQ’s output port, and measures corresponding voltages at point A and B of the circuit via DAQ’s input port. At the end of the simulation, the VI displays the graph of diode current vs. voltage the voltage across the diode on the front panel (Figure 2).

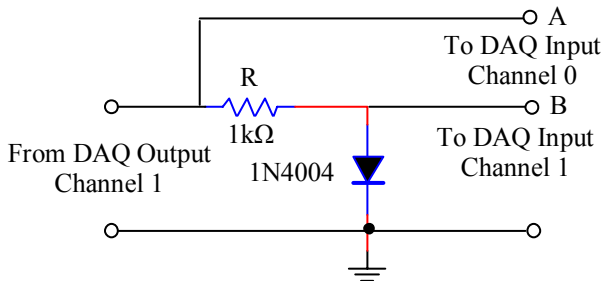


Figure 1. Diode forward characteristics

The data acquisition and other operations performed by the VI are shown in the block diagram (Figure 3) and those are explained elaborately as follows. One multiple point analog output object and two multiple point analog input objects of LabVIEW are used in the block diagram of the VI for sending signal to the input of the circuit and reading voltages from the circuit respectively. Channel 1 of DAQ’s output port is used to send signal to the input of the circuit whereas channels 0 and 1 of the DAQ’s input ports are used to acquire the input and the output voltage of the circuit respectively. The current through the diode is calculated by dividing the difference of voltages measured at points B and A (channel 1 and channel 0) by the value of the resistor

whereas the voltage across the diode is the voltage measured at point B (channel 1) with respect of the circuit ground.

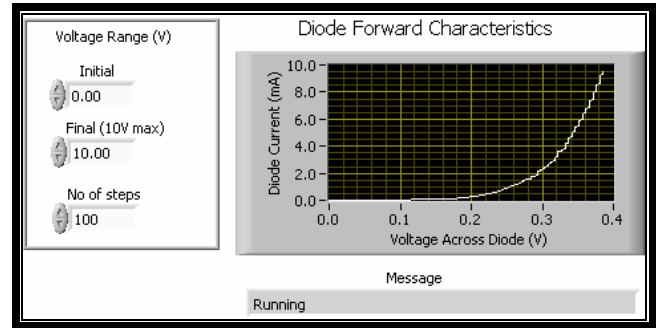


Figure 2. Front panel of diode forward characteristics

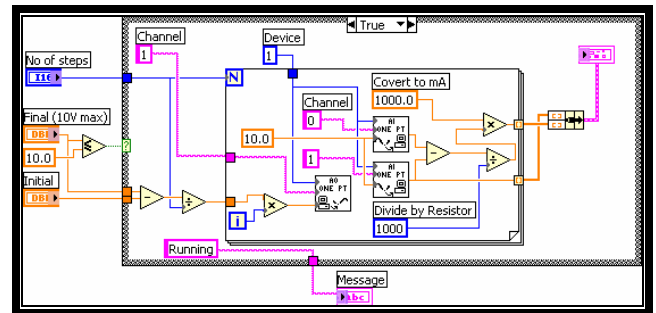


Figure 3. Block diagram of diode forward characteristics

Half-wave rectification of an AC signal that utilizes the circuit shown in Figure 4 is demonstrated in the next example. The front panel and the block diagram of the corresponding VI are given in Figures 5 and 6 respectively.

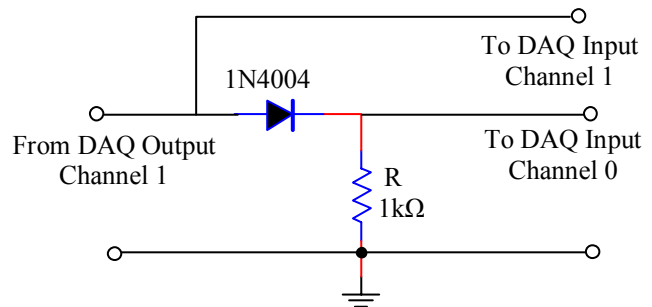


Figure 4. Half-wave rectifier circuit

The front panel of this application contains two sections such as Function Generator on the left, and input-output waveforms of the circuit on the right. The function generator enables the user to generate four types of signals such as sinusoidal, triangular, square, and sawtooth waveforms. The signal type may be selected by clicking on the up or down arrow on the enumerate object located on

the front panel. Controls are also provided for frequency, amplitude, sampling rate, number of samples, offset, phase, and duty cycle when square wave is selected. The function type and its associated parameters are all bundled in a cluster on the front panel. In addition, the front panel displays the input and the output signal of the half-wave rectifier circuit. The simulation can be stopped at any time by pressing the 'stop' button located at the bottom of the left side of the front panel.

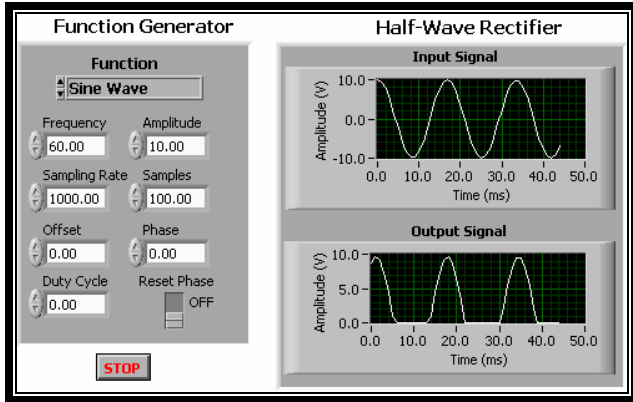


Figure 5. Front panel of half-wave rectifier

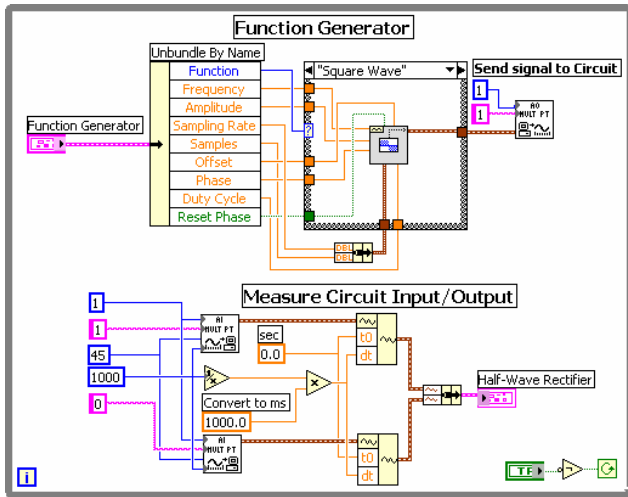


Figure 6. Block diagram of half-wave rectifier

Like front panel, the block diagram (Figure 6) contains two sections one of which is designated as Function Generator. The Function Generator generates the waveform of the type of function selected from the front panel. The other section of the block diagram called Measure Circuit Input/Output shows how the voltage at the input and the output of the circuit is measured via channel 0 and channel 1 of the DAQ's input port (AI MULT PT). The measured data are subsequently sent to the graph object for display.

Next, full-wave rectification of an AC signal is described. The full-wave rectifier circuit, the front panel of the VI, and the block diagram of the VI are shown in Figures 7, 8, and 9 respectively. The full-wave circuit employs a bridge rectifier. The diodes used in the circuit are all of type 1N004 and the transformer has a turns-ratio of 2. The load resistor (R) has a value of $1k\Omega$. The signal generated by the function generator is applied to the primary of the transformer via channel 1 of the DAQ's output port. Channels 0 and 1 of the DAQ's input port are used to measure the input and the output voltage of the rectifier circuit respectively both with respect to the circuit ground.

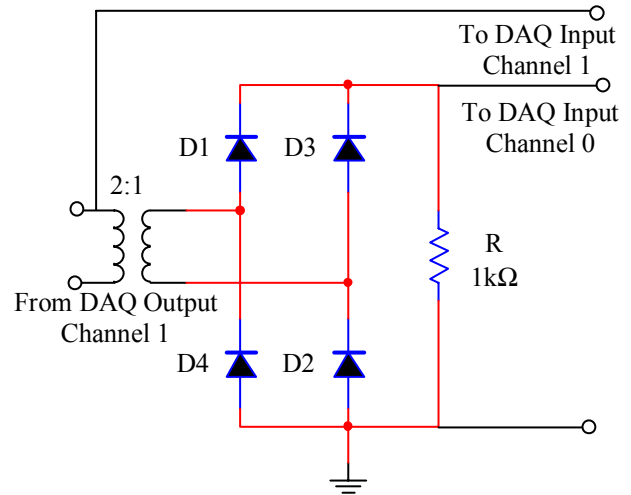


Figure 7. Full-wave bridge rectifier circuit

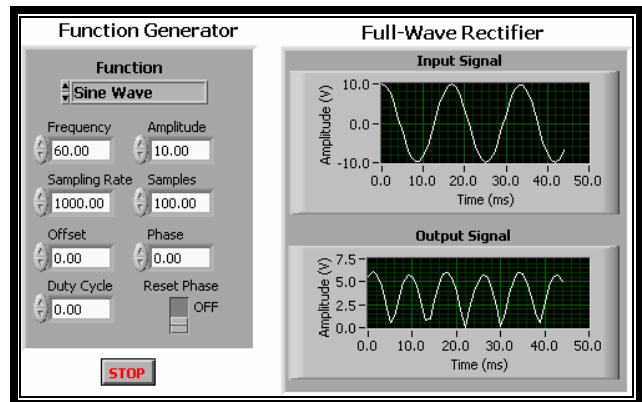


Figure 8: Front panel of full-wave rectifier

Lastly, the display of input and output voltage of a bridge rectifier DC supply when a capacitor of $330\mu F$ is connected across the load is demonstrated. Figure 10 portrays the front panel of the VI. The block diagram of the VI used in this application is same as that of the block diagram of full-wave rectifier without the filter.

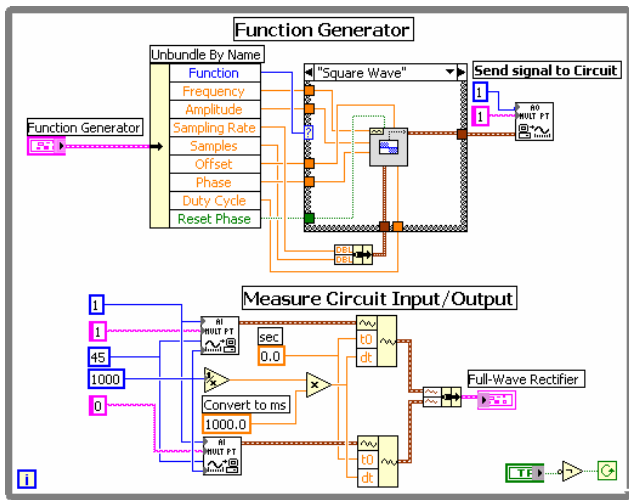


Figure 9: Block diagram of full-wave rectifier

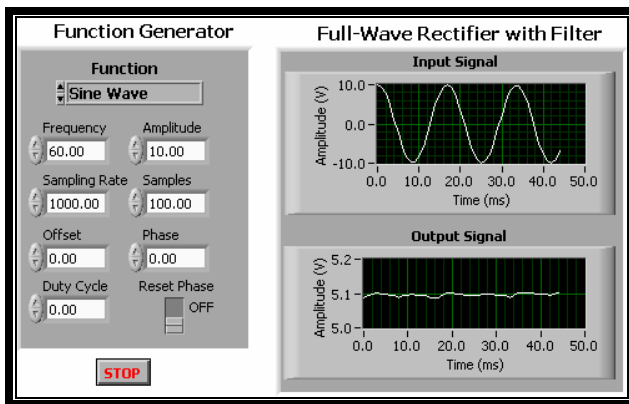


Figure 10. Front panel of full-wave rectifier with filter

user) has complete control of the application. At any time during the process, the host computer can take control of the application away from students.

The JAVA Applet running on the student side sends a request for connection to the program running on the Web Server. The program then sends the connection request to the controller as well as accepts the request from the student. When the access is granted a link from the student to the controller is being established to transfer commands and data. The detailed steps in gaining access and full control of front panel via Internet can be explained in the following paragraphs. The exchange of prompt messages between the host computer and the student computer during the process of gaining control and releasing control of the front panel are also demonstrated through display of the following web pages.

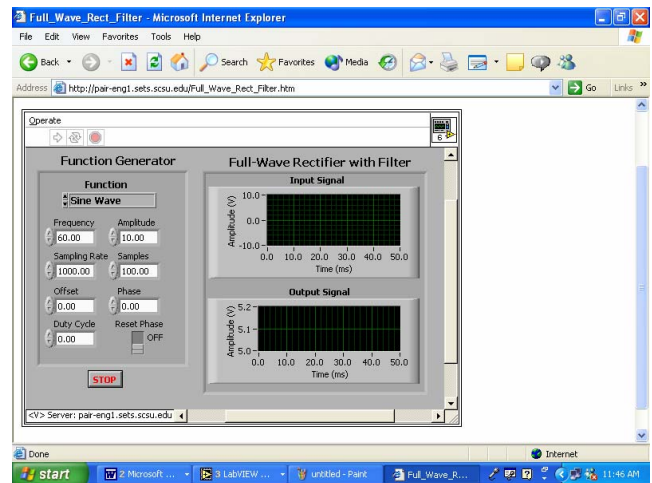


Figure 11. Web page of front panel

2.2 Online Virtual Laboratory Experiment

One of the useful features of LabVIEW is that it comes the "Internet Developer Kit" that contains tools such as Web Server, Web Publishing Tool, and Remote Panel Connection Manager. An application of the VI is first created using the Web Publishing Tool. The Remote Panel Connection Manager is used to enable the Web Server which in turn allows us to publish the front panel of the application. The Universal Resource Locator (URL) address of the application is generated as soon as the application is published. The images of the front panel of the published application can be accessed by student from any web browser after the Web Server is enabled. Only the host computer should have LabVIEW installed and the student needs only access to a web browser. The student simply needs to point the web browser to the web page using the URL address of the application. The acquisition still occurs on the host computer, but the student (remote

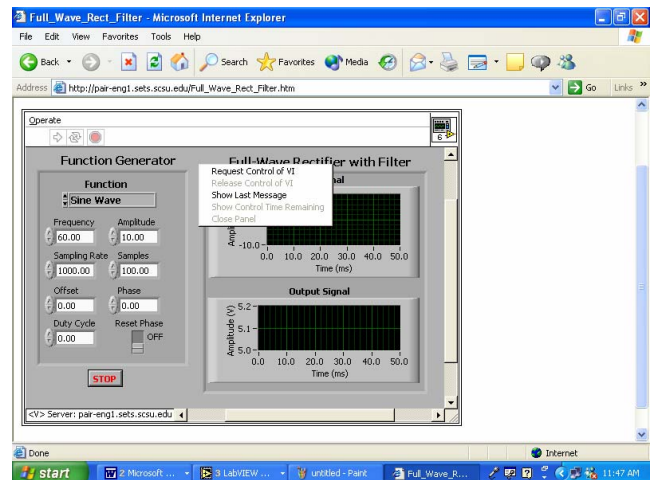


Figure 12. Request for control from student

In this demonstration we are using the full-wave rectification with filter application. Figure 11 is the image of the front panel accessed via the URL address of the VI with Internet Explorer web browser. To gain control of the front panel, the student sends a request for control from the host computer (Figure 12). This request is sent by selecting the “Request Control of VI” option of the pop-up menu that appears after the right-click on the front panel image. After the request for control is issued to the host computer, a control is granted by the host computer along with a message “Control granted” sent to the student’s computer shown in Figure 13. At the same time, control transfer message appears on the host computer that is depicted in Figure 14.

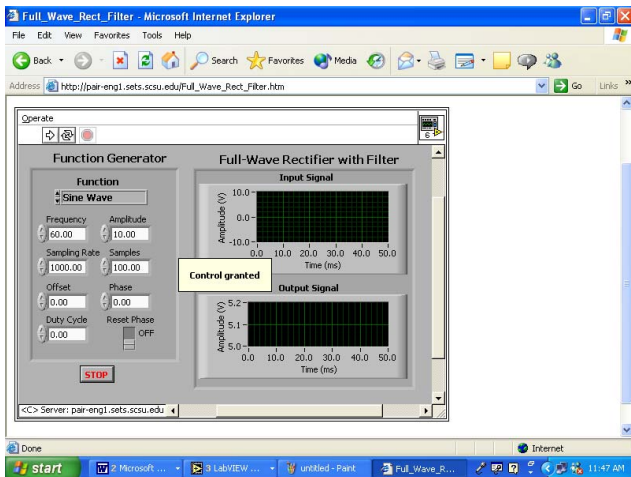


Figure 13. Student granted full control of front panel

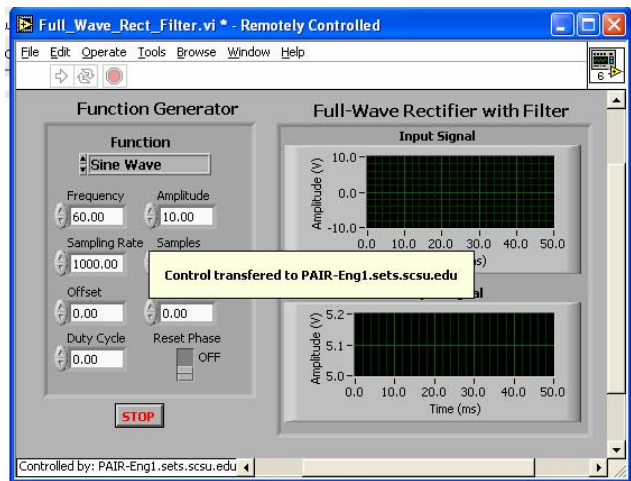


Figure 14. Control transfer message on host computer

After the transfer of control from the host computer, the student can operate all controls and knobs on the front panel to complete the application which is portrayed in Figure 15.

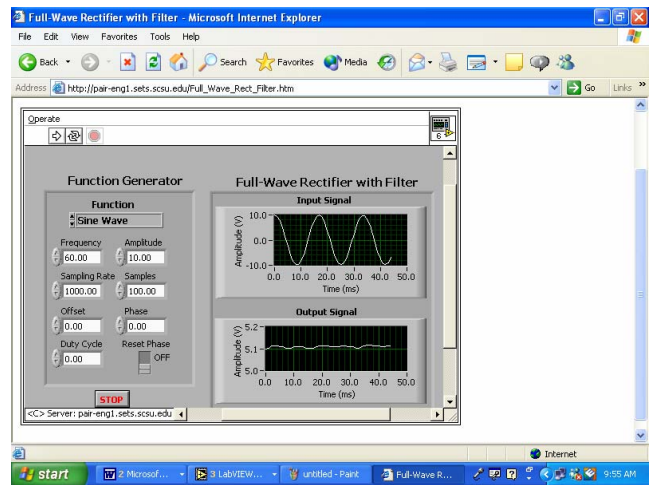


Figure 15. Remote data acquisition by student

The control can be released by the student by selecting the “Release Control of VI” option of the pop-up menu as displayed in Figure 16. Following this action, a message “Server has control” appears on host computer as shown in Figure 17. In addition, the host computer can lock control, take away control from the student at any time during the process.

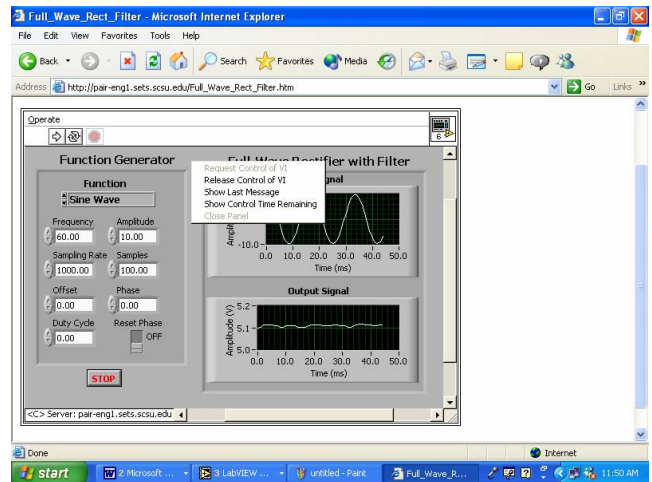


Figure 16. Release remote control by student

The results of the experiments described above demonstrate that LabVIEW with the associated hardware is effective in conducting laboratory experiments in-class or remotely which is cost-effective. Several laboratory experiments for the electronics course have been developed which will be implemented in our virtual instrumentation laboratory and will replace the existing traditional experiments. The virtual instrumentation laboratory is equipped with 15 Pentium IV computers loaded with National Instrument’s LabVIEW software package and

National Instrument's DAQ card installed. Works are in progress for the implementation of the remote experiments.

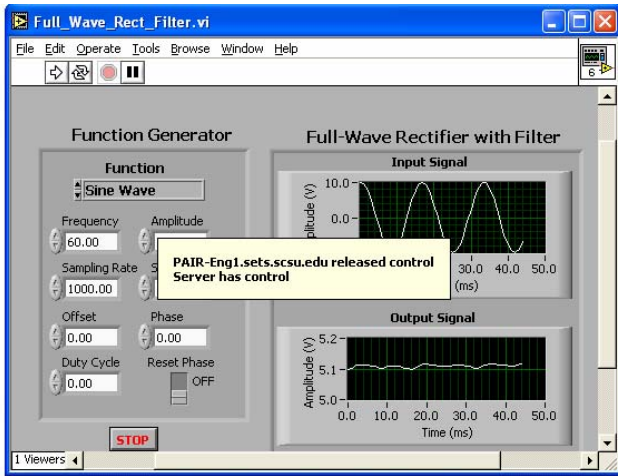


Figure 17. Release control message on host computer

3. Conclusions

This initiative is undertaken to develop on-campus and online virtual remote laboratory experiments in electronics for undergraduate program in Electrical Engineering Technology at South Carolina State University which will provide real world relevant laboratory experimentation at a fraction of the cost of traditional instruments. 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 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 Kit. This work will be extended to include virtual laboratory experiments for the control systems and robotics courses.

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