Integration of Virtual Instruments into an EET Curriculum

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Abstract

Laboratory exercises and computer usage are an integral part of the Engineering Technology Programs. These exercises help to improve the students’ problem solving, critical thinking, and technical communication skills and require upgrading of laboratory and computer facilities. But in recent years there has been a decrease in resource allocation making it increasingly difficult to modernize the laboratories to provide adequate levels of laboratory and course work.

This calls for an alternative cost-effective method of modernizing laboratory resources and one way to do this is through the introduction of the virtual instruments concept to existing laboratory and courses. This paper describes an on going process: the integration of virtual instruments into various Electrical Engineering Technology (EET) lecture and laboratory courses so that our graduates can be well trained with the latest technology.

I. Introduction

The ET programs are designed with laboratory exercises and computer usage as an integral part. The laboratory exercises provide verification of the basic theory and reinforcement of the underlying principles; acquaintance with physical components and equipment; greater attention to the theoretical limitations; ability to communicate; critical thinking and observations; and the application of logical analysis and computer usage to solve real world problems. This is also true of the Electrical Engineering Technology (EET) programs at the South Carolina State University (SCSU).

The EET program curriculum at SCSU requires six (6) one (1) semester hour laboratory courses covering areas like Circuits, Electronics and Communications, Digital and Microprocessors, Power Systems and Electric Machines, Control and Robotics, and PLC and Virtual Instrumentation and one (1) three (3) semester hour computer aided design course. These courses provide the student with competence in the use of analytical and measurement equipment.

These laboratory courses also help to enhance/introduce the student to the following:
a. Verbal and written communication skills.
b. Working in team concept
c. Use of simulation software
d. Use of data sheets
e. Use of standard design practice
f. Importance of completing the assignments in time

This requires upgrading laboratories with modern equipment and calls for increased funding and resources. But in recent years there has been a decrease in resource allocation making it increasingly difficult to modernize the laboratories to provide adequate levels of laboratory and course work. This calls for an alternative cost-effective method of modernizing laboratory resources and one way to do this is through the introduction of the virtual instruments concept to existing laboratory and courses.

This paper describes an on going process: the integration of virtual instruments (VI) into various EET lecture and laboratory courses so that our graduates can be well trained with the latest technology. The EET program faculty has developed a laboratory called Computer Based Virtual Engineering Laboratory (CBVEL) with funding from the Department of Defense (DOD) where VI modules for various EET laboratory courses are being developed and tested.

SCSU has ongoing evening off-campus course offerings of upper-division courses leading to a Bachelor of Science degree in Electrical Engineering Technology at selected South Carolina technical colleges. This program is designed for the employed technical college graduates who possess an associate degree in Electrical/Electronics Engineering Technology and who wish to obtain a four-year degree in the evenings. The EET program faculty is also developing Internet based VI modules to be used by our off-campus students. Modification of our existing laboratories through the introduction of VI concept will help us better educate and train our graduates to serve the needs of the technological and engineering community.

The CBVEL consists of IBM compatible computers with appropriate software and hardware (LabVIEW, HI-Q, Virtual Bench, PXI Systems, DAQ Cards, etc.) from National Instruments (NI), and is connected to the School of Engineering Technology and Sciences (SETS) network and existing equipment. Virtual Instrument (VI) modules for different courses and research areas are currently developed. Examples of some of these VIs are Circuit Analysis, Electronics, Communications, Digital Signal Processing, Control and Power Systems, Mathematical Modeling, Networking, and Digital Filters. These modules will be used to better train the engineering technology, sciences, and information technology graduates. Some of the research areas that will be benefited by this laboratory are Non Destructive Testing, Power Quality Analysis, Control and Robotics, Intelligent Sensors and Distributed Control, Fuzzy Logic, and Space Science.
II. Components used in CBVEL and application areas of LabVIEW

a. Components in CBVEL

The following are some of the components of CBVEL. The major components of this CBVEL are 12 PXI, 166 Mhz computers from NI and 20, 350 Mhz INTEL Pentium computers from Gateway. Besides these the PXI systems are equipped with NI components such as High-Speed Data Acquisition (DAQ) Function Generator Cards, Multimeter Cards, Oscilloscope Cards, Training Modules, Stepper and Servo Motion Control Cards, Virtual Bench Software, IMAQ Vision Cards, Field Point Dist. Systems, and Switches. Virtual Bench software is used to use these cards for different simulation and laboratory exercises. The motion control, vision, and distributed control cards are primarily for research. All these cards are installed in different ports of this PXI system. The Gateway computers are equipped with LabVIEW and HI-Q software and other software like PSPICE, Visual Basic, C/C++, MatLab, etc. The student and faculty use these computers for simulation purposes.

b. Application Areas of LabVIEW Software

The following are some of the application areas of LabVIEW:

Simulation; Data Acquisition; Data Processing - built in analysis library that includes signal generation, measurement, filters, windows, curve fitting, probability and statistics, linear algebra, numerical methods; Instrument and Control; Object oriented/graphical programming; Fuzzy Logic; Genetic Algorithm; and Joint Time and Frequency Analysis. Many industries, academic institutions, and federal agencies such as DOD, DOE, and NASA use it.

III. List of VIs and description of a few of the VIs

a. List of VIs

Table 1 provides a list of VIs that can be used in various EET courses to introduce students to the concept of virtual instruments. Some of these VIs listed below were developed from scratch and some of them were borrowed from different books and the NI web site and were modified as needed. This list consists of 23 projects with 89 VI modules that address various EET courses and the EET faculty is constantly upgrading the VI modules to address the needs of changing technology.
### Table 1 - List of VI modules

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Name of VI</th>
<th>Number of individual VIs</th>
<th>Level of Complexity</th>
<th>VI Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>Calculator, Calculator with Menu, and Second order equation (Graph)</td>
<td>3</td>
<td>Introductory. Introduces to LabVIEW items.</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 2</td>
<td>VIs to solve mathematical equations</td>
<td>2</td>
<td>Introductory. Introduces to LabVIEW items.</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 3</td>
<td>VIs to solve mathematical equations</td>
<td>3</td>
<td>Intermediate. Introduces to LabVIEW items.</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 4</td>
<td>Ohm’s Law and Series Circuit (KVL)</td>
<td>2</td>
<td>Intermediate. Circuit Analysis</td>
<td>Simulation Laboratory</td>
</tr>
<tr>
<td>Project 5</td>
<td>Capacitor Charging &amp; Discharging</td>
<td>1</td>
<td>Intermediate to Advanced Circuit Analysis</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 6</td>
<td>Plotting Freq Response &amp; Calculating Bandwidth, Center Freq, etc.</td>
<td>1</td>
<td>Intermediate to Advanced Circuit Analysis</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 7</td>
<td>Amplitude and Frequency Modulation</td>
<td>2</td>
<td>Intermediate to Advanced Communication</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 8</td>
<td>Application of Modulation and Demodulation</td>
<td>1</td>
<td>Intermediate to Advanced Communication</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 9</td>
<td>Number Systems, Truth Table of Gates, Simulating logic equation, and Digital LED</td>
<td>4</td>
<td>Intermediate Digital Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 10</td>
<td>Combinational Design</td>
<td>1</td>
<td>Intermediate Digital Electronics</td>
<td>Simulation Laboratory</td>
</tr>
<tr>
<td>Project 11</td>
<td>Extract Sine Wave IIR Filter</td>
<td>2</td>
<td>Advanced Signal Processing</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 12</td>
<td>555 Timer VIs</td>
<td>11</td>
<td>Intermediate to Advanced Electronics</td>
<td>Simulation Laboratory</td>
</tr>
</tbody>
</table>
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</tr>
</thead>
<tbody>
<tr>
<td>Project 13</td>
<td>Measuring Time Constant</td>
<td>3</td>
<td>Advanced Circuit/Electronics</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Project 14</td>
<td>LED and Photodiode</td>
<td>3</td>
<td>Advanced Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 15</td>
<td>Operational Amplifier Basics</td>
<td>4</td>
<td>Intermediate/Advanced Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 16</td>
<td>Operational Amplifier Circuits</td>
<td>11</td>
<td>Intermediate/Advanced Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 17</td>
<td>Voltage to Freq. Converter</td>
<td>14</td>
<td>Intermediate/Advanced Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 18</td>
<td>Voltage Divider and Calibrations</td>
<td>3</td>
<td>Intermediate/Advanced Circuits/Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 19</td>
<td>Frequency Analysis</td>
<td>6</td>
<td>Intermediate/Advanced Circuits/Electronics</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 20</td>
<td>DC Motor</td>
<td>2</td>
<td>Intermediate/Advanced Power Systems/Machines</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 21</td>
<td>Internet Addresses and Classes IP Routing using Visual Basic</td>
<td>2</td>
<td>Intermediate/Advanced Computer Networking</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 22</td>
<td>Bode Plot, Root Locus, Feedback</td>
<td>3 (to be developed)</td>
<td>Intermediate/Advanced Control Systems</td>
<td>Simulation</td>
</tr>
<tr>
<td>Project 23</td>
<td>Matrix Analysis</td>
<td>5 (to be developed)</td>
<td>Intermediate/Advanced Linear Systems</td>
<td>Simulation</td>
</tr>
</tbody>
</table>

b. Description of a few of the VIs

We have developed VIs for circuit analysis, electronics, communication, signal processing and filters, power and control systems, and information technology courses. The faculty and
students use these VIs in various lecture and laboratory courses. The VIs can be categorized to two types: Simulation VIs and DAQ VIs. The Simulation VIs concentrate on simulating circuits and systems. The students compare the results of the theoretical calculation to results of simulation and determine the percentage of error. In the Laboratory VIs, the students build their projects on breadboard and develop appropriate VI modules to test their design. To test and debug their design, they connect the circuit to appropriate interface cards (multimeter, function generator, oscilloscope, DAQ system, etc.) in the PXI system module, apply required input(s), and observe the output(s). Some projects may require saving the data generated from the projects to save in text file(s) for use by EXCEL and LabVIEW software programs for further analysis. The students compare the results of the theoretical calculation to actual results obtained from laboratory testing and determine the percentage of error. Then they present their findings in a written report and in some cases present their design in the class orally.

The circuit analysis VIs cover Ohms law, series circuit, voltage divider, parallel circuit, current divider, series-parallel circuit, capacitor charging and discharging, inductors, series and parallel RLC circuits, resonance, and frequency response. These VIs use different built in LabVIEW functions such as digital controls for input, formula node and for loop for mathematical equations, and digital indicators, graphs and charts for output.

The electronics VIs cover designs dealing with Diodes, Operational amplifiers, and Timers. Currently we are developing VIs covering transistors and other electronics devices. The objectives of the Operational Amplifier VIs are to assist the student (a) learn how an Op-Amp can add, subtract, and average its input signal(s) and (b) build an op-amp circuit which sums two independent and separate input signals. The following is a list of components used to design and test these VIs:

- A computer with National Instruments LabVIEW software.
- National Instruments DAQ board (inside computer).
- National Instruments SC-2075 Breadboard Connector (outside computer).
- A 741 Op-Amp.
- An assortment of resistors (At least two 10 k-Ohm, one 5 k-Ohm, and one 100 k-Ohm).
- Cables and wires for connecting the previous equipment together, such as:
  - Two BNC-to-banana converters
  - Two banana-to-alligator clips
  - Connection wire
Front Panel of Summing Operational Amplifier VI

Mathematical Equations:
\[ V_{out} = -R_f \left( \frac{V_1}{R_1} + \frac{V_2}{R_2} \right) \]

For \( R_1 = R_2 = R \); \( V_{out} = -(R_f/R)(V_1 + V_2) \)

For this VI, the following are used:
\( V_2 = 0, R_1 = R_2 = 10 \text{ k-Ohm} \) and \( R_f = 100 \text{ k-Ohm} \).

\( V_1 \) value is generated by the VI (-0.5 V to 0.5 V in 40 equal increments)
\( V_{out} = -5 \text{ V to 5 V} \)

Inputs to Op Amp Tester VI

Enter Actual \( R_f/R \) (Measure \( R_f \) Measure \( R_1 = R_2 = R \), Determine \( R_f/R \)).

Scan Start Voltage: -0.50
Scan Stop Voltage: 0.50
Number of Steps: 40
True Delay (Sec): 0.10

I/O DEVICES - CHANNELS

Out Device: 1
In Device: 1
Out Channel: 0
In Channel: 2
True Low Limit: 5.00
True High Limit: 5.00

VI OUTPUT - Transfer Characteristics
(Vin Versus Vout).

Plot of Vin Versus Vout from Test File Created from Test Data During RUN Time.

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IV. Remote Access VI

The VI modules described above can easily be accessed from distance locations over the Internet. The faculty has developed remote access and control VI modules using LabVIEW Front Panel and Real Time engine to achieve this objective. This VI module was tested using the SCSU and SETS network and performed satisfactorily. The faculty is currently enhancing this remote access module by including the image acquisition capabilities. The students at off-campus locations will be using this VI module to complete laboratory and course work for various EET courses.
The remote site computers don’t need LabVIEW but need the LabVIEW Front Panel and Real Time Engine. For dedicated hardware based experiments, these dedicated instruments will be connected to the experimental setup and appropriate VI modules will be designed and developed to remotely conduct the experiments. The dedicated instruments (voltmeters, scope, etc.) must have GPIB or other NI compatible programmable interface.

V. Conclusion and Discussion

We have developed a number of other VIs for other courses. We could present only a fraction of the VIs here because of the page limitations. The remote access component of the CBVEL is currently being enhanced through the addition of image acquisition and camera capabilities. The remote access feature of our CBVEL will enhance the existing distance learning courses.

The CBVEL described in this paper uses twelve PXI systems along with twenty Intel Pentium computers. The PXI systems also use various NI components. The use of PXI systems and the NI components increases the equipment budget. To limit the cost, the laboratory could have been designed using only the Intel Pentium computers with DAQ cards. We have decided to use PXI systems in our CBVEL because of the following reasons:

a. Compact nature and ruggedness of the PXI systems.
b. To address various research areas.

The combination of virtual instruments and the Internet can create more powerful, flexible, and cost-effective instrumentation systems. Some of the advantages and applications of the Internet Based Virtual Instrumentation are as follows:

- Move information rapidly from source to destination.
- Remote Monitoring and Control
- Collaboration with other researchers
- Distribute Computing.

Some of the limitations are:

- System may fail to deliver if the network is down.
- Information may be contaminated due to viruses.
- Competitors may steal information by tapping into the network.
- Remote access may not be possible if the system is inside a “firewall” and the appropriate port(s) must be opened for remote access.

Proper network design and user training can adequately address these limitations.
VI based instruction will provide a truly modern environment in which students and faculty members can study engineering, technology, and sciences at a level of detail, and this will be possible because of the versatility of LabVIEW and other products from NI. The Internet based Virtual Instrumentation using front panel and real-time engine of LabVIEW will assist us to provide laboratory experience for our off campus graduates.

VI. ACKNOWLEDGEMENTS AND SCOPE FOR FUTURE WORK

We are thankful to DOD/AirForce for providing us the funding to design and develop this laboratory. This work was funded in part by a PAIR grant from NASA-MURED to SCSU under NCC 5-454. We are thankful to NASA for providing us with this grant. We are also thankful to Dr. James E. Payne, Associate Dean of SETS and Professor of Physics, Dr. Donald Walter, Associate Professor of Physics and Principal Investigator for the NASA PAIR project for their help and support to conduct this work.

We plan to incorporate the following provisions to our VI in the future:

1. Data Socket and FTP provisions to save files in the client machine generated by the VI.
2. Real time image acquisition using Web camera and web camera software.
3. Increase number of licenses and made this VI available in the web for experimentation by other academic institutions.
4. Modify and use this VI to perform remote experiments on various engineering, technology, and science subjects.

VII. Bibliography


NIKUNJA K. SWAIN

Nikunja Swain received his B.Sc. and M.Sc. in Electrical Engineering, M.S. in Electrical and Computer Engineering, and a Ph.D. in Energy Engineering. He is registered professional engineer (PE) in South Carolina. Currently he is a professor of EET program at SCSU. He has published number of papers related to graphical programming and virtual instruments.

MRUTYUNJAYA SWAIN

Mrutyunjaya Swain is an Assistant Professor of Computer Science at South Carolina State University. He received his B. Sc degree in Physics and M.S degree in Computer Science from India, and currently he is working on his doctoral degree in Computer Science. He has published number of papers on the application of LabVIEW in education and research.

JAMES A. ANDERSON

Dr. Anderson’s areas of specialization are in Electro-Optics, Solid-State Devices/Microelectronics, and Microwave and Optical Communications. He has performed research and design at various industries, worked as a consultant and professional engineer and has been a University Professor. Currently he serves as Professor and Dean of the School of Engineering Technology and Sciences (SETS) at South Carolina State University.