AC 2012-3696: DEVELOPMENT AND IMPLEMENTATION OF I-LABORATORY FOR INSTRUMENTATION, SENSORS, MEASUREMENTS, AND CONTROLS COURSES

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Development and Implementation of i-Laboratory for Instrumentation, Sensors, Measurements and Controls Courses

Abstract

Computing, information and communication technologies have strong impacts on education, by significantly improving the distance and online collaborative learning, via the virtual or remote experiments and simulations. One of the distinguishing features of engineering technology education is the laboratory work and hands-on experience as an integral part of the curricula. Their purpose is bringing the students closer to real situations that they may encounter in industrial settings. Instrumentation and measurement (I&M) are among the most important concepts that students learn in the course of engineering programs. Laboratory assignments illustrating these techniques provide students with learning opportunities and practical experience, encouraging sustained student interest and retention. Unfortunately, incorporating laboratory experimental student activities in engineering curricula is constrained by space, administrative and budget limitations. On the other hand online engineering practice is offering nowadays new potential for training in sensors and measurement technologies and procedures. Virtual laboratories add a significant value to engineering curricula in a variety of cases. Whether it is a complement to a hands-on experience or a substitute when a traditional lab is not feasible, virtual laboratories are a valuable educational resource. Virtual and remote-controlled experiments are originated from the attractive opportunity of exploiting the Internet advantages to control instrumentation and conduct measurement processes from any location and at any time. This project intends to provide more efficient sharing of expensive measurement equipment. We are planning to develop a set of virtual and remote-controlled measurement experiments, such as: transducer electronic data sheet creation and testing, mechanical material characteristics, acceleration and speed measurements, temperature sensor characterization, etc. Students will be able to conduct any of these experiments on their own schedule. By contrast to a traditional lab that requires multiple workstations to be placed in a physical space and attended by trained staff, i-Labs can provide the use of a workstation simultaneously to several students. Therefore it provides laboratory activities for students at a relatively low cost per user. Other important features of remote and virtual labs are: availability, security, flexibility, and portability. Our planned i-Lab allowing the users to perform real measurements, sensor tests and calibrations may be used on a wide variety of other courses with minimal administrative cost. Two strategies are planned to be used in our design and implementation: the use of proprietary languages like LabVIEW and MATLAB-Simulink and the use of standard programming languages. The success of this project in an education and research-oriented experimental facility will advance the state of art of education in the fields such as I&M, sensors and controls by contributing to new experimental concepts, and simulations, and by creating a motivating environment for the engineering practice. The i-Lab set-ups planned to be developed during this project are used in both ET undergraduate and graduate courses. They also may be used as models for the similar developments in other courses.

Background and Project Rationale

The engineering, science, and technology field, at present, is very dynamic due to recent advances in computer and other technologies. These advances have resulted in numerous computer programs to solve traditional and novel problems. These programs use the computer's increased computational capabilities and assist in the design, development, and control of complex systems in a matter of minutes. Automation is becoming part and parcel of every industry, and industries need a trained workforce to manage this new development. Engineering and technology graduates must have a comprehensive background covering a wider range of technical subjects. The graduates must be proficient in the use of engineering and scientific equipment, conducting experiments, collecting and analyzing data, and effectively presenting the results[1-4]. This is especially true for the graduates of engineering and technology. Furthermore, these graduates must be well-trained in courses and laboratories such as electric and electronic circuits; microprocessors; computer programming; computer aided design; electronic and data communications; networking; control and robotics; electric machines and power systems; PLC and numerical methods, controls, instrumentation, quality control, and others.

In today's engineering education world in general and in the measurement and instrumentation field, in particular, the main hurdle is the increased cost and complexity of the laboratory equipment and instrumentation per activity station combined with the increased student enr2ollment on one side, and the budget limitations for the laboratory technicians and equipment, on the other side. The development of computing and information technologies has opened new possibilities in realization of experimental teaching in the field of measurements[5-7]. Low price of microprocessor's components and systems, made possible the realization of remotely accessible laboratories, which can be used for education. Those laboratories provide students to access measuring system via Internet and directly carry out real experiments without their physical presence. Interactive experiments are fundamentally different from their batched counterparts. Primarily, interactive experiments require control of lab hardware while the user sets parameters and observes results. This is in contrast to the batched model where experiments are queued and run when the lab hardware is available. An interactive experiment, then, must commit the lab hardware to a single user for the duration of their session and may require scheduling. Another main difference between interactive and batched labs involves the role of the Service Broker. Interactive experiments require real-time control and, potentially, much greater bandwidth between the lab client and the lab server. Because of this, the batched notion of a Service Broker that uses web services to route all communications between the laboratory client and laboratory server will not work effectively in an interactive i-Lab.

Physical experiments are indispensable because they offer the only possibility of making students cognizant about the differences between mathematical models of nature and nature itself. It is possible to increase the capacity of instructional laboratories without raising the cost per student significantly by opening them for remote access and lab work 24/7. In this paper an on-line workbench mimicking a hands-on workbench in a laboratory for electrical experiments is presented. Here mimicking means that students on their computer screen are able to recognize the instruments and other equipment that most of them previously have used in a hands-on laboratory. In the on-line workbench, mouse-cursor-on procedures supplements hands-on ones. One cost-effective way of achieving this is through the use of simulation software programs, and a number of simulation software packages are available for these purposes. These software packages play an important role in education and are used to deliver training for all kinds of activities, from piloting sophisticated aircraft or ships to operating nuclear power plants or complex chemical processing facilities. There are numerous uses of simulation, starting from simulation of simple electric circuits to complex tasks such as electromagnetic fields, heat transfer through materials, networking, computer circuits, game programming, or beam loading with the ultimate objective of providing illustrations of concepts that are not easily visualized and difficult to understand. Simulators are also used as an adjunct to and, in some cases such as distance learning courses, as a substitute for actual laboratory experiments. In many instances, students are required to verify their theoretical design through simulation before building and testing the circuit in the laboratory. Studies show that students who used simulation prior to conducting actual experiments performed better than the students who conducted the laboratory experiments without conducting simulation first. Also, simulation is used to model large and complex systems. There is no doubt that simulation cannot replace the physical hands-on experience, but simulation can also enhance the teaching and learning experience. The objective of this paper is to discuss a set of software simulations, designed by the authors and their effect on student learning in instrumentation & measurements course.

LabVIEW Capabilities and Proposed System,

The development and use of programmable measurement systems have been widely explored. The possibility of modifying the measurement procedure simply by changing the algorithm executed by the computer-based architecture without replacing the hardware components makes the experimental activity easier. Virtual measurement systems have been introduced to simplify the design, implementation and use of programmable measurement systems by adopting a visual interface. Networking has also been introduced successfully in measurement to interconnect different instruments and data processing sites into a distributed measurement system (DMS). Industries that develop and use DMS are migrating away from proprietary hardware and software platforms in favor of open systems and standardized approaches. The exponential growth of computer and internet technology enables the development of complex hybrid systems such as remote laboratories where experiments can be remotely accessed, monitored and controlled[10-12]. This new interpretation of the measurement process offers to anyone the opportunity to interact with the laboratory at any time, reducing at the same time the experiment cost per user and extending the capabilities of the entire experimental framework.

LabVIEW is very easy to learn and it can rapidly be applied in regular teaching and in practical applications[9-12]. LabVIEW is a programming language, equivalent to C++, Visual Basic, or any other language[10-13]. However, it is the *only* widely accepted graphical programming language. Graphical programming is a language of the future and carries with it many important programming concepts. The visual representations bring programming closer to the human side of the human–machine interface, just as high-level languages tipped the accessibility scales relative to assembly languages. Moreover, LabVIEW has proven to be an invaluable tool in decreasing development time in research, design, validation, production test, and manufacturing. Besides this, the major advantages of LabVIEW include ease of learning, using and debugging, the simplicity of using the interface (front panel of a LabVIEW program) particularly for a user with little knowledge of LabVIEW programming, modular development, complete functionality, available tools and resources, reliable performance and the capability of controlling equipment.

There are four critical elements of the LabVIEW development platform[11-13]:

1. Intuitive graphical programming language
2. High-level application-specific tools
3. Integrated measurement and control-specific capabilities
4. Multiple computing targets

We can program instrumentation and measurements courseware using the LabVIEW's highly effective graphic programming tools. This approach enables undergraduate students to integrate the applications of physical instruments on the basis of having grasped theoretical knowledge, and also encourages them to create virtual instruments by themselves. So, this can cultivate undergraduates' hands-on ability and creative thinking, which in turn can raise their whole learning level. LabVIEW software developed by NI Corporation is based on computer's visual virtual instrumentation, providing a very flexible platform for measurement technology. Remote real-time control of processes is receiving considerable attention in the academic and industrial communities. Various technologies are developed to perform the remote real-time control using Internet-based technology[13-19]. LabVIEW is one of the well-known software packages used in process control applications. LabVIEW uses various protocols such as TCP/IP, DataSocket, etc. that allow remote control using Internet. Several universities have developed Internet-based process control laboratories for distance education using LabVIEW and its communication protocols[11]. Due to his versatility and capabilities LabVIEW is one of the most used packages for development of Remote Labs. Most of the work reported so far uses Internet Toolkit, DataSocket, and so forth for developing Remote Labs, which require clients to have software developed in LabVIEW. **We are focusing on using the approach of virtual experiments, which needs a standard web browser with relevant plug-ins running on any type of minimal hardware platform without any specific requirements.** This simplifies the client side, so that students can concentrate on experiments rather than on learning the client interface. Further, the logistic involved is also simplified as the student is no longer required to obtain and install the experiment-specific software. It is also less expensive.

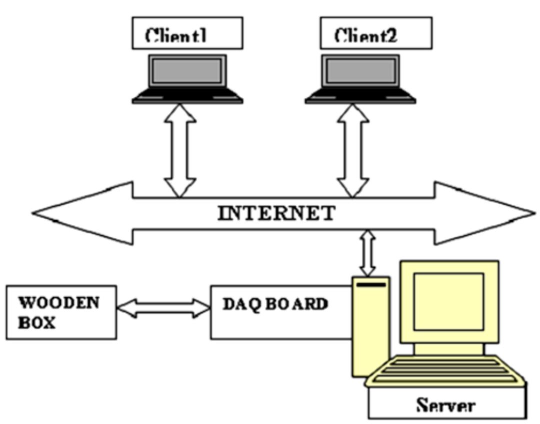


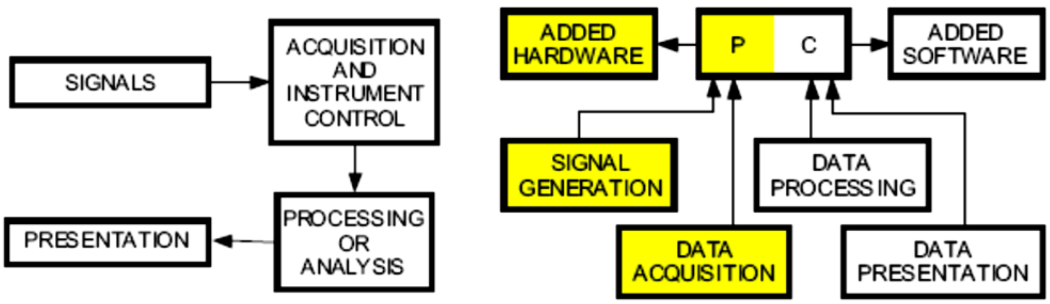
Figure1 Internet based control setup

Figure 1 shows the Internet based control setup of the proposed system. A box whose temperature has to be controlled is connected to the server computer using a DAQ board. The server is connected to the internet and is assigned static IP address. The clients could be any PC with network interface card that can run a LabVIEW program. The architecture is modular and facilitates easy integration of traditional experiments on characterization of sensors and transducers. This is illustrated by implementing the experiments on characterization of temperature and pressure in this architecture. The web pages are developed from Virtual Instruments (VIs) programs using Web Publishing tools in LabVIEW. LabVIEW Web Server is used for hosting web pages. The server programs are also developed using LabVIEW. This experimental setup can be controlled from any remote PC connected on Internet. An intuitive GUI with steep and short learning curve is essential for any web-based experimental facility as it would not only facilitate in performing experiments but would also encourage the students to perform experiments without any supervision and traditional help. A VI consists of two main parts, the front panel and the block diagram. The front panel can be used to develop intuitive GUI as LabVIEW provides rich inbuilt and customizable objects.

Using LabVIEW and DAQ to Build a Temperature Sensor

The concept of virtual instrument is frequently used in industrial measurement practice, but not always with precisely the same meaning. For some people, virtual instruments are based on standard computers and represent systems for storage, processing and presentation of measurement data. For others, a virtual instrument is a computer equipped with software for a variety of uses including drivers for various peripherals, as well as analogue to digital and digital to analogue converters, representing an alternative to expensive conventional instruments with analogue displays and electronics. Both views are more or less correct. Acquisition of data by a computer can be achieved in various ways and for this reason the understanding of the architecture of the measuring instrument becomes important. A virtual instrument can be defined as an integration of sensors by a PC equipped with specific data acquisition hardware and software to permit measurement data acquisition, processing and display. A virtual instrument can replace the traditional front panel equipped with buttons and display by a virtual front panel on a PC monitor. Virtual instruments are a means of integration of the display, control and centralization of complex measurement systems. Industrial instrumentation applications, however, require high rates, long distances, and multi- vendor instrument connectivity based on open industrial network protocols. In order to construct a virtual instrument it is necessary to combine the hardware and software elements which should perform data acquisition and control, data processing and data presentation in a different way to take maximum advantage of the PC. It seems that in the future the restrictions of instruments will move more and more from hardware. Such a general conception of virtual instrumentation is presented in Figure 2.

The lab will use insert-module approach in which students develop the LabVIEW code for temperature programming and insert it into a prebuilt VI template. This experiment involves measuring temperature using a thermocouple, and using feedback to control temperature ramp speed and ensure the actual temperature matches the desired value. Various tasks are involved in the VI, such as sampling analog signals, conversion of analog signal to a digital code, feedback control algorithm, and digital signal output for operating a solid-state relay to switch the heater, plotting temperature vs. time, and date storage. Once the VI template is completed, students are required to expand the VI so that different types of thermocouples can be utilized and various temperature programming modes can be realized. This i-Lab experiment mimics the temperature programming in commercial instruments. In this experiment, the students will also obtain basic skills in LabVIEW environment navigation, application creation, data acquisition, and instrument control. They are building a LabVIEW VI that will convert a raw voltage signal generated from thermocouple emulator to a temperature reading. The thermocouple voltage across the junction is then to the temperature (°C). The VI developed in this experiment is shown in Figure 3.



a) b)

Figure 2 a) The diagram of measurement process; and b) The general conception of virtual instrument

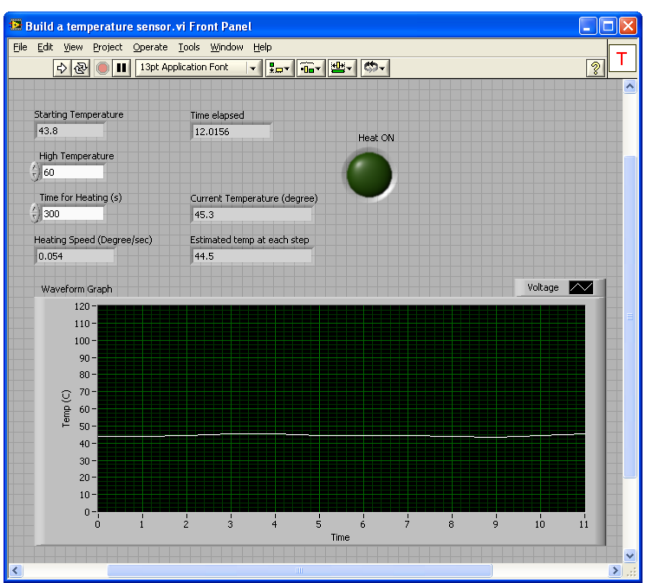


Figure 3 The front panel of the temperature experiment

During this experiment the students are required to perform the following tasks:

1. Run the VI created in previous part of the lab experiment measure the temperature using the

thermocouple. Having the temperature sensor connected to a multi-meter allows for direct comparisons, and making it much easier to troubleshooting the circuit and the program.

2. Check the calibration of your temperature sensor over a range of temperatures. Students are required to compare the readings of the two sensors in ice water, room temperature, and hot water. They must be sure that are providing time for the reading to stabilize the measurement.

Combined Virtual Pressure and Temperature Measurements

The configuration chart for the VI system is in Figure 4. The signals of chemical reaction are analog signals converted by sensors, such as temperature, temperature difference, pressure, pressure difference. The analog signals are converted into digital signals in the DAQ card or by standard chemical instruments and are sent to a computer. Finally, the digital signals are processed on the LabVIEW platform. The PCI-DAQ card method was the earliest method used in the construction of the VI. It utilizes a DAQ card to convert analog signals to digital signals, so that a computer can process the various analog signals. It provided a way of constructing the VI by using the computer's bus, input devices, output devices, software, and so on. It is still popular in the world of measurement and control on account of its wide use and applicability for use in various laboratories and teaching sectors. The analog signals from normal sensors are very weak, so they must be preprocessed and amplified before entering the DAQ card.

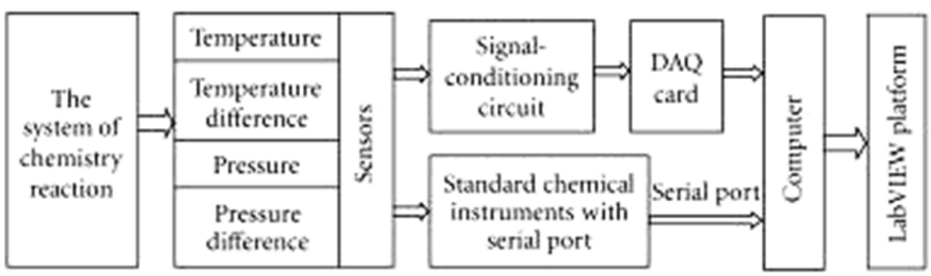


Figure 4 Configuration for VI system for combined pressure and temperature experiment.

The control panel of the virtual instrument is an interface between user and computer. Besides friendly interface and easy control, the corresponding test function can be started up by a simple manipulation. It should also be able to finish user's task successfully. Software is a key section of the VI. Given different software packages, the VI can have different functions. The program is designed by selecting different events and a corresponding VI panel will open and enter the chemical testing system as long as we click the corresponding icon, for instance, by clicking the *molecular weight* icon, the panel will show as in Figure 5. The program provides a helping function in that the user can get help by lighting the *help* icon or keeping the cursor on a few seconds, when some helping textual material will display to describe the function of the modules and give the user some information about the experiment. There are different tasks and data processing methods in different chemical testing systems, but the basic procedures, data acquisition, data filtering, curve fitting, real-time displaying, calculating, and generating the report of results are the same. Therefore, one program can be made as a shared sub-VI for different chemical VIs to use. During the design program based on LabVIEW, the sub-VI is a key element to modularize and layer the modular program and it corresponds to function or subprogram in text-based programming languages. User can call each VI as a sub-VI [7], and the number of sub-VIs is limitless. Moreover, a sub-VI can be the subroutine itself. By using a sub-VI during the development of a program, we can save code, reduce developing time, and raise efficiency. It is also easy to debug and manage.

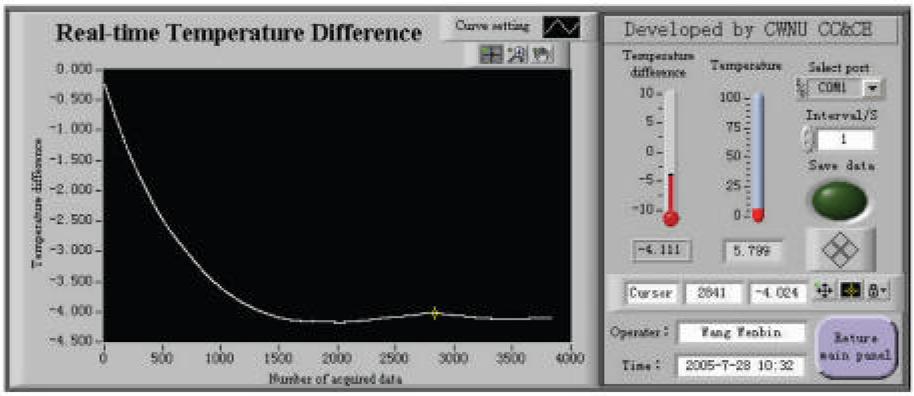


Figure 5 Front panel for determining molar mass with freezing point depression.

In a general way, the testing system of the chemical VI is able to acquire plentiful data at tremendous speed, but the whole data is discrete. During data processing, we sometimes need to fit discrete data to a curve, obtain its equation, and get intersection points of some curves, for example, we need to get the intersection points of some curves in drawing the binary metal diagram and determining molar mass with freezing point depression and we need the curve equation in measuring the surface tension of a solution. There is no function to obtain an equation directly, so we have to program it by ourselves via calling correlated functions in LabVIEW. The program for curve fitting and obtaining equations automatically is shown in Figure 5. The testing data is automatically fitted, respectively, in given fitting models, and the mean square errors (MSEs) of fitting effects are sent to an array, then according to the least MSE, computer confirms the best fitting model or fitting order. The fitting models are linear fitting, exponential fitting, and general polynomial fitting, which are found in functions “Mathematics”. Fitting, and the comparing array elements are achieved depending on Array Max & Min function. When making a curve fitting in case structure the corresponding fitting result displays instantly. The program sets a sub-VI of writing equation again, which has a function for converting the best coefficients to strings, and write expressions $f(x)$ and $y = f(x)$, which have different functions in different conditions, for example we must use the form $f(x)$ in the function Eval $y = f(x)$.VI or Integration.VI. If we use the form $y = f(x)$, the program cannot run. However we have to give the form $y = f(x)$, when we write the equation. Now we can solve the problem by connecting the right output terminals in different circumstances.

Due to the limitations of this paper's length, other common modules such as data acquisition, real-time dynamic display, elimination of excess data, and curve fitting for the construction of chemical VIs are not discussed. After developing and debugging the sub-VI, we can create a property node and call it up as a module when we need. Every sub-VI has a connector pane, and every connector pane has several terminals. The programmer simply connects the controls or indicators with terminals but need not worry about the internal structure of the sub-VI. In a sense, input and output terminals correspond to formal parameter and actual parameter in C language, respectively. Select an appropriate terminal pattern for the sub-VI by right clicking the connector pane. There are 36 kinds of patterns to select or edit by increasing or decreasing terminals. For example, the sub-VI for fitting curve has three input and two output terminals, which are connected to an array of fitting coefficient control, digital precision control, model of fitting control, and an expression of equation indicator for *f* (*x*), *y* = *f* (*x*), respectively. When LabVIEW calls a sub-VI, ordinarily the sub-VI runs without displaying its front panel. But some sub-VIs need to display their front panels when called and to close their front panels after being called, such as the sub-VI for redisplaying data. There are two ways to set its properties. The first way is to select VI properties, select window appearance from the category pull-down menu, click the customize icon, and set its dialog box. The second way is to right click the sub-VI icon and select sub-VI node setup from the shortcut menu. The first way requires every instance of the sub-VI to display its front panel when called, but the second way simply displays its front panel when called.

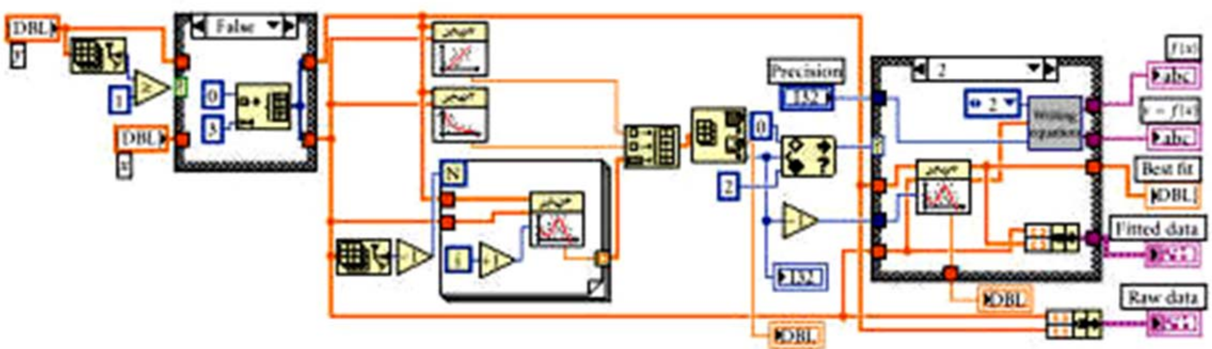


Figure 6 Program for curve fitting and obtaining equation automatically.

The authors designed VIs for measuring temperature and pressure based on LabVIEW. These instruments were composed of four representative physical chemistry experiments: drawing a binary metal diagram, determining molar mass with freezing point depression, determining the constant of the reactive rate in the decomposition of peroxide, and measuring the surface tension of a solution by the pressure of froth. These experiments can determine the temperature, temperature difference, pressure, and pressure difference of the system, respectively. In these experiments, we can take the measurements by the PCI-DAQ method or standard chemical instruments serial port method. A manipulator can combine the sensors, signal-condition circuit or standard chemical instruments and corresponding data processing modules, according to the actual condition in the laboratory and the concrete requirements of the experiment, thus the system of chemical testing VIs can be constructed easily and quickly. The VI can be used in extensive applications because of its flexibility. It can be used in numerous experimental systems, such as determining temperature and temperature difference of fusible heat, burning heat, determining the pressure and pressure difference of pure liquid saturated steam pressure, the disposed pressure of solid.

This system solves the problem of communication between the sensors or between standard instruments and the computer, which are unfamiliar for most chemical workers, and the common problems for designing chemical VI to measure temperature, temperature difference, pressure, and pressure difference. When the user needs to test the temperature and pressure which are beyond this system, then he can compose a new measuring system to meet the requirements of the new testing by transferring the function designed modules and combining them, thus avoiding a waste of manpower and material resources. This means that developers can design customized measuring instruments according to their own requirements. Exploiting VIs based on LabVIEW has many advantages, such as a user-friendly working panel, ease of manipulation, complex data processing, drawing and printing the result at the click of the mouse. Moreover, using the application builder tools that belong to LabVIEW itself to create standalone applications and installers or shared libraries (DLLs) for VIs, the user can run and extend independently from the LabVIEW development environment. Altogether, this system has very great practical application value.

Vortex Tube Experiment controlled by a LabVIEW VI interface

The vortex tube is a unique device which converts a flow of compressed gas into two stream – one hotter and the other colder than the gas supply temperature. It contains no moving parts and functions using fairly simple fluid dynamic and thermodynamic principles to be briefly discussed below. Many technical applications of vortex tubes for cooling, air conditioning, and drying have been developed [20, 21].

The general flow pattern inside a vortex tube is as follows: high pressure air enters the tube tangentially at one end and produces a strong vortex flow in the tube. The gas separated into two streams having different temperatures, one along the outer wall and one along the axis of the tube. It was observed that the flow consisted of a colder region in the center of the tube that rotated as a solid body [22]. A flow with a forced vortex as a central core and a velocity distribution corresponding to that of free vortex outside the core is called a combined vortex [20-22].The gas on the outside of the tube is adiabatically compressed resulting in an increase in temperature. This gas is also at a higher pressure so it can be drawn off at the control valve. The cooler gas is confined to the inner core of the tube so it can be withdrawn from the opposite end of the tube through an orifice plate. The separation of the gas into two streams having different temperature is caused by viscous forces in the gas which induce a pressure distribution in the tube. The gas in the high pressure region is compressed and heated while that in the low pressure region is expanded and cooled. This description of the operation of a vortex tube resulted only after many experimental observations and a detailed analysis [20-22]. The *First and Second Laws of Thermodynamics*, however, present us with a simple way to evaluate any thermodynamic system to determine whether it is thermodynamically valid. In this experiment, students will perform a First and Second Law analysis of a vortex tube to “validate” its performance.

The learning objectives of this experiment are: applying basic and intermediate concepts and equations of thermodynamics to study and evaluate a vortex tube experiment; to asses experimentally the Second Law of Thermodynamics (increase of entropy principle) and to analyze the performance of thermodynamic system. The method chosen is based on using LabVIEW software to operate virtual instruments and control center, and to collect data for different flow conditions. Plot data as directed and discuss the meaning of your results. The instrumentation used and presented in Figure 7 consist of flow meters, temperature and pressure transducers, flow transducer/controller, copper tubing, tube fittings and connectors tools, DAQ board (NI 6000 series) and PC.

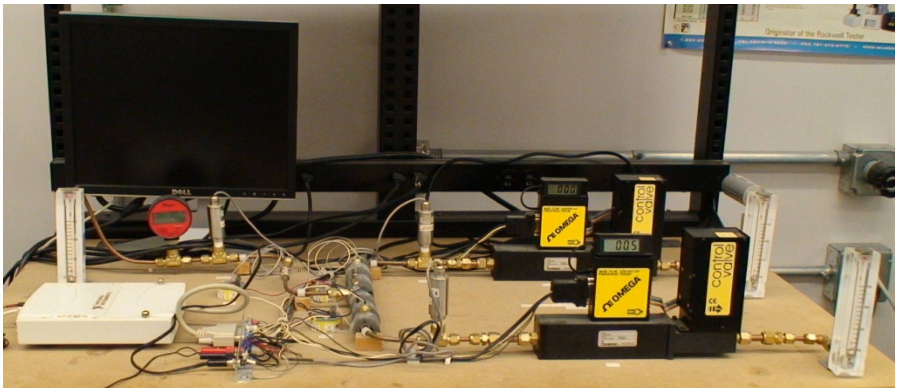


Figure 7 The Vortex tube experimental layout

This experimental setup is connected and controlled by a LabVIEW VI presented in the Figure 8 a) and b), designed and refined by the authors. Students have only the option of viewing the front panel that was created as a friendly and flexible interface to perform the experiment smoothly and data collection. The students can see in real time the temperature, pressure and flow variation, being able to control the flow rates and record the temperature variation in both branches of the vortex tube.

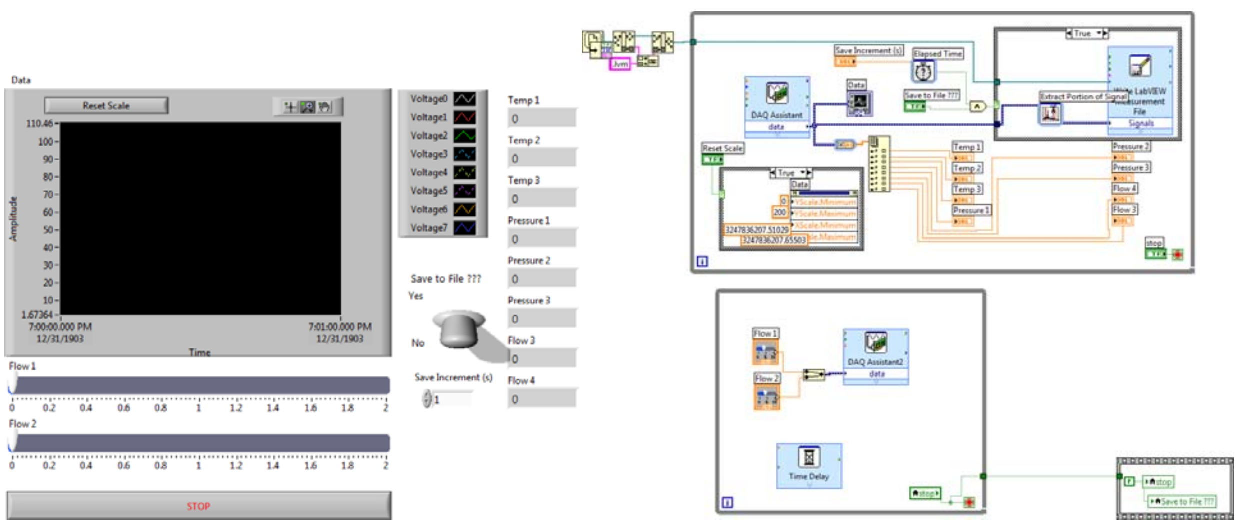


Figure 8 a) Front panel b) Block diagram

The VI shows and allows the collection of eight parameters: inlet temperature, and two outlet temperatures (hot and cold ends), inlet pressure and two outlet pressures as well as two flow rates displayed on virtual instrument screen and to the right side in a numerical display. Temperatures are displayed in degrees Celsius, pressures are displayed in atm, flows are displayed liters per minute (L/min). The flow control slide bars for Flow 1 and 2 starts at zero. The virtual switch on the numerical display allows the data logging to the file initially set. By moving the flow slides to various positions, students will record data pertinent to various situations allowing them to observe how the temperature difference increases as the flow rates are increasing. Using Excel functions students need to determine the average for each of these eight parameters and also the uncertainty of these parameters.

Further, students can perform an energy balance using the results of mass balance and the measured temperatures and to solve for the rate of heat transfer from the control volume. Another task will be for them to evaluate the total rate of entropy production per mass of air flowing through the control volume using calculated mass flow and heat transfer rate, being able to infer conclusions about the thermodynamic process in the vortex tube. The entire experiment can be performed either onsite or remotely operated and visualized via the front panel of the VI.

This laboratory activity has been an integrant part of our ET core course "Thermodynamics and Heat Transfer Lab" for the past 4 years out of which the last 2 years was taught by one of the authors. The course received very good student evaluations (3.5/4.0, 3.8/4.0).

Student Evaluation

When adopting these LabVIEW experiments the student feedback, using surveys was considered very important and a valuable tool to assess the effectiveness of our project. In our evaluation the students are asked the following questions:

Q1) The use of these types of experiments has increased the affinity to instrumentation and measurements course.

Q2) The use of LabVIEW based experiments has been interesting.

Q3) The effort imposed by become familiar with LabVIEW is worthwhile because of abilities and knowledge acquired.

Q4) The use of such LabVIEW based experiments has helped me to improve my academic results.

To answer the questions, students had to choose between five different answers with a numerical value: Fully Agree (5); Agree (4); Partially Agree (3); Partially Disagree; (2); Disagree (1); Fully Disagree (0). The student feedback was quitter positive with an average of 3.65 for all four questions, and higher scores for Q2 and Q3, 4.00 and 3.90, respectively.

Conclusions and Future Works

Laboratory experience is an important requirement of Engineering and Science Education. However, there are known problems associated with provision of lab experience in traditional environment due to paucity of space, time, and resources. A cost-effective and technologically feasible solution to this problem is to use web-based Remote Laboratories for addressing limitations associated with traditional labs. A web-based experimental setup has been successfully developed for performing experiments on temperature and pressure sensors. It demonstrates that traditional experiments, especially in the field of sensors and transducers can be made available in Remote Labs. It provides students with flexibility to perform experiments at their own schedule and convenience. The new experiments on other sensors and measurement procedures are underway to be developed.

Virtual instrumentation is fuelled by ever-advancing computer technology and it offers the power of creating and defining someone's own system based on an open framework. The combination of computer performance, graphical software, and modular instrumentation has led to the emergence of virtual instruments, which are substantially different from their physical ancestors. Virtual instruments are manifested in different forms ranging from graphical instrument panels to complete instrument systems. Modular instrumentation building blocks are becoming more prevalent in the industry and are allowing users to develop capabilities unattainable using traditional instrument architectures. Despite these changes however, the measurement paradigm remains unaltered. The VIs and the LabVIEW based experiments are considered a valuable experience by most of our students, helping them in the academic advances. This research combines the theory of technological vocational education and practical programming skills to develop a modern and industry-needed oriented virtual instrument technical course and teaching instrumentation and measurement techniques. This development process ensures the teaching materials will satisfy students, instructors and industry people. This approach not only provides professional knowledge, software design practice and technical operation, but also gives students a chance to learn modern industrial technology. The completion of this project will increase the technological literacy of the measurement field of technological vocational students and will give students advanced professional knowledge and higher technological ability, helping them to compete for future jobs.

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