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Case Study Booklet
Eastern Europe



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Using LabVIEW and PXI to Measure the Temperature and Density of Fusion Plasmas on a Tokamak COMPASS

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Industry:

Big Physics, Research

Products:

PXI-5152, MXI-4, PXI-6653, PXI-6552, PXI-8110, PXI-8331

The Challenge:

Developing a tokamak measurement system to meet the strict requirements for magnetic confinement of controlled nuclear fusion.

The Solution:

Using NI LabVIEW software and PXI hardware to create a complete fusion plasma measurement system that can be updated in the future if necessary.

"All channels from all chassis are tightly synchronized with the reference clock from the NI PXI-6653. Using NI TClk technology and built-in phase-locked loops, we can achieve less than 300 ps interchannel skew, even in this high-channel-count system."

Figure 1. Tokamak COMPASS Installed in IPP Prague

Nuclear fusion is the natural power source of stars. It is the process of multiple atomic nuclei merging together to form a single heavier nucleus. Joining light nuclei, such as hydrogen, creates a large emission of energy. Fusion has the potential to be a safe, clean, and virtually limitless energy source for future generations. However, demanding requirements make controlled fusion for civilian purposes very difficult. Magnetic confinement could be a way to overcome the difficulties of nuclear fusion so we can use this process as an energy source. Recently, we identified tokamaks as the most promising devices for magnetic confinement and, nowadays, tokamaks are closer to fusion than any other magnetic confinement or inertial fusion device.

Tokamak COMPASS

A tokamak is a machine that can sustain high-temperature and high-density plasma using a magnetic field. The Institute of Plasma Physics ASCR, v.v.i., a member of the European Atomic Energy Community (EURATOM), participates in the worldwide fusion research program. We reinstalled the COMPASS tokamak (Figure 1), originally located at CCFE Culham, United Kingdom, in IPP Prague, Czech Republic [1]. The first plasma was confined in December 2008.

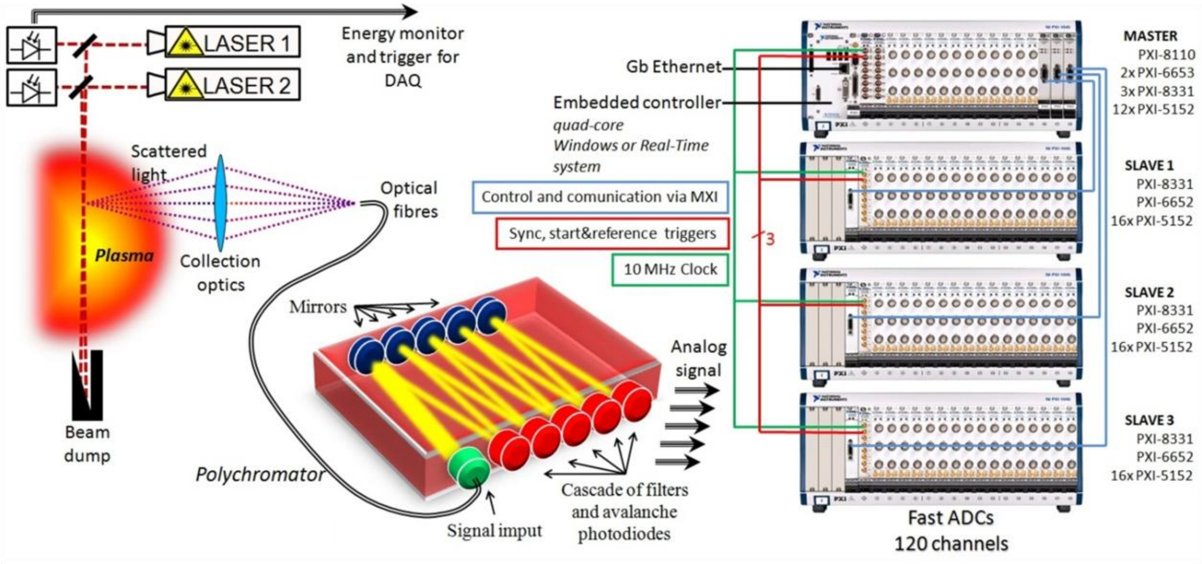

Figure 2. Scheme of Thomson Scattering System

Thomson Scattering

In order to research and control plasma behaviour and sustain its equilibrium, we needed a set of diagnostic tools. One of the most important parameters for fusion plasma research is the plasma's temperature and density. Thomson scattering (TS) is a unique diagnostic for this purpose. It is a laser-aided plasma diagnostic [2] providing highly localized measurements. Some drawbacks of TS are in its complex design and the considerable construction required due to its very low scattering efficiency.

The TS system is now under construction on COMPASS [3]. Figure 2 shows the schematic layout of this system. Basically, it consists of high-power lasers, polychromators to measure scattered spectrums, and fast analogue-to-digital converters (ADCs). We used two neodymium-doped yttrium aluminium garnet (Nd:YAG) lasers, both with 30 Hz repetition rates and 1.5 J maximum output energy. Laser light passes through the plasma and is partially scattered. Monochromatic light is spectrally broadened by the scattering. Scattered light from 56 spatial points is led by the complex of collection optics and optical fibres to polychromators (designed at CCFE, United Kingdom) where the incoming light is spectrally analyzed by a cascade of spectral filters and avalanche photodiodes (APD). The system uses up to five spectral channels for each polychromator for spectrum determination. Finally, the signal from each APD is digitized by fast ADCs.

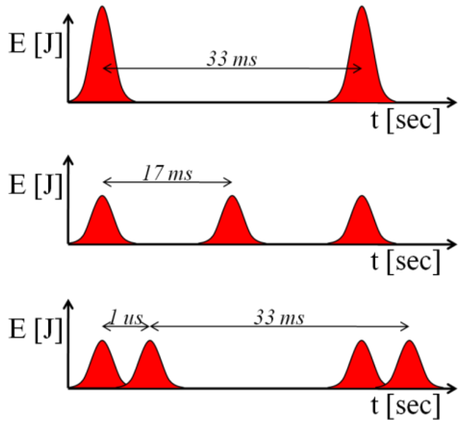

Figure3 . Laser Regimes

Data Acquisition Requirements

The duration of one laser pulse is 8 ns and lasers can operate in different regimes (see Figure 3): both lasers simultaneously, or both lasers separately with tuneable time delay (1 μs–16.6 ms). The requirements on fast ADCs reflect the need to digitize such signals with a sufficient sampling rate to reconstruct laser pulse time evolution.

System Hardware

We used a high-speed NI PXI-5152 digitizer and slow D-tAcq ACQ196CPCI ADC cards to synchronously digitize signals from all polychromators (120 spectral channels). The fast ADCs convert data with high 1 GS/s throughput, 8-bit resolution, and interchannel skew less than 300 ps. These ADC cards (two channels per card) have 8 MB per channel onboard memory and are housed in four PXI-1045 chassis.

The first chassis, also called the master chassis, houses an embedded quad-core PXI-8110 controller along with triggering and timing cards to synchronize the remaining three slave chassis. The master chassis stores data, performs calculations, and communicates with the slaves via MXI-4 technology (78 MB/s) and with the slow ADC cards and COMPASS control system (CODAC) via Ethernet. All channels from all chassis are tightly synchronized with the reference clock from the NI PXI-6653. Using NI TClk technology and built-in phase-locked loops (PLLs), we can achieve less than 300 ps interchannel skew, even in this high-channel-count system. The slow digitizers have 16-bit ADC per channel for true simultaneous analogue input with a sampling rate of 500 kS/s. We used two slow ADC cards, each with 96 channels, a 400 MHz reduced instruction set computing (RISC) processor, and 512 MB onboard memory.

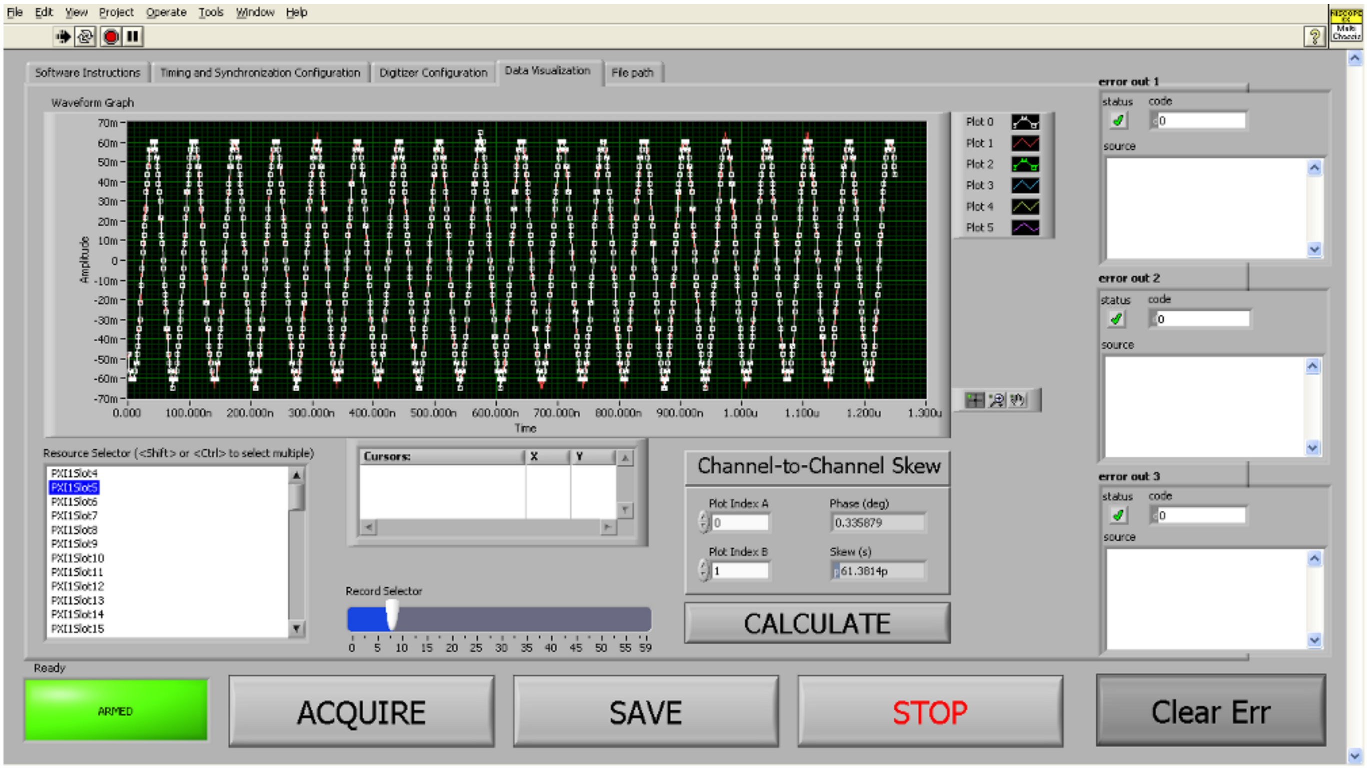

Figure 4. LabVIEW Control Routine

System Software

We used LabVIEW to write the program controlling the digitizers in the TS system. The basic software functionality includes parameter setup, arming the trigger, acquiring and displaying acquired records, and saving data to a file (see Figure 4.). We will include additional features such as analysis, data interfaces, and more in the future as necessary. The software runs on Microsoft Windows. We could use the LabVIEW Real-Time Module in the future for deterministic operation inside the tokamak control loop.

DAQ Features

The laser pulses trigger the data acquisition, so laser timing is currently the limiting factor of the real-time TS on COMPASS. Because TS DAQ hardware and software are modular, in the future we can increase the number of digitizers and possibly laser trigger them using the embedded computer in the master chassis. The data will be acquired in segments.

Thanks to the multirecord acquisition feature of the NI PXI-5152 digitizer, the segments can be acquired with as little as 1 µs between them. Each segment represents one laser pulse, or double pulses in the regime when lasers fire simultaneously or with a very small delay (less than 1 µs). A hardware trigger pulse coming from the lasers initiates each segment acquisition without OS intervention. After the experiment (plasma shot), we download all the segments together from the onboard memory of each digitizer to the embedded computer of the master chassis where the raw data is processed. Calibration data is stored there and it has access to the slow sampled background radiation from the slow ADCs and the laser energy data from the energy monitor. The system integrates the scattered signal, while the calculations of temperature and density performed are sent via Ethernet to CODAC.

Conclusion

COMPASS DAQ system for Thomson scattering diagnostic is able to measure evolution of scattered signal and thus gives us information we need to reconstruct the temperature and density profiles. It also let us measure signal from three planned laser timing settings we need for measure during different plasma condition.

Up to now we have tested all the Thomson scattering system and measure Raman scattering signal.

Acknowledgement

We would like to thank our English colleagues from Culham laboratory, namely Dr. Michael Walsh (ITER Organization, France) and Dr. Rory Scannell, Dr. Graham Naylor and Dr. Martin Dunstan (Culham Centre for Fusion Energy, UK) for great help and collaboration on this project. Part of the MAST design was adopted.

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Using LabVIEW to Develop the GammaKey System for Acquiring, Storing, Retrieving, and Processing Gamma Studies

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Products Used

PCI-6040E, DAQCard-6062E, LabVIEW, NI-IMAQ

Industry

Biomedical Engineering

The Challenge:

Improving the acquisition, storage, retrieval, and processing of gamma studies from analogue gamma cameras. Improving nuclear medicine diagnostics by prolonging the life of analogue gamma systems.

The Solution:

Use of National Instruments data acquisition (DAQ) hardware and NI LabVIEW software to design a Windows-based acquisition system that supports analogue gamma cameras in daily clinical practice. The images obtained by gamma cameras are called scintigrams. A scintigram is a two dimensional record of the distribution of a radioactive tracer (radionuclide) in a tissue and organ, and it is the basis for nuclear medicine. Nuclear medicine uses scintigrams to assist in diagnosing the malfunctioning of several organs (heart, kidneys, lungs, etc.) and tissues (bones, joints).

Many nuclear medical departments, especially in developing countries have analogue gamma cameras with hardware that is too old to work with newer computer OSs for image acquisition. The image acquisition hardware and software that was originally used with analogue cameras, is not available today. Since the most expensive and important components of the gamma camera (scintillation crystal used for detecting radiation) operates effectively, it became of interest to prolong the life of the analogue gamma system. Therefore we replaced the traditional, original Siemens MicroDelta computer systems, and we developed a Windows-based "GammaKey" system to acquire, store, retrieve, and process images from analogue gamma cameras. This system acquires three basic types of gamma studies: static (mono and dual isotope), dynamic (mono and dual isotope), and whole body studies. The system architecture used in this development is open and allows the inclusion of new studies that are of interest for nuclear medicine practitioners.

Figure 1. GammaKey Portable Configuration

Software Development and Integration

The GammaKey system includes the following:

- NI PCI-6040E multifunction DAQ module or an NI DAQCard-6062E for PCMCIA and a custom designed NI 4 BNC-to-68 pin connector block
- Desktop PC with features such as an Intel Pentium 4 processor, 3.2 GHz, DDR 512 Mb, and Windows XP, or laptop with features such as a Genuine Intel(R), 1.66 GHz, 0.99GB RAM, Windows XP
- Software developed using LabVIEW for data acquisition and visualization of images from gamma camera
- Software developed using LabVIEW and NI-IMAQ software for storing and retrieving images, offline image processing, and report generation
- Microsoft Access 2003 database

The only connections between an analogue gamma camera and the GammaKey system are two analogue input signals in the ±2.5 V range, X and Y describe the position of the gamma photon in the X/Y coordinate system of the gamma detector, and two digital signals, the Z1 and Z2 triggers, which indicate if gamma photons have enough energy to be used in an image visualization procedure – Z2 is only used for dual isotope acquisition. The frequency of the trigger Z pulses is 200 kHz. Each time when a gamma photon of sufficient energy arrives to gamma camera detector, a “high-level” Z signal is generated. Every “high-level” Z signal samples two analogue signals, X and Y, which represent the current position of the gamma photon in the scintillation crystal. The element of image matrix that has matrix index corresponding to the sampled coordinate pair (X,Y) will be incremented. This procedure is being repeated and at the end of image acquisition process, every element of image matrix will be assigned a value that corresponds to the number of acquired gamma photons of sufficient energy in the appropriate point. Different colour palettes are used as standards for different nuclear medicine diagnostics field (urology, nephrology, neurology, cardiology, etc.). The type of acquisition that could support this kind of gamma image visualization is analogue triggered acquisition with a high sampling rate.

We chose the NI data acquisition hardware that will support the following features:

- High sampling rate (500 kHz) that could support high-frequency gamma photon emissions
- Small interchannel delay (2 μs) for analogue input channels (X and Y) that provides the correct position of gamma photons
- Existing digital input triggers and the possibility to implement triggered data acquisition
- Programmable gain that allows for maximum use of the analogue-to-digital (A/D) converter range for the analogue input channels generated by the gamma camera (input limits ± 2.5 V)
- High resolution and linearity of A/D conversion (12 bits, relative accuracy ± 0.5 LSB, differential nonlinearity ± 0.5 LSB) that will not undermine the uniformity of gamma image acquisition

We also used LabVIEW to communicate with multiple applications on the same computer to develop an electronic patient record system. We used a Microsoft Access database to easily create a database with administrative data such as the patient’s identification number, name, and date of birth; the type of gamma study; date of examination; the medical expert’s name; and technical data about the gamma studies such as the isotope dosage, number of isotopes, image format, and type of collimator. Communication between the Microsoft Access database and LabVIEW applications for data acquisition and image processing is conducted using a LabVIEW library that supports the dynamic data exchange (DDE) protocol.

We used the LabVIEW environment to develop software for the triggered data acquisition and we used NI IMAQ Vision for LabVIEW toolkit (now called NI Vision Development Module) to quickly and easily implement image processing applications. Additionally, the NI-IMAQ Vision toolkit has a built-in image processing library that we used to implement the basic clinical analysis. The GammaKey image processing supports the following operations: “smoothing,” flood correction, contrast variation, calculation activities in regions of interest (ROI), dynamic curves drawing, and arithmetic operations of images. ROI analysis is the most commonly used processing method of gamma studies and the most important diagnosis method. Using IMAQ Vision libraries, we easily implemented an automatic routine for ROI extraction and calculation of ROI activation. This automatic procedure is comprised of Gaussian smoothing, conversion smoothing images to binary form, removing particles, filling holes, separating regions, and edge detection of separated regions. The final results of ROI analysis are the percentage ration of ROI activation for static gamma studies and the dynamic time curves of isotope distribution through the body for dynamic gamma studies.

In cooperation with medical experts, we developed a completely new routine for investigation of indium-111 platelets distribution and place sequestration that could be used for estimation efficacy of splenectomy (surgical removing of spleen). This method combines invivo static and dynamic gamma studies of the heart, liver, and spleen and an invitro blood analysis. This routine automates the previous manual study processing procedure and saves time in clinical practice. Also, the GammaKey system opens up possibilities for the implementation of other specific analysis methods that medical experts apply manually as part of clinical work or research.

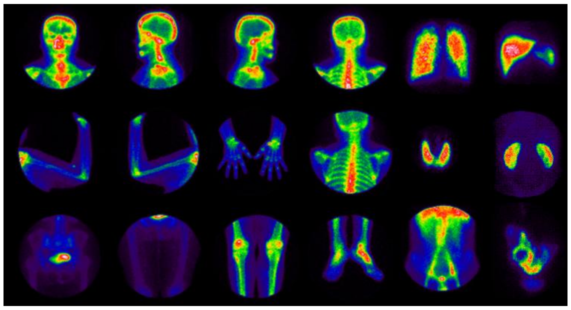

Figure 2. Example for Static Studies

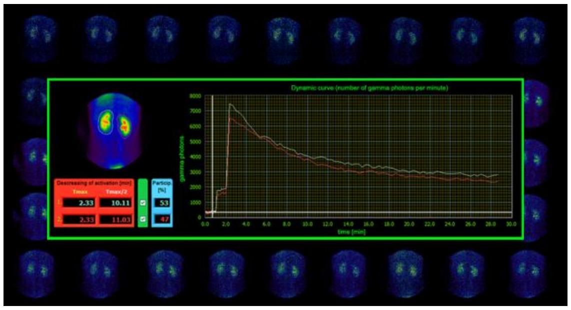

Figure 3. Example for Dynamic Studies

Benefits of the GammaKey System

Renewing analogue gamma cameras with the GammaKey system delays buying new expensive digital gamma systems. This low-cost upgrade, which costs about 5,000 €, makes it acceptable for all nuclear medical departments. Additionally, this interim solution is useful because it helps medical experts continue their activities in the medical imaging field and provides current and upcoming professionals with training on using the nuclear medicine equipment. This training prepares them to operate new systems if their departments provide them in the future.

Clinical Evaluation

The GammaKey system is currently used in daily clinical practice in five nuclear medical departments: in Clinical Center Vojvodina (since 2005, Center for Clinical Laboratory Medicine, Nuclear Medical Department) and in Clinical Center Belgrade (Neurology, Hematology, Urology and Endocrinology Departments (since 2007) in Serbia.

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Using LabVIEW and PXI to Design and Implement a Test Rig for an Electrical Steering System Prototype for Airplane Nose Landing Gear

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Industry:

Aerospace

Products:

LabVIEW, PXI-8106, PXI-6514, PXI-6624, PXI-6723, PXI-6255

Challenge:

Designing and implementing a test rig for the electrical steering system prototype of passenger airplane nose landing gear based on an AIRBUS A320.

Solution:

Creating a system based on NI LabVIEW software and PXI hardware using a real-time OS for quick development of the test and control application for the test rig, and ready-to-use LabVIEW functions to quickly develop our algorithm.

"With the PXI platform and NI LabVIEW programming environment, we efficiently developed our test rig control and measuring system. The hardware configuration leaves room to connect more input signals and to expand the system by using new measurement modules. Due to its modular design, we can expand our application by implementing additional functionalities. In addition, the ready-to-use signal analysis functions in LabVIEW will make that implementation process as simple as possible."

Introduction

The aim of the international distributed and redundant electromechanical nose wheel steering system (DRESS) project was to create a prototype of a passenger aircraft nose landing gear electrical steering system. The Institute of Aviation (IoA) Landing Gear Department scientists designed and manufactured an electrical steering system test rig prototype to simulate actual conditions. They designed the test rig to withstand quick and simple configuration changes due to the prototypical nature of the test object. Such flexibility in configuration changes almost always forces modifications in control and test rig hardware testing.

DRESS Test Rig Control System

IoA engineers designed, developed, and manufactured the DRESS test rig. They created the mechanical design and manufacture, as well as assumptions of the test rig control system. Veritech, a National Instruments Alliance Partner, developed the test rig control software. DRESS test program assumptions forced test rig flexibility due to both quasistatic and dynamic loads at the level of the nose landing gear wheels. The test rig needed to perform a wide range of tests. For example, we needed to simulate phenomena during a low-speed airplane taxi, as well as phenomena during a high-speed airplane touchdown. Therefore, we decided to build the system using interchangeable hardware and software configurations. As a result, we made two configurations according to constraints to simulate proper test conditions.

To simulate conditions during low-speed airplane taxiing, we chose a module powered by a hydraulic engine (ATCSS). In this case, low-frequency (up to 4 Hz), large-angle (up to 90^{o}), high-value torque occurs. To simulate touchdown and high-speed airplane ground movement, we made an electrically driven module (DCSS). This module unbalances the airplane nose wheels using two discs mounted in place of the original wheels. During dynamic tests, we can speed the wheels up to 4,000 rpm for high-value torque with higher frequency, but with limited twist angle (up to 5^{o}).

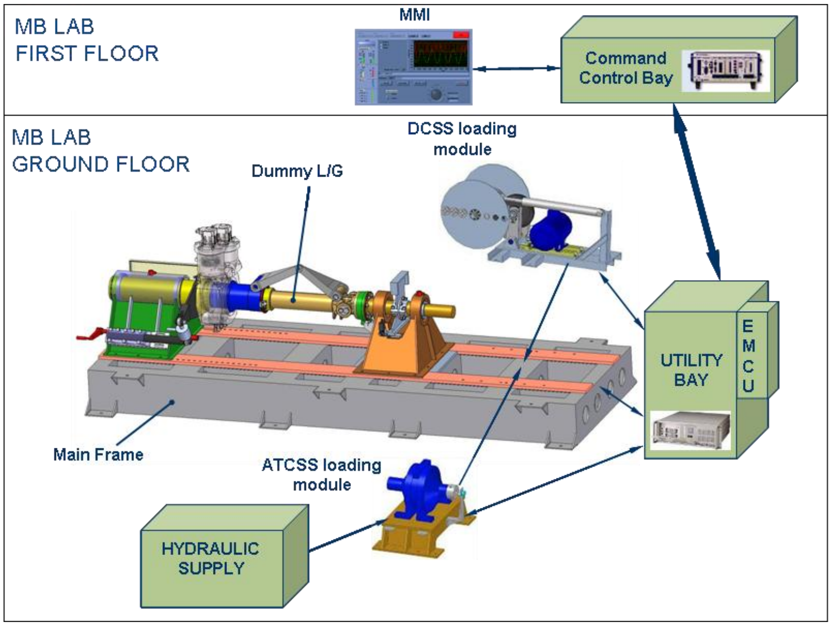
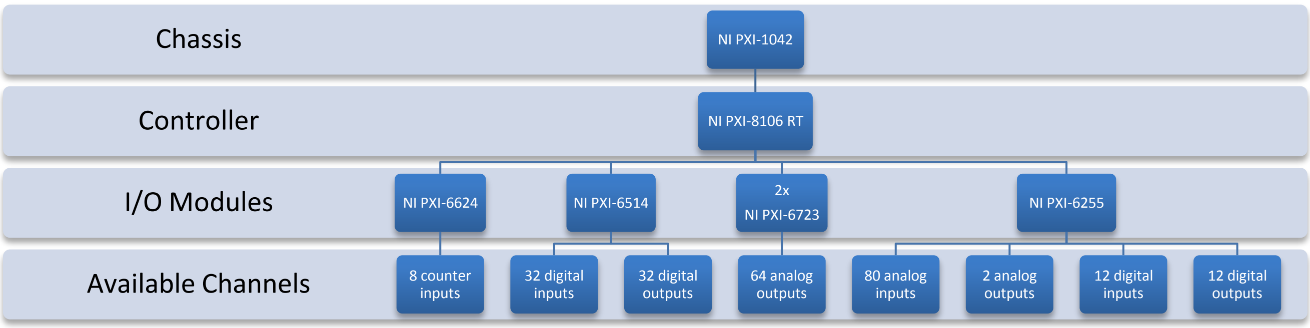


Figure 1. Test Rig System Architecture – Two Interchangeable Load System Configurations Controlled by One Computer-Based Control-Measuring System

With this solution, we created a test rig that meets the tests requirements and is compact enough to fit in the laboratory. We maximized the unique properties of the PXI measurement platform (for example, strict synchronization between the measurement modules inside PXI chassis) for high-quality, coherent sets of test data.



Channel Type	Analog Inputs	Analog Outputs	Digital Inputs	Digital Outputs	Counter Inputs
Available	80	66	44	44	8
Needed	52	60	24	22	4

Figure 2. PXI Computer Hardware Configuration

We used a new version of LabVIEW to create an application that divides its threads between two cores of the CPU for better stability and to execute all tasks within the desired time. The application can also detect the current mechanical configuration of the test rig by using proper identification solutions. The main part of our control-testing application maximizes the capabilities of a real-time OS. We used a real-time OS to make our application more stable, which is crucial because the test rig is located in a different room than the operators.

Besides application stability, which enhances test rig safety, we also faced a challenge to deliver properly timed, high-quality signals for external measuring systems made by other project participants. Application multithreading and PXI platform synchronization made it possible to deliver signals with as little as a millisecond delay. We generated scalable signals, which were measured directly by the test rig. We also generated signals resulting from the analysis of multiple measurement inputs, which required proper signal processing optimization and synchronization to achieve proper signal consistency under time constraints.

Conclusion

With the PXI platform and NI LabVIEW programming environment, we efficiently developed our test rig control and measuring system. The hardware configuration leaves room to connect more input signals and to expand the system by using new measurement modules. Due to its modular design, we can expand our application by implementing additional functionalities. In addition, the ready-to-use signal analysis functions in LabVIEW will make that implementation process as simple as possible.

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Using LabVIEW and PXI to Test ASICs

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Industry:

Science, Integrated Circuits

Products:

LabVIEW, NI PXIe-8106, NI PXI-4071, NI PXI-4110, NI PXI-6562, NI PXI-6259

The Challenge:

Designing and testing application-specific integrated circuits (ASICs) for physics and biology applications.

The Solution:

Using NI LabVIEW software and PXI hardware to create a Virtual Instrument to test ASICs as quickly as possible.

"We built a virtual instrument that reliably and quickly tests our products. It uses a variety of modular instruments, so we can perform necessary tests without using other devices. Our virtual instrument is built on dedicated software written in LabVIEW, so the user can set proper test configurations, ASIC parameters, and readout data, then analyze it illustrating the results on the graphical user interface. Thanks to this solution built on NI products, we have saved up to one year of testing."

Introduction

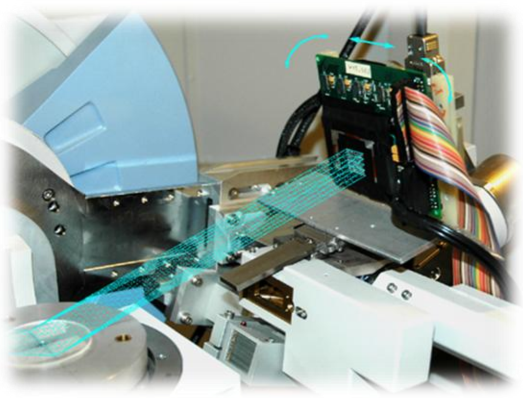

Figure 1. X-Ray Detection With DEDIX ASIC

Our physics solutions detect low-energy, high-intensity x-ray radiation (see Figure 1). We design a dedicated x-ray detector's readout ASICs, such as DEDIX [1], RG64 [2], and SXDR64 [3], which are used for readout silicon strip detectors, as well as chips like PX90 [4] that are fabricated using 90 nm CMOS technology and are used for readout pixel detectors (see Figure 2). Our chips contains up to few thousands readout channels working in single photon counting mode (they count every single photon hitting the detector if it has an energy higher than certain threshold). All of our chips consist of analogue and digital parts with specific digital communication interfaces responsible for controlling an ASIC and streaming out acquired data. Each interface may have a different number of lines, but can work with different digital I/O (DIO) speeds up to 200 MHz. We needed a way to test the ASICs as fast as possible so we could present the results and start working on further solutions.

Creating a Virtual Instrument

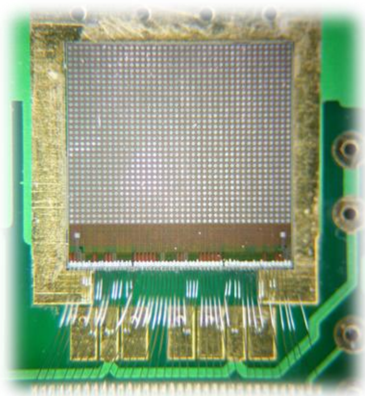

Figure 2. PX90 Chip Bonded to PCB

We test ASICs to make sure the fabricated chip parameters meet the requirements. To do so, we need to communicate with the chip, acquire data in the bit-stream form, and convert it to a meaningful representation. Then, we need to measure physical phenomena (in this case, the number of photons in given time period), and calculate ASICs analogue parameters from acquired data. We need to present the results in the best way possible to draw correct conclusions. There is no device on the market to meet these requirements, so we decided to build it ourselves using NI products.

Our virtual instrument (see GUI in Figure 3) is built on an NI PXI chassis with modular devices such as an NI PXIe-8106 controller with a dual-core processor for fast calculations and an NI PXI-6562 high-speed DIO module for handling control and data signals. We also used an NI PXI-4071 digital multimeter to precisely measure chip bias currents in the range of tenths of nA, an NI PXI-4110 power supply to quickly and precisely control certain potentials, and an NI PXI-6259 multifunction DAQ module for multipurpose measurements and setting analogue output voltage.

We chose National Instruments devices because they have well-prepared and easy to use drivers with a LabVIEW API which make it easy to use them in advanced applications. During the test, we set a delay for eight digital input lines referring to the output clock signal, and it took us just five minutes to implement this functionality using LabVIEW and the PXI-6562.

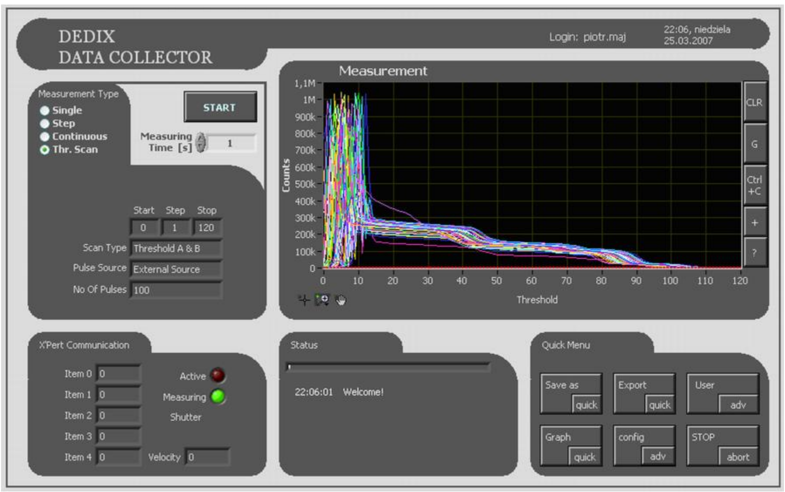

Figure 3. Front Panel of DEDIX Data Collector Virtual Instrument

After communicating with an ASIC, we work with the digital bit-stream, which is useful for observation and debugging a dedicated digital waveform data type. We used a variety of functions from the LabVIEW Functions palette to properly cut, move, and convert the bit-stream data and change it to useful representations of the x-ray intensity. From that data, we calculate ASIC parameters such as gain, noise, and DC level spread between channels or pixels. We use many mathematical functions such as differentiation, fitting (Gauss function and dedicated modified error function), many operations on arrays, and other basic data types. LabVIEW offers all of these functions and we can apply them quickly using the software.

The performance of the device is important because of the large amount of data collected. For example, the PX90 chip contains a 32x40 array of 1,280 pixels, which counts incoming x-rays, and needs a single analogue parameter (threshold scan) measurement to perform data fitting to all pixel data, and to calculate the chip calibration parameters needed to repeat the measurement 256 times. This means we need to repeat the data fitting procedure more than 300,000 times, and time is critical. With LabVIEW 2010, the programmer can configure the For Loop to use multicore processors. Using this feature, we speed up our calculations more than seven times on an 8-core processor.

Conclusion

We built a virtual instrument that reliably and quickly tests our products. It uses a variety of modular instruments, so we can perform necessary tests without using other devices. Our virtual instrument is built on dedicated software written in LabVIEW, so the user can set proper test configurations, ASIC parameters, and readout data, then analyze it illustrating the results on the graphical user interface. Thanks to this solution built on NI products, we have saved up to one year of testing. For example, the Japanese corporation Rigaku used one of our solutions [2] in a high-speed, position-sensitive detector system. With our new virtual instrument, the time we spent testing the ASIC used in the device was less than three months.

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Using LabVIEW and GPIB to Create a Remote Laboratory for Engineering Students

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Industry:

Academia/Research

Products:

LabVIEW, GPIB

The Challenge:

Developing a distance laboratory to perform various measuring and monitoring tasks, mainly on electromechanical machinery and power electronics controls.

The Solution:

Using NI LabVIEW software and GPIB to create a distance laboratory for electrical and mechanical engineers to access via the Internet.

"We created a successful distance control laboratory concept for electrical drive such as asynchronous (ASM), synchronous (SM) motor/generator and DC motor/generator measurements. Students can access and perform described experiments through any web browser."

Introduction

We wanted to use LabVIEW to create a solution for electrical and mechanical engineering students to experiment with measuring and monitoring freely and independently from their homes by using the Internet. We basically knew how to use LabVIEW in distance laboratories to measure electrical machinery and power electronics, and to assist self-paced learning. So, we prepared and tested simulations, measurements, and remote-control experiments, and then provided educational materials and support for students and Internet users to use with the distance laboratory.

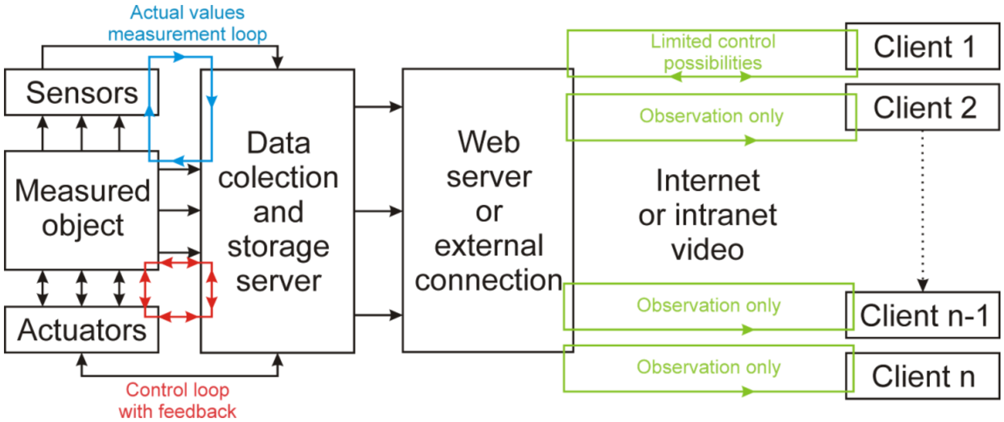


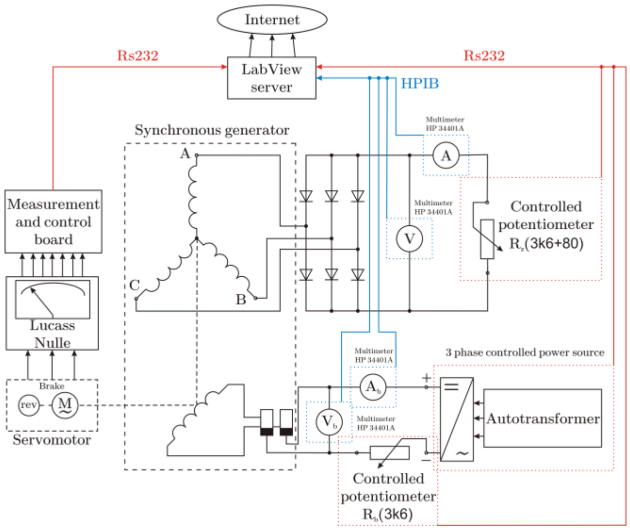
Figure 1. Automated Measurement System Concept with Internet Control and Monitoring

We created an automated measurement laboratory system that can be controlled and monitored using an Internet connection. The lab also includes various sensors and actuators, a data collection server, and a web server (see Figure 1). Our goals for creating this laboratory were as follows:

- Modernize the educational process – implement new technology and computer control to monitor and visualize a modern educational process
- Decrease the number of hours students have to spend in the lab by increasing our self-paced learning offering
- Offer practical experiences with real systems using only an Internet connection
- Offer access to more learning materials, such as manuals that include measurement descriptions and practical video presentations, through e-learning
- Implement real-time measurement system monitoring on real equipment by using a web camera and measuring and storing the acquired data

Distance Laboratory

The distance laboratory consists of various measurement examples mainly focused on electrical machinery and power electronics controls. The main part of the laboratory focuses on electromechanical machine measuring and monitoring such as asynchronous motor (ASM) (see Figure 2 and Figure 3), synchronous generator (SM), and direct current motor (DCM) (shunt, serial and compound motor/generator). The measurement of linear asynchronous motors is also included.



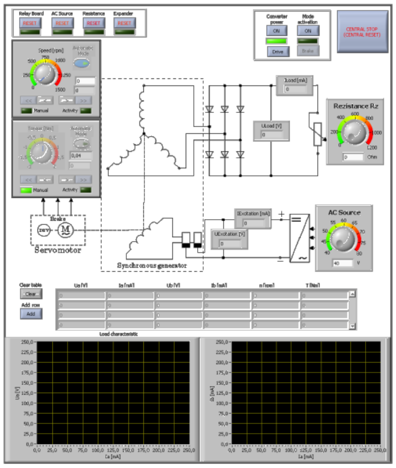
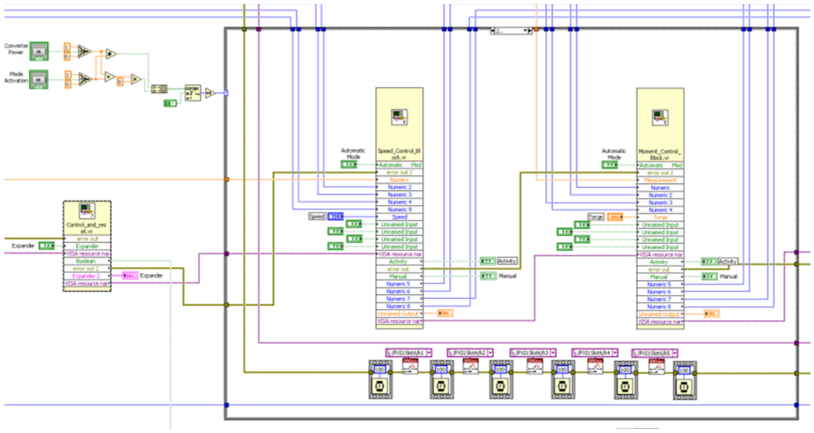


Figure 2. Distance Measurement of Electromechanical Actuators – Asynchronous Measurement Concept Test Design

Figure 3. Completed Design for Distance Measurement of Synchronous Motor in LabVIEW

Figure 2 shows the basic concept of the distance laboratory for asynchronous motor distance measurement. To correctly analyze and measure this motor type, you usually need four multimeters. In our case, we used only one multimeter controlled by GPIB. The changes between measurement points were realized by 64 solid state relays on the board (see Figure 7), depending on the measured value (current or voltage). Stepper motors regulate the resistance values and the AC power source in the distance laboratory.



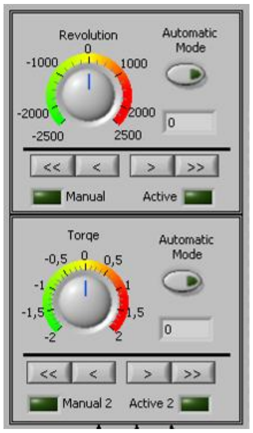


Figure 4. LabVIEW Block Diagram for Drive Converter Control System and Relay Control System

Figure 5. Forward Control Front Panel for Drive Converter Control

During the measurement, mechanical characteristics of the drives are verified (in the theory of electrical machinery also called torque characteristics). These characteristics are defined as a dependence of electromagnetic torque on rotors slip s (ASM), respectively on rotor speed n (DCM and SM). The real torque on the motor shaft is reduced by torque losses caused by mechanical losses and additional losses. The rotor speed is measured by a converter (frequency control of machine) and mechanically by a drive/brake module (servo-drive with various control modes – drive, brake, stepper, and inertia).

The main part of the laboratory consists of frequency-controlled servo drive/brake units used for torque and speed measurements for the motor mode and for driving on the desired rotary speed during the generator motor mode measurement. Through the LabVIEW front panel (see Figure 5), the user can set the desired speed and torque for the frequency converter panel. Figure 4 shows the simplified block diagram for the LabVIEW program.

DC machine measurement is realized for both modes: motor mode and generator mode. A DC motor in generator mode is also called "dynamo." According to the construction and connection of armature and excitation winding, this electrical motor can be used for various winding arrangements, such as serial excitation winding, shunt excitation (parallel connection of windings), independent (separate) excitation, and compound winding connection.

All of the measurements in our distance laboratory follow the well-known standards valid in European Union countries.

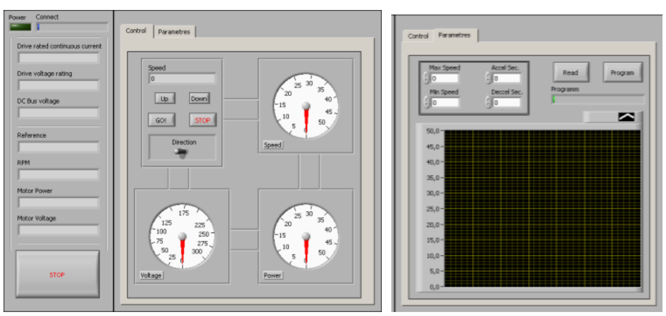


Figure 6. Front Panel for Distance Control Module of Linear Asynchronous Motor (LASM)

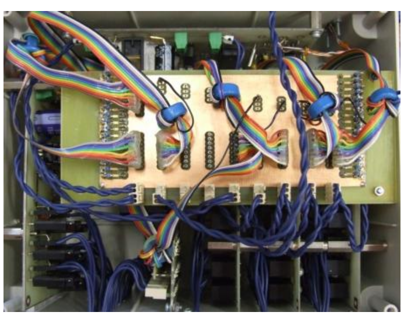


Figure 7. Design of Solid State Relay Board and Control Width Adjustment

The entire distance laboratory is monitored by web camera for optimal verification and interaction with the measurement. This way, the students or laboratory operators can visualize the work of the moving parts (rotation of the rotary machines and linear movement of the linear asynchronous motor as shown in Figure 6).

During the measurement, real rotational machinery is controlled and driven. Because of the possible delay caused by Internet connection, the operator must be patient with delayed system responses.

Conclusion

We created a successful distance control laboratory concept for electrical drives such as asynchronous (ASM), synchronous (SM) motor/generator, and DC motor/generator measurements. Students can access and perform experiments through any web browser. For correct functionality, we installed a real-time plug-in for distance measurements from the LabVIEW webpage. We also accepted cookies necessary for user number limitations. The main components of our distance measurement system were as follows:

- Automated measurement and distance measurement system focused on electrical machinery and power electronics measurements
- Basic idea of distance measurement and its applications in educational processes and e-learning
- Measurement equipment design and multiplexers (64-relay combined board, converter control board, resistance and power control design)
- Design of electronic components and control boards
- PXI server concept definition with acquisitions cards and LabVIEW programming
- Distance laboratory server, measurement, and feedback
- Integration into the education process

Figure 8. Department Web Page Design With Distance Laboratory Access for Internal Testing and with E-learning Module

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Using LabVIEW, CompactRIO, and PXI to Study Renewable Energy Sources

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Industry:

Academic

Products:

cRIO-9014, cRIO-9024, PXI, LabVIEW

The Challenge:

Developing a laboratory to study control algorithms suited to the challenging nonlinear and stochastic nature of specific energy sources, many control loops, and real-time millisecond operation.

The Solution:

Creating a custom laboratory using NI LabVIEW software and CompactRIO and PXI hardware and using advanced control and estimation techniques to investigate and develop microgrid control algorithms for renewable energy sources.

Pull Quote:

"We chose National Instruments software and hardware to create the LARES control systems because of its unique qualities of reliability, availability, and robustness. In addition, the modularity of the equipment gives us the option of future system expansion."

Introduction

As the importance of renewable energy sources rises, the importance of making them efficient and readily available also rises. As part of the global effort to develop and use renewable energy sources, we established the Laboratory for Renewable Energy Sources (LARES) in the Faculty of Electrical Engineering and Computing at the University of Zagreb. LARES conducts research specifically related to controlling wind and solar energy sources, as well as various forms of energy storage.

LARES Overview

We designed LARES as a microgrid consisting of a custom made wind turbine, an electrolyser for hydrogen production, a hydrogen fuel cell stack, and photovoltaic panels (see Figure 1). The purpose of the laboratory is to investigate and develop microgrid control algorithms, as well as to design algorithms to control specific energy sources. The laboratory researchers study ways to increase energy conversion efficiency for renewable energy sources using advanced control and estimation techniques.

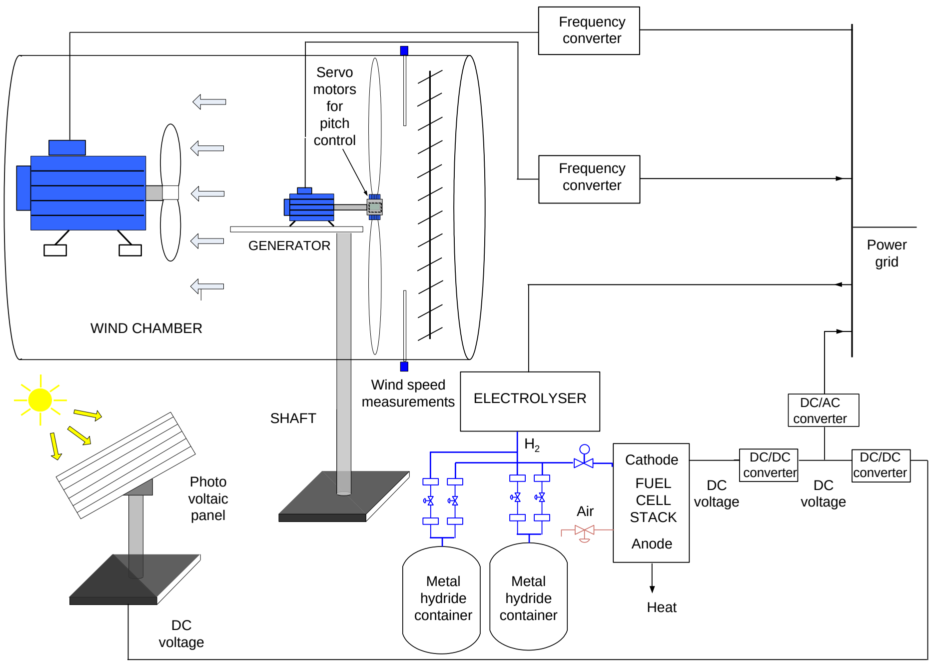

Figure 1. Scheme of Laboratory Setup at LARES

It's challenging to develop these control algorithms because renewable energy sources often display nonlinear, stochastic behaviour; the development requires many control loops; and it requires real-time hardware operation on a millisecond time scale. The nature of the renewable energy system requires complex control algorithms in addition to classical algorithms. We needed hardware that was fast enough to execute these complex algorithms in real time and a simplified way to program them.

To fulfil these requirements, we considered several hardware platforms, including programmable logic controllers (PLCs), industrial PCs, dSpace hardware that can be programmed with The MathWorks, Inc. Simulink® or MATLAB® software, and National Instruments hardware programmed with LabVIEW software. We based our requirements on computational speed, number and diversity of input and outputs, programming simplicity, and cost-effectiveness ratio. We chose National Instruments CompactRIO and PXI hardware.

Wind Turbine Energy Source

The LARES wind energy source consists of a wind turbine placed in an air chamber with artificial wind produced by a powerful blower (see Figure 2).

Figure 2. Wind Chamber with Wind Turbine and Powerful Blower

The electrical energy produced by a generator-driven wind turbine is conditioned by a controlled AC/AC converter.

The control system hardware is located in a control room and consists of a PC powered by NI LabVIEW and an NI PXI-1033 chassis. An NI cRIO-9014 with an NI 9219 universal analogue input module and an S.E.A. WLAN communication module are housed in the wind turbine rotor hub. Because we can program the amount of wind the blower produces and control the individual pitch of each turbine blade, we can investigate problems related to nonhomogenous wind speed and tower vibrations. The equipment in the wind portion of the laboratory is dedicated to investigating the behaviour of the system in nearly stochastic wind conditions, as well as developing a control algorithm for the system.

Hydrogen Plant

The hydrogen part of the laboratory (see Figure 3) consists of the electrolyser for hydrogen production, metal hydride hydrogen storage containers, a fuel cell stack, voltage converters, and a cooling system. The ON/OFF valves establish the paths of the hydrogen and oxygen flow. The control valves in the fuel cell system obtain the desired hydrogen pressure and hydrogen/oxygen flow ratio and regulate the stack temperature. The fuel cell stack output voltage is conditioned by a DC/DC boost converter.

Figure 3. Hydrogen-Based Energy Source Consisting of Hydrogen Storage, Fuel Cell, Valves, and Measurement Equipment

The control system of the hydrogen-based energy source in LARES is built on a PC program powered by LabVIEW and an NI cRIO-9024 controller with field-programmable gate array (FPGA) circuits and I/O modules in an NI cRIO-9118 reconfigurable chassis for real-time hardware control. The I/O subsystem uses an NI 9425 digital input module, an NI 9476 digital output module, a 24-bit NI 9219 universal analogue input module, an NI 9206 fast analogue input module, and an NI 9265 fast analogue output module. Figure 4 shows the cRIO-9024 controller and the I/O modules.

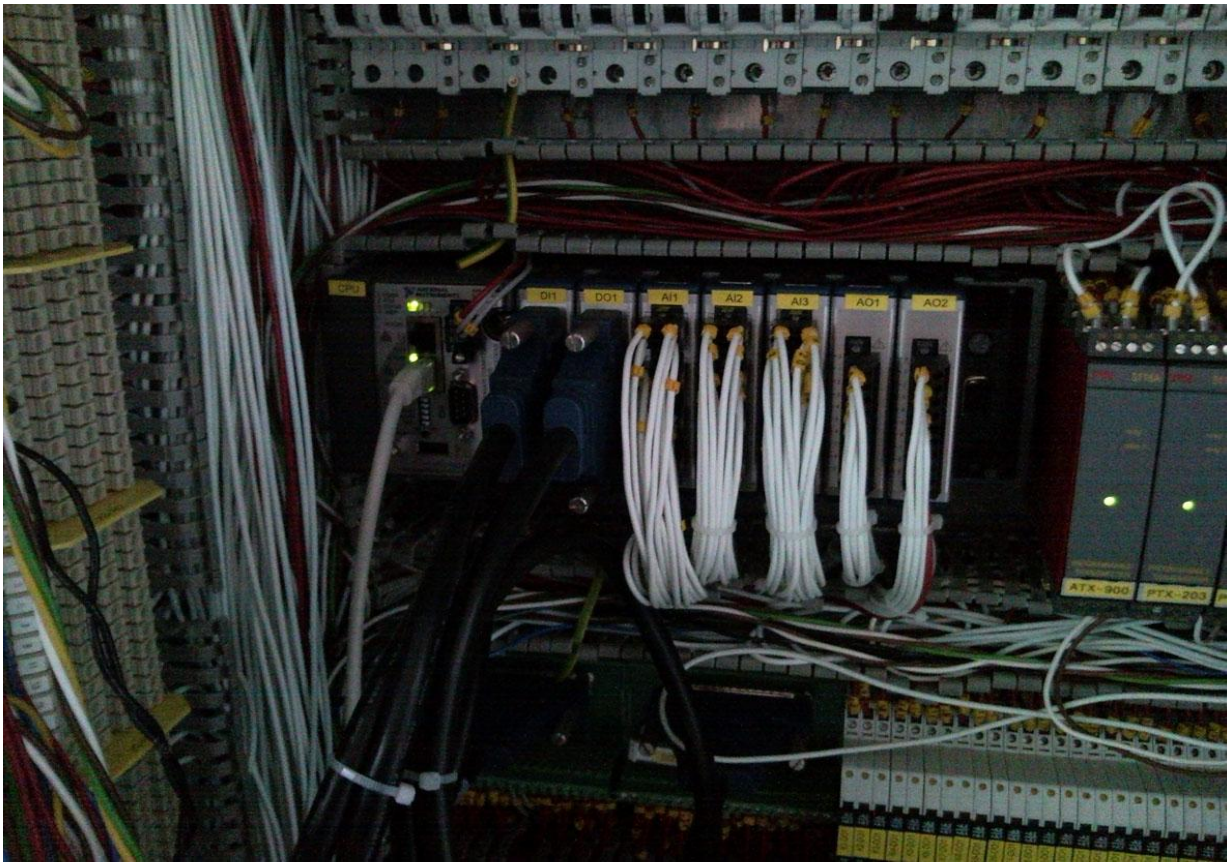

Figure 4. NI cRIO-9024 With Input and Output Modules

We developed the control software using the LabVIEW graphical development environment. The control software performs sequential and feedback control of the hydrogen plant, controls the voltage converters, and controls the safety and monitoring systems. The reconfigurable FPGA circuits in the NI 9118 chassis and fast analogue I/O are especially useful in boost converter control because all responses must be fast.

Photovoltaic System

The photovoltaic system is planed as the third plant in the laboratory microgrid. It will be based on photovoltaic panels placed on the building roof. The electrical energy from the photovoltaic panels will be transferred to the laboratory microgrid by controllable voltage converters.

Laboratory Functions

We built the laboratory to design control algorithms for specific laboratory energy sources, which includes advanced control algorithms such as adaptive control and model predictive control.

In addition to controlling the specific energy sources in the laboratory, we will develop algorithms for microgrid control. The algorithm will control the energy flow in the microgrid to obtain optimal energy production and storage by monitoring the availability of each specific energy source.

The microgrid based on hydrogen, wind, and sun power plants supports experimental research of the control paradigms needed for optimal synergy with other microgrid parts to reach specific objectives on a microgrid level (for example: maximum efficiency, maximum component lifetime, and maximum profit). Our research could be a good foundation for virtual power electric plant control.

Conclusion

We chose National Instruments software and hardware to create the LARES control systems because of its unique qualities of reliability, availability, and robustness. In addition, the modularity of the equipment gives us the option of future system expansion. The processor speed augmented with FPGA circuits makes complex control algorithm execution possible in real time. And last, but not least, the graphical programming interface simplified programming complex control algorithms and gave us fast prototyping.

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Creating Automatics and Robotics Courses Using LabVIEW, NI ELVIS II, NI CompactDAQ, and NI Vision

Authors:

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Industry:

Academic

Products:

LabVIEW, NI ELVIS II, NI CompactDAQ, NI Vision Builder AI

The Challenge:

Developing a coursework that combines fundamental knowledge with the latest technologies to prepare students for their engineering careers.

The Solution:

Using NI LabVIEW software, NI Educational Laboratory Virtual Instrumentation Suite II (NI ELVIS II), NI CompactDAQ, and NI Smart Cameras to create a series of state-of-the-art courses and labs

"The labs and experiments we created not only teach the Automatics and Robotics syllabus, they also give students experience with one of the most advanced, modern instrumentation laboratories based on NI LabVIEW and NI hardware."

Introduction

As teachers at a technical university, we try to combine fundamental knowledge with the newest technologies when preparing our courses. This gives our students a wider technical knowledge base, which is crucial in knowing how to use state-of-the-art technology to solve problems. We used National Instruments software and hardware to prepare a bundle of laboratory courses under the syllabus "Automatics and Robotics." The courses include electrical metrology, electrical materials, electronic circuits, telecommunication systems, electronic measurement systems, microprocessor systems, multimedia, and computer vision systems. The goal of the courses and lab work is to prepare students for the Certified LabVIEW Associate Developer (CLAD) exam which increases their marketability when searching for jobs after graduation. This paper presents some examples of the labs and experiments we created.

Employing NI ELVIS II Instruments in Electrical Materials Lab

In most of our labs based on NI products, we use NI ELVIS II prototyping boards. To protect the boards, we designed and fabricated casings (see the left side of Figure 1) to protect against dirt, dust, and other dangers. The required electronic elements and specially prepared wires fit in kit boxes (see the right side of Figure 1).

Figure 1. Casing for NI ELVIS II and Student Laboratory Kit

Electrical Materials Syllabus

We offer second-year Automatics and Robotics students rudimentary laboratory classes in electrical materials. During the class, students perform a variety of experiments using NI ELVIS II. They learn about physical structures for constructing electronic components through exercises such as testing light-sensitive structures and temperature-dependent components and examining field effect and properties of the p-n junction. The lab gives students a chance to test various types of electronic elements such as photoresistors, photodiodes, phototransistors, optoisolators, thermistors, silistors, thermocouples, junction field-effect transistors (JFETs), metal-oxide-semiconductor transistors (MOSFETs), rectifying diodes, Zener diodes, and LEDs.

Experiment Procedure

Each task usually involves assembling a simple measurement circuit directly on the NI ELVIS II prototyping board, testing specific elements with NI ELVISmx measuring instruments, determining their main characteristics, and calculating principal static and/or dynamic parameters. The variety of components and distinct configurations of the measurement circuits give students an opportunity to familiarize themselves with many available NI ELVISmx virtual instruments, including a digital multimeter (DMM), voltmeter, ammeter, and ohmmeter, 2-channel oscilloscope, function generator, variable (symmetrical) power supply (VPS), Bode analyzer, and 2- or 3-wire current-voltage analyzers.

A Sample Experiment: Examining Optoisolators

In one of the experiments dedicated to light-sensitive structures, the students thoroughly examine a popular PC817 optoisolator (Sharp) made of a photo transmitter (emitting diode) and a photodetector (phototransistor). This experiment includes measuring the optoisolator input characteristics, determining the output characteristics for various operating conditions, taking the transient characteristics, then calculating the current transfer ratio (CTR) for several working points. Moreover, the students estimate dynamic parameters of the optoisolator, measure Bode characteristics, and assess the passband. Figure 2 illustrates the selected measurement circuit assembled in this experiment.

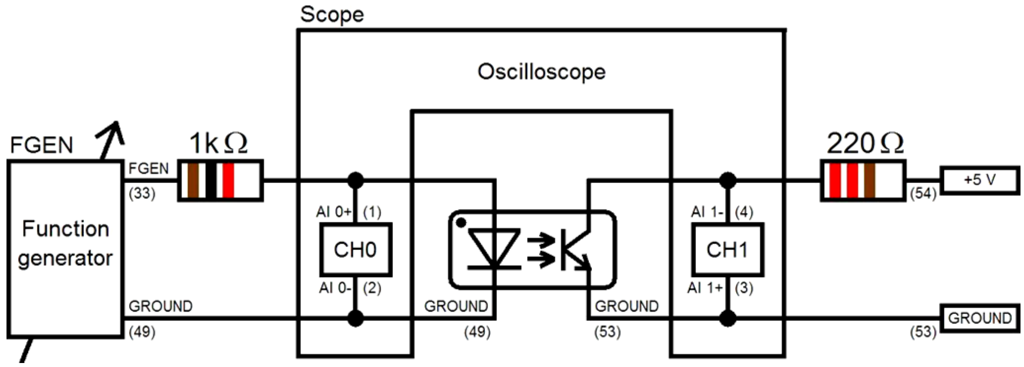

Figure 2. Examining Dynamic Properties of the Optoisolator

Electrical Metrology

In an electrical metrology course, also offered in the second year of education, students use NI ELVISmx instruments to learn methods of measuring resistance, capacity, static and dynamic parameters of operational amplifiers, and selected 4-pole circuits. To perform these exercises, the students work with much more advanced circuits compared to those used during the electrical materials course.

Electronic Systems Laboratory

In the electronic systems lab, students build on their experience from previous courses and learn the basics of NI LabVIEW graphical development software. This lab is a set of exercises to familiarize students with the basics of electronics. To support the testing environment and obtain a set of measurements, such as numerical and graphical results, the students use LabVIEW to create an application (see Figure 3). These experiments include half-wave and bridge rectifier, transistor basics, operational amplifier schemes (linear and nonlinear), astable, monostable, and triggering circuits using a classic NE 555 chip.

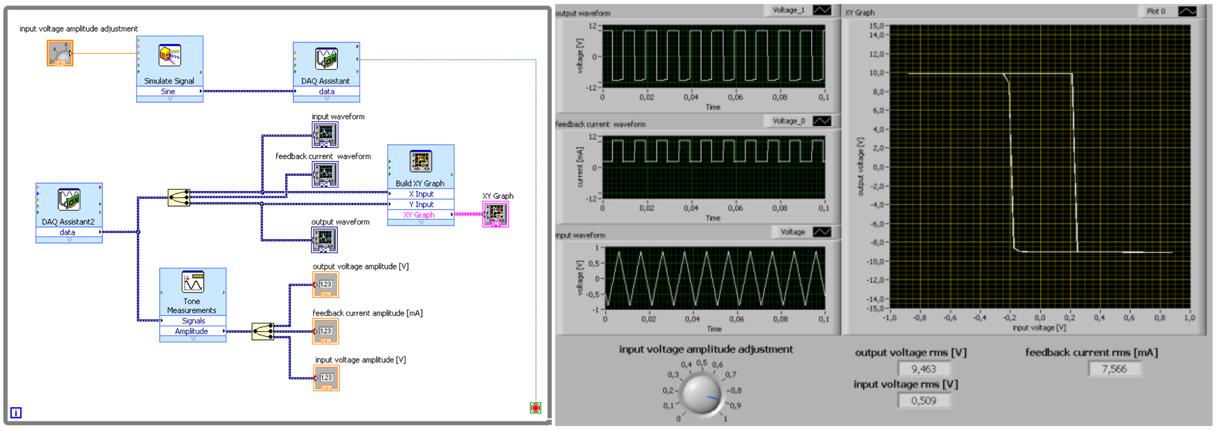

Figure 3. Block Diagram and Front Panel for Testing Operational Amplifiers

Microprocessor Systems and Telecommunications Laboratory

The microprocessor systems lab, as well as the telecommunications lab, contains exercises that use NI Elvis II with third-party boards. To teach microprocessors, we use a Freescale MC9S12C128 microcontroller board equipped with many types of interfaces and built-in modules (see Figure 4). In the telecommunications lab, we use the Emona DATEx board and a set of prepared experiments.

Multimedia and Computer Vision Systems

We offer advanced courses using NI software and hardware to master students. At the master level, students have earned their Bachelor of Science degree, have basic knowledge of LabVIEW and the NI ELVIS II environment, and can use their experience to solve advanced problems. Up to now, we prepared multimedia and computer vision systems labs at this level. The labs are equipped with an NI 1742 Smart Camera, LabVIEW, and NI Vision Builder for Automated Inspection (AI). Besides the typical testing boards for the computer vision course (connectors with conductors, cotters, and 2D barcodes), we prepared a board with integrated circuits (see Figure 5).

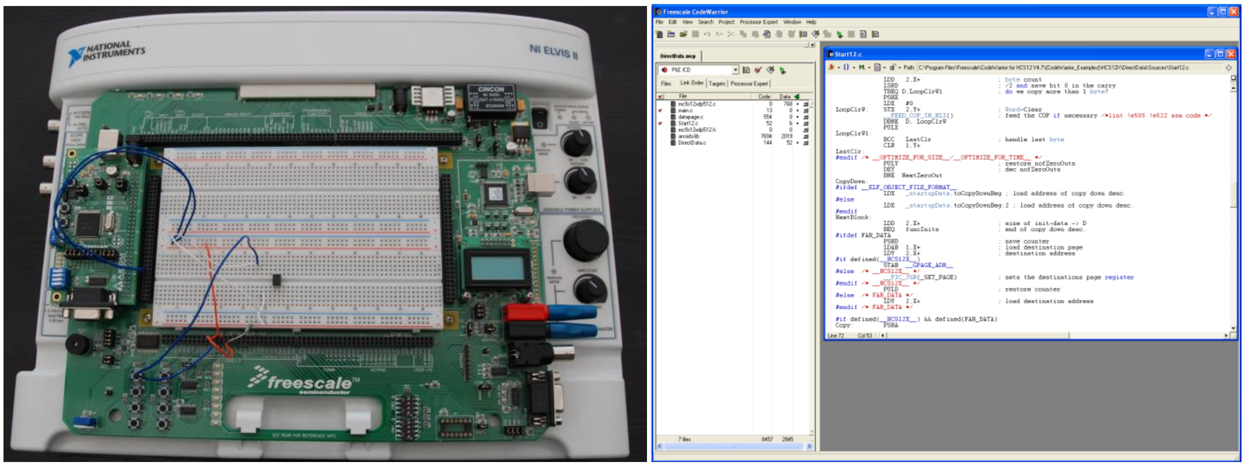

Figure 4. NI ELVIS II With Freescale Board and Freescale Code Warrior Environment

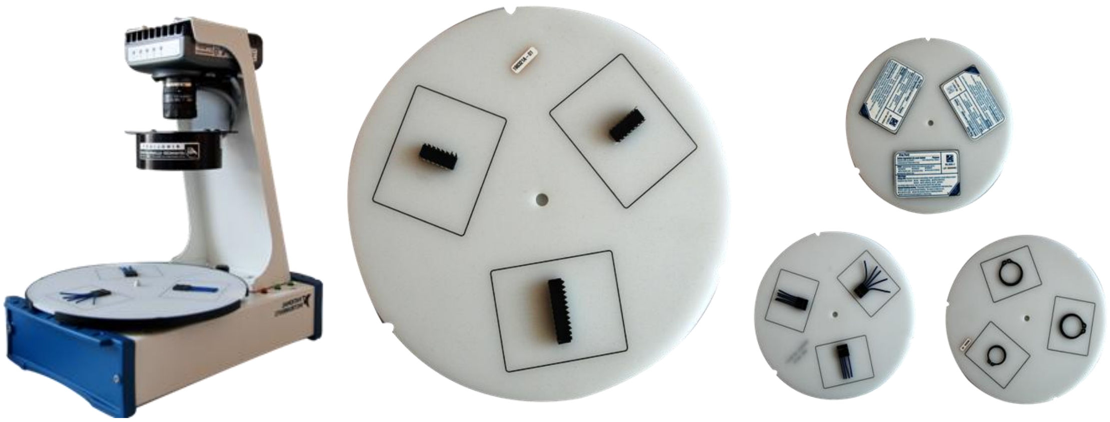

Figure 5. NI 1742 Smart Camera and Testing Boards

To prepare for the automated inspection application, students learn about video processing, as well as programming using Vision Builder AI and advanced LabVIEW functions.

Summary

The labs and experiments we created not only teach the Automatics and Robotics syllabus, they also give students experience with one of the most advanced, modern instrumentation laboratories based on NI LabVIEW and NI hardware. We are arranging to have our courses and labs approved by the LabVIEW Academy program. As an additional way to prepare students for the CLAD exam, we sometimes offer a short review course during half-term breaks.

e-learning in Education of Instrumentation & Measurement

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Abstract:

The paper gives a short review of reasons for developing and adopting a new e-learning model in the field of Instrumentation and Measurement as part of Electrical Engineering. First, a description of the e-learning evolution in the last 10 years is presented. Then it follows a description of the relation between e-learning and the scientific community. The next part is devoted to the practical implementation of e-learning in Instrumentation and Measurement. The main topics considered as the elements of a Virtual Laboratory are: project design, simulations of experiments and remote access to a (real) laboratory.

Keywords: ICT, distance learning, electronic book, distributed system, virtual instrument, virtual laboratory.

1. INTRODUCTION

It is a well-known fact that ICT has grown very expansively in the last several years. It creates great possibilities and gives us new tools that **we can learn and creatively implement!**
At the same time, ICT creates new, difficult tasks and challenges, which can be the sources of some fear.

This fear is because:

- the expansion of a new technology very often **exceeds the expectations, ideas and imaginations** of a number of people;
- people observe the growth of science and technological progress and see them as **a source of threat**;
- a high level of unemployment, competition and environmental devastation establishes questions about food supplies;
- some people are forced to change jobs many times in their life;
- more and more people who cannot work all their life at a **high activity level** fall behind; and,
- globalization produces a high level of structural changes, exceeding the potential of many people.

Education is a serious remedy for those fears because: **Education prepares people to work and live** and lets them understand the world, "refresh" their knowledge and follow changes. An **educated staff** is the meaningful element of the production, together with capital and technology. **"High-Tech"** comes more easily to regions with educated staffs.

The generality, universality and necessity of education should have the highest priority in an Information Society.

In the behaviourism model, a computer and the Internet were considered to be a "blackboard" with higher functionality. In the constructive model, the computer and Internet play a role in cognitive tools. Now is the time to answer the question: What is the best way to implement new ICT tools in research & development and education?

The European Union declaration at Lisbon includes very important parts related to the education of all people. For example: "… *Europe will need to invest more in its young people, education, research and innovation, so that we can provide our society with the assets and outlook to generate wealth and provide security for every citizen* … ."

"… *To give to all citizens the same opportunities of improving his/her degree of instruction and to promote the institution of a life-long learning system* … "

The European Commission has established the European Training Foundation (ETF). Its mission is to assist partner countries in developing quality educational and training systems and putting them into practice. The ETF work program is structured around a series of projects, such as TEMPUS, SEE, MEDA, EECA, etc., which take place in the partner countries to facilitate the reform of vocational education and training-and-employment systems. Due to wide political and social transformation, there is an increasing need for new teaching approaches similar to those in older European countries. E-learning seems to be the best way to reach these objectives because it removes physical, geographical and cultural barriers to education and enables learners to choose their own learning paths and times. The assumption that education should not be separate from our professional and family life has led many societies to provide and develop new systems of distance learning. The advantage of distance learning over a traditional model of education is in its flexibility. That model of education and its tools are directed to the needs of an individual, it enables self-managed learning, saves time and ensures cost savings, including travel costs and the cost of accommodation. The education is usually home-based, which guarantees friendly and comfortable learning conditions. New developments in ICT have enriched traditional classrooms with new e-learning tools and has improved learning quality in both residential universities and geographically dispersed learning groups. Of all the technical innovations, the Internet has become an indispensable tool in the introduction of new technology to education, and its growing impact on the future of the educational model is inevitable.

The computer and Internet enable:

- e-mail correspondence,
- access to source materials stored on web sites and CD-ROMs,
- solving tasks and problems,
- writing reports, projects, etc.,
- online meetings, and,
- discussions with lecturers and other students.

Questions that were taken into account are topics that will be discussed in the framework of the working group “e-tools for Education in Instrumentation & Measurement” (etEI&M), operating within the IEEE Instrumentation and Measurement Society, Technical Committee TC-23 Education in Instrumentation and Measurement.

2. EVOLUTION OF E-LEARNING TECHNOLOGY

In the last 20 years, e-learning technology went through a great evolution. The experience with learning in general and, specifically, e-learning has proved that the reason for a lack of advancement is strongly correlated to the learning model. The process can be approximately characterized by Table 1, presented below [9]:

Table 1

Years	Level of activity	Knowledge sources	Retention Factor
1990	Reading	e-mails, e-papers online, self-study guides	20-40%
1995	Reading and watching	online course with static visuals, online PPT presentations	40-50%
2000	Reading, hearing and watching	online courses with audio-video animations, recorded real lectures, exercises	40-70%
2004	Reading, hearing, watching and talking	interactive real live e-classes and e-courses, audio-video conferences	50-75%
2006	Reading, hearing, watching, talking and doing (designing)	online courses with audio-video animations, simulations, web-based exercises	65-95%

Technological progress has a very strong influence on learning models. It has been summarized in the following points [9]:

Fundamental progress in technology:

- Greater computer power,
- Smaller computer size,
- Greater network speed,
- Higher network availability,
- Wireless Networking, Security and privacy.

Technological progress results:

- Users are always online,
- All information and knowledge resources are online,
- Digital media is everywhere,
- Streaming media,
- Rich multimedia,
- Hands-on exercises, animations, simulations, games,
- Embedded systems.

Influenced learning trends:

- Ubiquitous learning,
- Mobile learning,
- Collaborative learning: Web-based communities,
- Lifelong learning,
- Global knowledge resources,
- Reusable objects-based learning content,
- All students are always online.

But, what is very important to the crucial phase of the learning process in the scientific and engineering fields is *practical training activity*. It ensures a good transfer of knowledge from the teacher to the students. Teaching in Instrumentation & Measurement science has more important necessities: students have to work on *real instrumentation* in conditions that are as realistic as possible. They should have an opportunity *to repeat* the same experience several times (trial-and-error mode).

In summary, it can be mentioned that the facts and demands are the following [9]:

- Fast obsolescence of knowledge,
- Global knowledge resources (not local),
- Technology-based education and life-long training,
- The need for *Just-In-Time* subject/topic-specific knowledge/training,

- Flexible access to post-university lifelong learning,
- Skills gap and demographic changes drive the need for new learning models, and the available support includes the following aspects:
  – Access to the Internet is becoming a standard at work and at home,
  – Advances in digital technologies enable the creation of interactive, media-rich learning content,
  – Increasing bandwidth and better delivery platforms make e-learning more attractive for learners,
  – A growing selection of high quality e-learning tools, products, and services,
  – Use of standards facilitates the compatibility and re-use of learning objects produced by various developers.

3. MODERN ELECTRONIC BOOK

One of the most important factors, even in a new concept of education, is still the textbook. Thanks to new ICT tools, the new version of textbooks used in distance learning is much more flexible and creative than previous ones. Usually these kind of books are known as "electronic books." The didactic materials of the particular courses, Instrumentation & Measurement, can be prepared by professors and experienced lecturers in the form of electronic lectures (books) and stored on CD-ROM. Certainly, the same content can be placed on websites, available via the Internet. Electronic books have the advantage of presenting the whole material of a single subject on one CD. The cost of multiplying it is relatively low. Creation of the material can be done with Dynamic HTML technology (HTML, Cascading Style Sheets, Java Script and FrontPage tools). Because of nearly unlimited space, besides traditional educational content it can include:

- Auxiliary software,
- Set of publications and "source readings,"
- Addresses and links to other knowledge sources: e-libraries, archives, collections,
- Questions/answers and tests,
- Animations,
- Simulations of experiments.
-

A proposed structure of the electronic book is presented in Figure 1 [2].

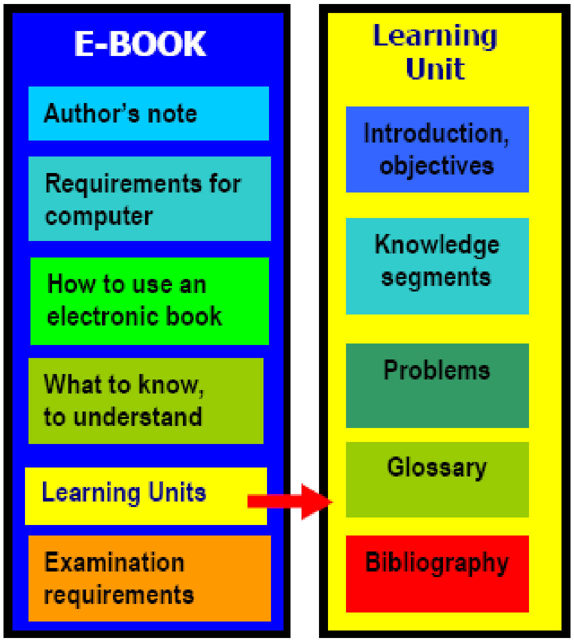

Figure. 1. Structure of the Electronic Book

The tools that can be implemented in the creation of an e-book, can be divided into three categories:

Traditional tools:

- Texts,
- Fonts: bold, italic, colour, etc.,
- Equations,
- Drawings,
- Photos,
- Background colour and texture.

Multimedia tools:

- Text comments,
- Audio comments,
- Video comments,
- Animation of drawings,
- Animation of presentations.

Advanced tools:

- Generators of tests, "Local" simulations, "Distance" simulations,
- Simulated experiments,

- Remote experiments.

Additional tools compatible to HTML

- Java Applets
- FLASH Modules

The **Java** programming language plays a very important role in preparing multimedia applications. It is a very useful tool in writing network applications. Java can be run under any operating system. Java applets can be introduced into the HTML text of any e-book. They can be improved and animated. Simply put, Java is able to enrich multimedia content throughout web sites with animation, advanced graphics, sound and images with no need to introduce additional applications available through the web browser. A very complex program can be distributed through the polymorphic network of the Internet with no need to know what kind of operating system is used by the student. An example of a Java applet is presented in Figure 2.

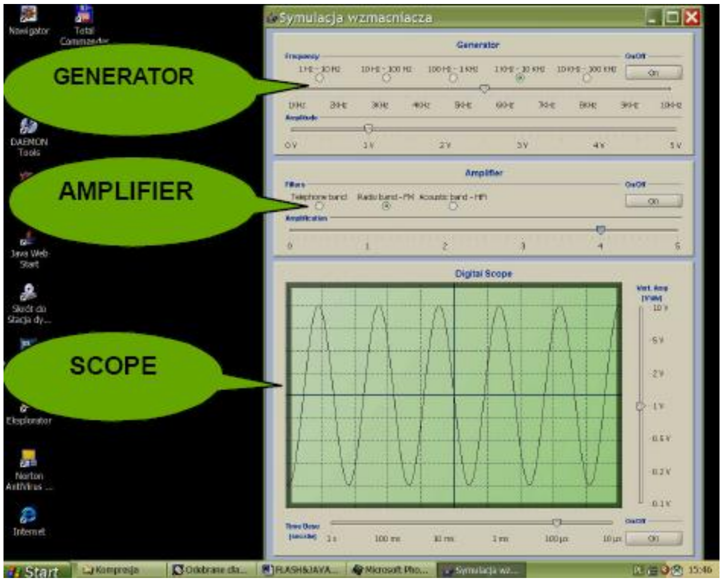

Figure.2.The Set of Instruments Prepared in Java Applet Form

This example of a Java applet is prepared as a set of instruments connected together and creating a measurement system for investigating an amplifier frequency response. We can change the amplifier frequency band from “telephone” to acoustic Hi-Fi. The frequency response can be investigated manually, which is certainly intentional. The second, no less helpful tool in the area of animations destined for Web sites, is **Flash** from Macromedia. It generates small capacity files that work on most web site browsers. The Flash format, with the “.swf” extension, is based on a vector graphic in which information about each image pixel is not kept, as with a *bitmap*, but instead uses mathematical formulas to describe the shape, colour and layout of the object. With that information, the created file has a smaller capacity, and even complex animations are quickly loaded by browsers. The implementation of Flash animation is a very simple process and available to everyone. An example is presented in Figure 3.

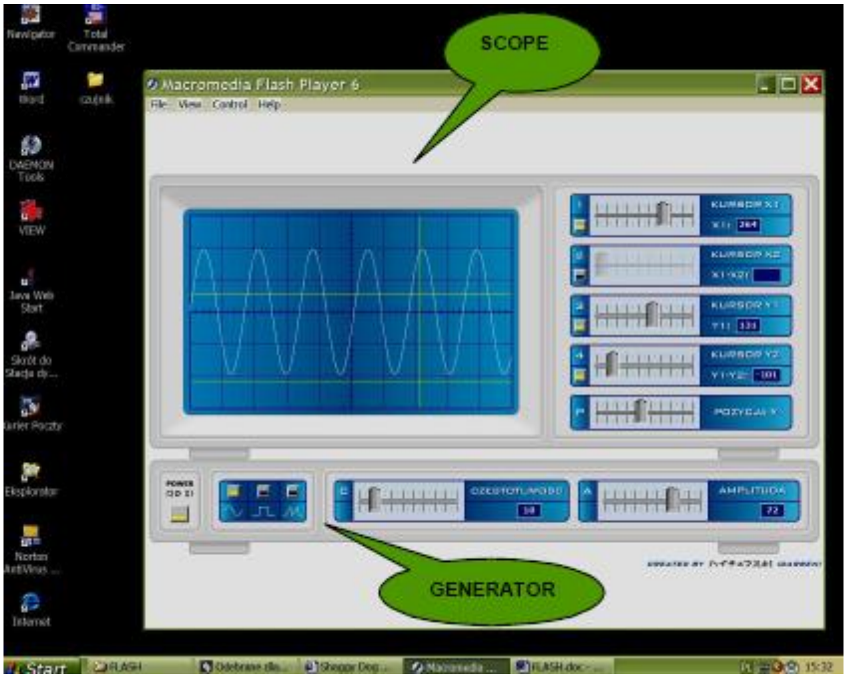

Figure. 3. An Example of the Flash Animation Module

On the monitor screen we can see two instruments: a function generator (on the bottom) and a scope (on the top). They are connected. The output signal from the generator can be seen on the scope display.
What can be observed in both cases is a modern form of the instrument front panels - like from fairyland. They have been prepared by students, which is the reason for that. The simulations described above are strongly connected to the idea of a **Virtual Instrument**.

4. THE IDEA OF A VIRTUAL INSTRUMENT

In order to construct a Virtual Instrument it is necessary to combine the hardware and software elements that should perform the 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, instruments will move more and more from the hardware side to the software side. Currently, the most popular way of programming VIs is based on a high-level tool software. With easy-to-use integrated development tools, design engineers can quickly create, configure and display measurements in user-friendly forms, during product design and verification. The most known, popular software tools are as follows:

- **LabVIEW (National Instruments)—**is a highly productive graphical programming language for building data aquisition and instrumentation systems (Virtual Instruments). To specify system functionality the user intuitively assembles block diagrams, which are a natural design notation for engineers. Its tight integration with measurement hardware facilities rapid development of data acquisition, analysis and presentation solutions.

- **LabWindows/CVI (National Instruments)—**is a Windows-based, interactive ANSI C programming environment designed for building virtual instrumentation applications. It delivers a drag-and-drop editor for building user interfaces, a complete ANSI C environment for building test program logic, and a collection of automated code generation tools as well as utilities for building automated test systems, monitoring applications or laboratory experiments.

The power of the software tool lies in the libraries, which enable:

- access to instrument **Interfaces** (GPIB, RS-232, VXI, DAQ)
- full control of autonomic **Instruments** (Instrument Library),
- creation of Graphical User Interface **GUI** (Graphics Library, User Interface Library,
- formatting and I/O Library),
- digital Signal Processing **DSP** (Advanced Analysis Library),
- access to global computer network **INTERNET** (TCP/IP, DataSocket, ActiveX),
- inter-process data exchange **DDE** (Dynamic Data Exchange).

The ideal tool enabling easy control of programmable instruments is a specialized command set called **SCPI** (Standard Commands for Programmable Instruments). SCPI dramatically decreases development time and increases the readability of test programs. It has its own set of required common commands in addition to the mandatory GPIB (IEEE 488.2) common commands and queries. Although IEEE 488.2 is used as its basis, SCPI defines programming commands that we can use with any type of hardware or communication link. It has an open structure. The SCPI Consortium continues to add commands and functionality to the SCPI standard. For example, the following command programs a digital multimeter to configure itself to make an AC voltage measurement on a signal of 15V, with a 0.005 resolution: MEASure:VOLTage:AC? 20, 0.005.

A dual-channel spectrum analyzer is a very impressive example of a virtual instrument. The block diagram of a spectrum analyzer designed especially for educational purposes is presented in Figure 4. It is made as a kind of "**home version**" for a personal computer equipped with a typical ***sound board***. Nearly all types of the software tools are equipped with functions servicing the sound board, which can be implemented instead of an expensive DAQ one.

Figure 4. Block Diagram of a Spectrum Analyzer Based on a Sound Board

In the case of DAQ implementation, the software part has been written under a LabWindows/CVI environment, so that the graphical user interface (control panel) has a user-friendly form. It is divided into three separate parts. Each part includes a different control panel. The user can select the most appropriate for the specific measurement or analysis function. It also is possible to build a hierarchical structure of control panels. A control panel designed for both signal and spectrum presentation in the online mode is presented in Figure 5.

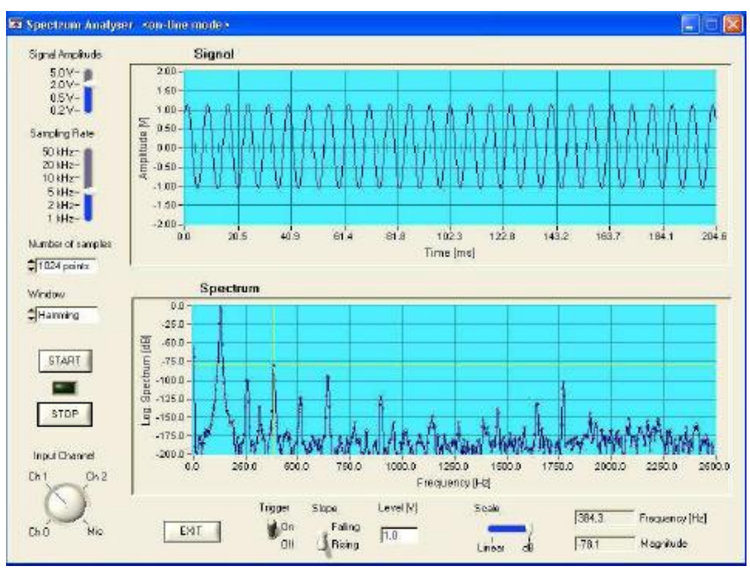

Figure. 5. Control Panel of Spectrum Analyzer in Online Mode

Further, a user can select two different control panels for the offline mode: control panel for signal presentation (Figure 6) and control panel for spectrum presentation (Figure 7).

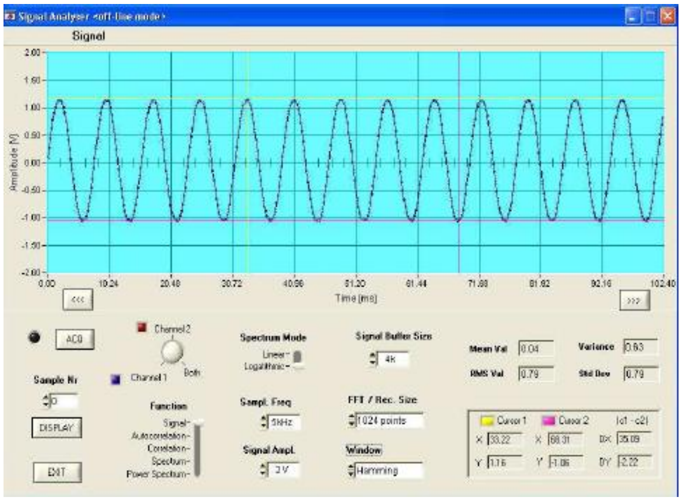

Figure. 6. Control Panel of Spectrum Analyzer in Offline Mode for Signal Presentation

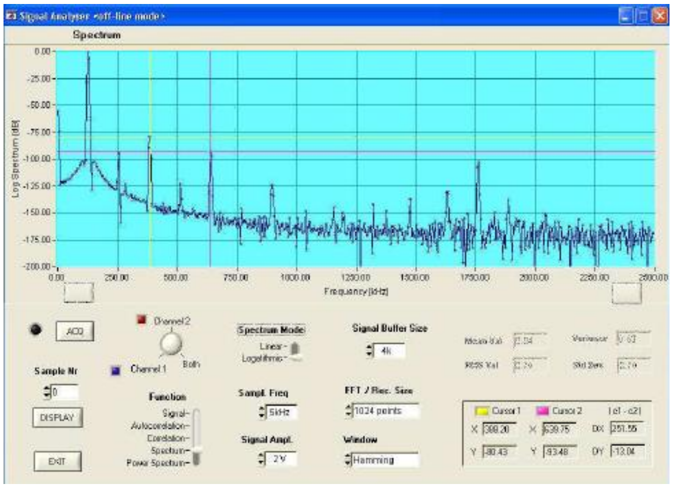

Figure. 7.Control Panel of Spectrum Analyzer in Offline Mode for Spectrum Presentation

An example of the reconstruction of cooperative real instruments (function generator Agilent 33120A and digital multimeter Agilent 34401A) prepared under LabWindows/CVI is presented in Figure 8.

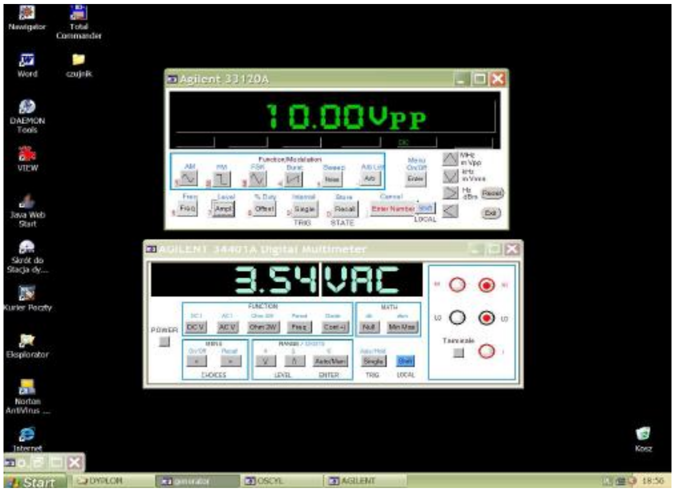

Figure 8. The Front Panel of a Real Instrument: Function Generator Agilent 33120A and Digital Multimeter Agilent 34401A.

One of the most natural environments for virtual instruments is in a distributed system, especially when we are taking into consideration a new approach to the education model (distance learning).

5. VIRTUAL LABORATORY

It seems that nowadays, from the viewpoint of measurement-and-control systems, LAN can be considered as a kind of measurement bus. Common Internet-based software can be used to provide easy data migration between the various communication pathways. Multicomputer processing systems are effective in creating complex systems by overcoming the limitations of a single computer concerned with the overall computing power or the number of signals to be acquired and processed. Standard software languages such as C and Java can be used with off-the-shelf development tools to implement the embedded network node applications and the web-based applications, respectively. Internet based TCP/IP protocols, Ethernet technology and/or DataSockets can be used to design the networking infrastructure. DataSocket is a software technology for Windows that makes sharing all measurements across a network (remote Web and FTP sites) as easy as writing information to a file. It uses URLs to address data in the same way we use URL in a Web browser to specify Web pages. DataSockets technology included with any software tool is ideal when someone wants complete control over the distribution of the measurements but does not want to learn the intricacies of the TCP/IP data transfer protocols. In all types of networked and distributed measurement systems, presented above, real-time operation and constraints are critical issues to be considered during system design to ensure the correct system operation. As previously mentioned, in the scientific and engineering fields, the crucial phase of the learning process is practical training activity that helps to assure a good knowledge transfer from teacher to students. In the area of Instrumentation & Measurement engineering, students have to work on real instrumentation in conditions that are as realistic as possible. They also should have the opportunity to repeat the same experience several times and even learn in a trial-and-error mode. As it already has been shown, VI can be used over the LAN or even the Internet in a quite easy manner. It is possible to give a user free access to the measurement results as well as let the user control the instrument remotely. The main drawbacks of introducing those elements into the laboratory experiments are the following:

- the high cost of measurement instrumentation,
- the high cost of management of experimental laboratories,
- a reduced number of laboratory technical personnel and their expensive continued training,
- an increasing number of students.

There is only one practical solution: to build Virtual Laboratories and share the limited resources of one or more laboratories among a large number of teachers and students over the Internet. The remote control of experiments and equipment over the web is an idea that is just being explored. Different tools are now becoming available for the remote control of instrumentation using network communication. Several demonstrations of camera control and data acquisition as well as simple experiments have already been made. Our knowledge concerning the processes resulting from experiments, ability to control these processes and a set of tools needed for digital recording and transmission are good enough to introduce a new model of laboratory research—*sc*. a Virtual Laboratory. The most important elements of a Virtual Laboratory are Virtual Instruments and Distributed Measurement Systems. The ICT tools that are very helpful in designing a Virtual Laboratory are listed below:

- Internet Protocols: IP, UDP, TCP;
- SOCKETS—available under Unix (and Windows 9X/NT as *winsock*) method of
- network communication between applications;
- "Client-Server" architecture: the *Server* must open the socket and wait for a connection.
- Attached to the open socket is a certain number, together called a *port. Clients* have to know
- the network address of the computer *(server)* as well as the port number;
- JAVA : Object-oriented programming language that enables the creation of the
- system software throughout a set of cooperating independent components
- (objects);
- Objects: real or virtual instruments, device drivers, servers, clients and lastly
- abstract objects like mathematical or logical functions.

By supplementing classroom teaching with web-based experiments, the student should be able to interact with physical systems, much in the same manner as modern experiments are carried out today, under computer control. Laboratories accessible from the Internet provide enrichment to the educational experience that is hard to obtain from other video-based remote teaching methodologies. Remote control of experiments and equipment over the web is an idea that is just being explored. Different tools are now becoming available for remote control of instrumentation using network communication. Several demonstrations of camera control and data acquisition as well as simple experiments already have been made [1][5].

The Virtual Laboratory can be organized in four different modes:

- Synchronous Mode (level 0)—Passive observation of an experiment conducted by
- the teacher;
- Remote visualization of an experiment (level 1)—Passive observation of an automatically working system;
- Remote control of an experiment (level 2)—Remote control and getting results;
- Remote project design (level 3)—Project design and implementation of their own system There are two, known approaches to developing the software :

- commercially available integrated development systems, *i.e*. LabVIEW and related software tools such as Measurement Studio;
- Object-Oriented Programming (OOP) such as those using Java and related technologies.

The main design objectives of a Virtual Laboratory are:

- portability,
- usability and accessibility,
- maintenance,
- client-side common technologies,
- security,
- privacy assurance,
- scalability,
- interconnectivity.

The software destined for system supervision (Learning Management System) should implement the following tasks:

- control single users and groups (authentication, password, authorization, rights),
- manager the communication process (between user and laboratory),
- monitor access to laboratory resources (systems, instruments, functions),
- manage laboratory resources (single instruments or groups),
- organize users (groups, rights to resources, rights under conditions, changes of rights, priorities),
- manage learners,
- keep track of their progress and performance across all types of training activities
- manage and allocate learning resources such as: registration, classroom and instructor
- monitor availability, instructional material fulfillment and online learning delivery.

In summary the LMS should include:

- Collaborative learning tools (chat, forum),
- Virtual classrooms,
- Test editing and management tools,
- Student activity tracking,
- Feedback tools,
- Statistical analysis tools,
- Access control and logs.
- Laboratory specific tools:

- Remote control of the instrumentation and the distribution of GUIs,
- Concurrency management for supervised and concurrent work sessions,
- Reserving resources,
- Scheduling requests.

The idea of a virtual laboratory, as remote access to a real laboratory is presented in Figure 9 [7].

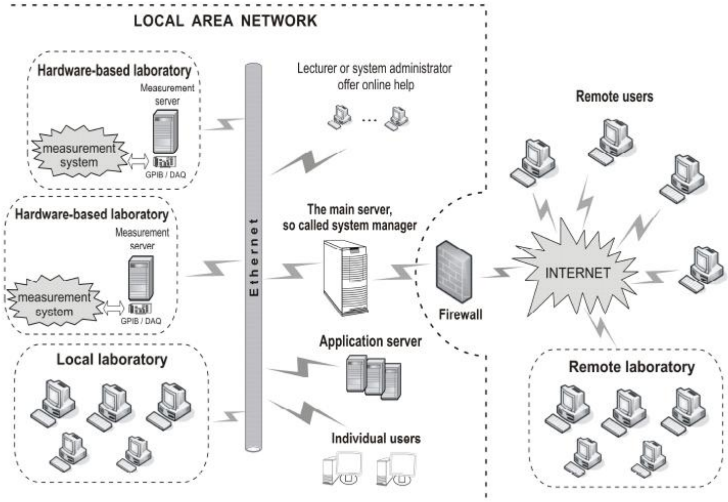

Figure 9. The Idea of a Virtual Laboratory (remote access to a laboratory)

The measurements can be presented in two modes: "on demand" and "online." The first mode includes two separate cycles: "*query cycle*" and "*answer cycle.*" In the "online" mode, the user has constant access to the instrument (an online selection of functions and parameters and results). The software must include two main parts: server application and client application. Each client includes a control panel with a virtual scope, prepared especially for running tests. The client can be attached to the server, which acts as a gateway to the real instruments. After login, a session is opened for programming instruments and receiving measurement data. Additionally, the server plays the role of controlling rights, maintaining security and much more (the concurrency of processes and multiple access). Certainly, the most important usage of a Virtual Laboratory is concerned with distance learning. Online experiments give the possibility to have an impact on a real process or object.
It is important that students understand the essence of events that take place in a measurement object, and familiarize them with measurement systems and techniques. This should be done without limiting the number of accessible instruments of a given measurement unit. Moreover, it is vital that students freely configure a measurement system and even build a faulty circuit. This should enable a student to better understand the problem on the basis of a "trial-and-error" method. Virtual laboratory software, though, should block any operations that may destroy hardware used by the measurement system. More experienced and skilled students will be given more freedom to conduct their experiments. Another important function of a virtual laboratory is access to the experiment in an "offline" mode. This could allow the user to learn, understand and partially solve

problems that he might encounter in practice. Such a system should enable the student to design and store the measurement unit architecture. This would minimize the time needed for remote access to real instruments that are essential to conducting experiments. Yet another useful function of a virtual laboratory is the possibility to simulate simple experiments that can be used to present a problem discussed during a lecture. This function may be very beneficial for users who are just about to learn how to use a virtual laboratory. The example of real remote access to a virtual laboratory is presented below. It is based on a simple measurement system for taking the frequency response characteristics of an amplifier (Figure 10).

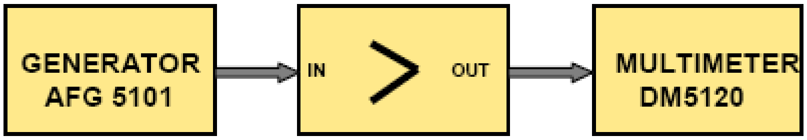

Figure 10. Block Diagram of the Measurement System for Taking Frequency Response Characteristics of the Amplifier

The system is based on "client-server" architecture and DataSockets technology. On the software side it includes a:

• **Server:** MS Windows Application written under a LabWindows/CVI environment, (Virtual Instrument panel placed on the measurement server).
• **Client:** MS Windows Application written under a LabWindows/CVI environment with remote access through DataSocket technology.

Clients have been prepared in three versions, for separate control of both instruments and the overall measurement system. The operating panels are presented in Figures 11,12,13 and 14.

Figure 11. Server Application Panel for DM5120 and AFG5101 Controller

Figure 12. Client Application Panel for DM5120 Controller

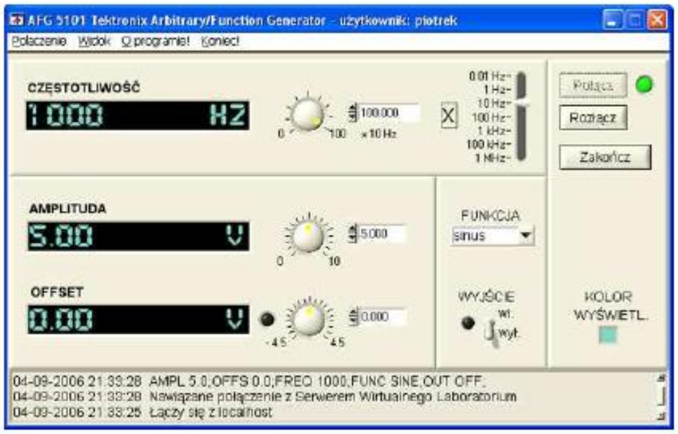

Figure 13. Client Application Panel for AFG5101 Controller

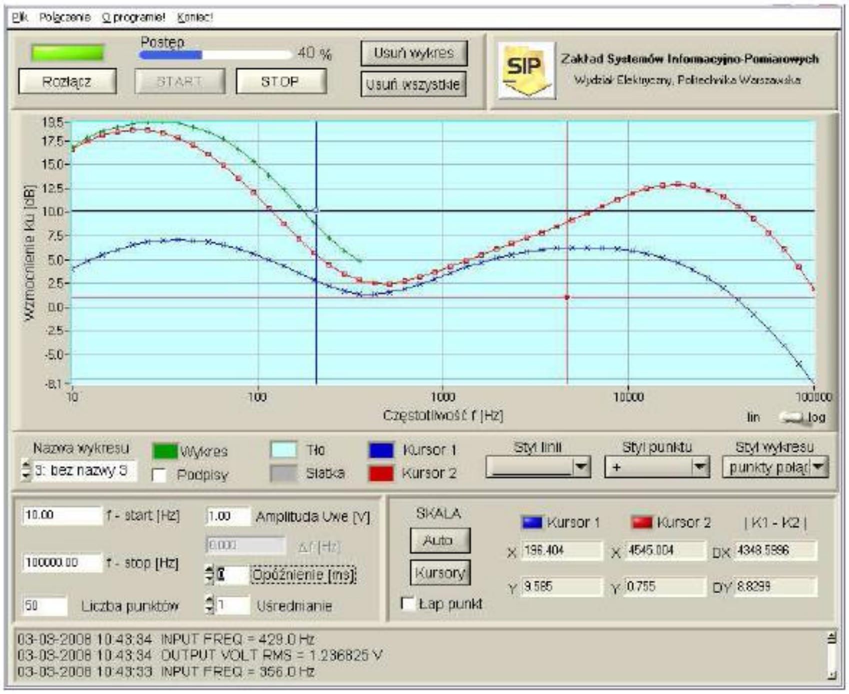

Figure 14. Client Application for Measurement System Controller

6. CONCLUSIONS

The introduction of e-books into the Instrumentation and Measurement teaching process and placing the measurement instrument in a distributed system based on the Internet enables creating advanced and flexible systems that make it possible to support the learning process. An important objective for the future is a remote Virtual Laboratory, a very useful tool for teaching purposes in distance learning. Students could access Virtual Instruments via a geographic network and directly carry out real experiments by use of a simple standard commercial Internet Web browser. In this way, a more complete educational proposal can be offered by several laboratories specialized in different measurement fields. The remote laboratory concept allows measurement resources located at various geographically remote sites to be utilized by a wide distribution of students. Experimental studies of physical events or objects with the use of measurement instruments help students to understand measurement procedures and measurement system structures. Thus, a virtual laboratory should be treated as a very attractive tool supporting education. Remote access to laboratories assures rational management of expensive and unique measurement equipment. In other words, it facilitates the integration of measurement resources. It is predicted that in the future, virtual reality techniques will develop so far that the Internet browser will be replaced by a 3D interface. Users will have the impression that they are walking inside a laboratory where all the instruments and units will look like real ones. Users may be even tempted to touch the instruments. Another objective for the future is the establishment of a network of universities offering distance education. This would lead to the creation of a new model of distance education based on the NETTUNO model. Nevertheless, one has to bear in mind that neither modern simulation techniques nor remote access to virtual laboratories eliminate the necessity of conducting experiments in real laboratories with the use of real instruments. Practical experiments play an important role in the process of gaining knowledge in the field of modern, complex technologies that are conducted on the basis of "trial-and-error" methods. This is of great importance whenever complex events cannot be described with the use of mathematical calculations.

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An Advanced Distortion and Power-factor Measuring Device Based on Virtual Instrumentation

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Introduction

The quality of the electrical energy delivered to consumers nowadays is highly influenced by the enormous number of small electronic and electrical loads that are drawing energy from the grid in bursts. According to recent studies, we are witnessing changes today in demand and energy usage. In fact, the new demand determines "new" load characteristics and trends when changes in the nature of the aggregate utility load occur. Electronic loads are strongly related to power quality through the implementation of AC/DC convertors that, in general, draw current from the grid in bursts. In that way, while keeping the voltage waveform almost unattached, they impregnate pulses into the current, thus chopping it into a seemingly arbitrary waveform and, consequently, producing harmonic distortions. The current voltage relationship of these loads, looking from the grid side, is nonlinear, hence, nonlinear loads. The existence of harmonics gives rise to interference with other devices being powered from the same source and, having in mind the enormous rise in the number of such loads, the problem becomes serious with sometimes damaging consequences and has to be dealt with properly.

The nonlinearity of a load means that the mains current now becomes more and more distorted, abandoning its basic sinusoidal—monochromatic—shape. Harmonics take more and more of a role in the energy balance. Bearing in mind that most of the larger loads and the distribution network (including the suburban transformers) are designed to work with the basic harmonic (that is, they are at the same time supposed to be in-phase with the main's voltage), serious problems are encountered if no design precautions are undertaken in advance. Unfortunately, the main part of the grid was designed many decades ago so there is no possibility to intervene within it. The remedy must be found in the loads. In other words, one must have knowledge about the properties of the load if one is to expect some quality in the main current. This is usually done at the production plant and distribution site levels. Field measurements are of interest, too.

Solution

Measurements of the distortion power factor (DPF), the harmonic distortion (HD) and the total harmonic distortion (THD) directly on the load is performed these days by dedicated measuring devices, the price of which are between \$5,000 and \$10,000.

There is, however, an incomparably cheaper yet more versatile measurement setup that will perform all the measurements needed for a characterization of the quality of small loads: active power, reactive power, apparent power, power factor, DPF, HD, THD, phase, etc. It has two parts: the LabVIEW virtual instrument and the NI USB-9215A acquisition module (Figure 1). The acquisition module acquires the signals (the load's current and voltage) including conditioning, performs A/D conversion, and transfers data to the computer. It has four channels of simultaneously sampled voltage inputs with 16-bit accuracy, 100kSa/s per channel sampling rate and $250V_{RMS}$ channel-to-earth isolation, adequate for voltage measurements up to the 40th harmonic (2kHz). It also provides portability and hot-plug connectivity via a USB interface.

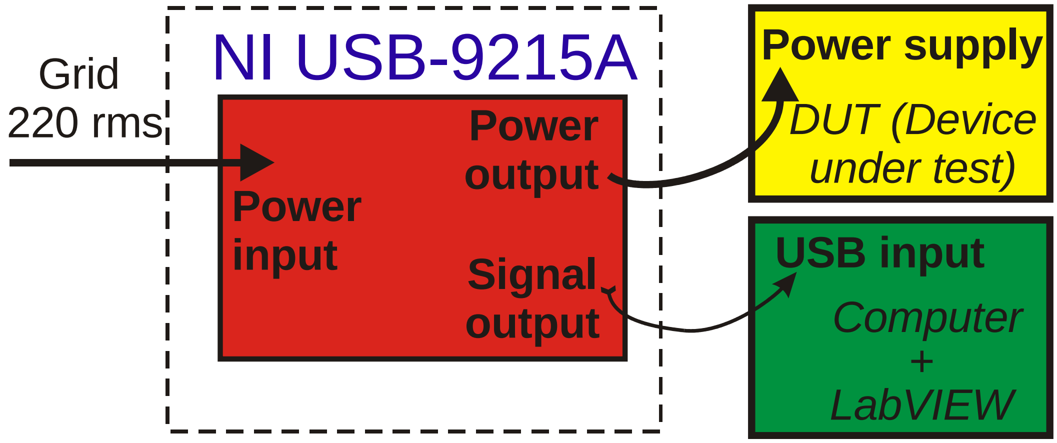

Figure 1. Schematics of the Measurement System

The computer is calculating the amplitude, the main frequency and all harmonics of both the load's current and voltage. It performs all the secondary calculations to produce the quality indicators. It offers a user-friendly graphical interface and presentation of the results (time diagrams, histograms, tables etc.). Finally, it performs management functions: archiving, log-in history, measurement statistics etc.

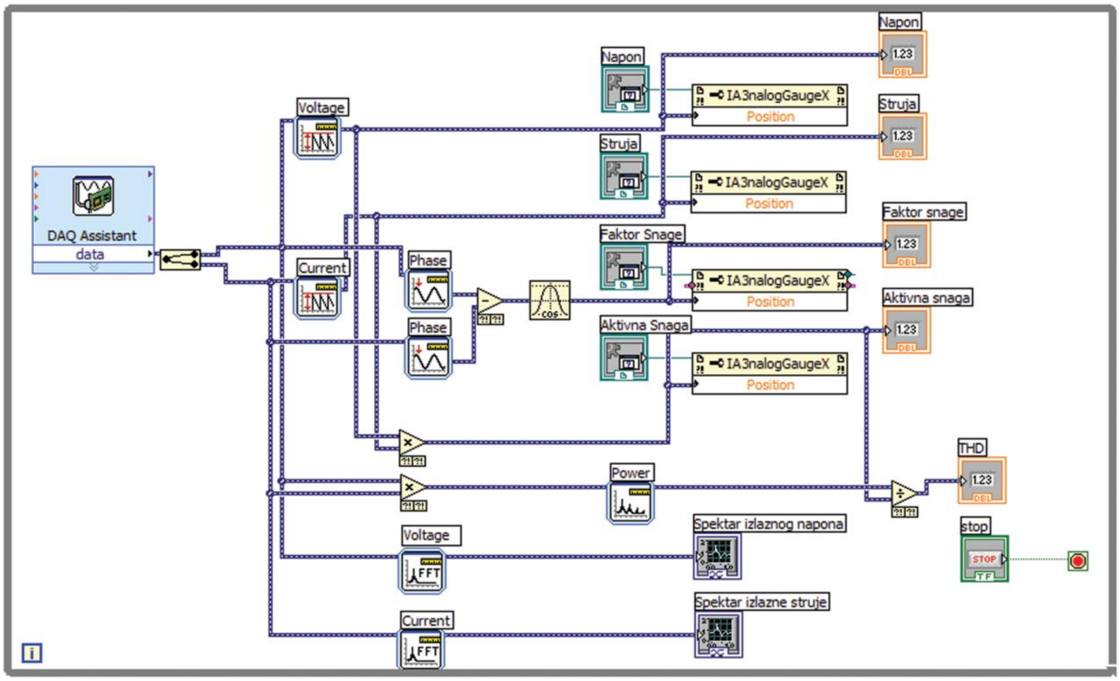

Figure 2. Main Thread of the Application

The software part of the power factor and distortion measurement system is found in the NI LabVIEW™ developing package (Figure 2). The virtual instruments consist of an interface to the acquisition module and an application with a graphical user interface. The interface to the acquisition module is implemented as a device driver. The USB-9215A module is supported by NI-DAQmx drivers. All the measurements are performed using virtual channels. A virtual channel is a collection of property settings that can include a name, a physical channel, input terminal connections, the type of measurement or generation and scaling information. A physical channel is a terminal or pin at which an analogue signal can be measured or generated. Virtual channels can be configured globally at the operating system level or by using an application interface in the program. Every physical channel on a device has a unique name.

The user interface of the virtual instrument consists of visual indicators. It provides basic functions for measurement. The indicators—gauges and graphs—show measured values. All measured values are placed in a table and, after the measurement process, in an appropriate file. The user interface also provides controls for data manipulation and saving measured values (Figure 3).

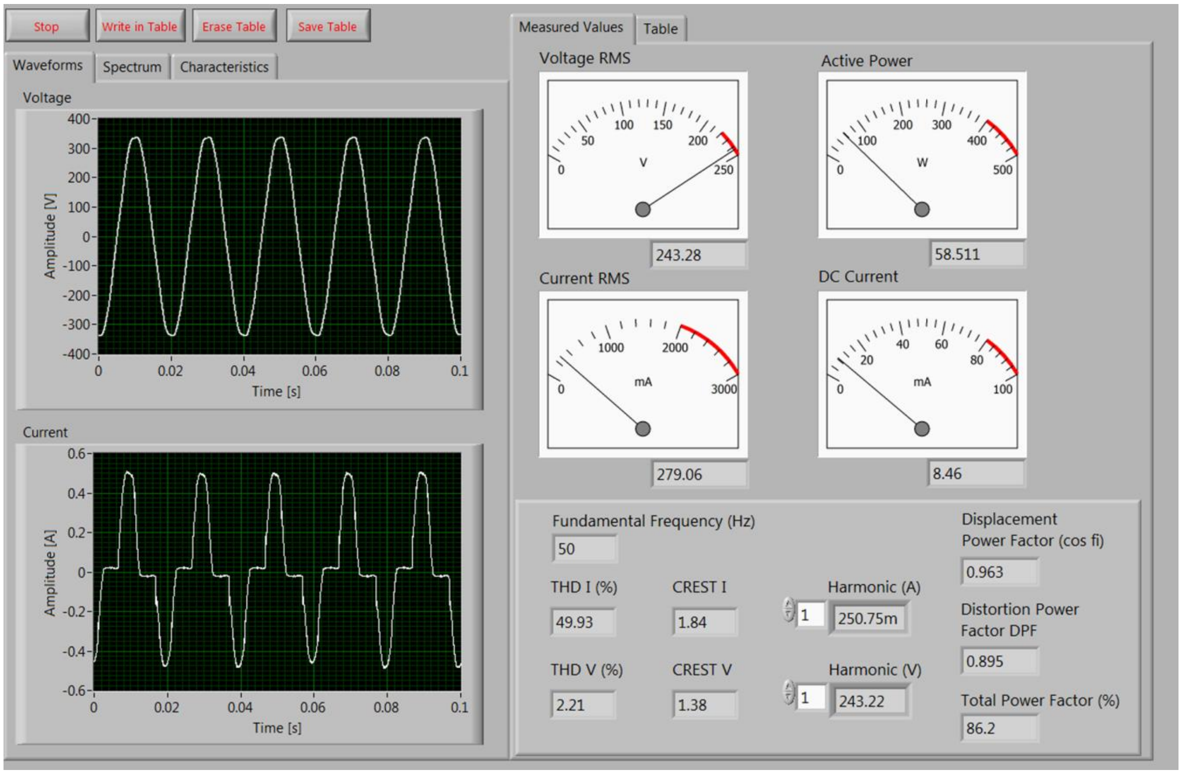

Figure 3. Interface of the Virtual Instrument

For better performance, the main application has been separated into two threads. The first thread has functions for file manipulation and saving measured values. All measured values will be saved in an HTML file format.

Conclusion

The main research goals of this project, produced by the electrical efficiency program of the Serbian Government, are related to the creation of simple and inexpensive methods and instruments for power-factor measurements and distortion characterizations of small electrical loads. A virtual instrument is capable of real-time sampling and measurement of the voltage and current of a device under testing, providing the possibility for a transient analysis in time and frequency. Measurement time depends on the storage capacity of the host PC.

ARMed and Ready.

Prepare Students for Future Embedded Challenges

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With today's constant evolution of electronics and software technologies, propelled even more by consumer demand, embedded computing is increasingly becoming an integral, often invisible component of the world around us. It is just about everywhere: in cars, medical devices, airplanes, factories, electrical networks, our living rooms and at work. Despite this ubiquitous presence, embedded computing is still an immature field, making it more difficult to introduce at an undergraduate level. That's why there is a continuous search for the right methods and tools to familiarise students with the embedded world.

Embedded computing is being introduced at Romania's Military Technical Academy (MTA) through a series of courses: "Microprocessor Architectures," "Specialized Computing Systems" and "Digital Signal Processors." Those courses have prerequisites in both the computer sciences and electrical engineering disciplines. Also, they constitute good prerequisites for application courses and provide fundamental preparation for the capstone project and final graduation thesis. The main objective of the "Specialized Computing Systems" course, scheduled for the fall semester of the student's junior year is to introduce embedded system design methods through examples of medium complexity applications. At the same time, the following objectives are considered: acquiring an overall vision of the existing embedded systems in the market and applications covered with them, knowing the special characteristics of the design of embedded systems, learning the main concepts about the design of embedded real-time applications, practicing design methodologies of embedded systems for medium complexity applications and designing a digital system for a specific application based on given requirements. To make the topics more attractive, the laboratory classes are basically small microcontroller projects. Dr. Bruce Land from Cornell University provided the inspiration in 2005 to choose the right approach of introducing design with Atmel AVR microcontrollers at the undergraduate level. Young students, though, are more attracted by the latest hardware and technologies, *e.g.*, ARM Cortex-M3 microcontroller, and several students from the department were recognised for their projects by the "Design Stellaris 2006" contest. That first contact with the Stellaris microcontroller prepared the academy for a new tool from the continuously evolving National Instruments Graphical System Design Platform: LabVIEW Embedded Module for ARM Microcontrollers.

By making use of LabVIEW, teachers can illustrate various algorithms on both PC and embedded targets. This portability not only shortens the development cycle but also invites students to further explore the theories and technologies hidden behind those graphics, enhancing understanding and allowing them to find easier practical solutions for their applications. A good example of such exploration was demonstrated at MTA by a sophomore student soon after the first release of LabVIEW for ARM in 2008. He developed a remote-control application in a single day, without having any knowledge about embedded control or communication. The application allows the movement of multiple sections of a robot arm in certain directions. Both programs, the user interface and the microcontroller firmware is developed in LabVIEW. Somebody familiar with LabVIEW will recognize the front panel of the virtual instrument from the example pictures , but here the three knobs are controlling the orientation of a real arm with claws that can grip something. The communication between computer and microcontroller is made over Ethernet using UDP datagrams. The user can remotely control four servos from the front panel of a virtual instrument running on a PC computer. The controlling data are formatted into a string and then sent to a microcontroller board loading UDP packets. The four servos are controlled by four pulses with modulated outputs from a Stellaris microcontroller (PWM0, 1, 2, 3 in Fig. 1).

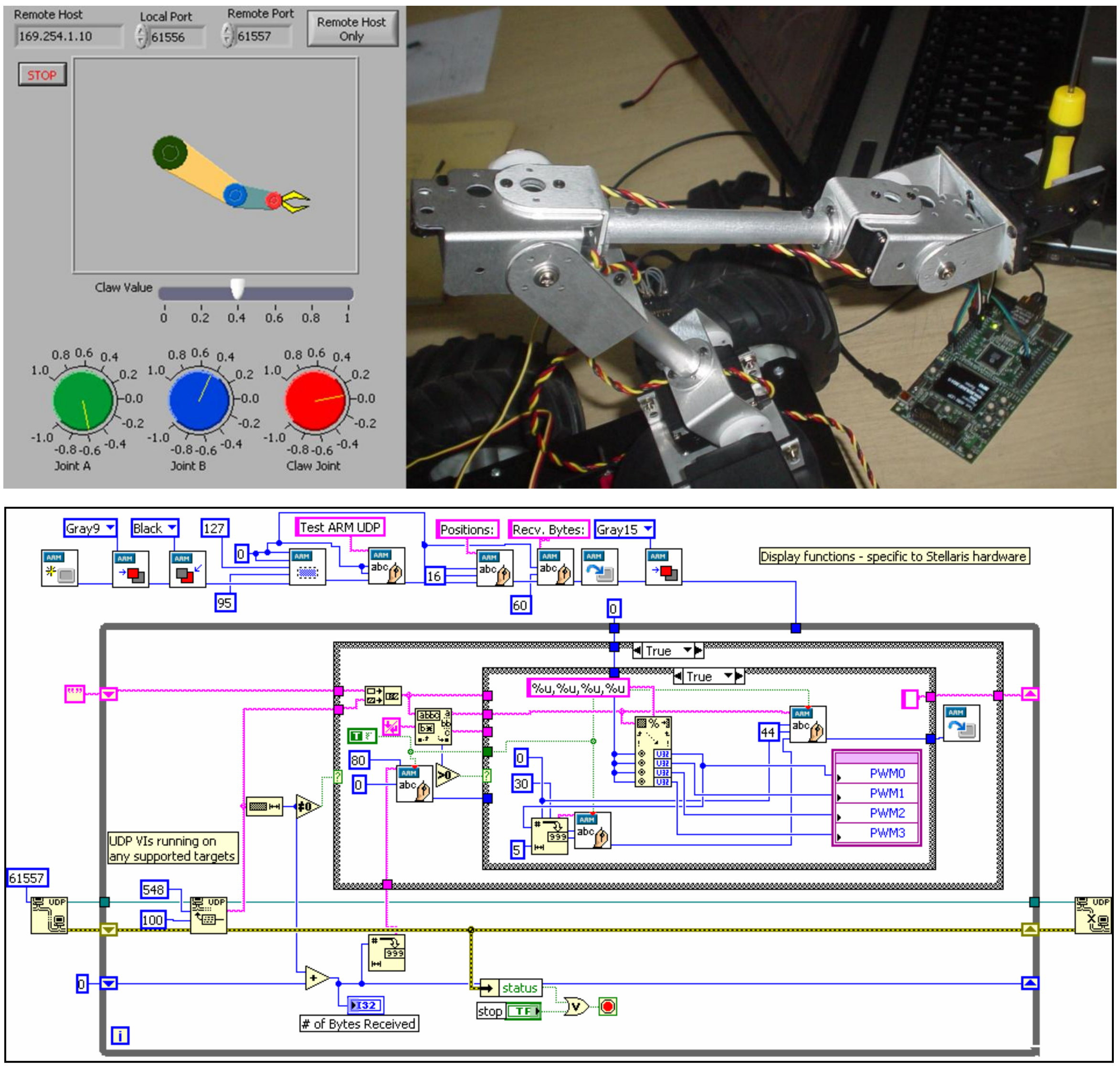

Figure 1. Robotic Arm and Block Diagram for the Microcontroller Target

This is a simple remote-control application, but this control from LabVIEW opens wide the perspective for advanced control algorithms that are not as accessible to sophomore students. The student actually “just played with some icons on a block diagram,” which encouraged the academy to go further and use LabVIEW for ARM and Stellaris microcontrollers in the lab. Of course, results came quickly with many other ideas turning into successful projects. While developing their designs, the academy’s students also were willing to do the bottom-up hard work whenever their requirements didn’t find a match in the implementation platform, such as connecting their sensors or simply drawing images on the tier 2 targets’ OLED (see Figure 2).

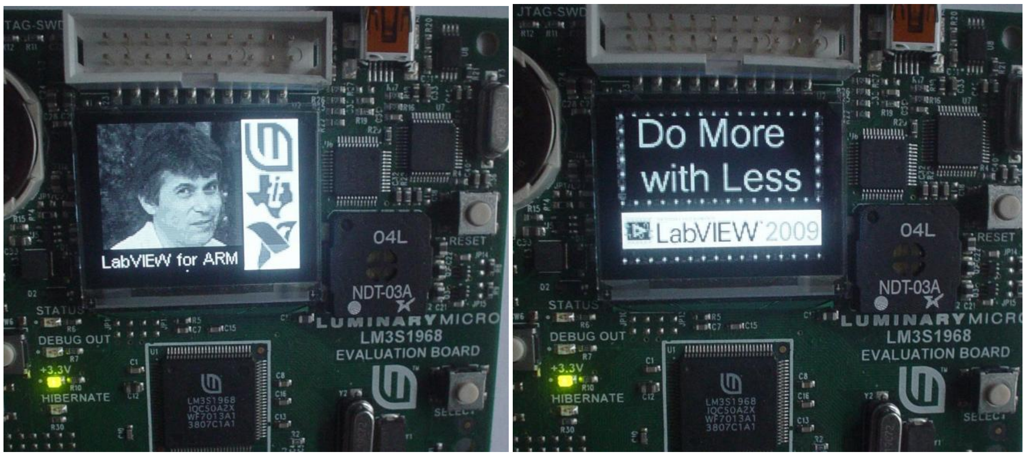

Figure 2. Images on Luminary Micro EKK-LM3S1968 Evaluation Board

For example, to develop an Internet radio player they ported an MP3 implementation, wrote necessary wrappers in C script and drew a radio server in LabVIEW 2009. Whether that approach was “Good Enough” can be confirmed by hearing Sarah McLachlan and couple Austin radio stations in a YouTube video (http://www.youtube.com/watch?v=k_sKl9eysy0).

The virtual environment enables new methods to be prepared for teaching embedded system development. For example, at the academy’s departments, a new curricula is being prepared. To bring some simplicity to the complex embedded computing field and to make things easier for the undergraduate level, we are proposing a new approach: reading–experimenting –thinking–more reading. Answers to the “what” and “why” questions are given in a Just-in-Time Teaching (JiTT) manner, but “how” things have to be done in practice is shown in hands-on experiments. This way, the students are involved in solving simple assignments shortly before lecture class. Responses to thought-provoking questions are used to organize the presentations of embedded systems and applications theory around student understanding. The ARM microcontroller-based hands-on experiments enhance this understanding by making use of the LabVIEW Embedded Module for ARM Microcontrollers.

This approach demands a closer instructor-student relationship and also, more student work. To further motivate the student to do voluntary supplementary work, the latest microcontroller technology and development tools were chosen along with the introduction of all programming languages in the spectrum, from assembler to C and further to the more abstract, graphical in LabVIEW. This creates a more stimulating environment for solving real-world problems—the main skill needed to be mastered by future engineers that will last their entire career.

Implementation of Neural Classifier in LabVIEW

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1. Introduction

In the following article we present the implementation of neural classifier in developed in NI LabVIEW environment. The classifier is based on Counter Propagation (CP) artificial neural network. The realization of the projected network was verified on a testing bench. As a result, a library that contains set of Virtual Instruments (in form of .vi files) has been built allowing using neural network in LabVIEW applications.

1. The neural classifier
1.1. Artificial neural networks

Artificial neural networks are built from single neurons grouped in layers. Neurons from one layer are connected to every neuron in another layer. Sometimes there is also feedback connection between different layers. The structure of the artificial neural network and neuron model is presented in figure 1.

a.

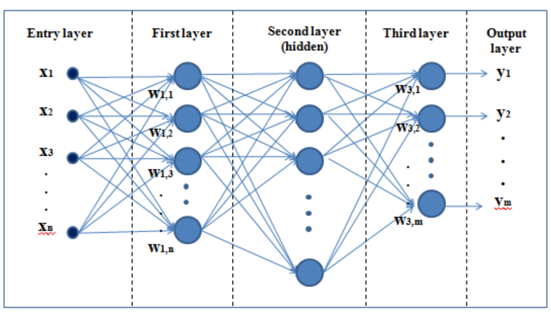

Figure 1/a. Artificial Neural Network

b.

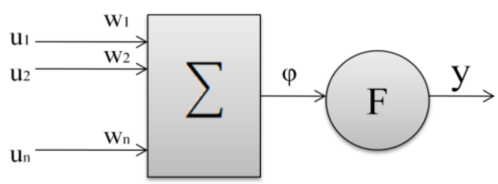

Figure 1/b. Biological Neuron Model

A natural neuron is built from dendrites which provide signals by synaptic connections to neuron nucleus. In the nucleus all provided signals are then summed. Signal is leaving the neuron by axon, where activation function is realized.

1.2. The neural classifier

Neural classifiers are widely adopted in diagnostics, because they allow mapping multidimensional symptoms into technically defined classes. Such mapping with mathematic formulas would be complex; however, neural networks can approximate this mapping.

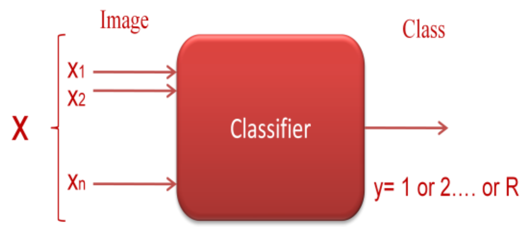

Figure 2. Scheme of Neural Classifier

Counter Propagation (CP) neural network is the compilation of Kohonen and Grossenberg architecture. The advantage of such approach is a theoretically unlimited ability to map input to output signals.

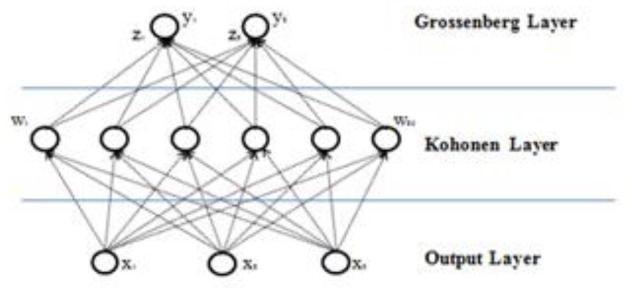

Figure 3. Architecture of CP Artificial Neural Network

Learning CP neural network happens in two steps: first the Kohonen layer is self-organized (Eq. 2), then the Grossenberg layer is learning on the basis of Widrow-Hoff learning rule (Eq. 4).

$$w_m^t x = \max\left(w_i^t x\right), \quad i = 1, \dots, n \tag{1}$$

$$w_m^{k+1} = w_m^k + \alpha(x - w_m^k) \tag{2}$$

$$w_i^{k+1} = w_i^k, \quad i \neq m \tag{3}$$

$$z_{ij}^{k+1} = z_{ij}^k + \beta(y_i - d_i)t_i \tag{4}$$

$$t_i = ||w_i - x_i|| \tag{5}$$

Where:
w - weight vector, x - input vector, y - output vector, d - learning vector, z - entry layer weight vector, k - time period, m - winning neuron number, n - number of neurons.

Counter Propagation neural networks can generalize and associate information. Relatively low demand for computing power needed for their realization results in wide adoption of CP neural networks.
This paper presents the implementation of Counter Propagation neural network in LabVIEW environment. In this document, neural classifier was used to recognize the technical state of rotational machines.

2. Implementation of Neural Network in LabVIEW

The authors built a NI LabVIEW library called *Neural Networks* that contains Virtual Instruments (VIs) for learning and implementing of Counter Propagation neural network. The first tool in this library is *Counter Propagation Network Learning* (Figure 4).

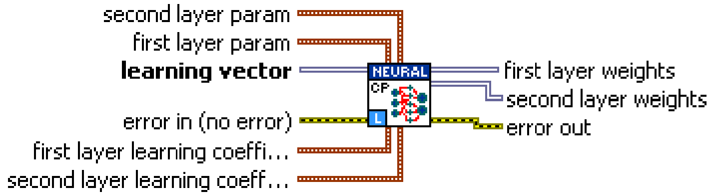

Figure 4. Counter Propagation Learning VI

This VI creates and learns Counter Propagation network. *First layer parameters* and *second layer parameters* terminal contains information of network architecture, such as: number of neurons, number of class, number of iterations, winning neurons number and number of neurons per class. VI returns weights of neurons, first and second layers, based on *learning vector*. This vector contains estimates of searching parameters.

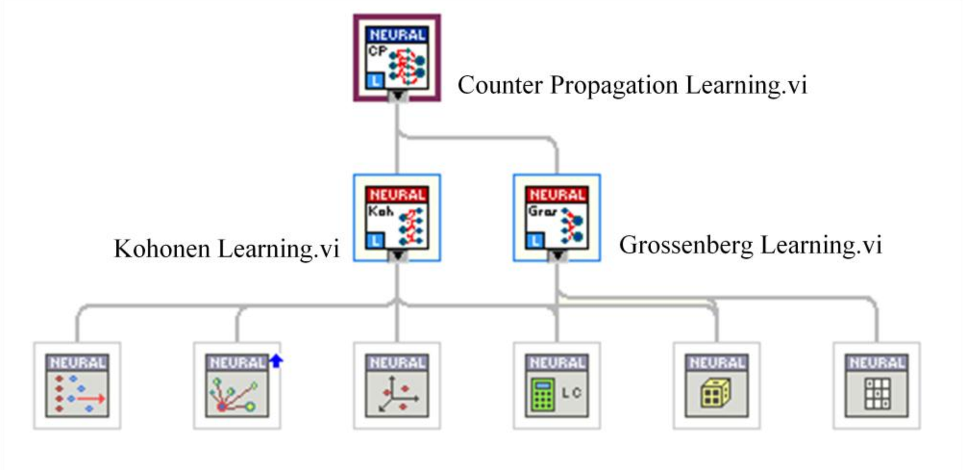

Figure 5. VI Hierarchy of Counter Propagation Learning

The library contains VIs to learn individual layers, such as *Kohonen Layer Learning* and *Grossenberg Layer Learning*.
The next tool in Neural Networks Library is *Counter Propagation Realization* (Figure 6).

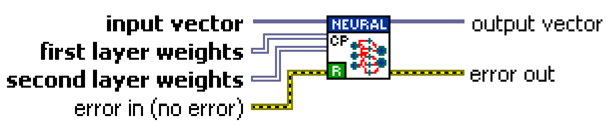

Figure 6. Counter Propagation Realization VI

This VI realizes previously trained Counter Propagation Network. The *first layer weights* and *second layer weights* terminal must contain weights of neurons calculated in the learning process. VI returns *output vector* based on estimates from *input vector.*
The Neural Networks Library contains also VIs to realize individual layers (Figure 7).

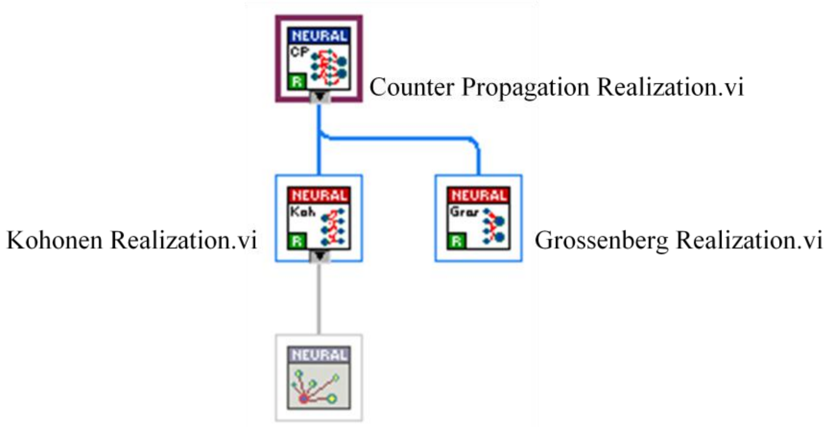

Figure 7. VI Hierarchy of Counter Propagation Realization

3. Neural Classifier Application.

The Neural Classifier Application was built based on a multithreaded structure in which three main parts can be distinguished: *data acquisition* with the highest priority, the *analysis* and *user interface* with the lowest priority (Figure 8). In the presented structure, the user interface thread plays the role of the master, who sends commands to other (slave) threads.

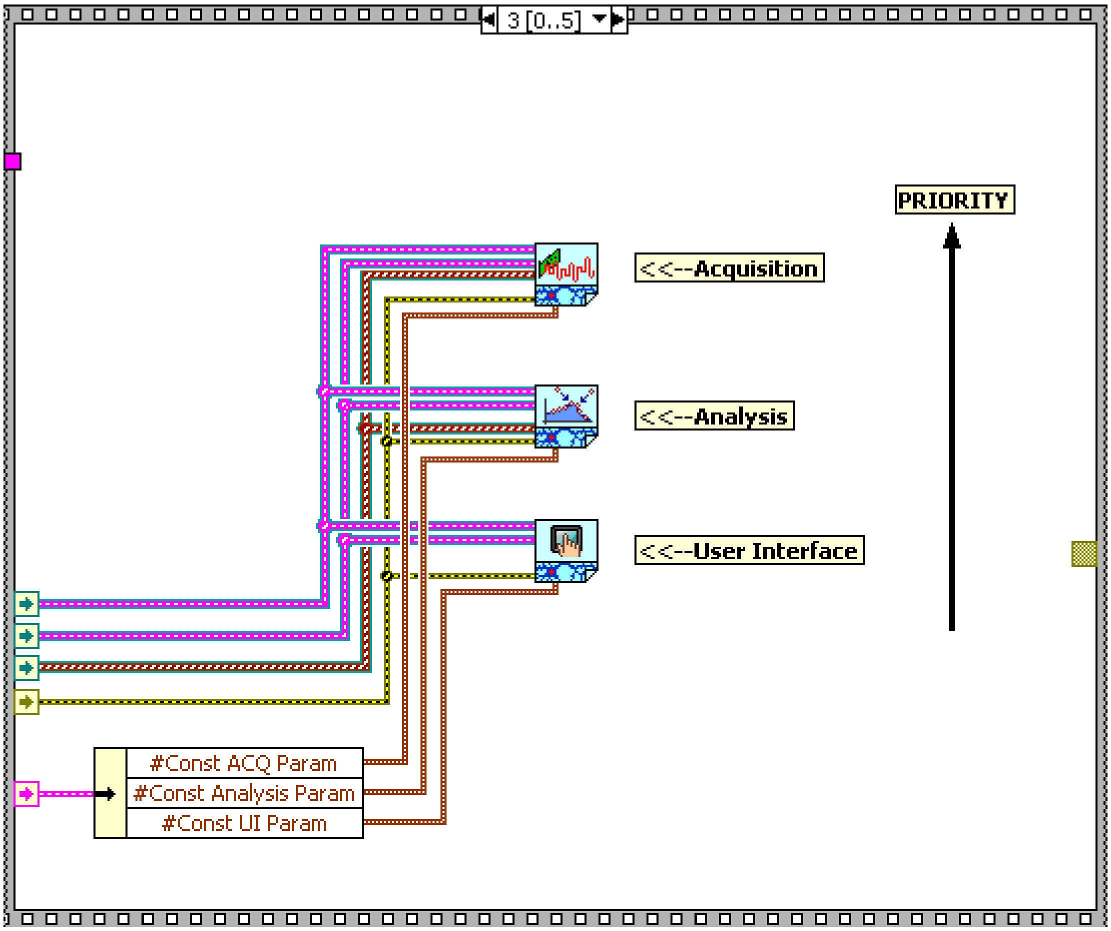

Figure 8. Neural Classifier - Application Structure

To validate the application, authors have conducted a diagnostic experiment, which was based on the assessment of the technical condition of a fan. NI USB-9233 boards were used to acquire vibroacoustic signal and marker-speed. The test bench and the block diagram are shown in Figures 9 and 10.

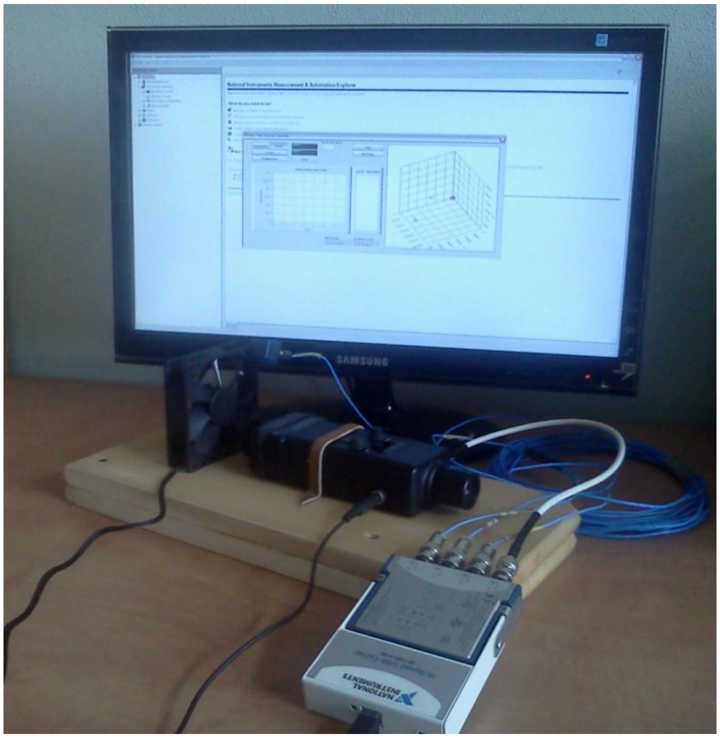

Figure 9. Testing Bench

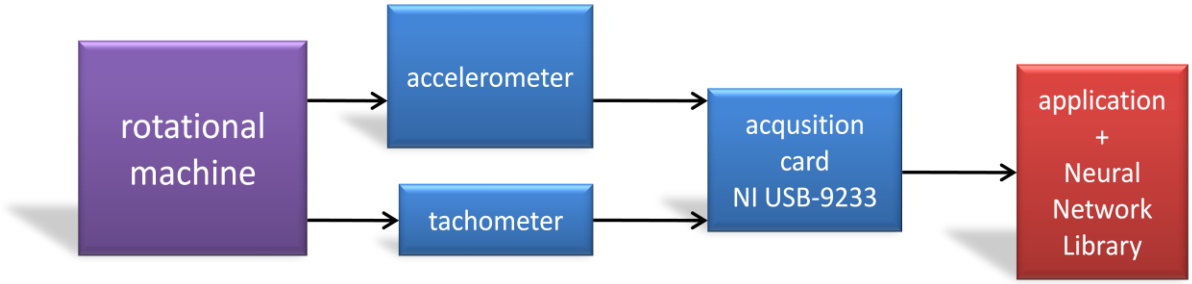

Figure 10. Block Diagram of the Test Bench

To determine the technical condition the authors used the estimates of the order spectrum designated by Order Analysis VIs from Sound and Vibration Toolkit.

As a result, the application was able to recognize the unbalance of the fan. The results can be seen on the Front Panel of the application (Figure 11). 3D graph presents recognizing symptoms by projected neural network: x axis presents first order, y axis – fourth order and z axis – fifth order. In the experiment two technical states of fan were being recognized such as "good" and "damaged". On 3D graph two groups of symptoms are presented for every technical state.

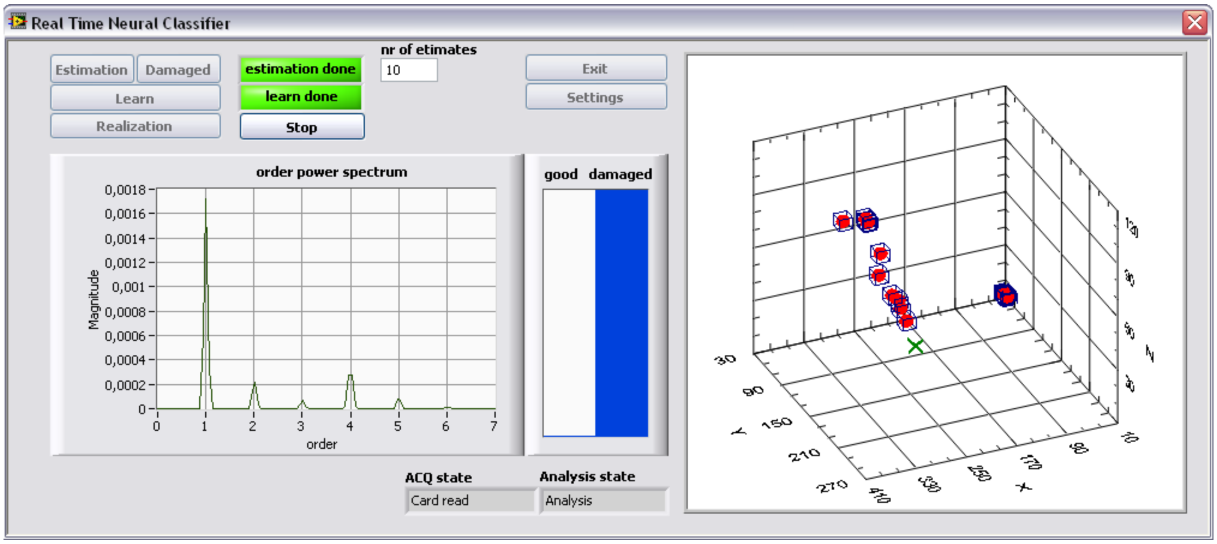

Figure 11. Neural Classifier - Front Panel

4. Conclusion

Currently there are no tools for the implementation of artificial neural networks in NI LabVIEW environment. This was the reason, why authors have built *"Neural Network"* library, which allows building CP neural network. Library has been tested on diagnostic rotation machines testing system. In the future the authors plan to extend projected library for other neural networks types.

NI ELVIS II Modules for Analogue and Digital Electronics

Author:

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The NI ELVIS II platform is designed for learning through interactive simulations and virtual instrumentation to build a bridge between theory and the actual behaviour of circuits. With the open architecture of NI ELVIS II, Esapi has developed laboratory exercises in the field of electrical engineering and informatics. Available laboratory exercises include:

1. MODULATIONS
   - Amplitude modulation
   - Frequency modulation
   - Pulse amplitude modulation
   - Pulse position modulation
   - Pulse width modulation
2. FILTERS
   - First order low-pass filter
   - Second order low-pass filter
   - First order high-pass filter
   - Second order high-pass filter
   - Active filters
3. AMPLIFIERS
   - Common emitter amplifier
   - Cascade amplifier
4. OSCILLATORS
   - Colpitts oscillator
   - Hartly oscillator
   - Wien oscillator
   - RC oscillator
   - CR oscillator
5. CONTROL AND REGULATION
   - First order system analyses (transient and frequency characteristics)
   - Second order system analyses (transient and frequency characteristics)

- Temperature measurement and regulation
- Active filters (transient and frequency characteristics)
- Step motor—control and regulation
- DC motor—control and regulation

Besides the possibilities of wiring circuits on a test board, ESAPI developed more than 30 different modules that can be put on the test board under the plug-and-play principle. The focus has been set on completing the task, measuring and understanding the principles and circuit characteristics. Worksheets with instructions are provided for all exercises in Croatian and in English.

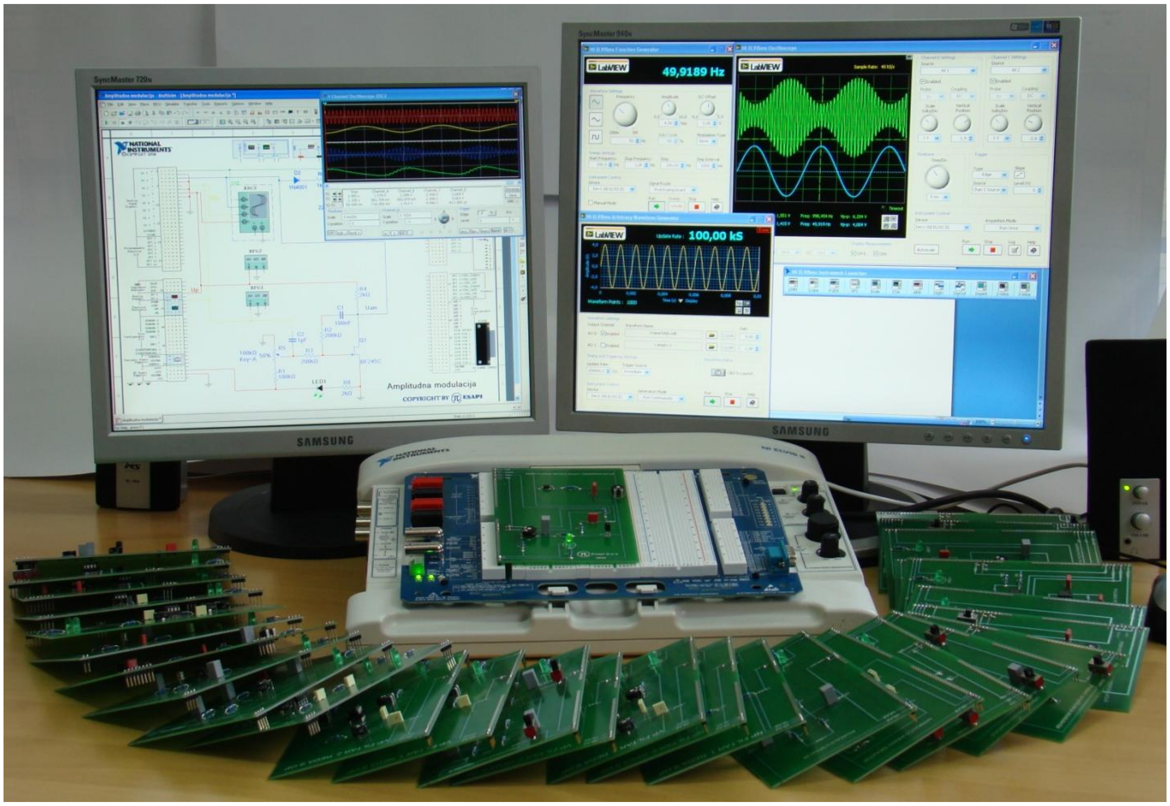

Figure 1. ESAPI Modules for NI ELVIS II

Several exercises will be shown as examples of how to approach the problem through theory, simulation and the actual circuit.

Example 1: Amplitude modulation

In this exercise, students perform the simulation in NI Multisim and record characteristics from the oscilloscope and Bode plotter.

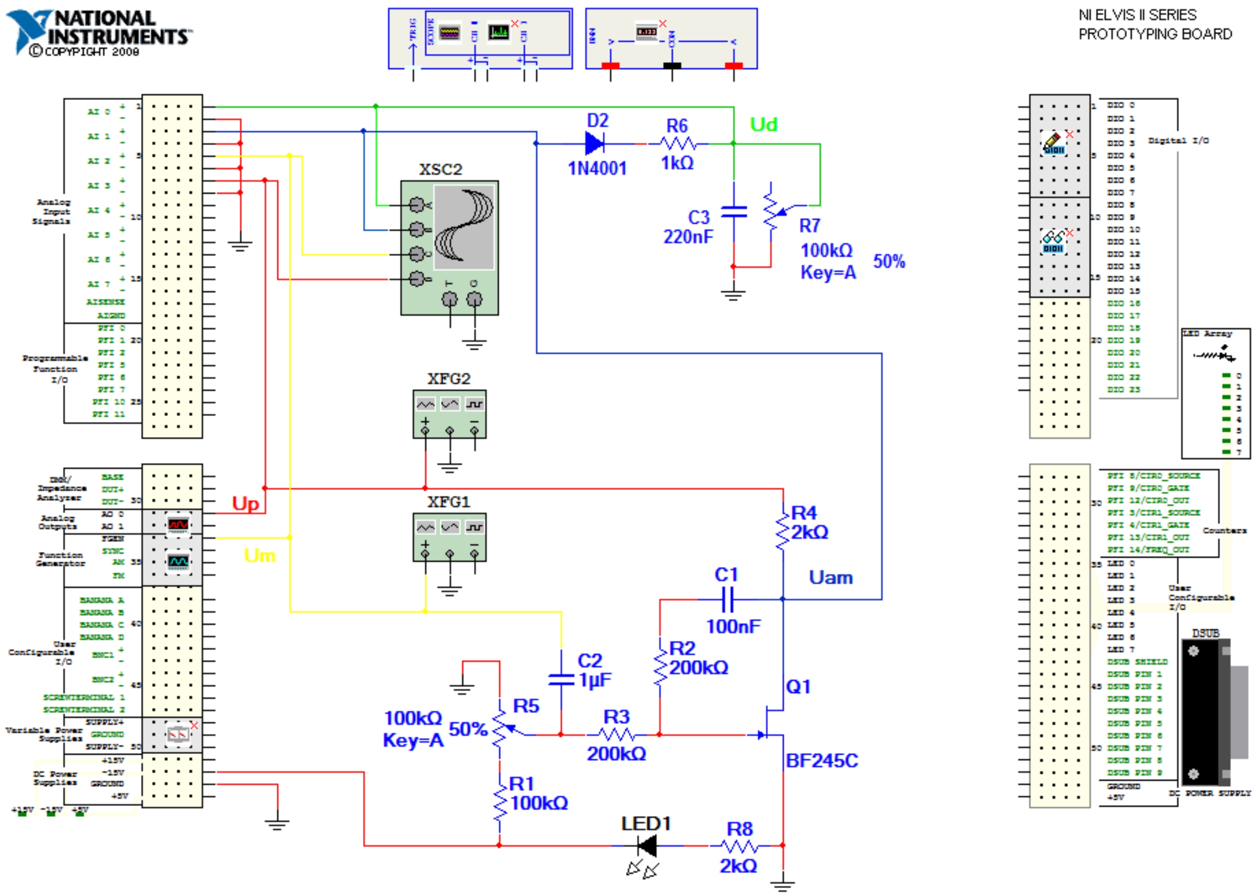

Figure 2. NI Multisim Scheme

The lower part of the scheme is an amplitude modulator made of n-JFET. The XFG2 generates a carrier signal in the Up position. It is connected to the JFET drain through a resistor. Modulation of the Um signal is generated by XFG1. The variable resistor R5 sets the negative voltage on the JFET gate. The Uam output amplitude modulated signal goes to a demodulator consisting of diodes, capacitors and variable resistors that can change the shape of the Ud demodulating signal.

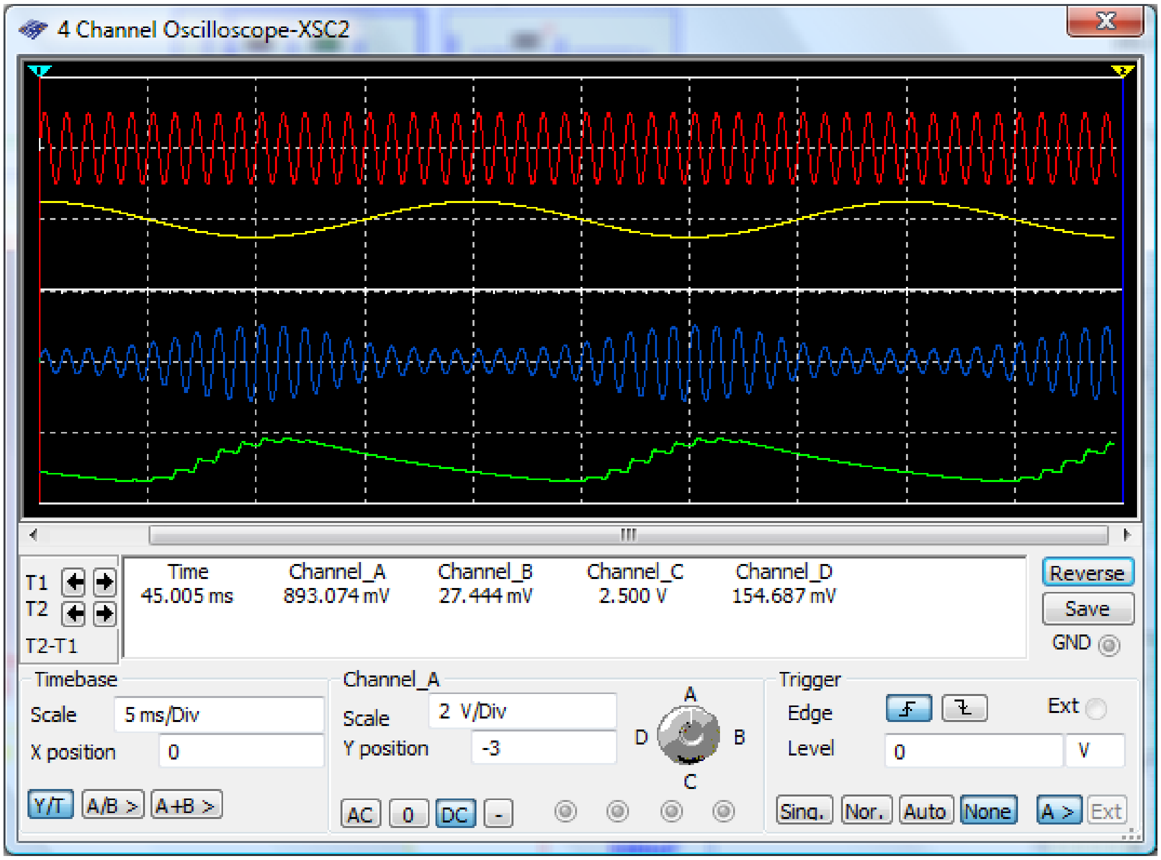

Figure 3. The Result of the Simulation

In the second part of the exercise, students insert a module on the NI ELVIS II platform, take the measurement on the real circuit and compare the results.

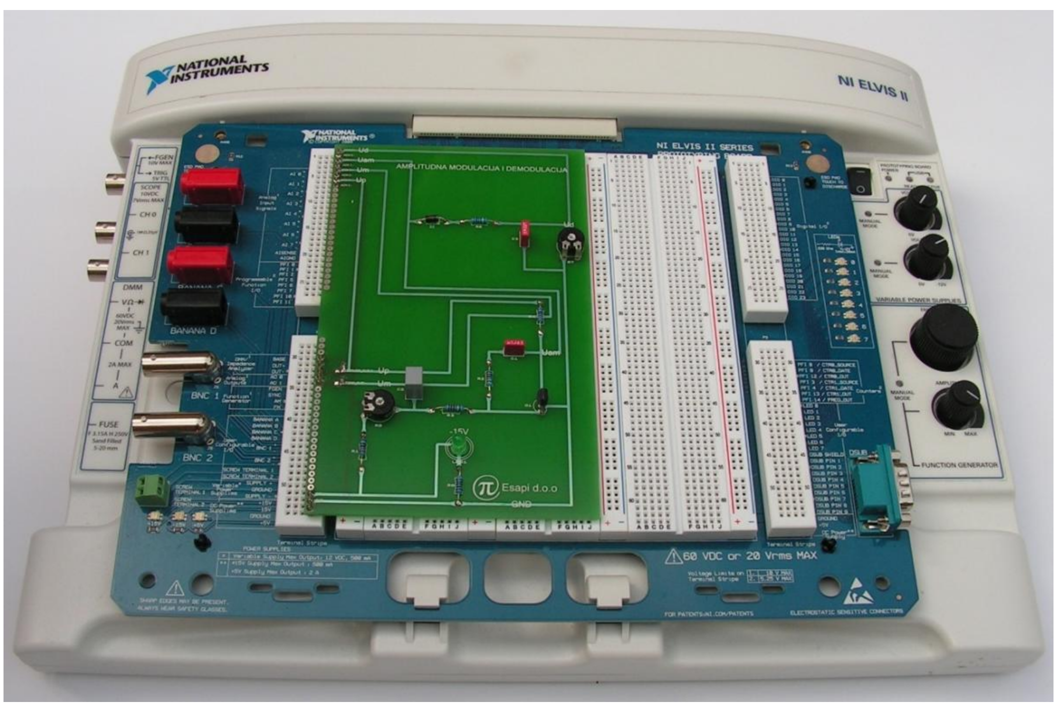

Figure 4. NI ELVIS II Module for Amplitude Modulation and Demodulation

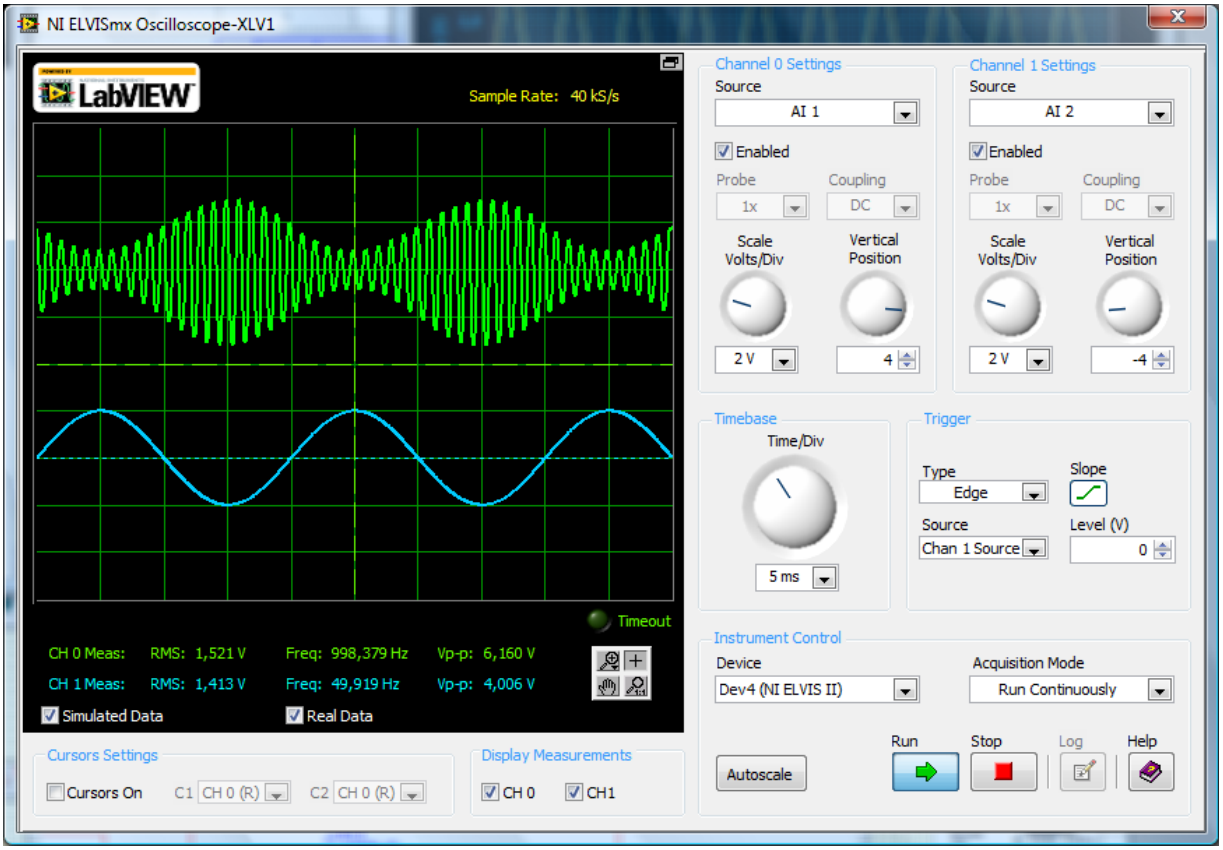

Figure 5. The Uam Amplitude Modulated Signal and the Um Modulating Signal form NI ELVIS II

Example 2: Step motor – control and regulation

In the introduction to this exercise there is a theoretical explanation of step motor structure and its properties. This exercise shows the principle of a unipolar step motor with a permanent magnet and 96 steps for a full circle. The LabVIEW program is a simple scheme and animation of the step motor connected to the NI ELVIS prototyping board. This is how the unipolar step motor looks inside and out:

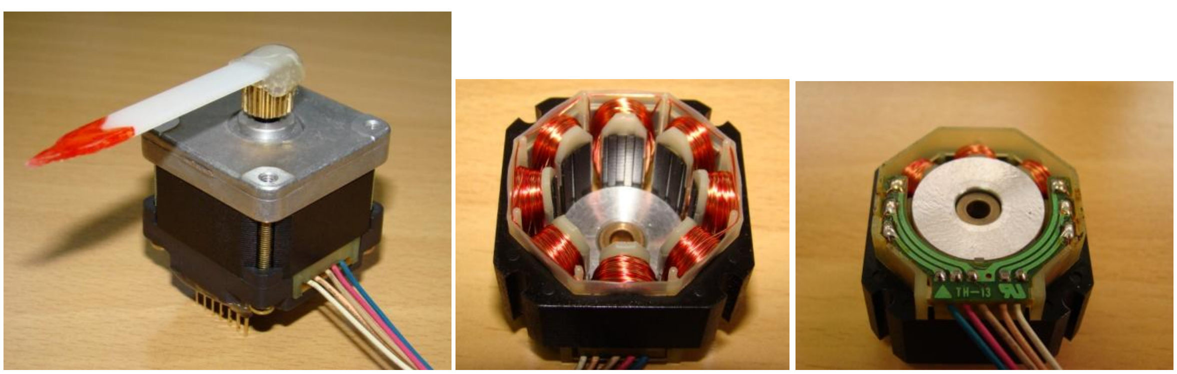

Figure 6. Unipolar Step Motor

According to the NI Multisim scheme, students have to connect circuit elements on a prototyping board and run the LabVIEW application.

NATIONAL INSTRUMENTS

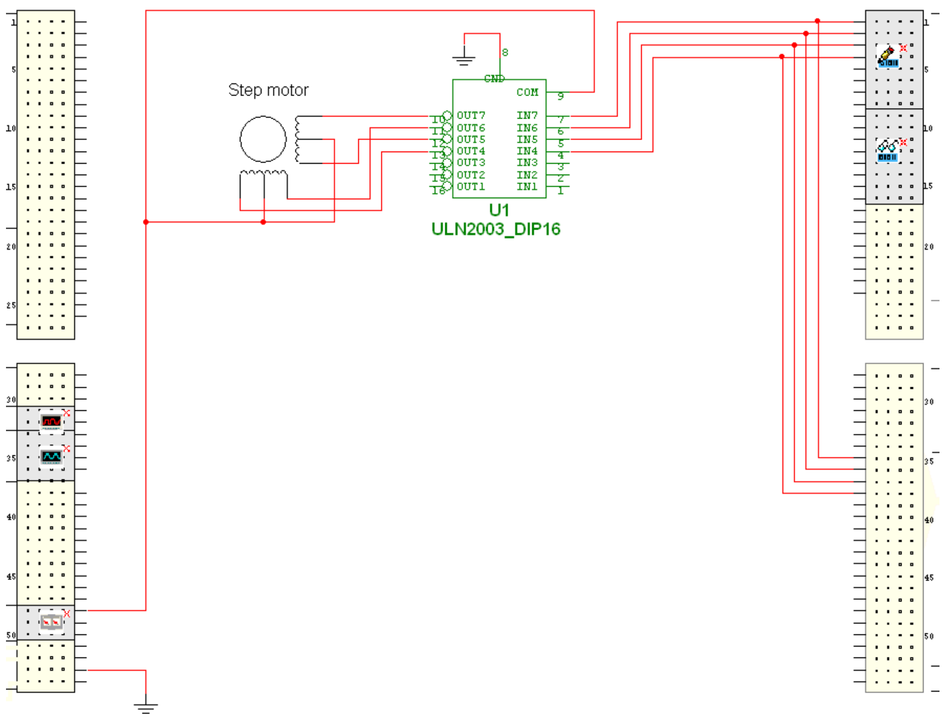

Figure 7. NI Multisim Scheme

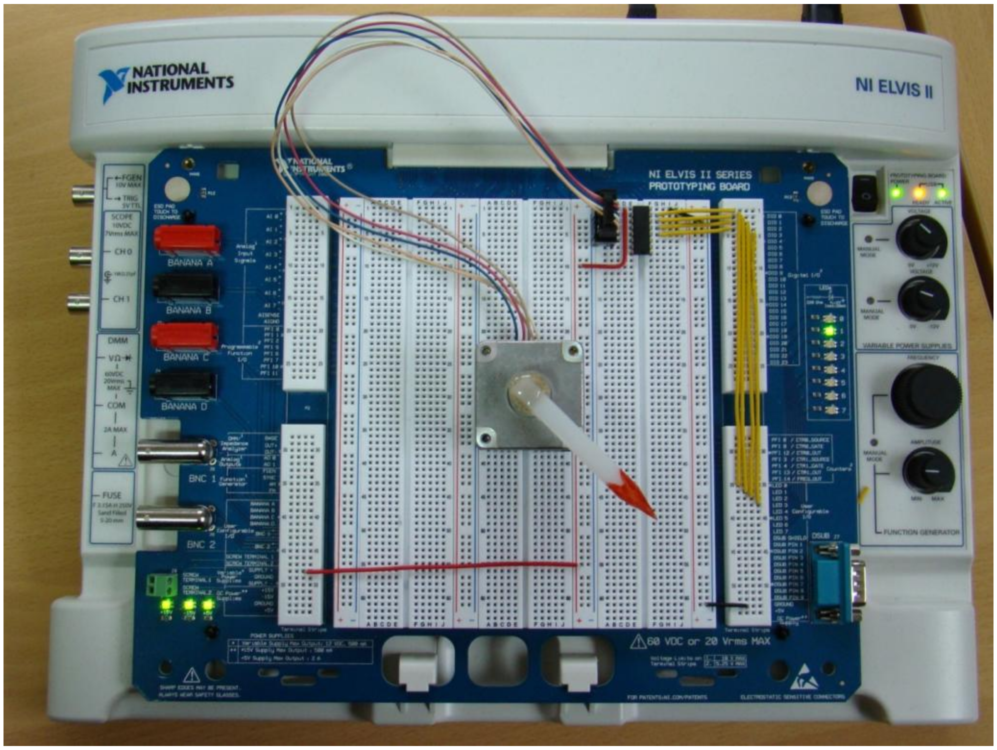

Figure 8. NI ELVIS Wiring

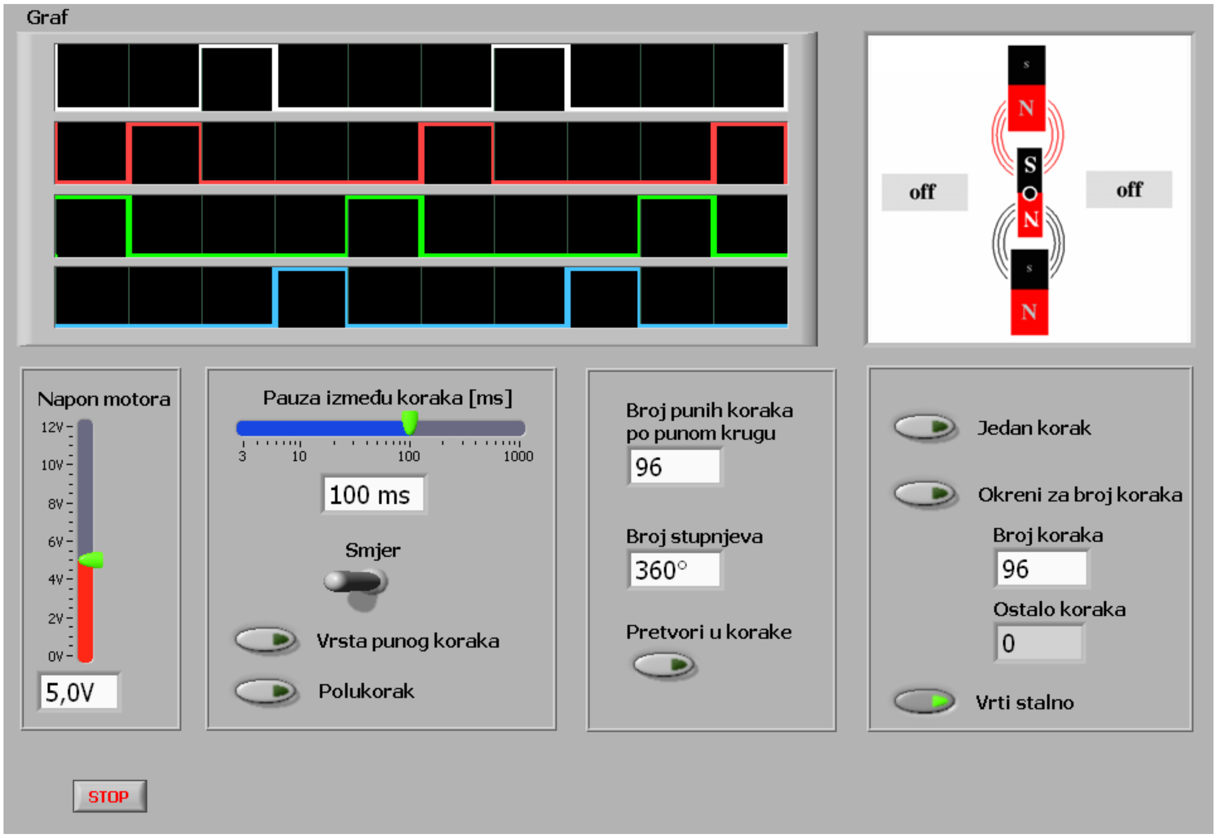

Figure 9. LabVIEW Application

Using the universal NI ELVIS platform in education and research institutions provides high-quality interaction between teachers and students. Students are directly involved in design and manufacturing exercises from different areas, combining the practical and theoretical knowledge they have acquired during their education. Subsequently, teaching performance is improved and students prepare themselves for modern approaches to acquiring knowledge.

As this is open architecture, it is possible to design applications based on the students' own requirements.

Preliminary Studies for Developing a Device for Ultrasound Computed Tomography based upon National Instruments PXI

Authors:

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[1] University of Debrecen, Faculty of Informatics,

[2] National Instruments Hungary Software és Hardware Gyártó Kft.

Abstract

The conventional non-destructive ultrasound-based diagnostic imaging system [1] where a manually operated linear transducer array only records reflections is widely used today. The spatial resolution of these instruments is around a few millimeters depending on the applied wavelength, focusing quality and user experience.
In Ultrasound Computed Tomography (Ultrasound-CT or USCT), however, a huge amount of transducers is arranged around the investigated area in a fixed geometry. This method eliminates the human error and therewith is capable of taking reproducible volume-images with sub-millimeter resolution and higher contrast than conventional instruments. Although the idea of ultrasound computer tomography goes back to the 70's [2] and some remarkable academic experimental instruments have been developed since then [3], building a commercial device has never been successful due to the huge data rate and time-consuming image reconstruction processes. Therefore, the development of a simple experimental USCT instrument can be both a technical challenge as well as an educational project to support experiential learning. It allows students to solve interesting problems and to build complex computer controlled instruments with data and image processing.

Our first simple experimental USCT instrument

Our measurement system consists of three main parts; a ring of eight transmitter-receiver pairs in a fixed geometry, a National Instrument (NI) PXIe based system for instrumentation as well as LabVIEW, LabWindows/CVI, C/C++ and SciLab software environments for data acquisition, image reconstruction and visualization (Figure 1). In the early phase of the development we were using microcontroller and FPGA technology to develop our first prototype. Later we chose a NI PXI because it enabled us to have a very flexible, scalable system with the ability of running a number of different test scenarios.

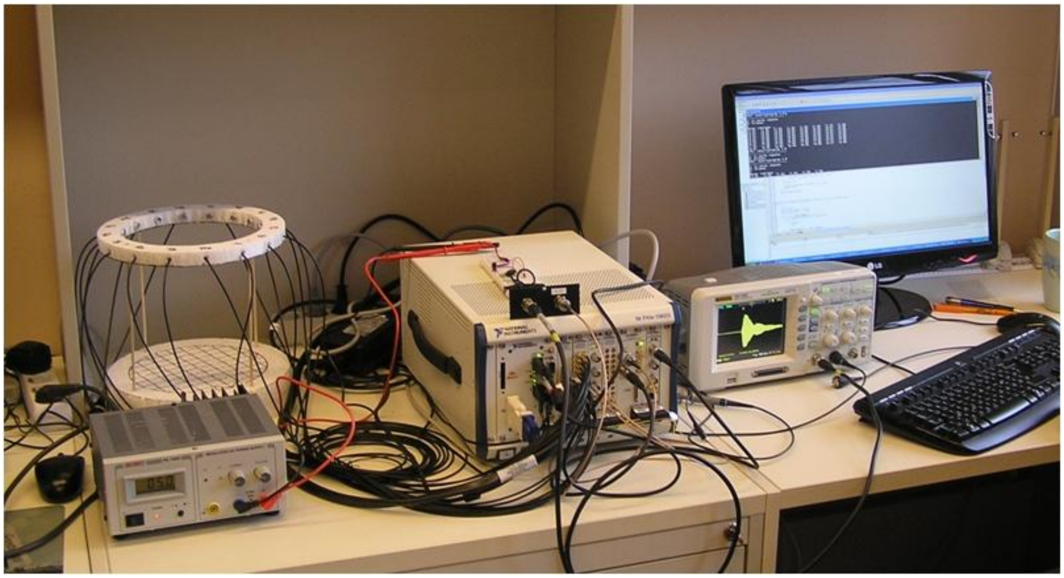

Figure 1. *The hardware of our first experimental USCT system.* ***Left:*** *The 200 mm diameter ring of eight transmitter-receiver pairs (Murata 400ST100 and 400SR100), called "Predator".* ***Center:*** *The NI PXI based system (NI PXIe-1062Q) equipped with Embedded Controller (NI PXIe-8106), Arbitrary Waveform Generator (NI PXI-5411), 500 MHz Dual 8x1 50Ω Multiplexer (NI PXI-2593) and 12 bit 200 Ms/s Digitizer (NI PXI-5124).*

The examined object simply was a 40 mm diameter cake jelly cylinder placed inside the detector ring in air as a coupling medium (Figure 2., Left).

Under power a transmitter emits a short pulse of 40 kHz frequency undirected beam with spherical wave front, while eight receivers measure the transmitted, reflected and scattered signals simultaneously. The received signals are amplified, digitized, frequency filtered, Hilbert-transformed for determining the envelope and stored in a binary file for latter image reconstruction. Another transmitter emits an ultrasound pulse and so on. These processes are being controlled by NI LabVIEW. NI LabVIEW and LabWindows/CVI applications also carry out all necessary calculations.

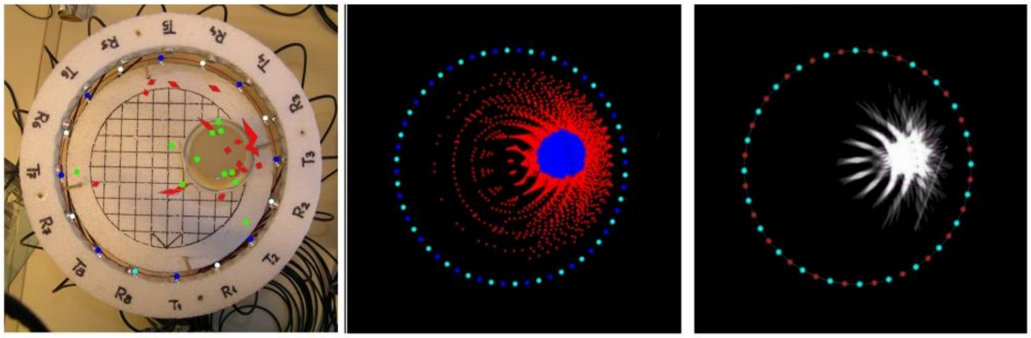

Figure 2. Left: *Measurement based Ultrasonic-CT reconstructions of jelly target by applying the Intensity-Changes (green dots) and Radon-Transform based Back-Projection (red areas) methods.* ***Center:*** *Our simulation for TOF and Intensity-Change based image reconstruction methods with 30 transmitter-receiver pairs. The red dots show the intersection of those lines where TOF or intensity changes happened. Blue dots show the reconstructed image of the target following our False Intersections Filtering Method.* ***Right:*** *Simulation of Radon-Transform based Back-Projection image reconstruction method with 24 transmitter-receiver pairs.*

Since the different shape and material of objects do influence the transmitted signal in different ways, tone can retrieve information about the internal structure of the investigated area by comparing the received field of signals to a reference that one has measured without the object in air.

We tested different image reconstruction methods, i.e. time of flight (TOF) and Intensity Change distribution as well as Radon-Transform based Back-Projection (Figure 2, Left). Furthermore, we have developed an effective algorithm for False Intersections Filtering and made sufficient simulations with the initial and larger number of transmitter-receiver pair for checking the scope of our models and future planning (Figure 2, Center and Right). For these calculations and for displaying data in the beginning we applied C/C++ and SciLab programming environments, but now we utilize NI LabVIEW and LabWindows/CVI. The parts developed in NI LabWindows CVI act as the user interface and basically as a framework. We had a modular programming approach, so it was possible to have code modules developed in different programming environments solving different tasks.

Summary

We succeeded to build and test a very simple experimental Ultrasound-CT. Although the spatial resolution of our preliminary measurements due to the small number of transmitter-receiver pairs was very low, we could understand the basic physical processes. Also we were able to test several different experimental configurations, the necessary basic instrumentation, algorithms and software environments. Furthermore, we had sufficient experience for further work towards using experimental arrangements with a higher number of 3D arranged transmitter-receiver pairs in fluid as a coupling medium. In all of these investigations the NI PXI platform as well as

NI LabVIEW and LabWindows/CVI software environments turned out to be the right choices because of their seamless connectivity with data acquisition and control hardware as well as their execution performance and flexibility.

Acknowledgement

The authors would like to thank National Instruments Hungary Kft. for supporting their work with contributing the PXI based measurement hardware. Furthermore, this work is supported by the TÁMOP 4.2.1./B-09/1/KONV-2010-0007 project. The project is implemented through the New Hungary Development Plan, co-financed by the European Social Fund and the European Regional Development Fund.

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Using LabVIEW and NI PXI to Optimize a Measurement and Automation System for Aluminium Electrolytic Capacitor Research and Development

Authors:

Dénes Fodor - *Member of IEEE*, Pannon University, Department of Electrical and Information Systems

László Kovács - *EPCOS* (*IT Student),* Electronic Parts and Components Ltd.

Industry:

Electronics

Products:

LabVIEW, PXI-1042, PXI-8185, PXI-6723, PXI-8420, PXI-GPIB

The Challenge:

Developing a measurement and automation system to facilitate electrolyte and capacitor research and development and providing a powerful database system for data retrieval and decision support.

The Solution:

Using NI LabVIEW software and PXI hardware to create a measurement and automation system that decreases research and development time for new electrolytic capacitors.

"This compact system gives us equivalent performance to a PC-based data acquisition and measurement control system with added functions such as trigger buses, increased bus speed, and rugged and modular packaging. We easily integrated the different measuring instruments, which can communicate through RS232 and RS485, into the system with the help of the NI PXI-GPIB and NI PXI-8420 communication modules."

Introduction [1], [2]

Capacitors play an important role in our world. They are in every electronic device, as well as energy storage elements, filters, advancers, and decouplers. The main features of capacitors are capacity (1 pF to 1 F), operational voltage (from 1.5 V up to some kV), operational temperature (from -55 °C to 125 °C), loss factor, size, and shape.

The four capacitors used most frequently in the industry are ceramic, foil, electrolytic, and tantalum. They are commonly used in applications such as coupling and radio frequencies, power supply, power storage, and power electronics. Electrolytic capacitors are the most common.

The main advantage of an electrolytic capacitor is a high capacity and voltage value due to its thin, but large, dielectric layer surface. Its main disadvantage is sensitivity to over voltages.

The main characteristics of electrolytic capacitors are determined by the electrolyte, the anode foil, and the paper separator.

The electrolyte generally consists of solvent (for example, ethylene glycol), acids and bases (usually organic), and different additives. Electrolytes are characterized by two major features: conductivity and breakdown potential, which are both dependent on the temperature. The change of conductivity as a function of temperature decisively affects the electric parameters of the capacitor. The chemical reactions that take place inside the electrolyte directly relate to the conductivity value at different temperatures, so it's important to quantify this relationship.

The conductivity and breakdown potential of the electrolyte influences the maximum operating condition of the capacitors. We use electrolytes with high conductivity in the low-voltage capacitors and the electrolytes with low conductivity in the high-voltage capacitors.

Measurement Types

Electrolytic capacitor research and development involves taking measurements related to both electrolytes and capacitors. Electrolyte measurements consist of six measurement programs as follows:

- *Conductivity(T)*: measuring the temperature dependence of conductivity. This measurement is one of the most important measurements.
- *Ph(T)*: measuring the pH value as a function of temperature. The structure of the program is completely equal to Conductivity(T), with the exception of using a pH meter instead of a conductivity meter. The measurement is important because the pH value of the electrolyte in the electrolytic capacitor must be in a specified range.
- *Mixing(pH with single temperature)*: measuring pH value as a function of the concentration of an electrolyte composition at a specified temperature. We use this measurement to set up the pH value of the electrolyte.
- *Mixing(conductivity with single temperature)*: measuring conductivity as a function of the concentration of an electrolyte composition at a specified temperature.
- *Mixing(conductivity with multi temperature):* measuring conductivity as a function of the concentration of an electrolyte composition at several temperatures. We use this, along with Mixing(conductivity with single temperature), to set up the conductivity value of the electrolyte.

- *Spark detector:* measuring the breakdown potential of the electrolyte.

The main capacitor measurements are as follows:

- *Spark detector:* the structure of the program is similar to the electrolytic with one difference – the object of the measurement is the impregnated winding with the electrolyte, in which case we want to know the breakdown potential of the paper electrolyte system.
- *ESR (Equivalent Serial Resistance):* this measurement is mostly used to determine the resistance of the capacitor at different frequencies and temperatures.
- *Gas pressure:* measuring the internal gas pressure of the capacitor in various operating conditions.

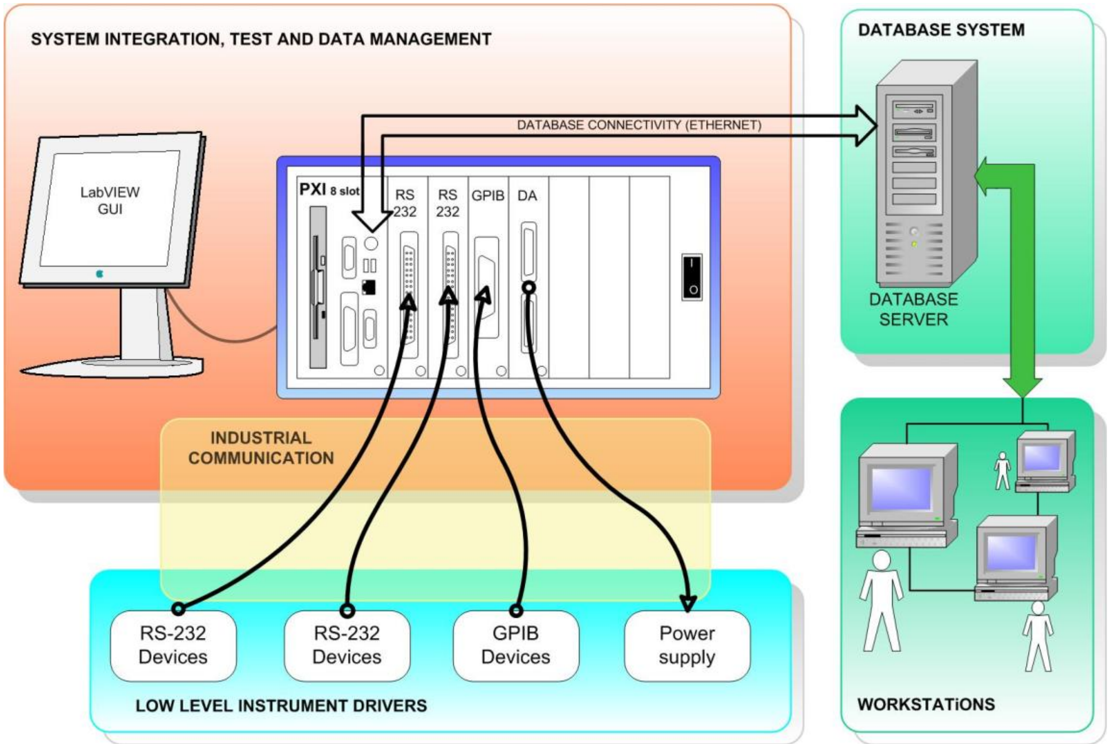

Figure 1. Automated Measurement System Architecture

Measurement System Architecture

The core of the automated system is the NI PXI-1042 chassis [3], with five modules including an NI PXI-8185 embedded controller [3], an NI PXI-6723 data acquisition module [3] for controlling the power supplies, and an NI PXI-8420 and NI PXI-GPIB for communicating with the measurement instruments via RS232, RS485 and GPIB [3] (see Figure 1).

This compact system gives us equivalent performance to a PC-based data acquisition and measurement control system with added functions such as trigger buses, increased bus speed, and rugged and modular packaging. We easily integrated the different measuring instruments, which can communicate through RS232, RS485, into the system with the help of the NI PXI-GPIB and NI PXI-8420 communication modules.

We also used the NI LabVIEW [5] graphical programming environment to develop the related communication routines (drivers) and measurement programs. We migrate the measurement results to a database where we can retrieve unpredicted and predicted data for evaluation and decision support [4].

Five out of the six electrolytic measurements share the same architecture structure (see Figure 2). The object of the measurement, the electrolyte, is located inside a double-jacketed vessel. Water is circulated by a thermostat in the external part of the vessel and the electrolyte is inside the vessel.

The pH meter and the conductivity meter provide the most important parameters. Each instrument has an electrode to measure the temperature, but only one is used during an experiment. The experimental setup requires the simultaneous operation of four individual instruments, such as a pH meter [7] [8], a conductivity meter [7] [9], a burette, and a thermostat [6]. Controlling and precisely following up the temperature is essential during the measurements so the thermostat device connects to the system every time. The burette is used only when we must know the variation of the pH or conductivity value as a function of a composition. The mixing type measurements give the relation of the conductivity or pH to the concentration of the examined component.

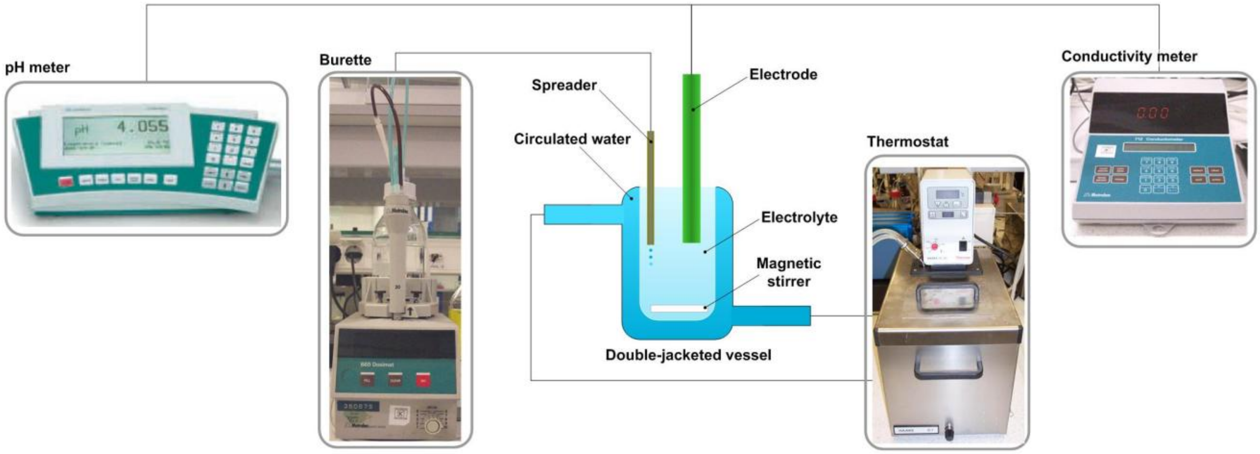

Figure 2: Diagram of Electrolytic Measurements

Conductivity(T) Measurement

The base of the software system is a framework originally designed to provide a common user interface for the different measurement programs. Despite the differences between the measurements, we integrated them into the above mentioned framework to manage the ports and instruments and to run the programs in parallel.

The measurement system includes at least 27 different measurements and we implemented them all in a similar manner. First, the user initializes the measurement, sets the measurement parameters, launches the execution, and leaves the program running on its own, sending the measurement results to a database system.

Two instruments are involved in this measurement: the thermostat and the conductivity meter. Before launching the program, the user initializes the measurement. During the measurement, the user can choose between two main tab controls ① (see Figure 3.): The *Set parameters* tab contains the parameters set for the measurement, while the *Measurement* tab shows the state flow of the measurement, graphs, and displays. The program cyclically executes the same steps. The state diagram ③ shows the current state of the measurement and the remaining time before the next phase.

First, the program sets up the temperature. On the temperature graphs ②, the user can check the measured temperature of the measuring probe and the thermostat. During *Stabilization time*, the temperature of the electrolyte becomes the same as the thermostat. Through the *Measuring & saving* phase, the important conductivity values ⑤ are locally measured and stored. The *Remaining time before the next measure* is shown with a progress bar ④. After the *Measuring & saving* phase, the program calculates the mean of the conductivity values from the stored data and only the results migrate into the database. The *Conductivity* ⑦ and *Temperature* ⑧ graphs show the conductivity and temperature as a function of the number of measures, which are the most important graphs because the user can check the electrolyte formation with direct correlation to the temperature. The measurement ends after the conductivity is measured at all the preset temperatures. The remaining time before the end of the experiment is shown during the measurements ⑥. The user can stop the program with the *STOP* button ⑨.

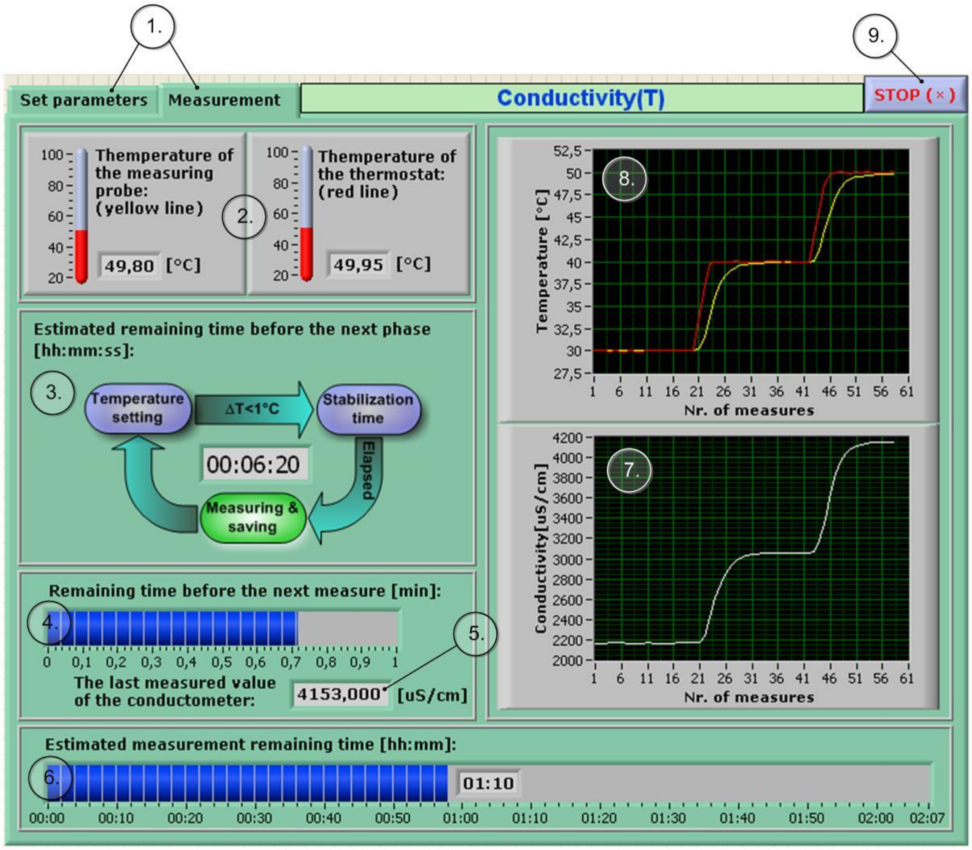

Figure 3. GUI of the Conductivity(T) Measurement Program

Results

Figure 4 shows how decisions are supported by the automated measurement system. Each dot represents a separate *Conductivity(T)* and *sparkling voltage* measurement result obtained at 85 °C by the automated system. From the graphical evaluation, users can select electrolytes with specific conductivity or sparkling voltages for further research.

With the help of the automated system, users can verify the formation of an electrolyte as a function of the temperature. Figure 5 illustrates measurement results of Electrolyte 1 and Electrolyte 2, which were performed with the *Conductivity(T)* measurement program. The conductivity of the electrolyte is measured more than once (usually 10 times) at the specified temperatures. The system calculates a mathematical mean from the measurement values at one temperature, indicated by the dots in Figure 5. As mentioned, the conductivity of the electrolyte decisively affects the electric parameters of the capacitor. Conductivity between 900 and 3,000 us/cm at 30 °C is considered low and conductivity around 10,000 us/cm at the same temperature is considered high. As Figure 5 shows, the conductivity of Electrolyte 1 measured at 30 °C is 1,500 us/cm and Electrolyte 2 is 2,300 us/cm at the same temperature, which indicates low conductivity in both cases resulting in high breakdown potential. For this reason, both electrolytes can be used in high-voltage capacitors.

Figure 6 illustrates the results of a capacitor type measurement. The resistance values of a capacitor as a function of frequency at different temperatures is given.

During capacitor development, we aspire to obtain as low a serial resistance as possible. To achieve this goal, we perform a series of experiments using different types of electrolyte and paper constructions.

Figure 6 shows the resistance values of the capacitor below zero degrees with linearity at lower frequencies (up to 1 KHz). Positive temperatures have the resistance values to show linear behaviours at frequencies above 1 KHz.

The application areas of the capacitors are based on the frequency dependence of the resistance value in different temperature ranges.

The *Mixing (conductivity with multi temperature)* measurement is an extended version of the *Conductivity(T)* measurement, which is completed using just a burette. With the *Mixing* measurement, we can observe the exfoliation of conductivity value as a function of a key component concentration of the used electrolyte (see Figure 7). The electrolyte conductivity is measured at 25 °C, 40 °C, 60 °C, and 85 °C many times (usually 10), without dosing the conductive salt solution. Each dot on Figure 7 represents a mathematical mean calculated from the measurement values at each temperature. After that, a predefined dosage from the conductive salt solution is added to the electrolyte and the conductivity measurements at different temperatures are repeated. The measurements are repeated 16 times, adding each time a new predefined conductive salt solution dosage to the electrolyte. Finally, the *Mixing* measurement results in 17 dots at each temperature.

According to the readings, the increase of the electrolyte conductivity is in direct relation to the quantity of the conductive salt solution.

The results can be applied to set up the conductivity value of an electrolyte.

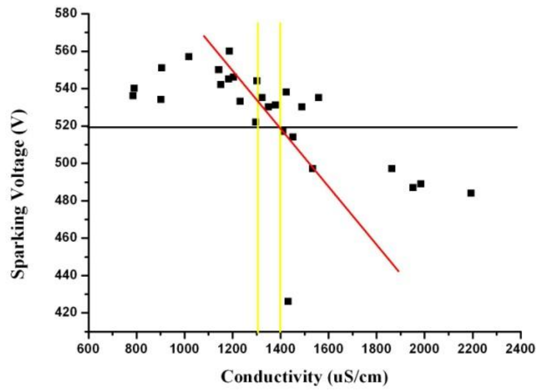

Figure 4. Conductivity Versus Sparkling Voltage of Various Electrolytes at 85 °C

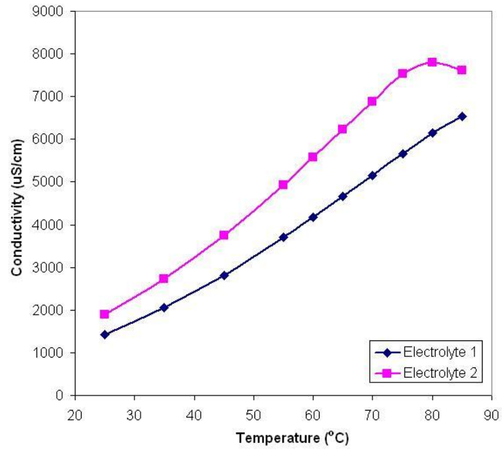

Figure 5. Result of the Measured Conductivity as a Function of Temperature of Electrolyte 1 and Electrolyte 2

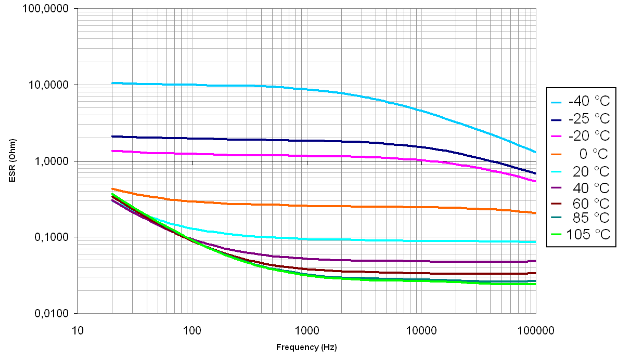

Figure 6. Result of the ESR Measurement, Capacitor Resistance as a Function of Frequency at Different Temperatures

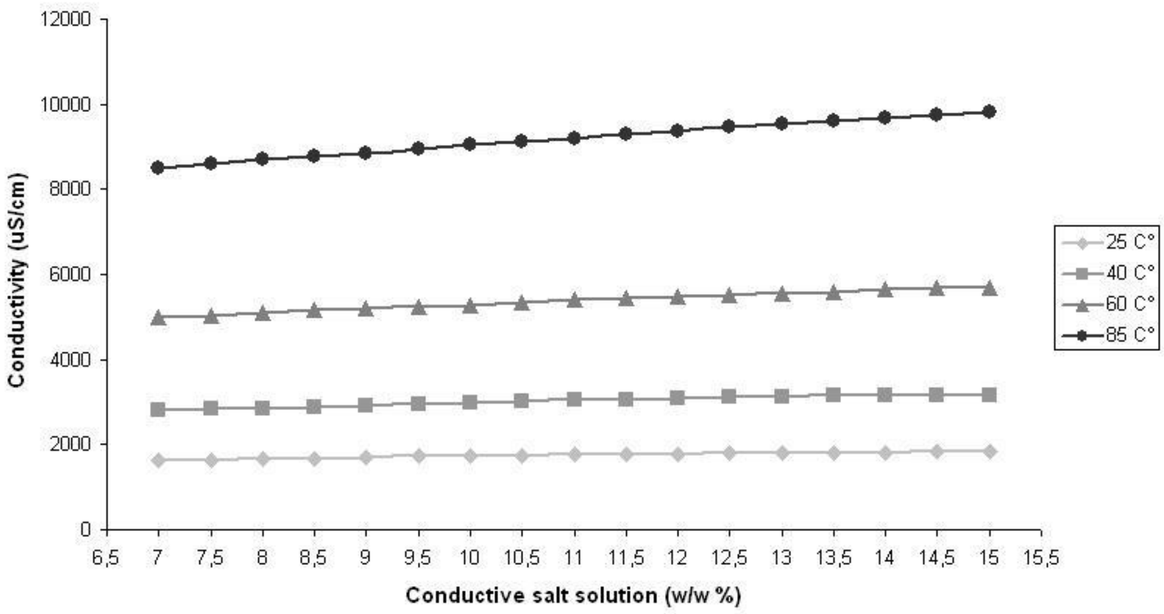

Figure 7. Electrolyte 1 Forming Conductivity as a Function of the Conductive Salt Solution Concentration

Conclusion

We created a system to automate more than 27 different electrolyte and capacitor measurements, all in a similar manner. The user initializes the measurement, sets the measurement parameters, launches the execution, and leaves the program to run on its own. It sends the measurement results to a database system where the data can be retrieved in a predefined or a nonpredefined way. After validating the measurement and automation system, we can make the measurements more precise and reliable, more fault tolerant (for example, missing of line voltage, open gate), and make the system run multiple measurements in parallel, which all contribute to speeding up the research and development of new components and devices.

After initializing a measurement, the system works on its own without help from the developer. The developed measurement system controls and harmonizes the different devices and supervises their work. The user simply checks the measurement phase by glancing at the screen. The program estimates and displays the running time of the experiment, allowing the researchers working on the lab to manage the instrumental resources and to schedule the new measurements in advance (for hours, weeks, and months). Another big advantage is the database system, which stores the result of each measurement in an easily searchable way. Users can create reports and diagrams automatically and reuse the results in later research.

Acknowledgements

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DC Motor Controller Using an ARM Cortex-M3 and the LabVIEW Embedded ARM Module

Authors:

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In this presentation, the authors will be showcasing the current results of an ongoing project: implementing a closed-loop DC motor controller using a Luminary Devices LM3S8962 ARM Cortex-M3 based microcontroller and the LabVIEW Embedded ARM module (LV ARM) as the graphical programming and code generation tool.

The LV ARM module is a C code generation tool, based on the Embedded Microprocessor SDK. The block diagrams are first translated to C code, grouped in a Keil uVision project (one of the “classic” IDEs for ARM microcontrollers) and then compiled. Some features worth mentioning include the possibility of debugging on the block diagram (as opposed to debugging the generated C code) and the ingenious way the interrupts are treated, via an interrupt handler subVI.

At the time of writing, only a couple of devices are supported by this module, among them the Luminary Devices LM3S8962, which is a powerful device based on an ARM Cortex-M3 core (256KB flash, 64KB SRAM, Ethernet, CAN, USB, 10-bit ADCs, PWM, timer/counter peripherals). For other devices, LV ARM provides a relatively user-friendly interface for custom configurations of graphically programmable access to the peripheral devices. Another development system tested by the authors (with less success than the LM3S8962) was the MCB2140 board from Keil.

Code generation—from LV ARM to executable binary

The basic principle behind LV ARM is the same for all high-level code-generation tools: the block diagram is “translated” to C code files, which are grouped under a Keil uVision project. This project is than compiled and assembled in classic fashion to obtain a binary file that can be downloaded to the ARM target.

In particular, the RTX kernel (a real-time operating system provided by Keil) is used as the base layer. The RTX kernel provides threading support for up to 16 threads. One downside is that the generated code size—for simple tasks—is much larger than for a traditional approach. During preliminary testing, an application that handles UART communication and displays results on the onboard OLED LCD was implemented in both classic C code and

LV ARM. The classic C-code implementation resulted in a 7KB binary file, while the LV ARM implementation resulted in a 30KB file. However, this discrepancy was not proportional when developing larger applications because most of the space in the 30KB file was taken by the RTX kernel (which is not useful in this particular circumstance, but can be a powerful and necessary feature in more complex multi-tasking applications).

DC motor speed measurement

Motor RPM measurement is physically implemented by means of 8 magnets that are equally dispersed on a disc attached to the rotor shaft of the motor and that pass by a Hall sensor. Eight digital pulses are provided per revolution. In order to obtain a measurement on the microcontroller side, the output from the Hall sensor was fed to a GPIO pin. An interrupt was configured based on a change to the GPIO pin; on each interrupt, a timer peripheral was reset and started counting; the time value when entering the interrupt gave the motor's RPM (RPM = (60*50M) / (8 * timer_value)).

The first aspect to be mentioned here is the very user-friendly manner in which interrupts are configured. Figure 1 shows this procedure.

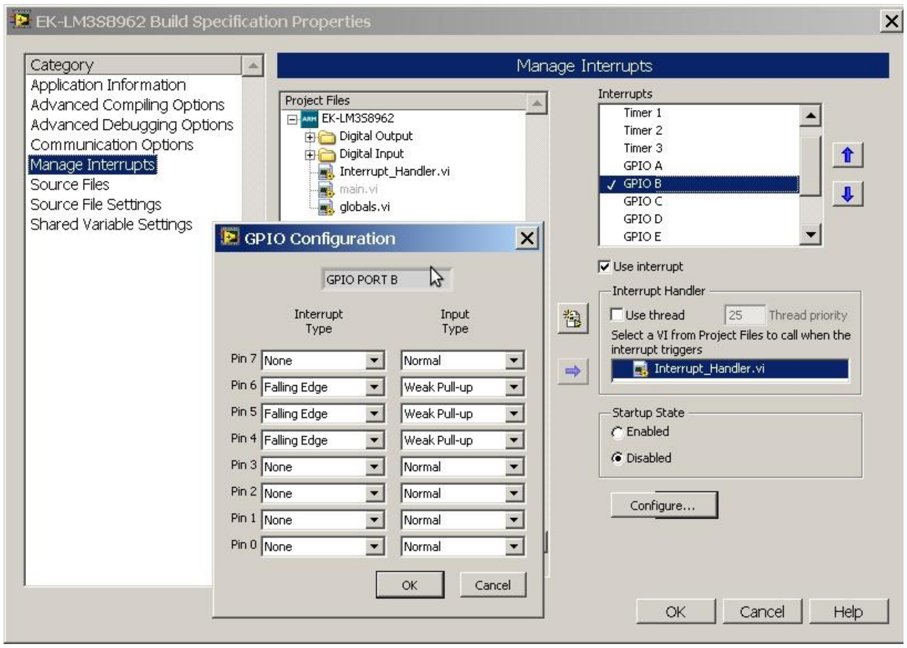

Figure 1. Interrupt setup

The second aspect is the interrupt handling routine—traditionally, a function in the C coding language—which in LV ARM is implemented as a special VI with 2 inputs: an interrupt vector (that determines the interrupt source) and "param." Figure 2 demonstrates an interrupt handler VI.

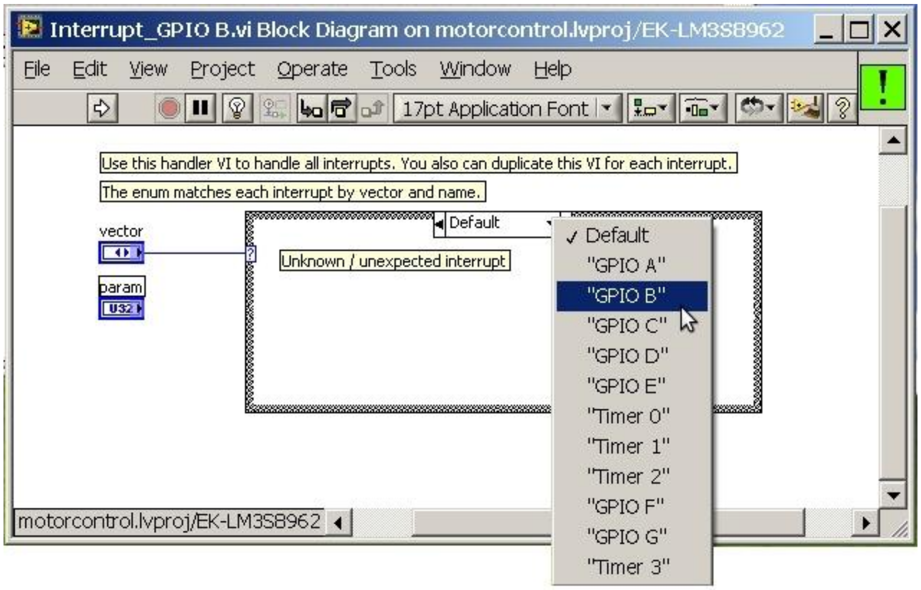

Figure 2. Interrupt Handler VI

An interesting fact is that the documentation provided with LV ARM does not explain the use of “param,” stating that it is not used. However, it was discovered by the authors that (at least in the case of an interrupt from a GPIO port) “param” provides a bit-masked value of the interrupt source (“vector” only provides the main source of the interrupt—GPIOA, GPIOB, etc—while “param” provides the information needed to determine the exact pin that triggered the interrupt).

The last aspect to be mentioned here is that, even for the “fully-supported” ARM devices, fine-grained control of the peripherals is not easily accessible. For example, the timer/capture peripherals can only be used as fixed-time interrupt triggers. However, using the versatile inline C node structure, and knowing that the peripheral driver library provided by Luminary Devices (a complete C code API for the device) is included in the project, configuring the timers in the desired operation mode was possible (continuous counting, reset on interrupt). Figure 3 depicts the method of using the inline C-node structure for fine-grained control over the peripherals and the above-stated interrupt source identification via the “param” input of the interrupt handler VI.

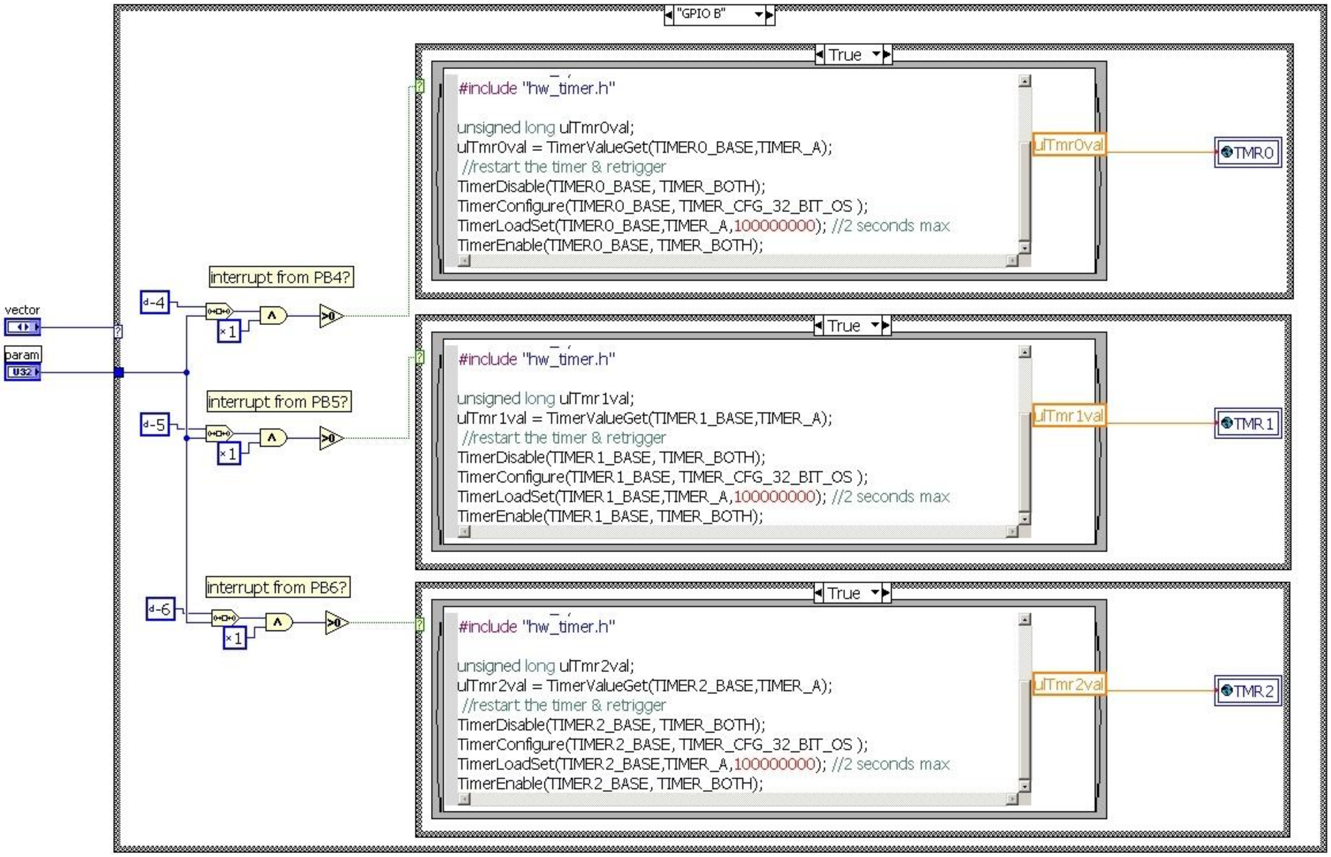

Figure 3. Using Inline C Nodes and Interrupt Source Handling

Closed-loop control

In order to achieve closed-loop control, a PID controller was implemented. A timed loop structure, with a 20ms period, was used as the main entry point (after peripheral configuration). The RTX kernel was successful at keeping the loop frequency stable at 50Hz, for PID controller operation at the same sampling frequency.
The PID subVI provided by the PID and Fuzzy Logic Toolkit was used. Fig. 4 shows the block diagram section that implements 2 PID controllers (for controlling two motors).

User interface and communication

A user interface VI was developed for the PC. This VI provides the user with control over the PID parameters, desired RPM setting (PID setpoint) and a few other parameters. The communication between the PC interface and the embedded platform is via an RS232 and is handled by the UART peripheral on the ARM device side, by polling the receiving buffer (instead of interrupts). All the UART-handling subVIs and string processing subVIs worked as expected.

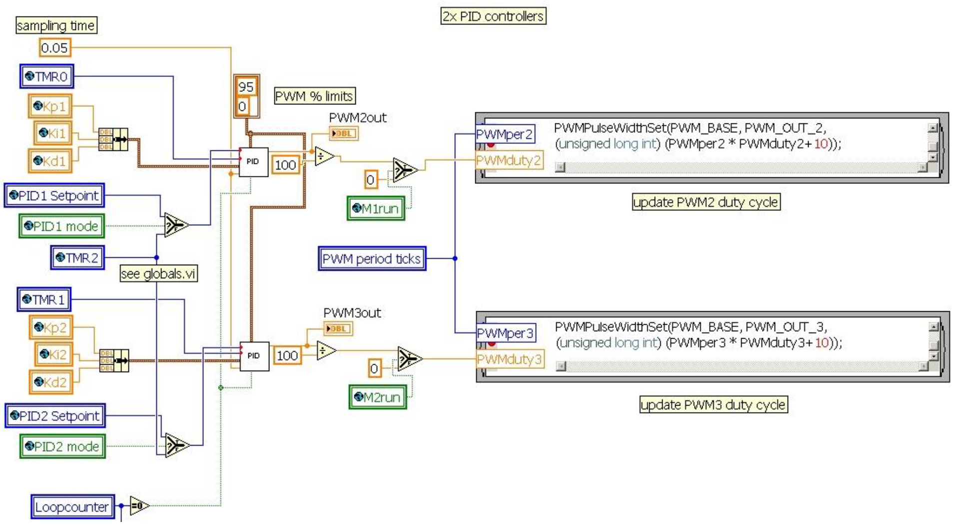

Figure 4. PID Controller

Conclusions and further work

The only problems the authors ran into when using the LV ARM module were peripheral-related (specifically timers and PWM). These were quite easily bypassed by using inline C nodes and the functions provided by the LM peripheral driver API.

All other features—UART, string processing, mathematical operations (even more advanced algorithms, such as the PID)—were found to work as expected.

Further work to be done includes replacement of UART communication with Ethernet, logging to a uSD card—all done via the subVIs provided by LabVIEW.

The next important step of the project is a hardware-in-the-loop test, to be done the moment the power stage & motor RPM feedback parts are completed.

Using the LV ARM module, the overall development time was reduced by as much as 50%.

Acknowledgement

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An Approach to Basic Electronics Laboratory Teaching at the Undergraduate Level

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Introduction

There are several approaches to the implementation of a computer-assisted laboratory for electronic education. In trying to keep the advantages of available concepts such as classical individual work, remote access laboratory, virtual laboratory and similar, this proposal is a mixed concept of a course laboratory for basic electronics at the introductory undergraduate level. A Computer Integrated Laboratory (CIL) allows for distance learning and virtual laboratory work while also keeping the physical experiment, substituting the majority of the instruments for virtual ones. The computer is used in practically in all phases of the work, starting from access and authorization, documentation, student-teacher interaction, simulation, virtual instrumentation synthesis, measurement control, distance learning and others. The results presented here are mostly related to virtual instrumentation development and physical laboratory work.

Among the technologies that enabled the blooming of this educational subject is clearly the development of the Internet. It brought several new procedures, commonly referred to as e-learning, distance learning, remote learning, collaborative learning and other similar ones. The Internet not only allowed for easy and cheap access to knowledge and better, faster student-teacher interaction but also introduced the possibility for new concepts such as virtual laboratories based mainly on simulations. The term "Remote" is now limited only by the borders of the Internet. In addition, several software packages such as LabVIEW™ enabled the development of what is now called virtual instrumentation, which completely simplified the subject of instrumentation. Thanks to this kind of software and accompanying hardware, practically every conceivable electronic instrument may be synthesized and made available to students at an incomparably low price.

A review of the solution

The goal of the laboratory work is to give students the possibility to experimentally verify theoretical lessons as they advance. The following exercises in basic electronics have been implemented:

- Diodes
- BJT–NPN and PNP transistors
- JFET

- MOSFET
- BJT Amplifier
- MOSFET Amplifier
- Multistage JFET amplifier
- Operational amplifier
- *Colpitts* oscillator
- Audio frequency power amplifier
- Rectifier and linear stabilizer

The layout of the laboratory is depicted in Figure 1.

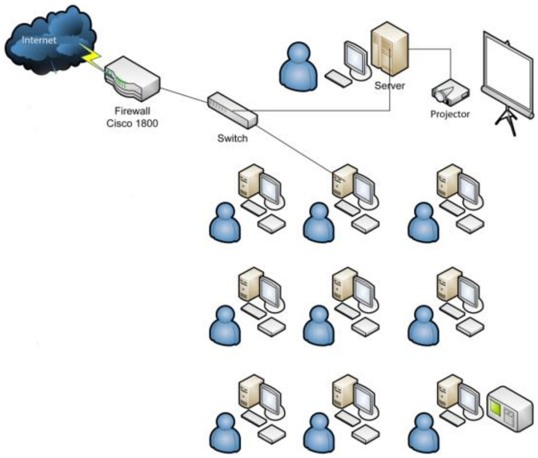

Figure 1. Layout of the Laboratory

The virtual instruments used for exercises that include diodes and various types of transistors have the characteristic curve tracer VI, which when used for amplifiers are a type of scalar network analyzer. An oscilloscope, frequency-meter and spectrum analyzer are also used to analyze specific electronic linear circuits.

Hardware implementation

The measuring unit, in our case, was implemented using the National Instruments USB-6251 acquisition module. The module has 16 analogue inputs with 1.25MS/s sampling rate, two analogue outputs with 2.8MS/s sampling rate, 24 digital I/O channels and two 24-bit counters. USB-6251 is a USB-based acquisition module. External signals or devices under testing can be connected with an acquisition module using a block panel. The analogue outputs of the acquisition module are used as DC voltage generators for the power supply and stimulus voltage. Maximal DC output voltage is limited to ±10V. This voltage is adequate for power supply, polarization and measurement of static characteristics of the semiconductor components. The measurement of voltages can be performed directly. Maximum input voltage is limited to ±10V. The measurement of currents can be performed only indirectly, by transforming current into voltage using a parallel resistor. In this implementation, a 100Ω, 1% tolerance metal-film resistor was used, due to the increased precision of the measurement. Consequently, the value of 1mA is equivalent to 0.1V. The value calculation is performed as a software function. The sampling rate of analogue inputs/outputs is sufficient to analyze transistor amplifiers and filters.

Software implementation

Virtual instruments are implemented in National Instruments' LabVIEW™ development package, which provides simple software creation and testing. Virtual instruments consist of an interface-to-acquisition card and an application with a graphical user interface. The user interface of the virtual instrument consists of visual controls and indicators. It provides basic functions for signal conditioning, measurement, and calculation of physical quantities. The user interface also provides controls for data manipulation and saving measured values.

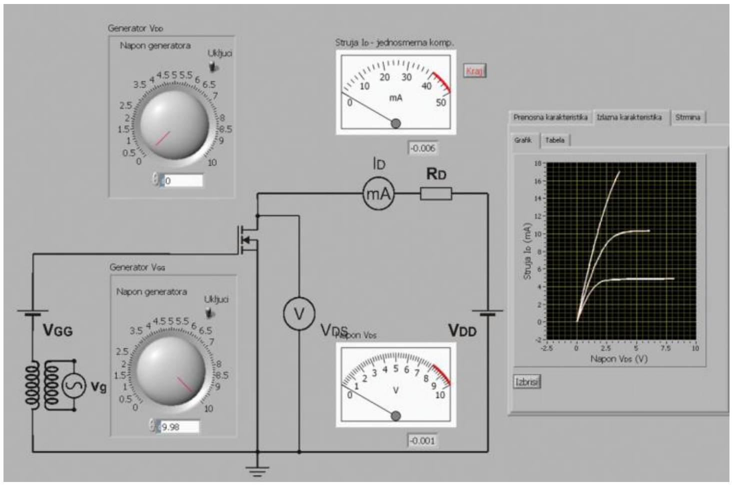

Figure. 2. User Interface of Component Characteristic Tracer—MOSFET Characteristic

The interface-to-acquisition card is implemented as device driver. Modules are supported by NI-DAQmx drivers. All the measurements are performed using virtual channels. A virtual channel is a collection of property settings that can include a name, a physical channel, input terminal connections, the type of measurement or generation and scaling information. A physical channel is a terminal or pin at which an analogue signal can be measured or generated. Virtual channels can be configured globally at the operating system level or by using an application interface in the program. Every physical channel on a device has a unique name.

The user interface (Figure 2) of the component characteristic tracer consists of visual controls and indicators. It provides basic functions for measurement. Visual controls—knobs and switches—provide control of analogue signal generation. The indicators—gauges and graphs—show the measured values. All measured values are placed in a table and, after the measurement process, in an appropriate file. The user interface also provides controls for data manipulation and saving measured values.

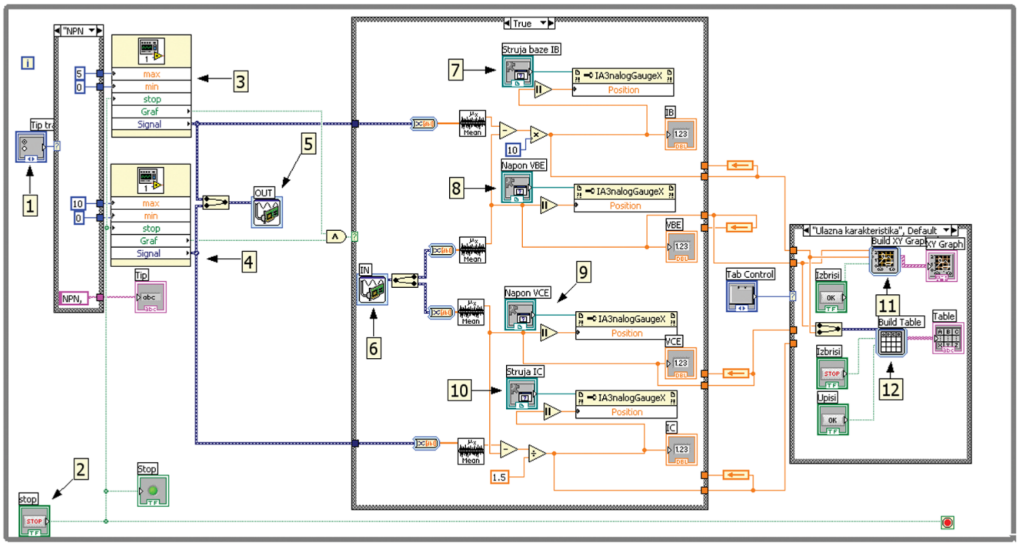

Figure. 3. Main Thread of the Application

For better performance, the main application has been separated into two threads. The first thread has functions for file manipulation and saving measured values (Figure 3).

Conclusion

A computer-integrated laboratory for analogue electronics has an educational purpose. The main goal of this system is to simplify the manipulation of instruments, speed measurement and notate the results, providing students the opportunity to concentrate on acquiring measurements. It can be successfully implemented at a graduate-level basic electronics course.

Inclusion of Virtual Instrumentation in the Learning of Electrical Measurements

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Electrical measurements course

The Faculty of Electrical Engineering and Computer Science at the University of Maribor offers first-level Bologna academic study programmes in Electrical Engineering, Mechatronics, Industrial Engineering and a professionally oriented study programme in Electrical Engineering. The electrical measurements course is compulsory for all those study programmes and serves as a basis for all subsequent laboratory courses. The goal of this course is to provide the student with basic knowledge about instrumentation and measurement in order to successfully design experiments and measurement systems.

The electrical measurements course contains 45 hours of lectures and 45 hours of practical laboratory work. The course for the professionally oriented study programme takes place in the first semester while for the academic study programmes are in the second semester. The lectures for the professional study programme are more practically oriented than the lectures for the academic study programme.

About 80 students of Bologna academic study programmes and 160 students of the professionally oriented study programme perform laboratory work every year. To allow the laboratory work to permeate students' minds, we must start with it early on in the beginning of the semester when the students start to attend the lectures. To fill the gap in theoretical knowledge, we start the laboratory work with a 16 hour hands-on LabVIEW course that lasts four weeks. After the LabVIEW course, the students perform traditional exercises. During the LabVIEW course, the students get basic knowledge about virtual instrumentation, which allow for the supplementing of traditional exercises with virtual instrumentation. Some exercises were prepared with the classical instrumentation and virtual instrumentation in parallel to demonstrate the differences. Twelve measurement work places, designed specifically for these exercises, are composed of (refer to Figure 1):

- laboratory table with built-in ordinary modular instruments such as function generator, multimeter and oscilloscope,
- various built-in power sources,
- a panel for Measurands,
- PC with Windows and all necessary software (LabVIEW, Multisim, Office, etc.),

- PCI-6024E multifunction data acquisition board from National Instruments with a connection module at the front of the table,
- GPIB plug-in controller from National Instruments with a connector built-in table.

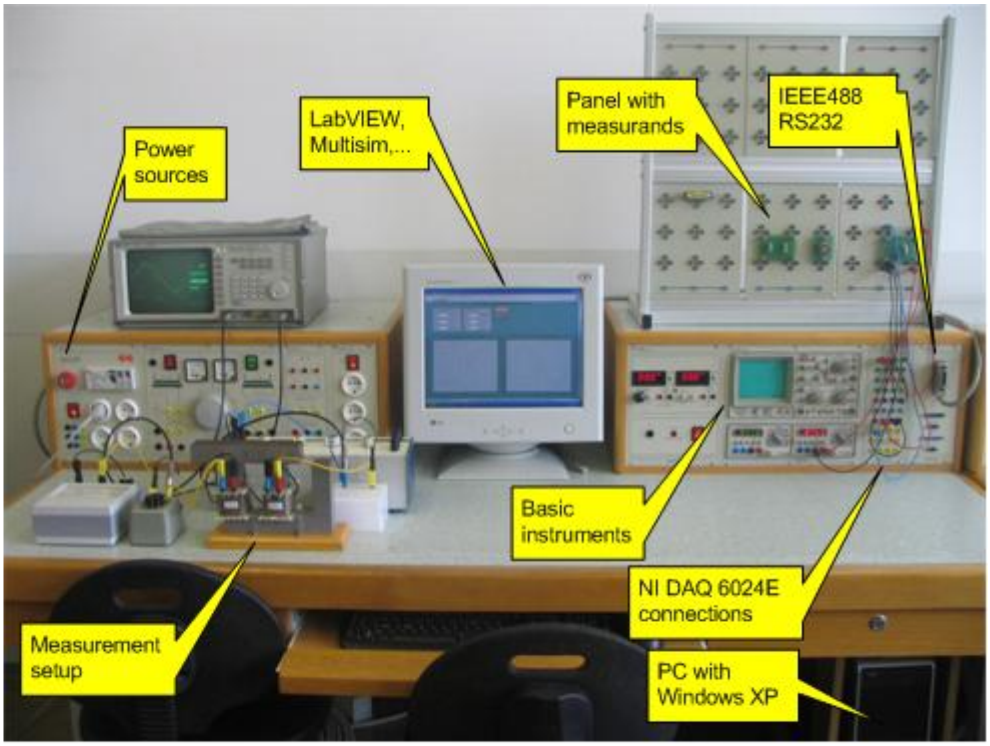

Figure. 1. The Measurement Workspace

The LabVIEW course

The concept of virtual instrumentation is to combine different hardware and software components to create a customized system for tests, measurement and industrial automation. Software is the most important component of a virtual instrument and LabVIEW has become the most popular development tool because of its easy-to-use graphical programming environment. LabVIEW also is used for experimental laboratory work in many subsequent courses. Therefore, the decision was made to incorporate the LabVIEW course into the laboratory work of electrical measurements. The course contains eight lessons over four days:

Day 1

1. Navigating LabVIEW
2. Creating, Editing, and Debugging VIs

Day 2

3. Developing Modular Applications
4. Implementing a VI

Day 3

5. Relating Data
6. Structures

Day 4

7. Strings and File I/O
8. Data Acquisition

Each lesson consists of a lecture and a set of hands-on exercises to reinforce the topics. The exercises complement each other and end with a temperature control application. In addition to this instructor-led course, the students are required to do homework and are encouraged to use the LabVIEW Student Edition, which they can buy on site.

WEBLAB.si

Students use LabVIEW virtual instrumentation in various courses during the study. In addition, LabVIEW also has been successfully utilized in a DSP-based remote control laboratory, developed at the University of Maribor. Remote laboratories are mainly used within the academic field to enhance classroom lectures, share research equipment and to supplement the learning process. In remote experimentation, users operate with the real system, although they are not physically present in the lab. The remote users can conduct their experiments by accessing the lab when they most need it and from a remote location that is more comfortable to them.

The DSP-based remote control laboratory developed at the University of Maribor is intended for use by students in the fields of automation, robotics and mechatronics. The structure of the remote laboratory is shown in Figure 2. The remote laboratory, available at www.weblab.si, is composed of embedded DSP-based control hardware (DSP-2 control systems) and a laboratory server. DSP-2 control systems are connected to the lab server, which in turn is connected to the Internet. The control systems implement a control algorithm and, through the analogue and digital I/O signals, drive the real process. At the same time, the LabVIEW virtual instrument (VI) for an individual experiment and the LabVIEW server are run on the lab server to enable remote control. An individual VI performs a data exchange between the DSP-2 control system and the lab PC, while the LabVIEW server enables remote operation of this VI. Virtual instruments for individual experiments are published on the Web using a LabVIEW built-in Web Publishing Tool. When a remote viewer enters an appropriate URL address, the LabVIEW front panel appears within the Web browser (Figure 3).

The remote laboratory includes a set of real objects under control (DC motor, nonlinear mechanism, SCARA robot, etc.), which are controlled by DSP-2 control systems. The remote user is able to run an experiment, adjust the process or controller parameters from a set of predefined parameters and observe system response in a graphical view (an example of a graphical user interface is shown in Figure 3).

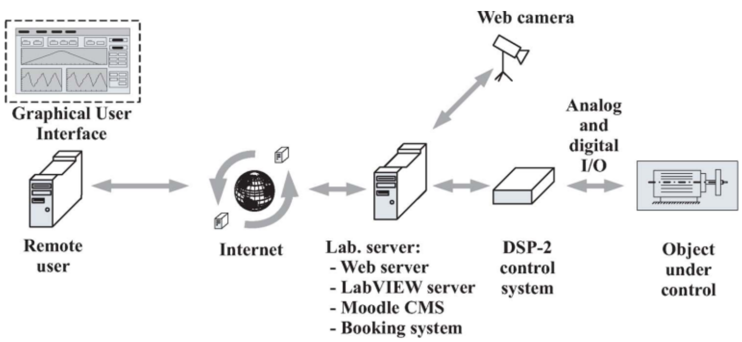

Figure 2. The Structure of the Remote Laboratory

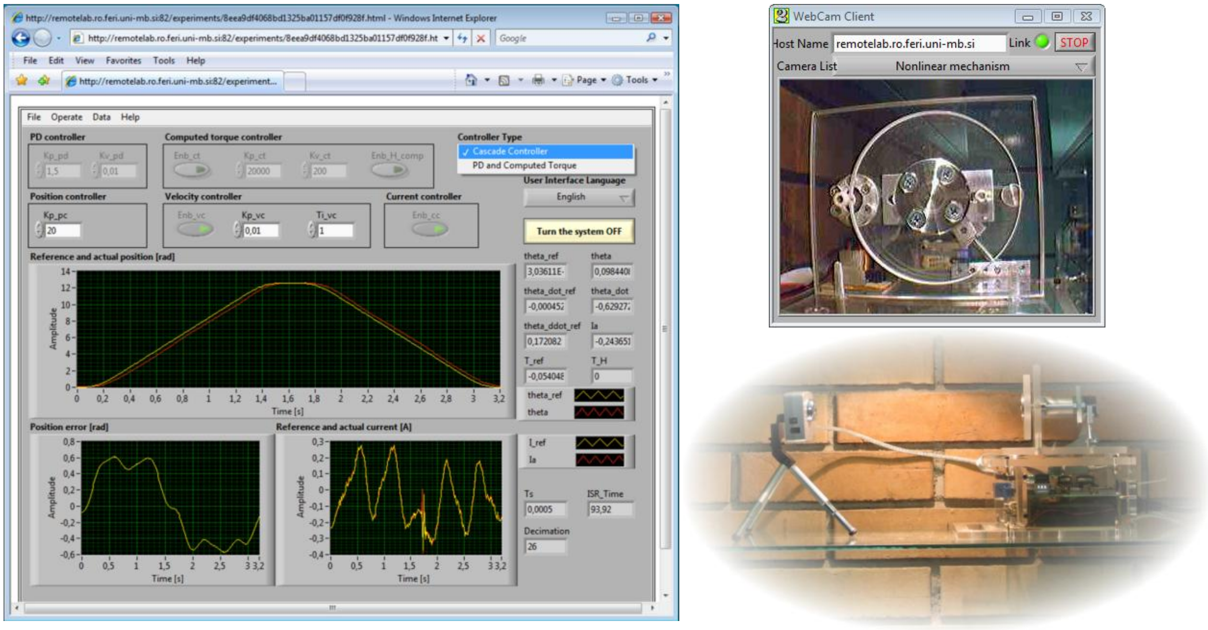

Figure 3. The User Interface for the Implementation of a Remote Experiment

Conclusion

Traditional laboratory work has been expanded with the LabVIEW hands-on course, which prepares students to use LabVIEW to create measurement applications. This course is also the basis for many subsequent courses that use LabVIEW. Some exercises were prepared with classical instrumentation and at the same time with virtual instrumentation to demonstrate the difference. LabVIEW also has been used in developing the remote control laboratory. The remote laboratory is being utilized by different undergraduate courses. The available set of remote experiments are used throughout the courses' homework assignments in which students are required to solve an actual control problem using the techniques they have learned in class and verify their designs on the actual system through the Internet. Discussions with students indicate that the use of the remote control laboratory has improved their understanding of the course material.

Author:

Lukáš Ertl - Brno University of Technology, Faculty of Mechanical Engineering

My name is Lukáš Ertl. I am studying at the University of Technology in Brno, Faculty of Mechanical Engineering. I am working on a diploma thesis under the lead of Eng. Pavel Houška, Ph.D., from the Mechatronics laboratory, Department of Automation.

I chose as the theme of my work to design and create control-and-measurement software for a mass spectrometer and deposition interface, which is built by Dr. Mgr. Jan Preisler, Ph.D., and his team from Masaryk University. Some parts of the hardware were not ready from the beginning of my work and I had just descriptions of a part of it. For example, the assembly for moving a plate with samples of chemicals. This assembly is made of two motors with encoders and their translation stages. Because I wanted to start work on the application, I had to solve the problem of how I could use or verify the created functions. National Instruments' LabVIEW (version 2009) has a new toolkit named SolidWorks Motion. This toolkit allows a connection between an application in NI LabVIEW and a 3D model from the modelling system SolidWorks 2009. I have created a model of this part with the given parameters and used it for simulating movement with the assembly.

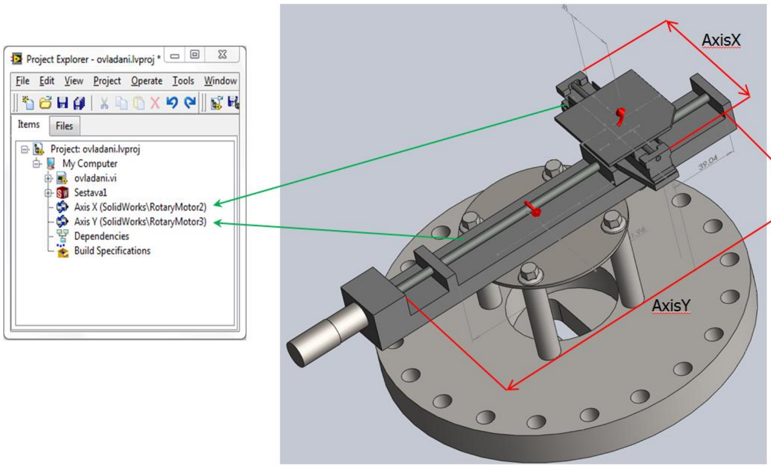

Figure 1. Inserting the Simulated Assembly from SolidWorks in NI LabVIEW

This simulation allowed me to verify some of my functions before I had the real hardware and components connected to the PC.

One alternative for this work could be to use some other software for programming or controlling, which would be compatible with a VRML visualization, for example Matlab or C++, but these are old and uncomfortable.
I knew that for controlling the assembly described in Picture 1, I would be using the NI 7344 controller. This was one of the reasons why I chose NI LabVIEW. Another reason was my knowledge of NI LabVIEW from my past work when I created my bachelor's thesis with this software and hardware. It is very simple to use because it is created and highly appropriate for technical applications.

The project used NI 7344 controller for movement with the plate. Next, I used the NI LabVIEW development system, with some toolkits such as IMAQ, SoftMotion and Application builder. IMAQ is used to get a picture from an external camera that is connected to the PC via a USB port.

NI hardware products are used for movement with the assembly. The software products are used for creating and building an ".exe" application that will run on the Microsoft Windows platform. I just appended the installation of a Runtime Engine from NI and the finished application will run on any computer on which it is installed. This function is very useful mainly with the compact deposition interface, which is connected to the PC simply via the USB port. So, there is no problem with connecting or controlling it using different PCs.

The project had use an acquisition card with a high sampling period. This card was not new but was part of another project years ago. The operating system used Microsoft Windows 7. The USB camera was not bought from NI, because the objective required zooming in on the sample. No NI cameras were compatible with this objective. For the deposition interface, a USB controller from a manufacturer of drives and translation stages was used. These are supported by NI LabVIEW.

Now I was told to order some licenses for Masaryk University. So I searched the NI website and found the products. When I contacted the business department they were very kind and helped me choose some toolkits that I will use for this project in the future. I had a complete order in a day.
This solution met well my objective. The creation of the application and work with the data is much easier than other development systems. The NI hardware is quick enough and very reliable, and especially good is the speed at which the software runs. I appreciated the possibility to control which CPU core will perform which operation. I have found this to be a very useful property of NI LabVIEW.

Using NI LabVIEW saved me a lot of time, because I could create the functions and test them without real hardware. The simulation was easy to create and worked fine. When I had the real components I just had to make some small changes, and since I had a working algorithm I could start to create other functions. Because this is an academic project, the licenses I had to buy were for the university and the academic prices saved us a lot of money.

New Control Software *KrIII* for Production of Radionuclide ^{81}Rb

Author:

Daniel Seifert - Nuclear Physics Institute of the Academy of Sciences of the Czech Republic v.v.i.

Nuclear Physics Institute, namely the Department of Radiopharmaceuticals, is a traditional producer of radionuclides that are used for research or commercial purposes. A very important radionuclide is the ^{81}Kr (its half-life is $T_{½}$ =13 s). It is used for medical diagnostic treatment (ventilation of lungs, chronic obstruction disease etc.). Due to its very short half-life, it is impossible to form radiopharmaceutical directly. This leads to the generator system that uses a mother radionuclide with longer half-life that decay to the daughter radionuclide. In this case, it is system ^{81}Rb ($T_{½}$ = 4,5 h) – ^{81m}Kr ($T_{½}$=13 s). It means that the production of ^{81}Rb is essential. Our department has over 10 years of experience in this production method. Generally, the production of radionuclides is a very complicated process consisting of many steps. A Fundamental item is a robust accelerator of charged particles and a target system.

The new control system *KrIII* is developed for a new target system, which is a unique device developed in our department too. It is possible to produce ^{81}Rb by a nuclear reaction $^{82}Kr(p,2n)^{81}Rb$. An operator of the target system manipulates with very expensive enriched gas ^{82}Kr. Due to economical reasons, it is necessary to recycle the gas after each irradiation. Gas manipulation is realized through the cryogenic transfer inside the closed evacuated (vacuum 10^{-5} mbar) device which also allows achieving the maximum pressure of 10 bar in the own target volume.

In the past the whole process of ^{81}Rb production used to be controlled manually. There was no data stored and the work performed by the operator was not controlled. In the past this led to the loss of the enriched gas ^{82}Kr and of course to economical loss. That is why a software control and a safer production process were necessary. National Instruments (NI) has excellent references in the fields of measurement and automation, which is why we decided to use NI products.

The *KrIII* software was developed in *NI LabVIEW 2009 and 2010 for Windows*. The hardware for the device controlling was *NI USB 6501* for valve control and *NI USB-232/4* to convert digital signals from RS232 bus to USB bus.

The software controls 10 pneumatical valves and reads values from two pressure sensors and one thermocouple. The software is designed as a stand-alone application for routine production. It allows operating in two modes. The first one is a manual mode that has valve control protection against the wrong combination of opened valves and the second one is an automatic mode consisting of an easy wizard which leads the operator through the whole production. The automatic mode controls the system according to the time set for each step of sequences and according to the values from sensors. There are two access levels to the software. The first one is the administrator level that allows the settings of sensors, users, time control for each step of sequences, value limits, etc. The second one is the operator level that does not allow any settings. The software creates two files. The first one saves online every operation to a .bin file containing the time, operation and attribute of the operation, date, name of the operator and the time of irradiation. The second file stores data from sensors to .txt file for the further evaluation. The software allows printing, viewing of previous production and also loading of actual production files. This is necessary in case the system fails due to some error coming from the system.

The new control software *KrIII* dramatically decreases the preparation time before irradiation from more than four hours to 50 minutes. Although KrIII allows safer manipulation with the gas, the main goal is a lower number of operators (from three to two) in the routine production. The lower preparation time and the lower number of operators bring lower costs for routine production.

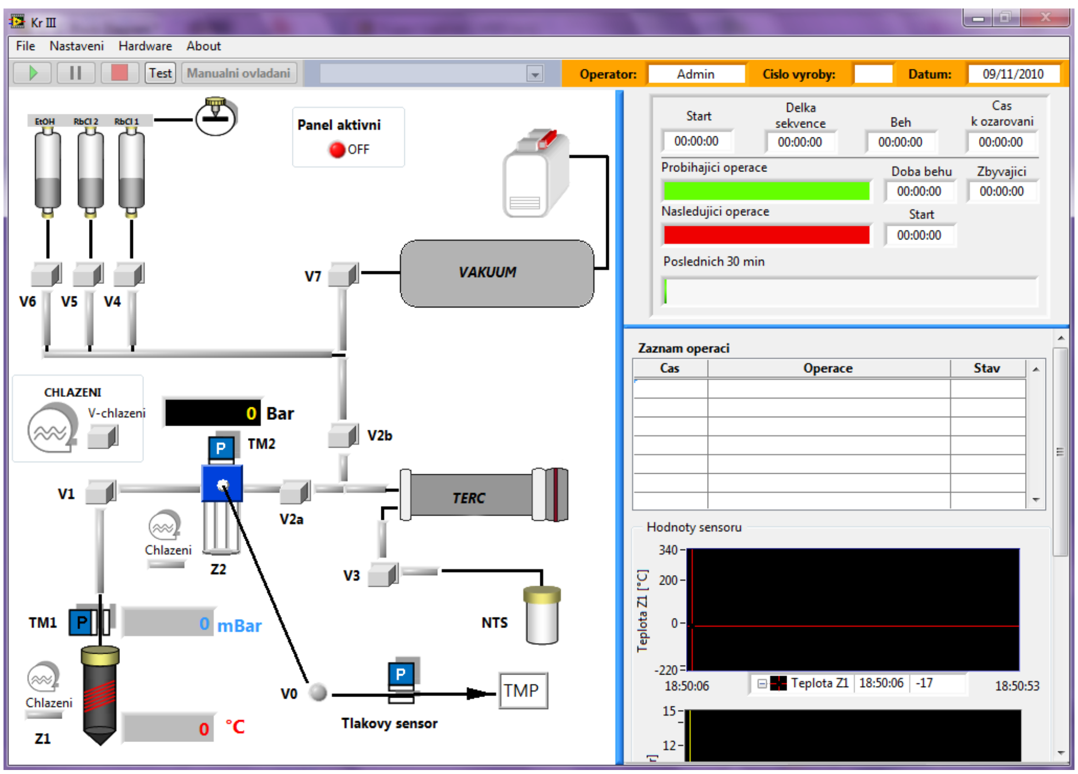

Figure 1. The Main View of the KrIII Software

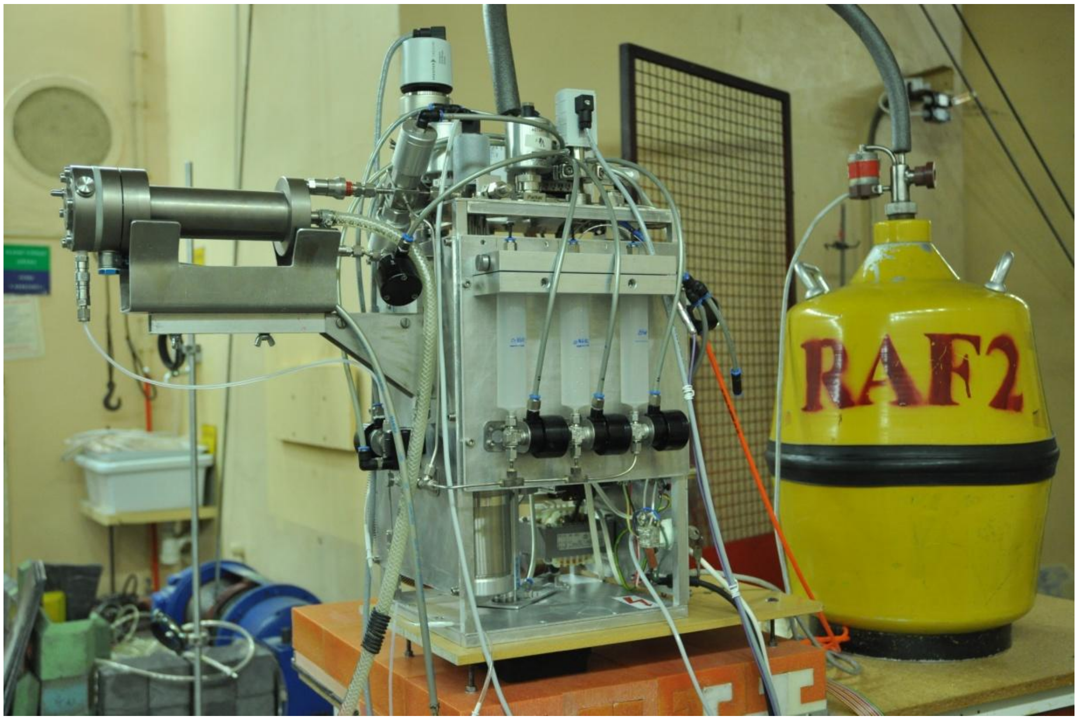

Figure 2. The Side View of the Device

Author:

Aurel Gontean - Electronics and Telecommunications Faculty, “Politehnica” University of Timisoara, Romania

This is one of the most complex projects at our university. We made a total of eight programs, six with the PXI industrial chassis and two with the CompactRIO system:

No	PXI Based Virtual Instruments	Information	NI Equipment Used
1.	Uout = f(Uin)	Transfer characteristic of a NAND gate + **WEBCAM**.	NI PXI-4110 and NI PXI-4072
2.	tpLH and tpHL	Propagation times of a NAND gate + **WEBCAM**.	NI PXI-4110, NI PXI-5112, NI PXI-5412 and NI PXI-5404
3.	Duty Cycle Analyzer	Study the signals of a duty cycle analyzer circuit with a **synthetic** logic analyzer.	NI PXI-6541
4.	Motor Control	Control DC motor speed.	NI USB-6251 and NI USB-6009
5.	Temperature	Measure the temperature in the laboratory.	NI PXI-6115 and NI PXI-6608
6.	Power Source	Virtual oscilloscope-based signal acquisition for a power supply.	NI PXI-5112
No	**cRIO Virtual Instruments**	**Information**	**NI Equipment Used**
1.	Motor Control cRIO	Control DC motor speed with cRIO.	NI PXI-4110, NI PXI-6733 and NI 9505
2.	Temperature cRIO	Measure the lab temperature with cRIO.	NI 9201

All these programs are accessible and controllable through the web from http://plst.etc.upt.ro. The servers used Windows and Linux operating systems and the LabVIEW web server and the web publishing tool were used for accessing and controlling the virtual instrumentation.

Our challenge was to make a nonconventional remote laboratory. Remote laboratories are associated with simulation, our goal was to demonstrate to students that they are experimenting with hardware and performing real-life experiments. For this we used web servers, the LabVIEW server and even a streaming webcam server to make it more realistic.

We had no alternative solution prior to NI technology that could do what we wanted.

We searched for a solution to integrate all the applications and make a remote lab and we found it in National Instruments.

We used a wide range of NI products:

- NI PXI-1044 Chassis
- NI cRIO-9112 Chassis with NI cRIO-9012 Controller
- NI PXI-4110 is a Triple-Output Programmable DC Power Supply
- NI PXI-4072 is a FlexDMM and LCR Meter, 6½-Digit PXI Digital Multimeter (DMM) and LCR Meter
- NI PXI-5112 is a low cost 8-Bit, 100 MS/s, 2 Ch (PXI) Digitizer/Oscilloscope
- NI PXI-5404 is a 100 MHz Frequency Generator
- NI PXI-5412 is a 100 MS/s, 14-Bit Arbitrary Waveform Generator
- NI PXI-6541 is a Digital Waveform Generator/Analyzer for Interfacing Applications
- NI USB-6251 is a 16-Bit, 1.25 MS/s M Series Multifunction DAQ, External Power
- NI USB-6009 is a 14-Bit, 48 kS/s Low-Cost Multifunction DAQ
- NI PXI-6115 is a 12-Bit, 10 MS/s/ch, Simultaneous Sampling Multifunction DAQ
- NI PXI-6608 is a High-Precision Counter/Timer with Digital I/O
- NI PXI-6733 is a High-Speed Analogue Output–1 MS/s, 16-Bit, 8 Channels
- NI 9505 is a Full H-Bridge Brushed DC Servo Drive Module
- NI 9201 is an 8-Ch, ±10 V, 500 kS/s, 12-Bit Analog Input Module, C Series

We also used third-party products such as motors, LM35 temperature sensors, 74HC00 NAND gate ICs and demo board, a duty cycle analyzer demo board, PICDEM Mechatronics evolution board from Microchip and even the Agilent 33250A function generator. We used third-party software, too, including MPLAB IDE for the Microchip PICDEM Mechatronics board, Linux operating systems and a full pack of servers that included DNS, mail, web, FTP, webcam, MYSQL database and DHCP.

Overall we are more than pleased with our results. We saved a lot of time and were able to do in a short amount of time as much as we would do with a whole group of engineers. We would not have succeeded without the help of National Instruments technology.

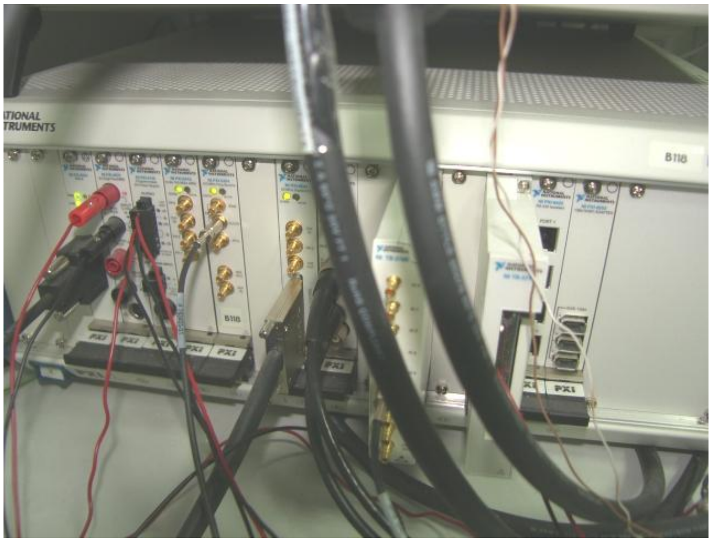

Figure 1. NI PXI-1044 Chassis

Figure 2. NI cRIO-9112 Chassis

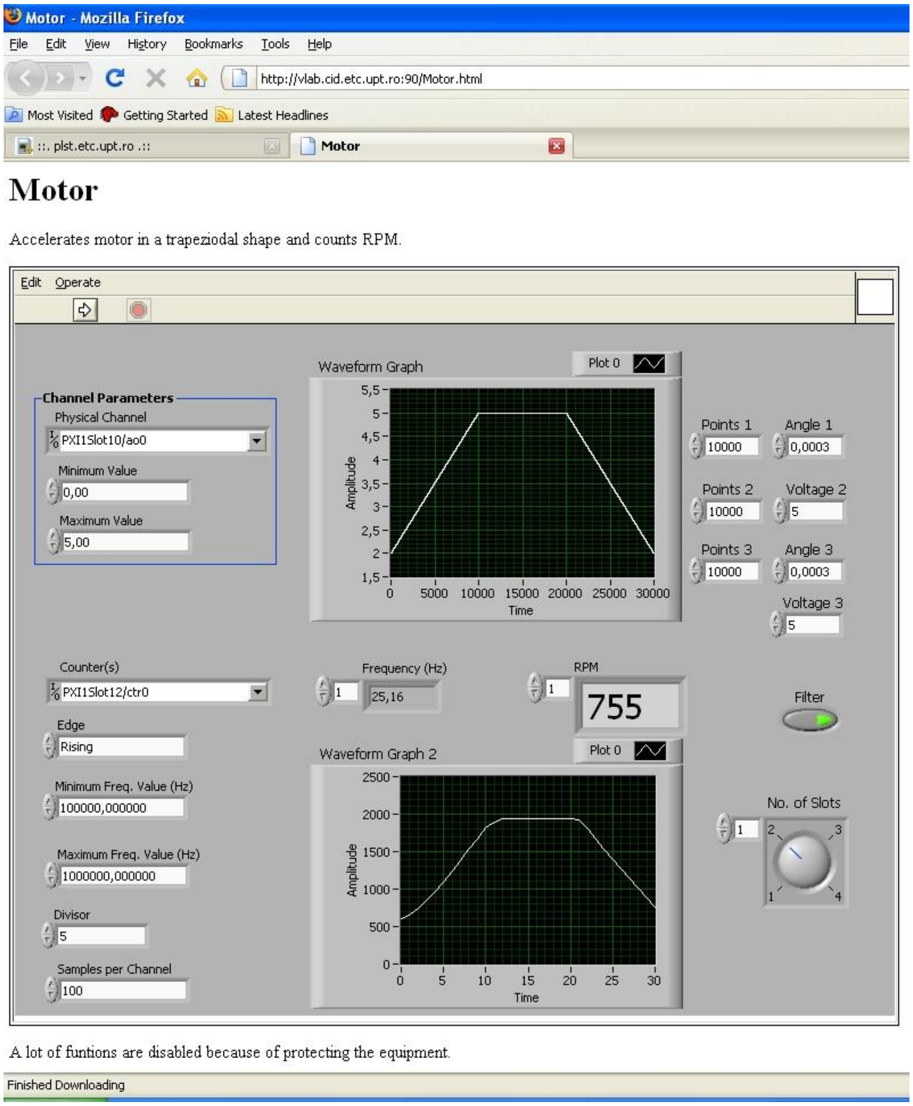

Figure 3. Motor.vi Accessed from Web

Building a Computer-operated Measurement System for the Detection of Carbon Monoxide Gas in Ambient Air

Authors:

Patricia Gherban Draut, Raul Ionel, Aurel Gontean - University "Politehnica" of Timisoara, Faculty of Electronics and Telecommunications

Industry:

Pollution detection/Environmental

Products:

LabVIEW, USB-6251, CB-68LPR

The Challenge:

Building a computer-operated measurement system for the detection of carbon monoxide gas in ambient air.

The Solution:

Interfacing a gas sensor and a computer with NI LabVIEW virtual instruments and data acquisition hardware, in order to read measurements, save and process data and display the calculated gas concentration.

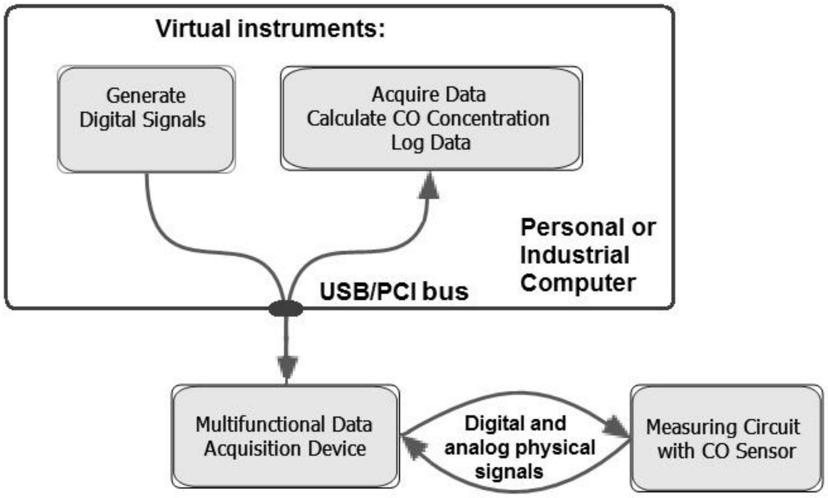

Figure 1. System Overview

Gas Concentration Measurements

To determine the presence of a gas or to calculate the gas concentration in the ambient air, one can choose between a dedicated stand-alone instrument, for example, a gas analyzer, and a gas sensor, that is a single component that needs to be included in a measurement circuit.

For this application, we selected Figaro's carbon monoxide solid state gas sensor, TGS2442, because of its reliability, low cost and small size. The sensor's functioning principle is based on metal oxides' sensitivity to certain gases. The resistance of a layer of tin dioxide, StO_2, inside the sensor enclosure changes depending on the concentration of carbon monoxide in the presence of oxygen. Therefore, by measuring the sensing elements' electrical resistance, the parts per million CO present in the air can be determined.

The sensor is composed of two elements—the heater element whose purpose is to increase the temperature inside the enclosure and facilitate the chemical reactions; and the sensing element whose resistance is measured with a voltage impulse, once per second, during an optimal detection interval. Along with the main measurement of sensor resistance, the data acquisition device also measures voltage values several times per second across the heater and sensing elements, in order to test for malfunctions.

Virtual Instrumentation

For this particular application, the data acquisition device must provide two analogue inputs, three digital output lines and a digital trigger for analogue acquisition. While the NI USB-6251 provides the required features and was chosen for the application, there are a variety of DAQ modules on many different platforms with these capabilities. The result is a very portable application in which the sensor can be connected to different hardware devices and different computers without the need to modify the software or the measurement circuit.

The virtual instruments need to accomplish two main tasks: to generate the digital signals required by the sensor for it to function and to acquire the analogue voltage values from the sensor. Both the signal generation and the data acquisition have to be executed in parallel and must be synchronized for optimum detection and gas concentration calculations.

We decided to build two separate VIs, one for each task. The first VI generates three digital signals and the second VI created for this application performs the analogue acquisition and all the required calculations. To ensure proper synchronization, the data acquisition in the second VI is triggered by the falling slope of one of the digital signals generated by the first VI. By extracting certain values from all samples acquired, the program can calculate the carbon monoxide concentration and determine if the sensor is functioning correctly.

Along with acquiring and processing data, the second VI's front panel displays the measured and calculated data through graphs, charts and numerical indicators. The user also can choose to save the measurements to a file. The screenshot in Figure 2 shows the front panel of the running VI.

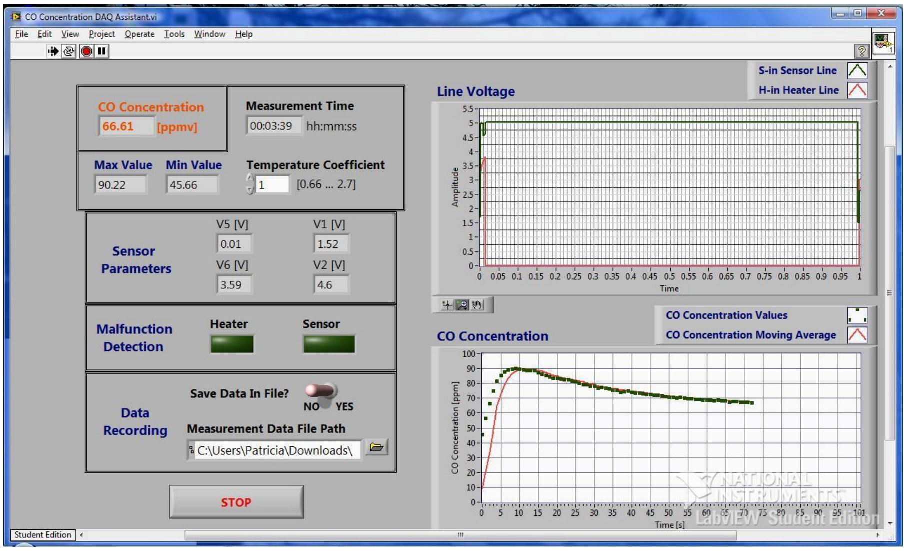

Figure 2. Front Panel of the Running VI

Conclusion

Throughout the development stages of the project it has become obvious how graphical programming creates a more flexible design environment with a more compact and versatile application. The inherent parallelism of the data flow concept, and of the NI DAQmx driver used for data acquisition devices, enhanced the use of multi-core processors and allowed the parallel execution needed for the precise synchronization between the signals.

The results obtained demonstrate how a solid state gas sensor can be used to measure gas concentrations, in a virtual instrumentation system. The main advantage of this method is the computer-based data processing that allows parallel execution of several instruments and easy access to logged data.

Balancing an Inverted Pendulum

– a LabVIEW FPGA & BLDC Motor Implementation

Authors:

PhD student Mihail Cernaianu, PhD student Paul Harfas - Electronics and Telecommunications Faculty, "Politehnica" University, Timisoara

This presentation is focused on a system developed by the authors as part of their diploma thesis.
The goal was to implement and reproduce a "classic" control theory problem: keeping an inverted pendulum balanced vertically. To make it more interesting, a brushless DC motor (BLDC) was chosen for this task, partly because it presented a greater challenge. An old, modified A3 printer was used as a "mechanical support." A potentiometer attached to the printer's cart was used as both the pivoting point for the pendulum rod as well as a position feedback sensor.

Figure1 below gives a general view of the assembly.

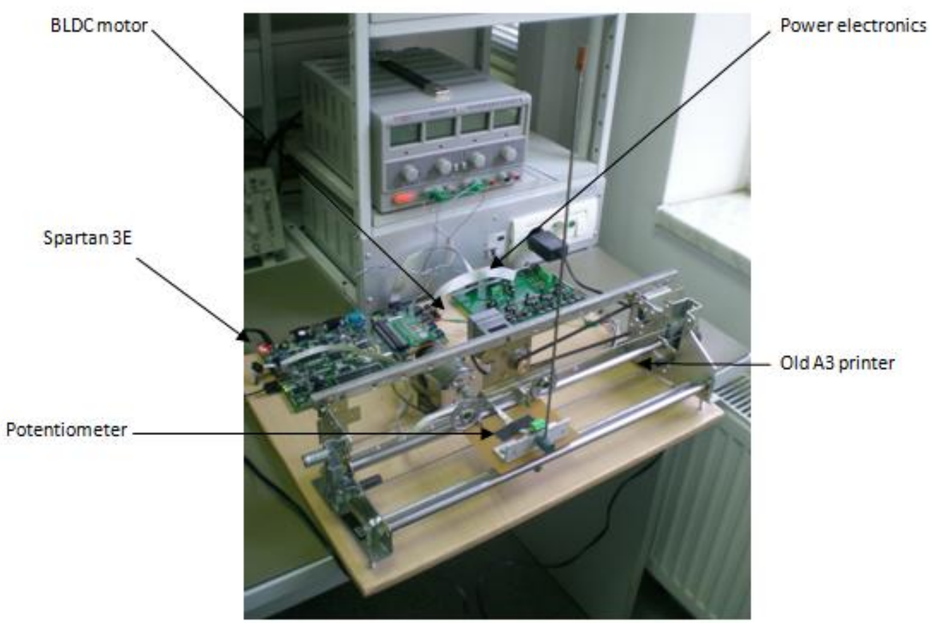

Figure 1. General View of the Project Experimental Setup

Thus, at a functional level, the system involves controlling a BLDC motor and a PID control loop. In order to achieve these tasks, a Spartan 3E FPGA development board was chosen. At the time of the implementation, this was the only non-NI product supported by the LabVIEW FPGA module. This solution was adopted because it presented a number of clear advantages:

– Ease of implementation: The authors do not have extensive knowledge of the VHDL language generally used for FPGA programming; developing a user interface on the PC is much easier using LV FPGA.

– Strict hardware timing control was a must, both for the BLDC control algorithm and the PID control loop; this can be better achieved by choosing an FPGA device over the classic microcontroller solution.

BLDC motor control algorithm

A BLDC motor is, basically, a DC motor turned inside-out. The rotor is made of a permanent magnet (usually six to 10 poles) and a stator comprised of three windings, also called phases. By properly energizing the three stator windings (two at a time), the magnetic field generated in the stator will "pull" on the rotor's permanent magnet. The BLDC motor used in this case was a 10-pole Hurst DMB0224C10002, powered at 48V. A power electronics stage was designed and built, consisting of a classic 3-phase inverter with MOS-FET transistors.

The method commonly used for BLDC motor control is called "sensored control" and is based on reading the rotor position by means of (usually) three magnetic sensors—called Hall sensors—equally displaced on the rotor shaft. Based on this reading, the two required stator windings will be powered to provide a maximum of torque to the rotor.

The block diagram screen capture below shows the implementation of the BLDC control algorithm in LabVIEW FPGA.

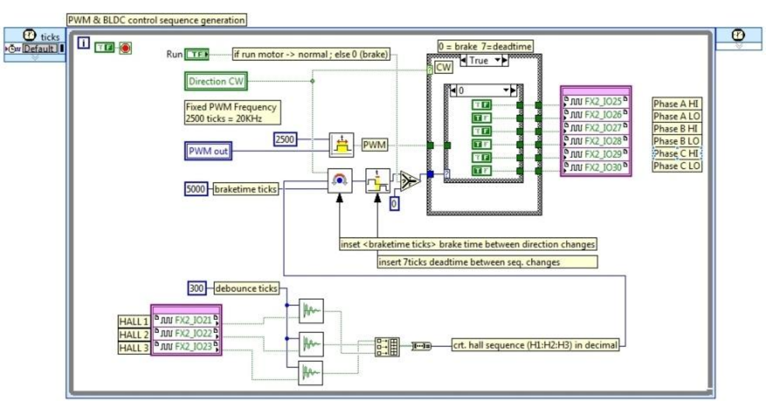

Figure 2. BLDC Motor Control Algorithm

An LV FPGA feature is the single-cycle timed loop control structure. This structure is later translated to VHDL as a "process" statement, making the code inside execute at the FPGA base clock rate—in this case, 50MHz.
The block diagram, above, functions as a single-cycle timed loop as follows: the three Hall sensors are read, then based on this reading, the appropriate two-phase combination is selected; next, a PWM signal is fed to the active high-side transistor of the inverter and a constant logic "1" to the low-side.

NATIONAL INSTRUMENTS

Some aspects worth mentioning:

- the Hall sensor input signals are software-debounced.
- a PWM signal is generated.
- there is protection in case of a CW/CCW rotational change.

All of the above are implemented by means of Boolean logic.

PID control loop implementation

The PID control algorithm was implemented in a separate loop while running at 30Hz. The implementation is straightforward, the only aspects worth mentioning here being the usage of only integer data types for the PID controller and the scaling of the inputs to span the whole uint16 data type range under normal (expected) operation.

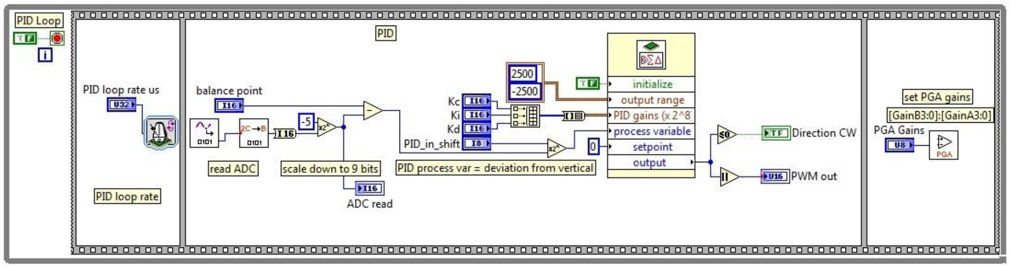

Figure 3. PID Implementation

The potentiometer value is read using the onboard ADC and scaled to uint16, this reading being the process variable for the PID controller. The setpoint is the expected reading when the pendulum is perfectly vertical. In the end, due to the large noise value of the readings from the ADC, a PI controller was preferred (Kd=0).

Results

Figure 4 shows the pendulum position (deviation) versus the desired (vertical) setpoint.

Figure 4. User Interface

The system was successful in keeping the pendulum balanced in the vertical position, and even compensating for relatively small perturbations when "bumping" the pendulum by hand. Larger perturbations bring the controller output to saturation and the system is unable to compensate for the angular displacement of the inverted pendulum.

Conclusion

By using LabVIEW FPGA, the development time was cut by as much as 60%, especially in this case, where the authors do not have much experience with the "classic" VHDL. Also, this implementation is much easier to follow. The only drawback, compared to the classical microcontroller solution is the higher cost of development.
Due to the fact that LabVIEW FPGA offers communication over USB with the host PC, it was at hand to develop a graphical user interface (shown above). Without the graphical feedback provided this way, tuning the PID parameters would have been much more difficult. Furthermore, due to the parallel nature of the FPGA, the communication does not interfere with the main function—the main program—as would have been the case with a microcontroller implementation.

Acknowledgement

This work was partially supported by the strategic grant POSDRU 2009 project ID 50783 of the Ministry of Labour, Family and Social Protection, Romania, co-financed by the European Social Fund–Investing in People.

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Applying NI ELVIS and NI LabVIEW in Training Students

Author:

László Kiss - Irinyi János Secondary School and Student Hostel, Kazincbarcika

In this school, electronic technicians are trained in a 4+2-system.

My aim is to modernize the teaching methods of electronics in secondary school, which involves electrotechnical and electronic basic measurements. During the modernization I want to pass the knowledge as efficiently as possible while at the same time keep the attention of my students.

Many problems can occur during measurements (with real instruments) in laboratories, even though it also has some advantages.

The problems occuring the most often include:

- Laboratory measurements require much preparation time;
- Sometimes there is a lack of suitable parts or material for measurements;
- Acquiring the measurements takes a lot of time;
- The results are not spectacular enough for some students;
- Modifying electrical circuits is time-consuming for students;
- The analysis of measurement results takes a long time;
- The assembled measurement system is not intelligent and is unscalable;
- Although these measurements are necessary for getting manual practice I was searching for solutions for these problems when I became acquainted with NI instruments and products.

NI was chosen, because they:

- are flexible,
- are a fair partner in business,
- believe the satisfaction of customers is very important,
- back the lifetime of products by NI itself,
- continually offer quality instruments.

ELVIS was chosen, because it:

- fits well with education,
- can be used without NI LabVIEW,

- is a multifunctional measuring instrument (representing 13 high-priced measurement instruments),
- can be easily mobilized,
- is compelling to students and easily can be worked with,
- is used not only in electronics,
- has 80% open source code,
- contains established measurement controlling programs that are easily scalable,
- can be applied in a wide area,
- gives correct answers to problems that occur.

At first, students learn the basic LabVIEW programming. After that they study the workstation and make simple, basic-level programs.

The following pictures show some examples:

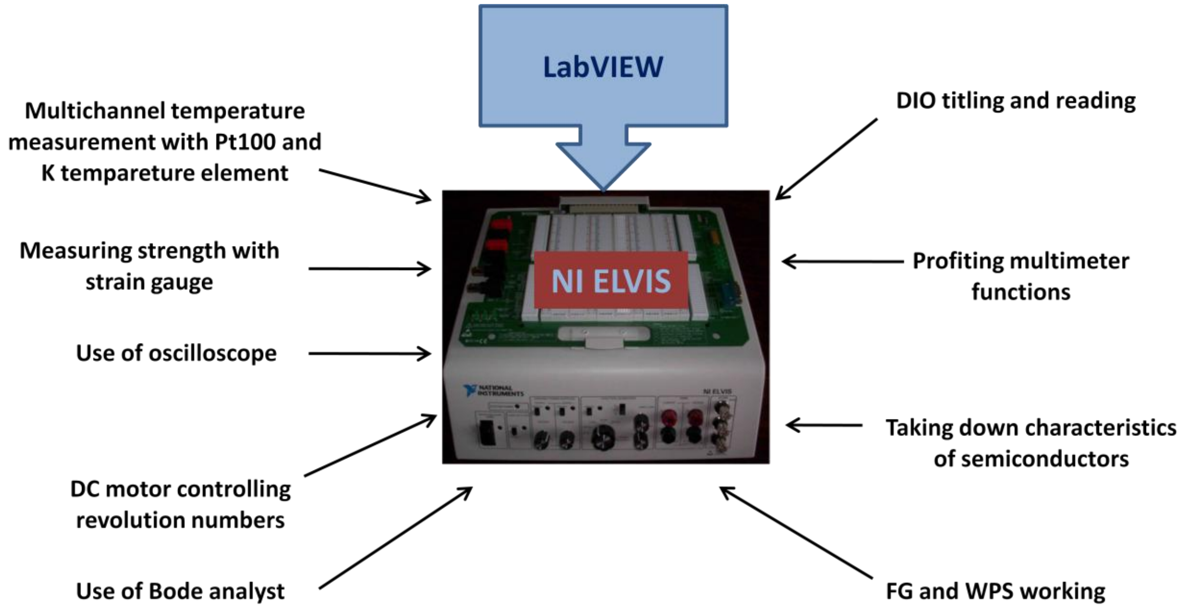

Figure 1. ELVIS Workstation How We Use It

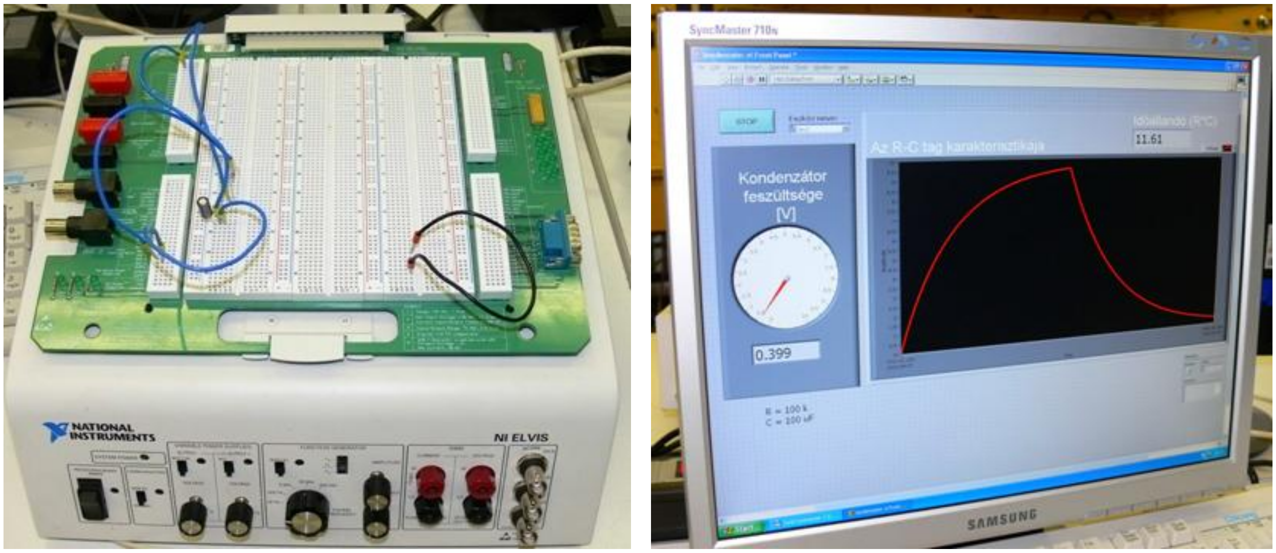

Figure 2. Electric Discharge and Charge process of a Condenser

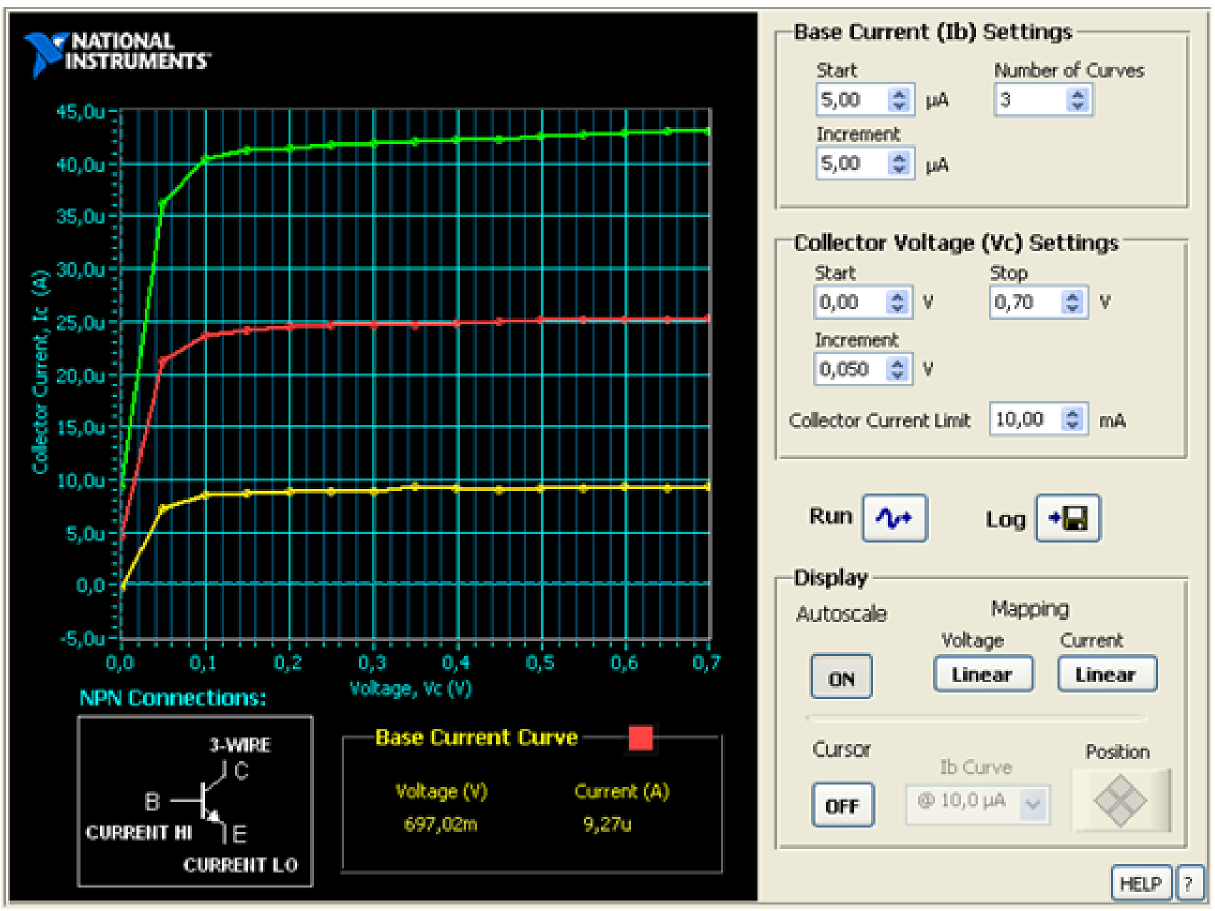

Figure 3. Taking Transistor Characteristics

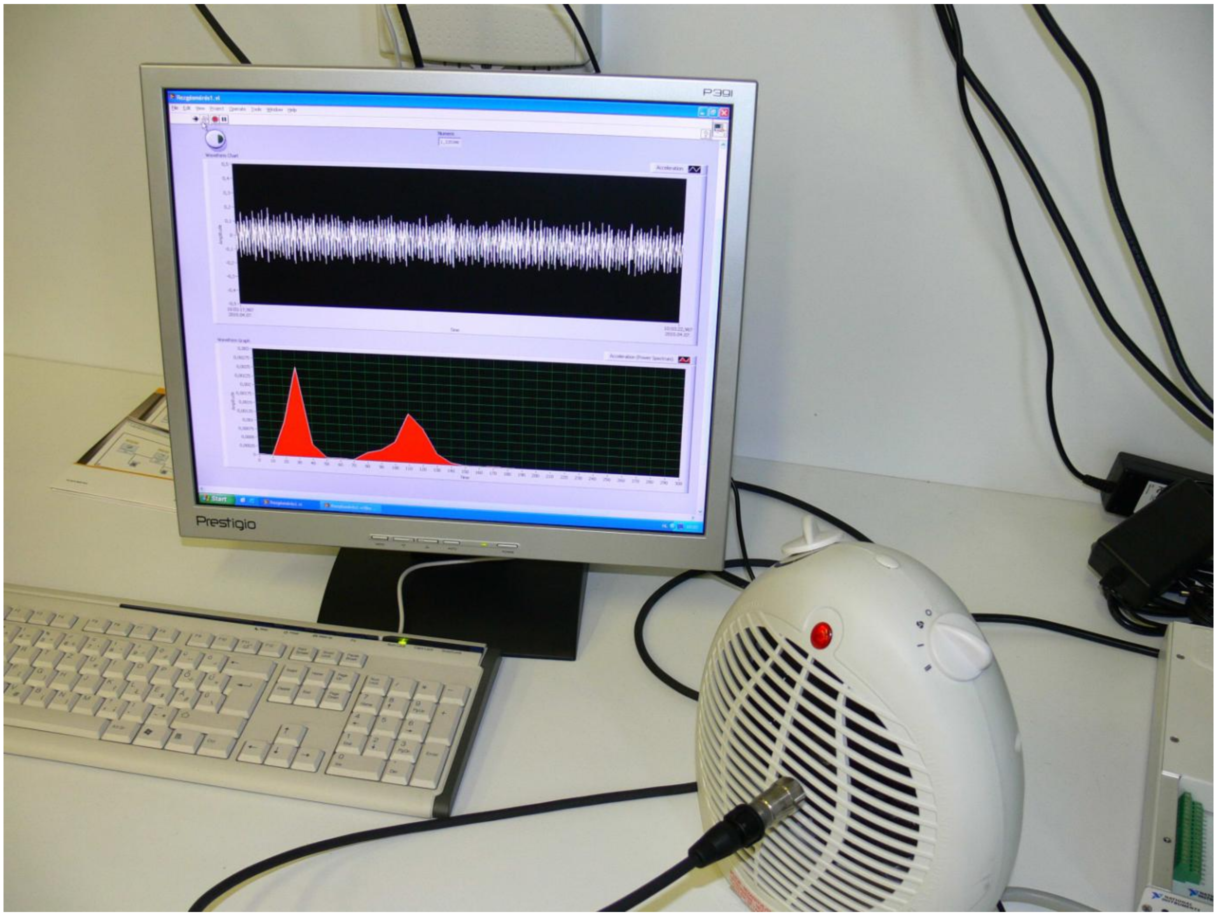

Figure 4. Vibration Measurement of Rotating Machine

The NI ELVIS workstation and NI LabVIEW program are suitable to teach applied electronics. The time used to take traditional measurements decreased by 50% using NI instruments. We can determine that the efficiency of work increased by 50%.

I keep in contact with the Engineering Office of NI in Budaörs and in Debrecen. I would like to say thank you to Mr. László Ábrahám the General Manager of National Instruments Europe Kft. and to Mr. Tamás Sárosi (District Sales Manager), Mr. Attila Péter (District Sales Manager) and Mr. Márton Litkei (Field Sales Engineer), the engineers who have helped me solve the problems.

National Instruments Tools in the Education of Budapest University of Technology and Economics, Faculty of Electrical Engineering and Informatics (BME VIK)

Authors:

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Introduction to BME VIK

The Faculty of Electrical Engineering was founded in 1949 at the Budapest University of Technology and Economics [1] and complemented with an Informatics unit in 1986. Today, BME VIK has about 1,200 new students and about 800 graduate students per year. BME VIK offers nine Bachelor's of Science programs (for in Electrical Engineering and five in Informatics) and 20 Master's of Science programs (eight in Electrical Engineering and 12 in Informatics).

Challenges in laboratory intensive education in B.Sc. programs

Both the Electrical Engineering and Informatics B.Sc. programs of education provide sound theoretical foundations and solid practical background: there are four semesters of basic Measurement Laboratories in each of the B.Sc. programs. In these four semester laboratory programs, students become familiar with the tools commonly used by the industry. The themes of these laboratories have to be up to date and follow trends of the industry. Two of these trends are the integration of measurement functions into one device, and the remote control of many such devices. To demonstrate these trends to students and prepare them to use such measurement systems, an appropriate tool is needed. Surveying the technologies used by our industrial partners and employers of our students, we found that in most cases National Instruments tools are used for the integration of measurement functions and remote controls. Therefore, in the semester with Measurement Laboratory 3, we selected the National Instruments LabVIEW environment to demonstrate the usage of measurement systems.

Basic LabVIEW education in the B.Sc. programs

The LabVIEW education in Measurement Laboratory 3 of B.Sc. programs consists of two, four hour-long laboratory exercises. The goal of the first four hours is to introduce the LabVIEW graphical programming language: the role of the front panel and block diagram, the creation and use of programming structures and data types. After this first part, students are able to build a functional generator from LabVIEW's graphical blocks by using the PC's sound card. The second block of the laboratory focuses on the remote control functions. In this part, students have to build a measurement system from the laboratory's existing measurement instruments, such as digital multimeters and function generators. By connecting these devices using a GPIB bus interface, students create a general purpose measurement system, which is able to measure the amplitude characteristic of a 4-pole RC circuit (Figure 1).

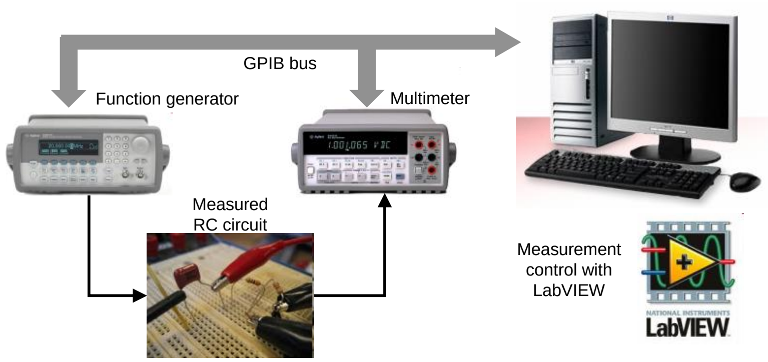

Figure. 1. Measurement System Exercise for the Informatics B.Sc. Program

Challenges in the Embedded Systems M.Sc. program

The Department of Measurement and Information Systems offers an Embedded Systems M.Sc. program. About 50 students a year select this program. The four-semester course covers topics such as the fundamentals of natural sciences and economics. Specialization topics include System Architecture, Software Technology, Real-Time and Safety Critical Systems, Information Processing and Embedded System Design. Elective courses present digital design with FPGA-based technologies, signal processing with DSP processors and parallel concurrent programming in embedded systems using microcontroller-based hardware. In the connected laboratories, many hardware tools with different architectures and development environments are used. In the System Architecture laboratory we intended to present a solution that can handle this whole set of architectures simultaneously.

The National Instruments cRIO system, as a solution for complex system architectures

The LabVIEW software tool and the cRIO system by National Instruments seemed an ideal solution to present a complete environment that can handle most of the architectures; the students are already familiar with them in an integrated way. The laboratory exercises use the cRIO systems to demonstrate the use of the same LabVIEW graphical programming environment from the high-speed, low abstraction level part of FPGA, through the real-time controller based embedded hardware, to the host PC (Figure 2).

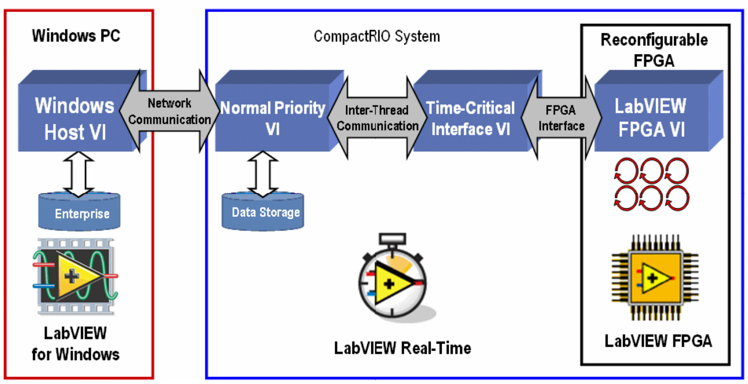

Figure. 2. cRIO System Architecture

Exercises cover each part of the cRIO programmer's model from the FPGA-based direct I/O control, through the real-time, PC-based stand-alone motor controller device, to a distributed measurement-and-control system using a host PC as a GUI-based measurement indicator and cRIO devices as transducers. At the end of these complex design-and-measurement exercises, students are able to use this technology to create distributed measurement-and-control systems. The time frame for this work is about 20 hours (five, four-hour sessions).

The LabVIEW programming environment offers a great benefit for students to use familiar technologies in an absolutely different way. For example, students in previous semesters learned how to program microcontrollers in assembly or C languages and how to create Verilog or VHDL descriptions to design an FPGA. But in this laboratory they will learn how to use higher abstraction-level technologies, which will generate these codes, so they need to focus only on architecture problems. Take, for example, the specification and allocation of system functions for FPGA–Real Time PC–Host PC levels, which is an absolutely different problem than they are used to solving. About 50 students a year are involved in these cRIO exercises in the Embedded Systems M.Sc. program.

National Instruments tools in project laboratory and diploma thesis

The M.Sc. programs at BME VIK end with long-term independent design topics for students and consist of two semesters of project laboratory and two semesters of diploma thesis work. Students can select from different topics including theoretical research, industrial development or a mixture of them. Some of the projects are direct HW developments, such as dedicated module development for the cRIO system (a high speed A/D module, or a 16-channel, 24-bit input module), while others are application-oriented, such as an acoustic source localizer or a table tennis acousto-electrical scoreboard. These later topics need an effective and easy-to-use measurement-and-control system to develop the hardware and software. In these projects, LabVIEW and NI hardware provide an easy-to-use solution for the students. Teamwork also is possible, such as with the Formula Student Project [2], which is a worldwide design competition for students. In this project, our students join with students from other faculties to build an automotive electronic system interconnected with a CAN bus for a racing car, which is developed by mechanical engineering students. National Instruments' CAN tools and the NI ECU Measurement and Calibration Toolkit made this development easier by providing an easy-to-use test environment.

References

[1] Home page of Budapest University of Technology and Economics: http://portal.bme.hu/langs/en/default.aspx

[2] Home page of the Formula Student competition: http://www.formulastudent.com/

Computer-based Measurement Systems and Nuclear Physics Experiment with virtual instrumentation at Palacký University in Olomouc

Authors:

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University Class on Computer-based Measurement Systems

Education in the field of applied and instrumental physics at the Department of Experimental Physics is focused on the application of physical principles in the instrumentation. As graduated of this department, one has to know how to build measurement and test systems with an easy configuration, user-friendly interface, and also with the possibility to run sophisticated experiments. In order to educate our students properly, we started to improve our lessons on **Computer-based Measurement Systems** (CMS) a few years ago. The improvement can be seen in the use of up-to-date measurement, control and testing systems based on reliable devices. Various products from National Instruments (NI) have been purchased and serve as modern equipment in the classroom. Our choice of NI is not accidental because NI provides a wide range of top-quality products with an enormous application field. Moreover, NI offers many types of free-of-charge text sources, manuals, seminars, case studies, articles, and provides special academic financial program.

In the basic lessons of CMS, students gain knowledge about the designing of measurement system based on various platforms. In the advanced lessons of CMS (next three semesters), students can design more complex systems using many types of sensors, actuators, and measurement devices. At the end of CMS lessons, students will be able to build computer-controlled experiments. In the CMS classroom, see Figure 1, we use LabVIEW 2010 (full development system). From a hardware perspective, we use a PXI system, equipped with a PXI-8156B controller, which runs LabVIEW RT and a PXI-6221 multifunction M Series DAQ board. The system is remotely controllable. Furthermore, a PPC-2115, an industrial panel PC, with a built-in touch screen prepared for remote system controlling, and PCs with USB-6221 and four PCI-6124E multifunctional boards do serve as local stations. We are very satisfied with the NI LabVIEW Robotics Starter Kit with NI Single-Board RIO-based controller, which we have bought because it enables us to learn more about the amazing world of robots, see Figure 2.

Figure 1. CMS and Electronics Classroom

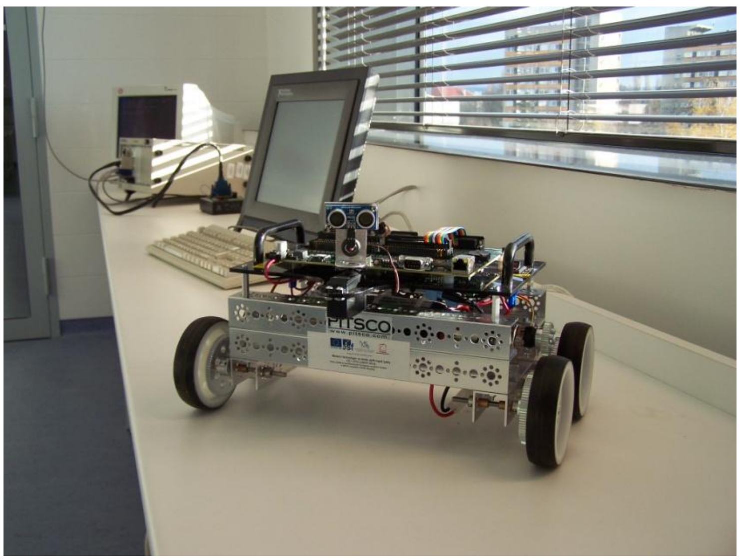

Figure 2. NI Robotics Kit, PXI System, and Panel PC

Nowadays, new lessons of **Virtual Instrumentation in Nuclear Physics Experiments** are in the process of being prepared. They will be taught next year for the first time. Students attending the lessons can learn about new principles of signal processing in the field of nuclear instruments.

This work has been supported by the project “Advanced Technologies in the Study of Applied Physics” in Operational Program Education for Competitiveness - European Social Fund (CZ.1.07/2.2.00/07.0018).

LabVIEW-powered DSP System for Nuclear Physics Experiments

Digital signal processing (DSP) systems are essential for nuclear physics experiments because of their performance in both the energy and time domain. They are particularly useful in time-resolved spectrometry, where the time-of-flight (TOF) value determines when a photon or particle arrives into the detector (i.e. radioactive decay can be studied). Many commercially available digitizers are used in these systems.

In this case study, the virtual instrumentation (VI) technique has been applied and enabled to develop a system which provides nuclear spectroscopic measurements such as amplitude and time signal analysis. The system designed for the high-rate DSP is based on a PCI-5124 digitizer which uses up to 200 MS s^{-1} real-time sampling with 12-bit resolution on two simultaneously sampled channels. The specific features of this digitizer and the selected VI concept make our choice to be very contributing to the fast development process and easy further improvement.

The developed system which uses two DAQ channels has been successfully applied in nuclear spectroscopy measurements and is employed in X- and gamma-ray spectroscopy as well. The system is fast enough to capture the pulses from different types of nuclear detectors, and the time resolution is sufficient to perform common time measurements. The presented system finds its application in the coincidence measurement where two channels are used for the start and stop of nuclear events detection. The system is sensitive to decay lifetimes in the range of tens of nanoseconds to seconds. In Figure 3, a block diagram of the system is shown.

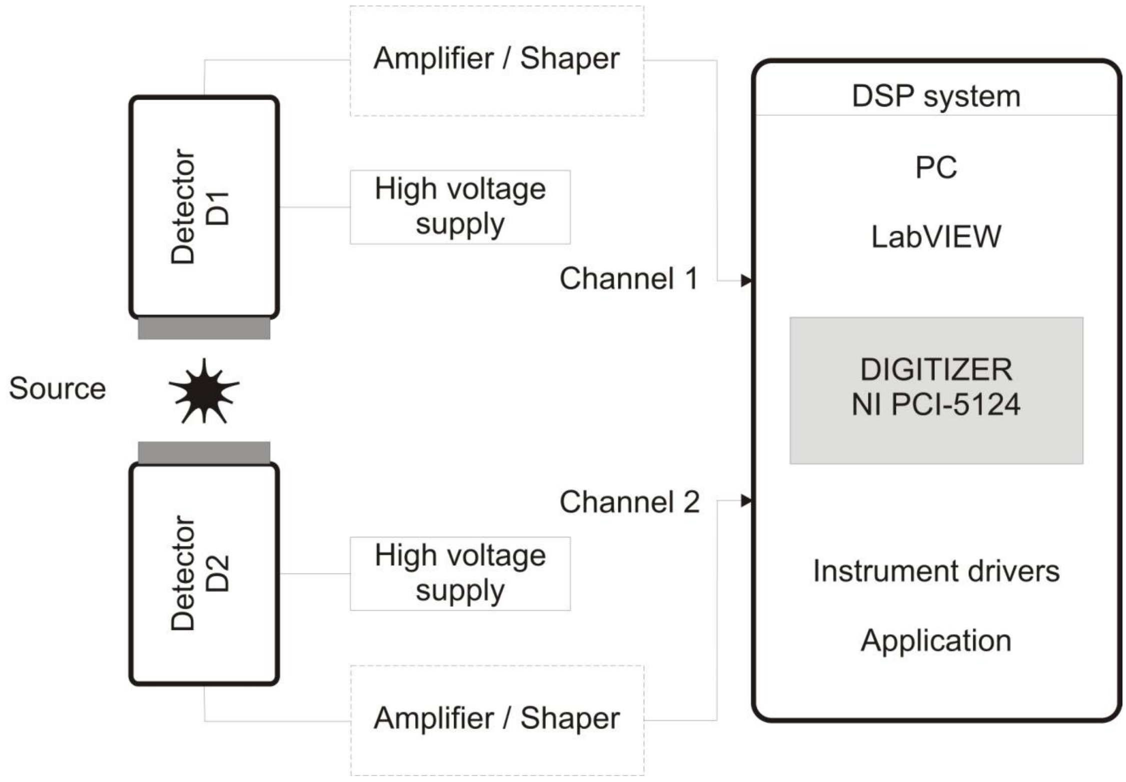

Figure 3. Block Diagram of the DSP System in the Experimental Setup

The sampled data are displayed in and processed by an application developed fully in LabVIEW, as shown in Figure 4.

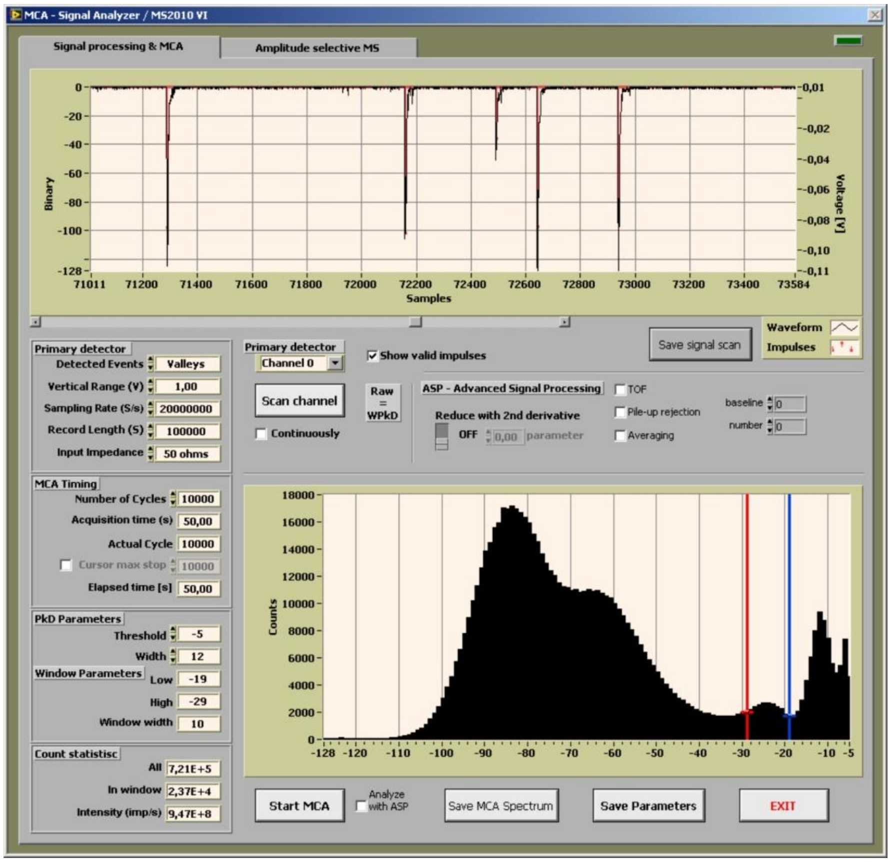

Figure 4. Signal and Multichannel Analyzer -Front Panel

The system performance was tested on the nuclear detectors with very short time pulses from 40 ns up to a few microseconds, and in the range of low and high energies of FX- and gamma-rays, from 6.3 keV to 662 keV (^{57}Co, ^{119m}Sn, and ^{137}Cs radioactive sources). The multichannel analyzer spectra were measured by means of the detector, amplifier with a capacitor, and digitizer and were analyzed by a code. The lifetime coincidence measurement of ^{57}Fe 14.4 keV excited state with a half-life of 98.7 ns was also performed.

In this study, high performances of the DSP system based on virtual instrumentation were directly evidenced by the spectroscopy application. Based on the results of our measurements, it can be concluded that the presented high-rate DSP system with 200 MS s^{-1} sampling offers a precise analysis. The developed TOF algorithm is very simple in realization and applicable for various detectors.

This work has been supported by the Operational Program Research and Development for Innovations - European Social Fund (CZ.1.05/2.1.00/03.0058).

PIC and CompactRIO™ Remote Motor Control

Author:
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I wanted to make a complex motor control. I decided to apply a trapezoidal signal to a motor and place it in a PID loop and read the motor's RPM with an optocoupler. Motors in lifts follow a trapezoidal pattern. A lift must accelerate, than it must have a constant speed and finally it must decelerate. I wanted to try it with two methods. The first one was with an NI PXI Chassis and the Microchip PICDEM Mechatronics board for the PID loop and amplification of the motor. The second was with the NI PXI Chassis and the NI CompactRIO for the PIC loop and amplification of the motor.

The technology from NI was a very good choice because I could solve a complex problem in an easy way.
For the first experiment with PXI and PICDEM Mechatronics I used the NI PXI-6115 + NI TB 2708 + SMB cable for the signal generation. This PXI card is a 12-Bit, 10 MS/s/ch, Simultaneous Sampling Multifunction DAQ. It has:

- four high-speed analogue inputs, 10 MS/s per channel, with onboard antialiasing filters;
- Deep onboard memory (32 or 64 MS) and extended input ranges to ±42 V;
- Two 12-bit analogue outputs, 4 MS/s single channel, 2.5 MS/s dual channel;
- eight digital I/O lines; two 24-bit counters; analogue and digital triggering.

For RPM reading I used the NI PXI-6608 + NI TB 2705 counter. This PXI card is a High-Precision Counter/Timer with Digital I/O. It has:

- 8-channel, 32-bit up/down counter/timer module;
- 32 digital I/O lines (5 V TTL/CMOS)—eight dedicated, 24 shared with counter/timers;
- high-precision oscillator;
- three simultaneous, high-speed DMA transfer capability;
- digital debouncing filters;
- 80 MHz maximum source frequency (125 MHz with prescalers);

The chassis used is the NI PXI-1044 with an external PC controller trough an MXI interface. For amplification and PID loop I used the PICDEM Mechatronics board from Microchip. For the first program only LabVIEW and the DAQmx drivers were used.

For the second experiment with PXI and CompactRIO I used the NI PXI-4110 for signal generation. This PXI car is a Triple-Output Programmable DC Power Supply. It has:

- three independent DC power supplies: - 0 to 6 V, 0 to 20 V and 0 to -20 V;
- all channels capable of delivering up to 1 A;
- ability to combine channels for higher voltage/current - up to 46 V or 2 A;
- 16-bit voltage setpoint and current limits, 16-bit voltage/current readback;
- additional 20 mA current range for precision source capability with 400 nA current resolution;
- maximum output power determined by power source - 9 W (from PXI backplane) or 46 W (from APS-4100).

For the RPM reading I used the NI PXI-6733 + NI TB-2705 multifunction DAQ counter input. This PXI card is a High-Speed Analog Output—1 MS/s, 16-Bit, 8 Channels. It has:

- eight high-speed digital I/O lines; two 24-bit counters; digital triggering;
- Onboard or external update clock.

The used chassis was the same NI PXI-1044. For the amplification and PID loop I used the NI-9505 C series module with the CompactRIO system. The C-series module is a Full H-Bridge Brushed DC Servo Drive Module. It has:

- continuous current of up to 5 A at 40 °C (or 1 A at 70 °C) at 30 V—for higher power add NI 9931;
- the ability to use data from the current sensor for flexible sampling times and filtering of the motor current;
- a full H-bridge brushed servo motor drive with a built-in encoder interface and current sensor;
- direct connectivity to actuators—fractional horsepower brushed DC servo motors, relays and lamps.

The chassis used for CompactRIO was the NI cRIO-9112 and the controller was the NI cRIO-9012. For the second program I used LabVIEW with FPGA, Real-time Modules and the DAQmx drivers.

Overall, I am very pleased, because I could complete my work in a short amount of time.

National Instruments products are every efficient and reusable, and working with them will save a lot of time. LabVIEW has a lot of premade functional blocks, leaving the engineer to think only about the logic of how to connect the blocks. LabVIEW's concept is to reuse code and not to remake every part from scratch, this saves time, but doesn't mean that LabVIEW is not powerful. Overall if we think about the large variety of hardware and software products from National Instruments we will be amazed.

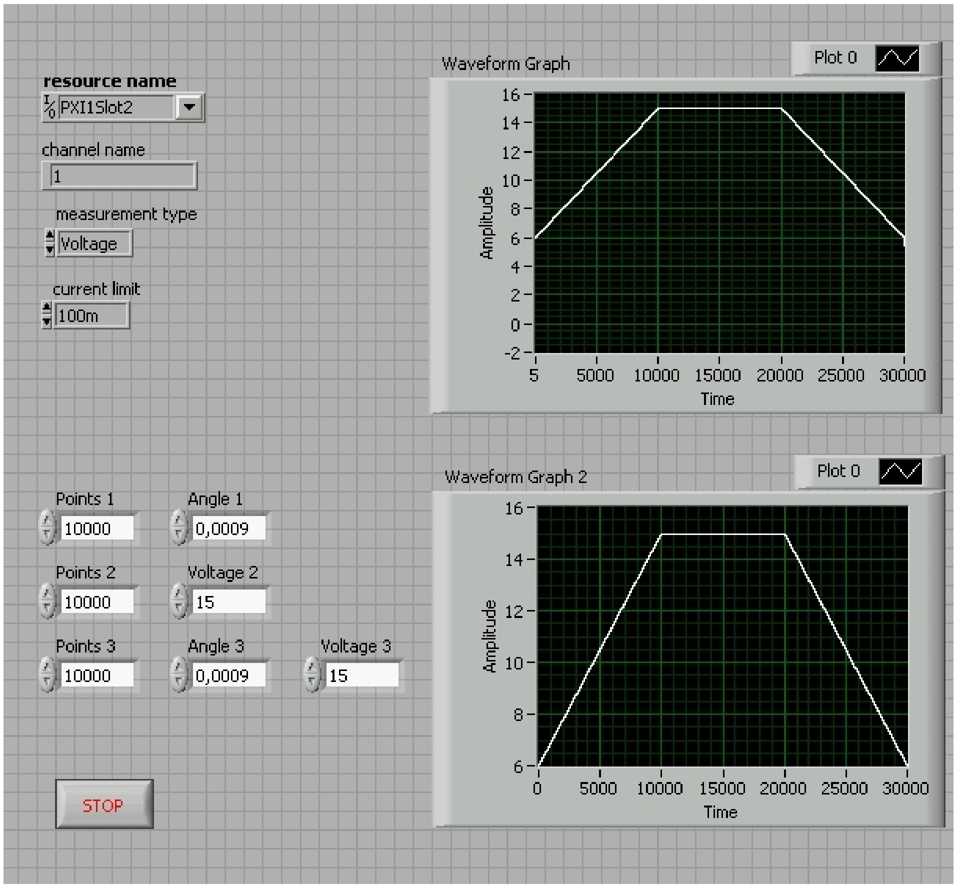

Figure 1. Trapezoidal Signal Generation

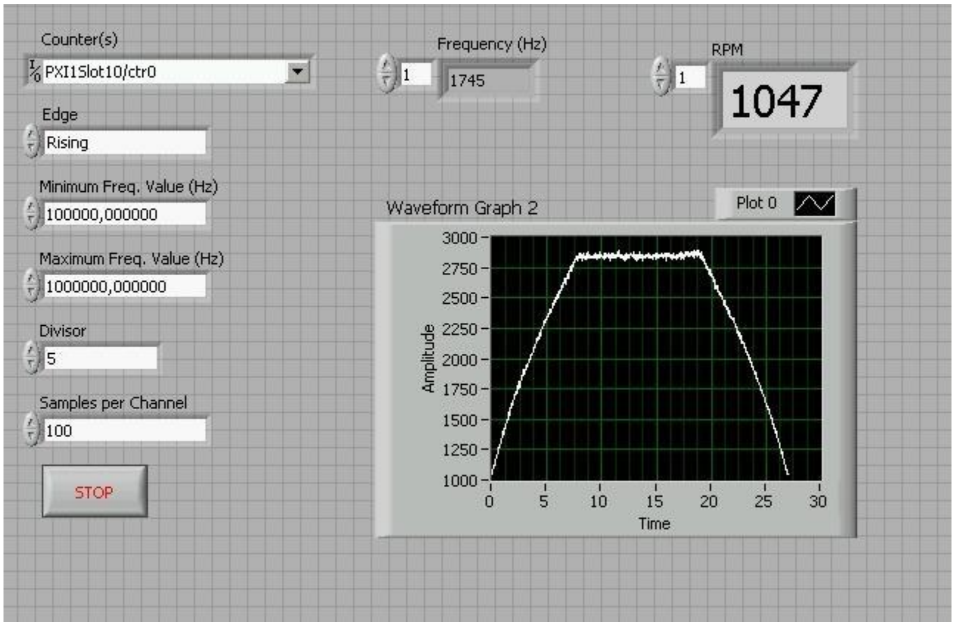

Figure 2. Motor RPM Reading

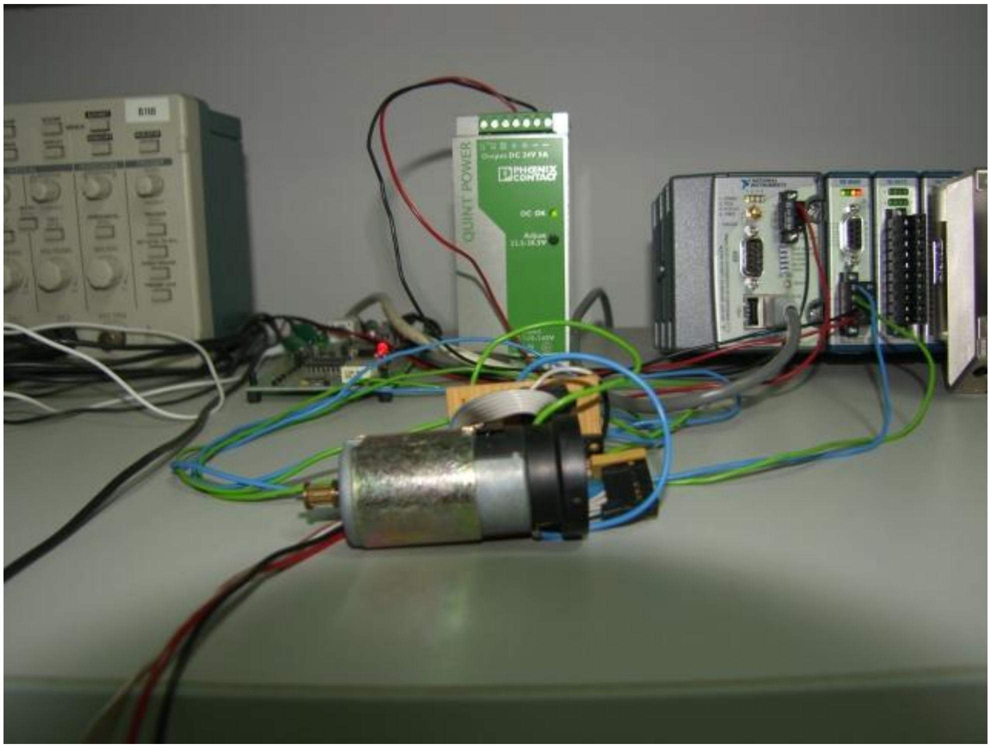

Figure 3. CompactRIO with Motor

Robotic Calibration and Simulation Stand for Trolleys Measuring Rail Geometry

Author:
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The main product of Commercial Railway Research, Ltd. (KZV), a company engaged in the development and manufacturing of diagnostic equipment for railway superstructure, is a system named Krab™. It is a trolley designed for continuous measurement of track geometry and features evaluation software. This device was developed not only for domestic Czech railways but also for export abroad. Like any measuring equipment, Krab requires regular calibrations. Thus, the developed calibration stand meets the technical requirements.

The Krab Trolley

During the measurement, the Krab trolley (Figure 1) is usually manually pushed along the track, though it can also be pulled or pushed by a two-way vehicle. The measurements of track geometry include an assessment of track gauge, alignment, top, cant and twist (change in cant) of the track. Krab is a chord measuring system, *i.e.*, top and alignment of the track is measured by the entrenchment of an asymmetric chord. The entrenchment of the alignment and top is measured only on a single rail. The situation on the other rail belt is calculated using gauge and cant signal. For a more accurate measurement of cant, Krab is equipped with an auxiliary twist arm. The measurement is performed with a final sampling interval of 0.25 m. The data is collected using a rugged PDA with Windows Mobile OS. Readings are then transferred to a PC and further evaluated.

Figure 1. The Krab Trolley on the Track

Stand Construction

The idea for a robotic calibration stand arose from the need to smoothen and refine the existing calibration method of Krab trolleys (and similar trolleys) as all the equipment in use should be calibrated annually. During development, however, an interesting idea appeared to also simulate trolleys on the track along with calibration. The Krab trolley is equipped with six sensors. One of them is a distance sensor, which can be simulated electronically. Therefore, it was sufficient to equip the stand with five motor drives.

The stand frame is composed of the upper part on which the trolley stands, and the lower part, which lies on the ground. Both parts are connected with joints. This connection allows the upper part to tilt with respect to the ground and thus to set the cant.

Because trolleys are produced in gauges ranging from 750mm to 1,668 mm, a corresponding mechanism allowing this range is used on the stand. Variation of the top and alignment is provided by a mechanism with two degrees of freedom. Movement of the twist arm is provided by a special mechanism.

All moving mechanisms are implemented using Berger-Lahr hybrid stepper motors. The stepper motor allows the tester to set up to 10,000 steps per revolution, but for use with the stand, 1,000 steps per revolution is sufficient thanks to the transmission. The conversion of the rotation-to-linear movement is provided by a belt drive and ball screws.

Control Hardware

For motion control, the PCI-7356 card from National Instruments (NI) is used. This card can control up to six stepper and DC motors, which can be plugged into the PCI slot of a desktop PC. The card also has eight analogue inputs and 64 digital inputs/outputs. The card also allows connecting a feedback input. In addition, the card allows onboard programming, so it can run application programs for motion control in real-time without using the real-time operating system. Used with the stand, the card works in a step/dir mode. This means that for every card, the engine generates two signals: step and direction. These signals are processed by a Berger-Lahr SD3-15 drive. Based on the step/dir signals, a converter generates a voltage signal in the form of three mutually shifted curves similar to a sine wave. These signals form a stator rotating magnetic field. The SD3-15 drives are powered by two BKE DC 24V switching power supplies.

As used, the stepper motors and motion control card are equipped with a step counter, so there is no need to use feedback sensors. Control is performed in an open loop. After turning on the stand, it starts running an initialization program, which sends all the drives to an exact position on their limit switches, from which a specific number of steps is counted. Thus, the stand establishes its starting position. The practice has shown that this technique works very well, except that one must consistently ensure the position of the limit switches.

LabVIEW

The PCI-7356 can be programmed easily in the LabVIEW graphical environment, which includes, *inter alia*, the NI motion controller with many features specialized for NI motion-control cards. Two basic programs were created in LabVIEW: calibration and simulation programs.

Calibration Program

The calibration program works in two modes. The first mode is the control of individual axes, which are intended for manual calibration using the Krab PDA so the movement to the desired position will be defined by the user. The second mode is automatic calibration (Figure 2), which takes place in the following steps: first, the stand is put in preprogrammed positions; next, the positions are programmed to form a closed loop and at each location, data is retrieved from Krab sensors and stored on the PC; after the cycle is complete, the calibration constants are calculated on the basis of the stored data; and last, the calibration protocol in MS Excel is generated in one click using ActiveX.

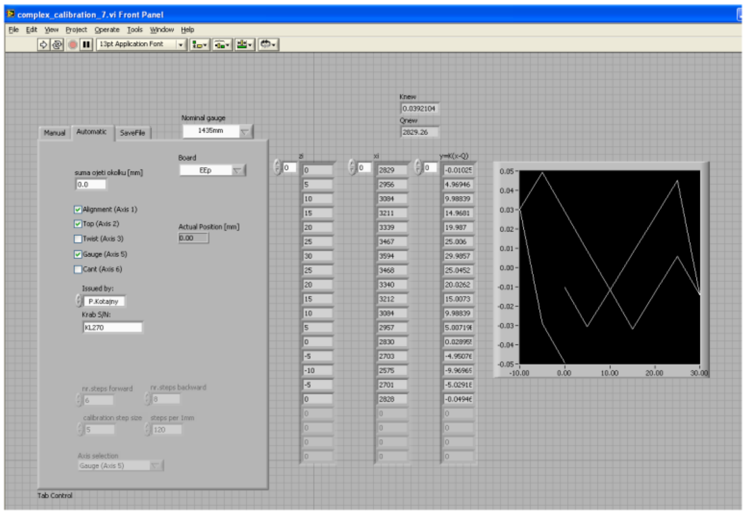

Figure 2. Automatic Calibration

Simulation Software

While running the simulation program, the Krab trolley is in acquisition mode. The stand performs the signals measured in the track or artificially generated signals. The Krab trolley evaluates and records the stand behaviour. After the simulation is finished, verification can be done comparing the recorded and performed signals. This will reveal any errors in the tested trolley.

The simulation software program is running in two parallel loops. This is not a problem because LabVIEW manages parallelism. The program uses PCI-7356 card with a buffer, to which data is added at the time, when the number of samples sinks below a set limit. Since the stand is equipped with five drives, the last axis serves to

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generate an incremental rotary encoder signal with the help of two D-type flip-flop circuits.

Conclusion

The calibration and simulation of the stand (Figure 3) was already tested and proven during numerous previous calibrations and simulations. The hybrid stepper motors used seem to be very precise. They do not lose step and do not suffer from unwanted resonance, as with motors with permanent magnets. Perhaps the only disadvantage of these motors is that when disconnected from their power sources, they hold for a moment and lose their position. This deficiency was solved by using the motor brake. Using the LabVIEW development environment and a large quantity of ready-made features, one can easily and quickly program control applications. The advantage of the solution is also the ability to easily and quickly add new features, which is expected in the future.

Figure 3. Calibration and Simulation of the Stand

Asynchronous Motors with Virtual Instrumentation in an Educational Demonstration

Author:

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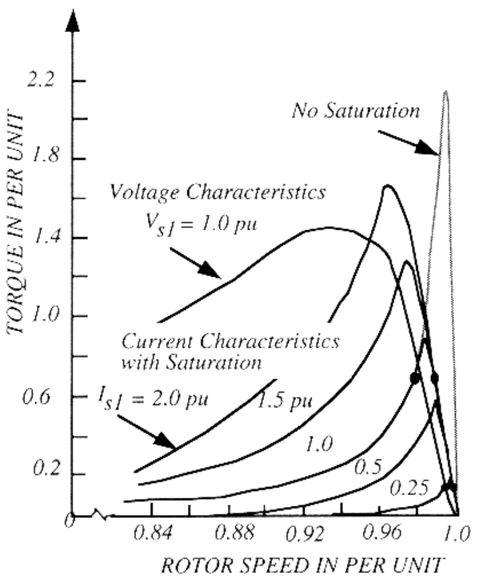
I would like to introduce my educational project about asynchronous motors. The project began at the Óbuda University's Kandó Kálmán Faculty of Electrical Engineering. This department has traditional education methods with the goal to put the main focus on practical rather than theoretical knowledge because students must know and use electrical devices. This project will demonstrate the asynchronous motor's characteristics diagram in the lectures of Energetics I.

The main goal was to build a model that can demonstrate the asynchronous motor's main characteristics while in operation. This system had to show the results in real-time and move easily so that my teacher could use it as a demonstration in his lectures. The model needed to contain an operations screen that showed the current, voltage and revolutions while braking or freely running. The selection of the display instrument also had the criterion that the revolutions be displayed on the board so that students could clearly see the results when braking or not. The graph in Figure 1 was an addition goal to have drawn on the board.



2. The motors.

Figure 1. Operation Graph

Figure 2. The Motors

For this project, I used two asynchronous motors. One motor worked as the driving motor and the other as a generator and brake. These motors were connected to a common crankshaft. I chose a plastic material for the coupling because if the bushing were to fail only the plastic would break. The revolutions are measured through a plastic plate with holes. There were eight holes in total, spaced equally. The motor's connection points were terminated on the front panel of the device.

As the measurement is complex, I needed to measure different voltage and current data at different points and times. The first idea was to use electrical multimeters with storage functions and then read out and calculate the current point on the graph. That takes a long time and students would not have liked that. The second idea was to develop an embedded measurement system as a virtual instrument solution, using processors to calculate and show the estimated data. The problem with this was it required a lot of time to develop a circuit, check and write the solution, using another program just for the visible part. Also, it is not flexible. If I want to modify just a little point, I need to redesign the whole circuit.

The best solution was to choose the USB Data Acquisition features by National Instruments. The NI-USB 6229 DAQ device suited my aim for both the geometrical and collected data requirements. This tool has 32 channels, with 16-bit resolution. These channels have analogue inputs, outputs and also two counters. I used this hardware to measure voltages between -10V and 10V, switching the motor on and off. The motors operate on $230V_{AC}$, so I applied transformers between them. The current was measured on a very accurate instrument resistor as voltage and then the current was calculated. The revolution's signals were acquired by two methods: one method was an LED diode that sensed changes in the voltage. The other method was a magnetic-based Reed-relay technique. At first I wondered if the motor worked on a constant revolution on every load so I put in an oscilloscope to check the signal and I saw the graph in Figure 3:

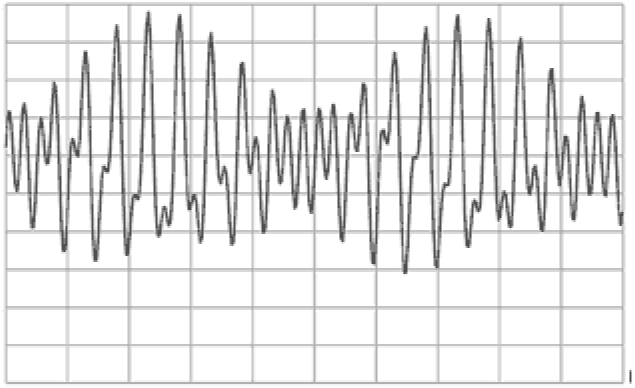


Figure 3. The Measured Disturbance of Magnetic Field on the Semiconductors

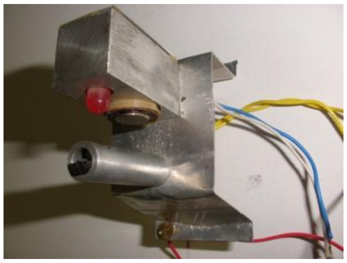


Figure. 4. The Sensors

The periodic signal showed me that the magnetic field created by the asynchronous motor was cramping my measurement. So I used the Reed-relay based revolution measurement. It did not show me any disturbance. I used the disturbance of LED and a photo sensor as an example of the magnetic field's capacitive coupling. The next step was to choose a platform for the application. The NI's LabVIEW platform was my choice. This platform contains every tool that I need and it is easy to program it by "drag and drop" methods. The visualization also was solved, because LabVIEW shows it as well. The connection to the USB DAQ device was easy with the DAQ Assistant. I used LabVIEW 8.5 on the Windows XP platform on a P4 laptop. I used simple VI elements to acquire data because they use less power and it is simpler to manage the data. The other big benefit is the system is fully graphically based. It was easier to demonstrate the source code and find errors than with script-based languages.

Figure 5. Students at the Energetics I Lecture (symbolic picture)

Figure 6. The Powerful LabVIEW Product Family

Conclusion

To summarize, my experience with National Instruments products was successful. I could develop a demonstration device in a very short time and demonstrate it in a professional way. The Hungarian National Instruments Support Team also helped me to achieve my goal to find the best solution and the best product for my project. They help me greatly to find the best solution and the best product for my project. On the "big day" my professor and I were able to demonstrate this device and explain it successfully. The students were interested about the programming language and also the powerful LabVIEW programming methods. After our demonstration, many students in our research area are getting to know LabVIEW and do the same projects.

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