VIRTUAL INSTRUMENTATION – A KEY FOR TEACHING METROLOGY AND QUALITY ENGINEERING

M. J. Korczynski, R. Gozdur
Institute of Theoretical Electrotechnics, Metrology and Material Science,
Technical University of Lodz, ul. B. Stefanowskiego 18/22, 90-924 Lodz, Poland.
E-mail :jerzykor@ck-sg.p.lodz.pl, gozdur_r@ck-sg.p.lodz.pl

Abstract. Teaching the practical aspects of engineering to potential engineers is a very important part of their education and it may also play a key role in their understanding of the engineering courses taught at universities. This paper describes how a virtual instrumentation based laboratory can be used to teach undergraduate students in "Metrology and Quality Engineering" at the Electrical and Electronic Engineering Department of the Technical University of Lodz. The low cost involved in building the laboratory was achieved by setting it up as a multifunctional flexible laboratory with shared resources. The individual work areas are connected via an INTRANET and can also be made available on the INTERNET, although there are some minor limitations while experiment are being performed at different remote locations. The experimental work areas each have PC based computer equipment which is grouped into three types of experimental benches: the first is equipped with a multifunction I/O or dedicated PCI cards, the second with desk top instrumentation and the third as a calibration work station. All student work areas, or benches, are supported by the full version of LabView® Ver. 6 software. These three groups form a kind of bank of instruments and are accessible from other computers, local or remote. The master stations, equipped with a MIO cards, are configured in such a way that the individual channels of the multifunction I/O cards can be assigned to individual PCs on the local net or distinct computers using a TCP/IP protocol. Sharing of a complete MIO PCI card is quite obvious, but access to individual channels on one PCI MIO card is a new idea and therefore had to be develop here at Lodz, exclusively for this application in our laboratory. The subjects supported by the virtual instrumentation are listed in the paper and the importance to quality engineering is highlighted and emphasised in the paper. The laboratory, as described, can facilitate distance learning in a practical way in many engineering subject areas.

Keywords: Virtual Laboratory, Virtual Instrumentation, Quality Engineering.

1 INTRODUCTION

Developments in both science and technology require university courses to be updated on a regular basis and have not only to be able to follow these new developments, but also have to create mentors aware of the rapid changes in science and technology. This development process, however, depends on the type of course being offered. One can consider course development processes as being very similar to industrial product development and, therefore, we can say there are 'platform, derivatives and breakthrough products' in the context of developing new course modules or degree courses. The quality subject area, in this respect, could be considered as development of a 'derivative' or even a 'breakthrough' product as nothing of this kind really exists in the mainstream subjects of the current degree courses in electrical and electronic engineering disciplines. The most recent addition – the books titled "Scientific Metrology", and "*Measurement Data Handling"* written by J. McGee, W. Kulesza, M. J. Korczyński, and I. Henderson - now being used as a text in the undergraduate class teaching at the Łódź University can be considered as a "derivative" or "breakthrough" course material. This assertion is based on the fact that it is a novel course, developed and presented to the electrical and electronic engineering students as a module for the first time. The developed programme is a 3-year undergraduate study in Metrology and Quality Engineering. The demands of the new courses made us search for an effective, low cost laboratory solution to teach the practical aspects which are very important for students future career.

2 SUBJECTS TAUGHT IN VIRTUAL LABORATORY:

Quality Engineering and Metrology is a 3½ year undergraduate study programme developed, under TEMPUS S-JEP 12204/97 for the Electrical and Engineering Faculty of the Technical University of Łódź, Poland.

The three and half year curriculum developed at Electrical and Electronic Engineering Faculty of the Technical University of Lodz has a block of basic subjects: Mathematics, Physics, Material Science, Basic Electrical Engineering, basic Computer Engineering, English and Communication Skills and a group of specialised subjects such as:

1. Digital Signal Processing for metrology
2. Quality assurance and Management
3. Measurement systems in Quality
4. Advanced probability theory and statistics for quality engineering
5. Inspection and testing and auditing for certification and accreditation
6. Modelling and simulation of measurement systems
7. Advanced sensors and actuators
8. Total Quality Management
9. SCADA systems and Interfaces in measurement devices
10. Measurement for environment monitoring
11. Reliability of Hardware and software. Software Testing and Certification

As laboratory training plays an important role in preparing an engineer for the market place and practical hands on experience also makes it easier to understand theory – therefore, a need to develop a cost effective and unified set of laboratories was realised. This was achieved by studying in depth the needs of all the specialised subjects. The results of this study are presented below.

If we use virtual instruments: software plus an adequate set of sensors mainly with electrical output signals, if we apply DSP, a set of Desk Top Instruments, a calibration station and all of them connected to computers, then we achieve a high performance laboratory, flexible and where the following skills can be developed:

1. Calibration Procedures (CP); precision measurement technique included.
2. Interfacing of instrumentation, configuration of SCADA systems, Desk Top Instrumentation (DTI); Data Acquisition Systems
3. Designing of Instrumentation (DI). based on ADCs, DACs, IMQ boards, PCI based Extension for Instrumentation (PXI), Signal Conditioning Extension for Instrumentation (SCXI),

These skills are used for teaching methods, DSP, data acquisition and data handling. It is necessary to mention that the 'Software soldering bolts' realised by Virtual Instrumentation is the most economical way to teach instrumentation design.

3 VIRTUAL LABORATORY - THE SYSTEM OF SPECIALISED LABORATORIES

Education and training in Quality Engineering requires:

a. Training in Calibration Procedures (TCP); Precision Measurement Technique included. Need of precise calibrators and process calibrators.
b. Training in interface instrumentation, configuration of SCADA systems, For this need a Desk Top Instrumentation (DTI); Teaching: Data Acquisition Systems, Data Handling, Instrument Interfacing.
c. Designing Instrumentation (DI). Virtual instrumentation, with PCI Extension for Instrumentation (PXI), Signal Conditioning Extension for Instrumentation (SCXI), are used for teaching methods, DSP, data acquisition, data handling. 'Software soldering bolts' realised in Virtual Instrumentation provides the most economical way to tech instrument construction.

All of the instrumentation, which have been selected for laboratories purposes, will be used in a remote and multi-access mode throughout local classroom, Faculty computer net and other locations by using a use of TCP/IP protocol and a specialised server and client protocol available from LabView.

The configuration of the virtual laboratory based on virtual instrumentation are presented in Figures: 1 and 2.

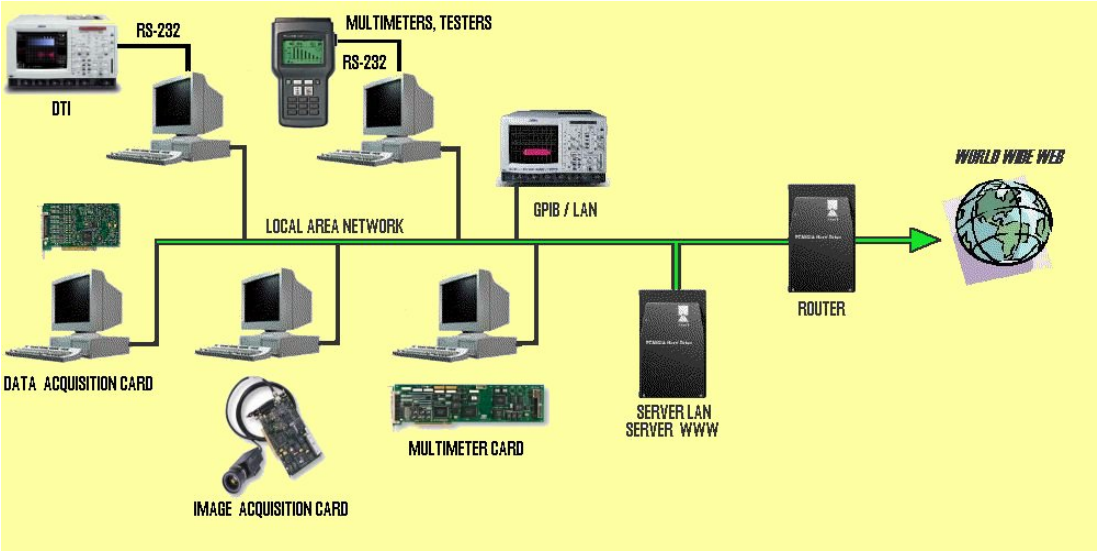

Fig. 1 Flexible laboratory for teaching purposes

It allows us to minimise the cost of providing laboratory students benches, keeping a big variety of experiments and to be ready for remote access to labs from other universities.

One aspect which will help much is a Virtual Computing Net with an interactive mode for both teacher and students.

It is worth mentioning that a proposed system of laboratories could facility up to 600 undergraduate students of the Faculty.

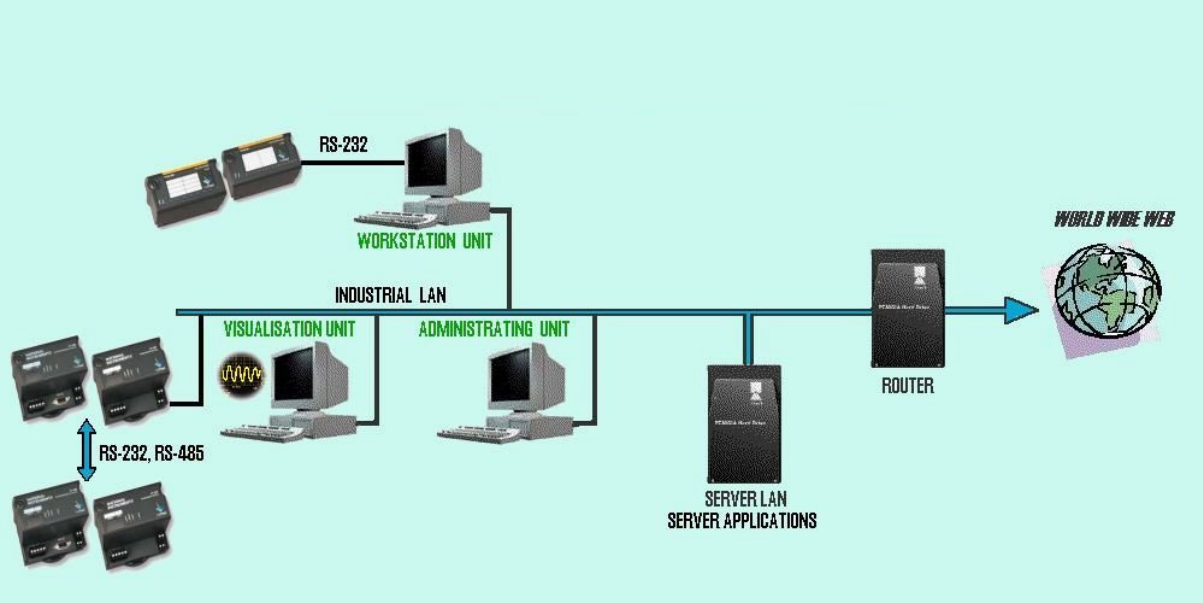

Fig. 2 Flexible laboratory for teaching territorially distributed systems

A virtual laboratory based on virtual instrumentation is the key for effective teaching.

The most important features of virtual laboratories are: flexibility, easy of development and fast modification

As today's measurements any mainly digital, the path from the sensor to its digital form and eventual processing of the transformed signal is a key to the teaching of metrology. All measurement methods, theory of uncertainties, sources of errors are applied to the new digital form of measurements. The actuality of so far developed theory of measurements is now used for digital measurements with all Information Technology achievements.

All ADCs used in laboratory are connected to a computer net, a remote and multi-access mode throughout local Faculty computer net and the access for remote locations using TCP/IP and a specialised sever (DSTP) and client (DCTS) protocols from LabView.

This allowed us to minimise the cost of laboratory students benches, keeping quite big variety of experiments and to be ready for remote access to labs from other universities.

One of our goals is to built a laboratory in co-operation with other universities, that is more economical and hence more efficient.

We can offer our extensive resources to other universities and will use resources which are offered to us. One what will help much is a Virtual Computing Net with an interactive mode for both teacher and students.

It is worth mentioning that a proposed system of laboratories could facilitate up 600 undergraduate students of the Faculty.

Virtual instrumentation, used for real measurements is based on a general purpose PC computer with a user friendly G-language, Matlab scripts or Test Point scripts, Java scripts and applets plus sensors, conditioners, Sample and Hold modules, filters and converters (ADC, DAC, IMAQ boards) which communicate to CPU of computers via any type of communication interface: internal and external like ISA, PCI, PCIMCIA, serial parallel, USB Fire Wire 1394, FieldBus, GPIB, Ethernet) The very important role are playing DSP of captured data processed preferably on line.

4 EXAMPLE OF THE BENCHES WORK BENCH

One of the example of students' experiment in the area of DSP is described here. The full software will be presented at the seminar.

The experiment is divided into two sections. The first one is about general features of signals of different waveform and the second concern Fourier Transform. The contents of the experiment are as below:

1. General features and digital conversion of signals
   - minimal and maximal value
   - mean and rms value,
   - period, frequency and time duration of waveform
   - auto- and cross-correlation of signals,
   - amplitude power density
   - integration and derivation of signals
   - filtering of time variable signals
2. Metrological aspects and properties of DFT and FFT transform
   - sampling frequency and number of samples
   - consequences of the variation of sampling frequency, non-stability of measured signals, number of samples different from non-integer power of 2.
   - spectral analysis of the signal of unknown parameters
   - observation of aliasing
   - applying of over-sampling and antialiasing filters to reduce aliasing effect
   - FFT and IFFT for determinations of THD coefficients.

The special friendly use application based on a TestPoint software environment was developed. In one packed the students can chose generators, monitor in time domain, transform to frequency domain and measure all mentioned above parameters. The errors caused by mismatching a number of samples, improper sampling and time variation of the measurement window is in the scope of analysis in the experiment. The students are dealing with both software generated and real hardware signals. It means that students become familiar with the most common sources of errors which occur in real life. This stand allows us to simulate the sampling voltmeter with simulated ADC with a different number of bits and simulation of FFT analysers of different parameters.

5 CONCLUSIONS

The new laboratory is designed to teach students: calibration, design of new instrumentation and interfacing and is needed by graduates who would like to work in Metrology and quality Engineering, as the scope of lectures is manly in Information technology.

The virtual laboratory with virtual instrumentation was developed for the new three and a half year study programme "Metrology and Quality Engineering", at the Electrical and Electronic Engineering Faculty of The Technical University of Lodz to support teaching: sensor science, calibration procedures, design of instruments, interfacing, as well as programming and reliability in quality area.

Although the physical resources available and also the money were very limited and the planned subjects supported by the laboratory are from different areas, the virtual laboratory with its flexibility has allowed us to complete the task at minimal cost.

The Virtual laboratory is using today's technology, is using DSP extensively, the 'workbench' can be accessed from distant locations, so the laboratory is a 'seed corn' for co-operation with other laboratories in providing students and research institutions with a flexible set of dynamic experiments.

The application of touch screens for virtual instrumentation is at present under development in our laboratory and this we believe will finally convince even the sceptics, who are opposed to virtual instruments. They want to keep touchable knobs, trimmers and switches as found in conventional analogue and digital instrument. They need to accept that virtual instruments are the real instruments of the future!

The laboratory will be developed to serve as an interdisciplinary laboratory for automation of industrial process in the Mechanical and Textile Departments at our university.

REFERENCES

[1] Arpaia P., P.Daponte, M.Marinov Measurement Systems Distributed on Geographical Networks for Educational Puroses International Workshop on Virtual and Intelligent Measurement Systems (Annapolis, 29-30 April 2000), Annapolis, MD, USA, p. 62-68.

[2] Bertocco M Platform Independent Archtecture for Distributed Measurement Systems, IEEE Instrumentation and Measurement Technology Conference, (Baltimore,USA,1-4 May 2000), Baltimore, USA, 2000, p. 648-651

[3] Drnovšek, J. Bojkovski, I. Pušnik, P. H. Osana, McGhee J., Weckenmann A., Measurement related study program "Quality Engineering", XIV IMEKO World Congress, Tampere, Finland, June 1997

[4] Drnovšek, J., Osanna P.H., McGee J., Weckenmann A., Bojkovski J., Pušnik I., Metrology education in a Quality Engineering Undergraduate Study Program, OIML Bulletin, BIML, Vol. 40, (No. 1): pp. 8-12, 1999

[5] Fuerst W., Lynn P. A., Digital Signal Processing with Computer Applications, John Willey & Sons, 1999, ISBN 0-471-97631-8

[6] McGhee, J., Kulesza W, Korczyński.J., Henderson I. Teaching Measurement and Instrumentation in English at the International Faculty of Engineering, 9th Intenational Symposium on Electrical measurement in industry, IMEKO TC-4Technical Committee on Measurement of Electrical Quantities, Glasgow, Scotland, September 8-9, 1997.

[7] McGhee, J., Kulesza W, Korczyński.J., Henderson I., Scientific Metrology, ACGM LODART, Łódź, Poland, first addition, September, 1996, reprint, July, 1998, ISBN83 904299 9 3

[8] McGhee, J., Kulesza W, Korczyński.J., Henderson I., Measurement Data Handling, ACGM LODART, Łódź, Poland, first addition, 2001, ISBN83-7283-007-x

[9] Mulgrew B., Grant P., Thompson J.; Digital Signal Processing, Macmillian Press Ltd, London, 1999, ISBN 0-333-74531-0

[10] Oppenheim A.V., Schafer R.W., Discrete-time Signal Processing, Prentice-Hall,Englewood Cliffs, NJ, (1989)

[11] Penarrocha V.M.R,.Bataller M.F, Virtual Instrumentation: First Step Towards a Virtual Laboratory, International Workshop on Virtual and Intelligent Measurement Systems (Annapolis, 29-30 April 2000), Annapolis, MD, USA, p. 52-56.

[12] Rak R.J, Virtual Instrumentation, Elektronizacja (9) (1999) 9-13