

Laboratory Test Benches Development for Engineer's Education

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I. INTRODUCTION

Design and development of up-to-date automated industrial production as well as experimental systems for research work in different areas of science and technology are in need of qualified scientists and engineers who can rapidly and efficiently solve various problems using advanced technologies. Training these specialists in the system of higher and vocational education requires application of advanced and intensive educational technologies, radical modernization and continuous improvement of material and technical basis along with information and methodology basis.

In addition, students are required to learn much more information and obtain practical experience in the area of study for successful activity in their future careers spending not so much time, they spent before. Moreover, even if students complete their education and become engineers, they should continue their studies, periodically raising their level of qualification in order to be an up-to-date engineer and satisfy to the state-of-the-art industry trends.

It goes without saying, that there is no way to solve the problems of increasing education quality without involving advanced information technologies and distance education methodology and facilities developed on the IT basis [1]. Application of these technologies to electronic textbooks creation and knowledge testing systems development allowed to speed up the process of information and teaching materials updating. It made them more accessible for students and facilitated teachers' work.

However, engineering education, aside from theoretical courses, also assumes acquiring practical skills in investigating real-life physical objects and phenomena, both natural and man-made. Students can acquire these practical skills only when making experiments during their practical and laboratory classes using suitable equipment, various metering instruments and systems, special-purpose software, allowing them to study the of the real-world objects, design and test new products.

The paper considers the problems of creating the up-to-date laboratory base for teaching and learning students of engineering, mathematics and sciences. Also, results of development and application of educational laboratory test benches and laboratories are presented, which can be used both for traditional laboratory classes organization and e-learning systems.

II. GENERAL PURPOSES

In the modern educational laboratory each workplace consists of the following components – test subject or its physical model, measurement and control tools, auxiliary

technical equipment and personal computer with general and special software.

Usually a personal computer serves as storage of reference and educational information required for the laboratory class. Also it is a central part of computer-aided design systems for different products and materials. Obviously a personal computer should be used to control educational experiment, including all measurement instruments; to process experimental data and to automatize laboratory practical work, as a whole. At the same time, measurement and other functions of laboratory test bench are efficiently realized with data acquisition (DAQ) boards plugged in motherboard of personal computer and applied software is developed in graphical development environment National Instruments LabVIEW (Laboratory Virtual Instrument Engineering Workbench) [2,3].

The authors applied the approach mentioned when creating a range of hardware and software systems for equipping educational laboratory test benches and laboratories, as a whole.

A. Measurement instruments

The complete functional set of multi-purpose measurement instruments "Intelligent Virtual Instruments Suit - 2" (IVIS-2) are suggested to use as one of the most complicated and expensive components. Following items are included in the set (some of them are illustrated in figures below):

1) Arbitrage Waveform generator

This generator (4 channels) is intended to stimulate the research objects. It is presented in Fig. 1.

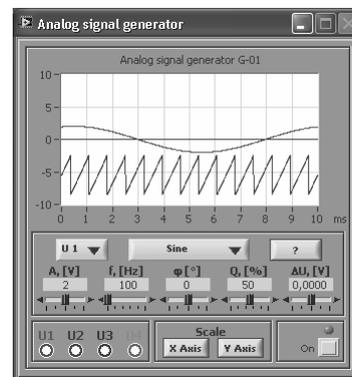


Fig. 1. Front panel of the arbitrage waveform generator.

The one of typical periodic waveforms can be selected (fixed level DC, sine, sawtooth, triangle, noise or analytic expression) and the signal characteristics are defined here.

2) *Oscilloscope*

The front panel of developed oscilloscope (4 channels) is shown in Fig. 2.

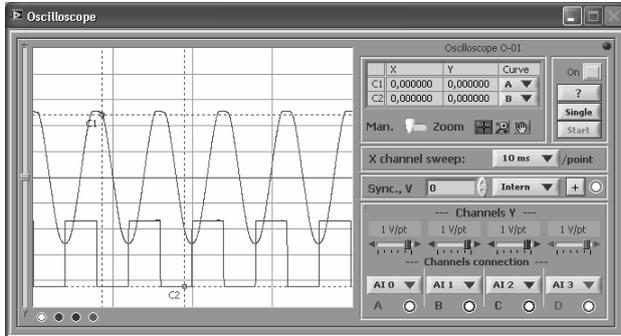


Fig. 2. Front panel of the 4-channel oscilloscope

The oscilloscope offers experimental observation for real signals at checkpoints of the test subject. It supports internal and external synchronization modes and also it measures amplitude curves and time intervals of signals by the instrumentality of 2 cursors, allows scaling the plot on the screen.

3) *Multimeter*

Up to 4 multimeters are available in the set. The front panel is demonstrated in Fig. 3.

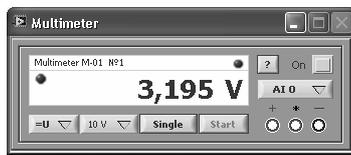


Fig. 3. Front panel of the Multimeter

This instrument is intended to measure mean and root-mean-square AC and DC voltage and current in electric circuits. The results of analog-digital conversion are processed, averaged in specified range and represented on the digital indicator.

4) *Frequency meter*

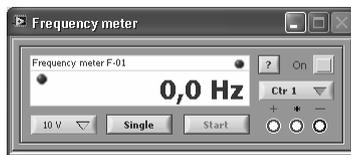


Fig. 4. Front panel of the frequency meter.

Frequency meter (front panel is presented in Fig. 4) realizes the frequency measurement of periodic signals. The measurement can be processed for digital (impulse signal with normalized amplitude) or analog signals through one of the 4 inputs. In the latter case the frequency value is rated by fundamental harmonic.

The set of instruments examined above serves for evaluation of analog signal amplitude characteristics and can be used for measurement techniques studying, practical skills acquirement with experimentation of electronic devices.

IVIS-2 also includes instruments, which allow user to process findings and organize complicated research of the devices under test.

5) *Spectrum Analyzer*

Developed spectrum analyzer evaluates measured content spectrum and visualizes it on the plot. The input data are results of voltage measurement from oscilloscope. The spectrum analyzer fulfils the next list of functions:

- Computation of signal spectrum (amplitude, phase, energy);
- Applying windows to the time signal (Hanning, Hamming, Blackman-Harris an other);
- Averaging of signal spectrum;
- Visualizing the results in terms of the original units or decibels (dB).

6) *Two-terminal networks and four-terminal networks volt-ampere characteristic Analyzer*

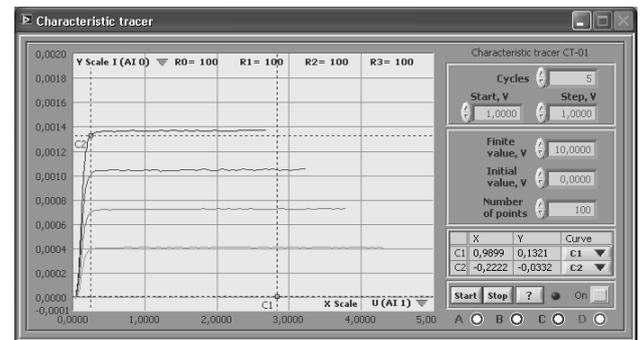


Fig. 5. Front panel of the two-terminal networks and four-terminal networks volt-ampere characteristic analyzer.

This instrument (Fig. 5) provides characteristic computing for two-terminal networks and four-terminal networks, such as volt-ampere characteristic of diode and transistor output characteristics. Construction of graph is realized by series of cyclic measurements for test subject's reactions through 4 channels of data acquisition module.

Two-terminal networks and four-terminal networks volt-ampere characteristic analyzer also has ability to take characteristics in all over 4 quadrants of XY plane (input and output characteristics of bipolar p-n-p and n-p-n transistors, unipolar transistors, diodes and others). All processed curves are visualized on the XY graph, where user has possibility to choose any desired channel for X and Y axes and view voltage and current values. These values can be measured in arbitrary points of the curves with the help of two cursors.

7) *Frequency-response Analyzer*

This instrument offers amplitude-frequency characteristic and phase-frequency variation processing for signal measured. All of them are displayed on the graphs with the representation parameters specified by user. For data acquisition it can be able to assign frequency sweep limits of signal, number of samples per decade. Visualization process supports scale selection (linear or decibels) and work with cursors. There also parameters for computation

are specified (such as frequency limit of specified signal attenuation or gain slope).

8) Digital generator

The digital generator is intended to generate different types of discrete test impact on the digital outputs (TTL) of DAQ-board. The test impacts are displayed as graphs of each digital line state changed in time. It is possible to use up to 16 lines of digital port. Data are visualized in automatic and step-by-step mode. The digital generator allows generating impacts of the following types:

- single value;
- marching "0";
- marching "1";
- toggle values;
- ramp values;
- random values.

9) Logic states analyzer

This instrument (front panel is shown in Fig. 6.) measures and analyzes digital signals, generated by test subject on the TTL inputs of DAQ-board. Up to 16 lines from digital input are used. Data input can be synchronized either internal or external clock frequency.

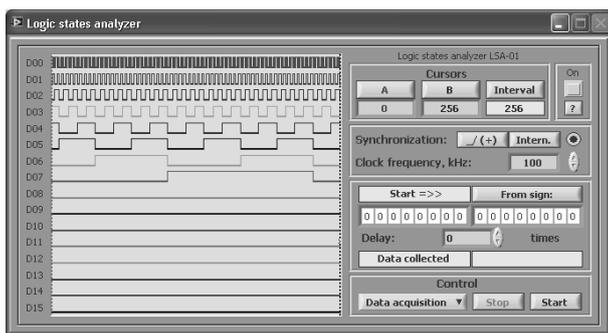


Fig. 6. Front panel of the logic state analyzer.

Data acquisition executes in different modes. It can be positive or negative launching on 16 digits word with the number of time steps delay defined by user. It is possible to mask arbitrary launching word digits, to save data in file, to compare results with pattern, to search data or convergence time steps and others. States of test subject are displayed in the form of timing charts, state tables or tables containing comparison results with pattern.

10) General features of IVIS-2

This set of instruments is based on DAQ-device NI PCI-6259M providing sampling resolution of 16 bits for analog signals in the range of $\pm 10V$ and sampling interval for 4 μs . Testing of digital devices are realized in real time with sampling rate up to 10 MHz. DAQ-device is replaced by more high-performance DAQ-board, in case it is necessary to improve performance specifications of instruments, first of all to increase the sampling rate. At the same time you do not need software correction.

However, the instrumentation set presented allows executing sufficiently complicate educational experiments in different disciplines. This set has advantages and disadvantages of proposed set of instruments in comparison with National Instruments ELVIS instrumentation set wide used at many institutions [3]. It should be noted, the instrument suit based on NI ELVIS has limited resources,

when digital devices are investigated; it ineffective exploits resources of data acquisition module. Furthermore, the price of this laboratory station is comparatively high.

B. Local area network laboratory

The suggested set of instruments (IVIS-2) might be included in the structure of universal laboratory test bench, which easily specializes in specified discipline by test subject changing. Consequently, in spite of comparatively low cost of such approach (9 modern instruments were realized on the one DAQ-board), expenses of laboratory organization, which includes 8-10 workspaces, will be too high.

The expenses essentially decrease, if the laboratory is created with modern network techniques. This advantage is possible with National Instruments technologies of virtual instrumentation to develop this type of laboratories and to replace stand-alone measurement instrumentation with rigid functionality by reconfigurable virtual instruments are easily combined into networks.

In this case, only one set of technical equipment based on DAQ server is required. The special software for this server receives information from the client software modules; realizes direct control of DAQ-board input/output channels; organizes generation of necessary stimulus to test subject; measures the test subject reactions; gives back information about test subject status to the client software modules.

According to the suggested structure of laboratory organization the laboratory [2,4] is realized (Fig. 10), which includes following list of studied subjects:

1. Electronics
2. Analog circuit-engineering
3. Digital circuit-engineering

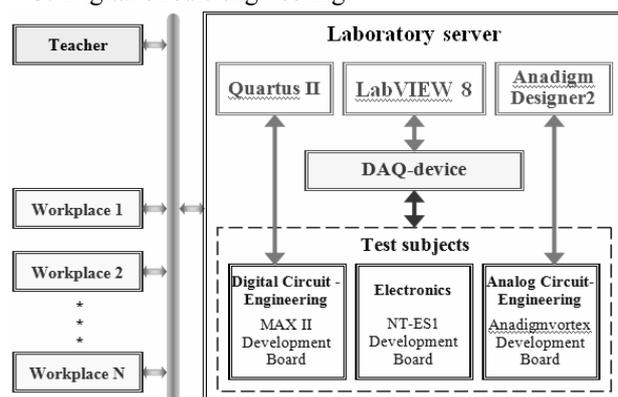


Fig. 10. Structure of universal laboratory "Electronics and Circuit-Engineering".

1) The DAQ-server equipment

It is significant that as a basis for test subjects in digital and analog circuit-engineering, Field Programmable Gate Array (FPGA) and Field Programmable Analog Array (FPAA) modules are used. AN221K04 Anadigmvortex Development Board, bearing FPGA, and Altera MAX II Development Board, containing FPAA, are part of the equipment. The functional structure of FPGA and FPAA takes advantage of configuring these boards for most fundamental types of electronics and circuit-engineering components investigation. At the same time it is available for generating the individual task for each workstation.

The prototyping board NT-ES1 is used for test subjects in electronics. This board includes everything, required for electronic components connection.

It should be noted, the DAQ server is created with LabVIEW DSC (Datalogging and Supervisory Control Module) in the form of Periodic I/O Server. That allows reducing the time response between the client and the server to 1 second, when the number of client workstations not greater than 8. It is fully enough, when students experiment with one or the whole of test subjects. NI Shared Variable technique is applied to organize the network interaction between software modules. It allows creating the network transmission using Publish Subscribe Protocol, which is clear for common users. The Shared Variable is similar as either variables of LabVIEW development system. As distinct from them, it is used to transfer different types of data between distributed virtual instruments. National Instruments claims that, at the same time all duty cycle of network is minimized.

2) Student's workplace

Each student's workplace dispenses with installing the DAQ-device and requires only a personal computer with special set of virtual instruments for remote control of test subject and server's equipment (examples are presented in Fig. 7, 8).

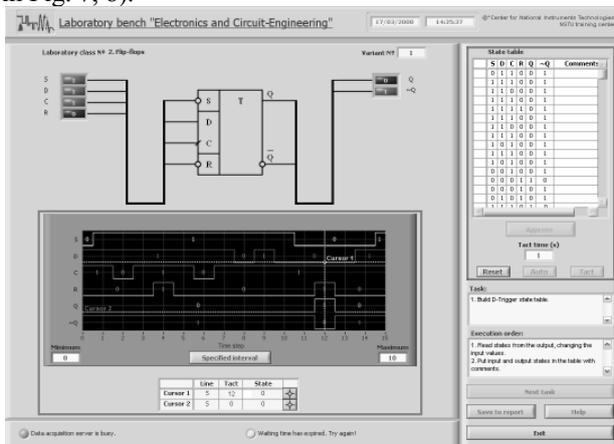


Fig. 7. Front panel of experimental software module for digital circuit engineering on the student workplace

This software is also used for processing of the experimental data, visualizing the results, students authorization and report generation of the end of laboratory class.

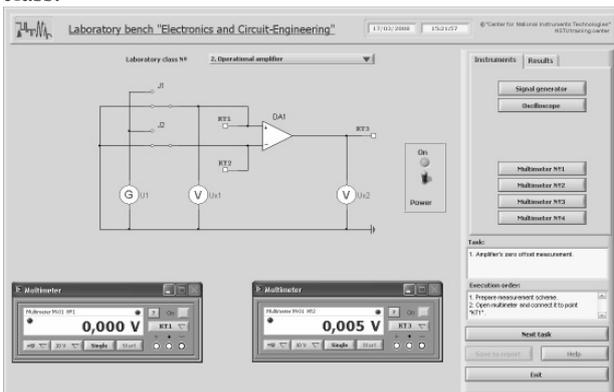


Fig. 8. Front panel of experimental software module for analog circuit engineering on the student workplace

On the teacher's workplace special software module is created (Fig. 9).



Fig. 9. Front panel of teacher software module

It registers groups of students, grants access to the laboratory class, generates variants of the laboratory work and teaching instructions and also controls network functioning. All necessary information appends to database and at the end of work a special report is generated, which includes data common for teacher's book (title of discipline, title of the laboratory work, list of students, grades).

The list of laboratory classes given below allows understanding the capabilities of the network laboratory:

1. Rectifying and Zeners Diodes
2. Transistors
3. Amplifiers
4. Active filters
5. Comparators and rectifiers
6. Analog differentiators and integrators
7. Combinational logic
8. Flip-flops
9. Registers
10. Counters

The laboratory software makes it possible to extend either list of works on each discipline or laboratory class list. In particular, laboratory classes will be created on the same hardware and software. These laboratory classes are the "Fundamentals of measurement techniques", the "Fundamentals of control theory", the "Microcontrollers and signal processors".

Realized structure of software and interaction principles between software modules both in the IVIS-2 and in the laboratory "Electronics and Circuit-Engineering" allow to use one suit of technical equipment available for each workplace and append new or change existed techniques in laboratory practical work without program correction. It is possible to update this software, which allows studying modern techniques of electronic (analog and digital) devices development, such as "silicon workshop".

C. Web-laboratories for e-learning

You can get Global Network access to the laboratory considered above by means of LabVIEW programming environment. In that case, the laboratory classes can be given in e-learning mode. It opens the new features in educational process and creates the necessary prerequisites for students' self-study learning, provides raising the level of specialists' skills capability and post-degree education.

For any virtual instrument created in LabVIEW integrated Web-server can be switched on with minimal effort, which allows users connection to remote resources and objects of educational laboratory. The client can be

any computer connected to the Internet running a simple browser. Once connected, the client will see the same front panel as the local host and also have the same program functionality. But, this approach is not unified and not flexible as compared with NI DataSocket technique, which used by authors for e-learning test benches development. The DataSocket Server accepts and stores information from data sources and relays it to other data targets. When you run a DataSocket Server on a computer, you make data easily accessible to DataSocket Readers and Writers on the same computer or other computers connected though a TCP network, such as the Internet. This technique is more suitable for e-learning system solution, because it gives the ability to develop test benches are available in operative mode for many user and more functional than integrated Web-server.

The web-laboratory “Microcontrollers and signal processors” set up at NSTU in 2003 may become a prototype of multidiscipline e-learning laboratory [5]. The server-dispatcher is the main part of the laboratory. It encloses the web-site of the laboratory, and the administration software. This site contains information and educational materials, special software tools for designing microprocessor-based systems, service programs and so on. The dispatcher distributes queries to test benches, which realize control functions of program-technical tools for microprocessor-based device design systems.

User applications are loaded into Internet Explorer browser or are installed at the end user’s computer and provide full access to distant test bench resources. The equipment of users bench includes two-channel oscillograph, programmable voltage source, pulse generator, binary and digital indicators, switches and buttons, development boards for various microprocessor-based devices and subsidiary software (Fig. 10).

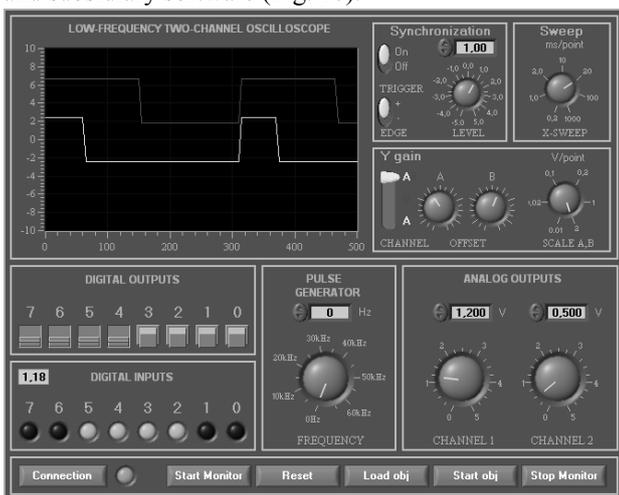


Fig. 10. The front panel of “Microcontrollers and signal processors” test bench

The cumulative experience in applying web-laboratory for education will be used for its modernization coupled with the set of instruments IVIS-2, introducing better performance attributes and extended functionality. In the se-

quel, it is proposed to build the web-laboratory based on NI Shared Variable and PSP technique, which allow improving the quality of network services and abilities of distant test benches.

III. CONCLUSION

Thus, National Instruments virtual instruments technology allows creating modern automated test benches following traditional scheme based on autonomous test stands with complete technical devices suit and test subjects or using local network with one shared technical devices suit and one test subjects suit connected to laboratory server. Integration of systems, created in web within these principles, provides infinite capabilities for e-learning. In this case, the technology of virtual instrumentation has some additional preferences:

- The ability of modern and unified realization of educational workspaces are based on personal computers applying;
- The unification of laboratory equipment and software;
- The ability to vary and to complicate the tasks of study;
- The prerequisites to decrease the execution time of hard tasks are appeared;
- The ability to create the computer-based information system on the teacher’s workspace;
- The unification of educational operating programs and materials at different departments and faculties by same branches;
- The reduction of costs to update the laboratory base and maintain the equipment.

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