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The Laboratory Stands with Remote Access for Teaching of the Experimental Courses

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Abstract **– The laboratory stands controlled remotely allow students to perform laboratory exercises in the courses with need of experimental work. Accessibility of the virtual laboratory standsin situ and across the Internet was the basic condition. The control program was developed in the LabVIEW. Remote user can change measured subject remotely using web browser Internet Explorer or in situ by user interface on the control server near the laboratory equipment. User interface of all stands simulate real laboratory instruments. Virtual laboratory stands were designed for the courses of "Electronics" and "Sensor systems".**

Keywords – Remote teaching laboratory, Simulation of laboratory stands, LabVIEW

I. INTRODUCTION

The main task of virtual laboratory stands (VLS) in the technologically oriented courses is to enable students to achieve practical verification of theoretical knowledge and to offer comparison of results from circuit simulation with experimental ones [1], [2], [3]. Experimental laboratories for education are equipped with expensive instruments and a lot of experimental tasks are rather time consuming. It doesn´t allow to perform laboratory tasks for all enrolled students. Remote access to the laboratory stands allows students to perform practical verification of the theoretical knowledge anytime from anywhere. Simulation of the real problems is a utility parallel to the experimental work [4], [5]. Training stands were designed for the courses "Electronics" and "Sensor systems" [9]. Manipulation with the artefacts with known physical parameters is the limitation of the remote access in the subject "Sensor systems". However, some nonelectrical quantities for sensor testing could be generated remotely like temperature, light by electrical controlled heater or LED diodes. In general, there are two scenarios on how to perform laboratory tasks.

The measurement laboratory object controlled remotely represents the first scenario. The measurement branch allows students to measure properties of output signal acquired from the object as reaction to the known stimuli. Measurements on the real electronic circuits in the course "Basic electronics" are such examples. Some laboratory tasks in the course "Sensor systems" could be arranged under similar scenario.

Second scenario is represented by laboratory tasks which can be performed in situ across user interface on the near server with simulated laboratory instruments. Manipulation with measured samples is being performed by experimenting students sitting at the laboratory workplace. In the laboratory exercises on "Sensor systems" this scenario allows to measure quantities which can't be generated by DAQ interface. Laboratory exercises were the manipulation with measured samples is performed by teacher according to predefined measuring time scenario could also be performed remotely. Using signal acquired from real objects and memorized in the data bases is another option [7], [8], [12].

II. ARRANGEMENT OF LABORATORY STANDS

The group of VLSs for set of experimental tasks controlled by the laboratory server represents one virtual laboratory (VL). Proposed VL meets the following requirements:

a) Each single VLS is dedicated for one laboratory task. The control program on the VL server contains pages for each VLS simulating instruments in the laboratory around the measured object. The page represents graphical user interface containing pictures of the real standalone instruments, necessary to provide measuring tasks on the chosen VLS. Pictures of existing physical instruments available on the market are used in order to provide students with exercises as realistic as possible. Control buttons and setting knobs on the image of each virtual instrument are mouse operated. Measured results are displayed on numerical or graphical displays placed in the same position as on the real instruments.

b) The programme representing a configuration of virtual instruments necessary to perform one laboratory task allows both local control by mouse and remote control for authorized user through Internet by web browser. All programmes for creating all VLSs and their local and remote control were prepared in LabVIEW programming environment using available toolboxes. Using tool boxes integrated to the E-learning system is another option [6] with reduced range of drivers to the DAQs.

c) Laboratory server runs multiple VLS accessible remotely or locally, for each laboratory. Remote control of laboratory server allows authorised users to control all virtual work places by the laboratory server sequentially using the queuing principle available in LabVIEW toolbox. The authorisation of distant access to the VLS is given by supervising teacher for defined time interval.

III. IMPLEMENTATION OF EXPERIMENTAL WORKS IN CURRICULA

- Authors chose the experimental courses suitable for implementation as proposed VLS in the courses “Electronics” and “Sensor systems”. Exercises in a experimental laboratory provide students with specific skills which can also be acquired with the shared VLS.
- Laboratory exercises in the course “Electronics” are based on measurements performed on the real electronic circuits. The advantage is that all stimulating signals and switching among different circuit modules can be performed remotely without support of teaching supervisor. The following VLS are available for the measurement on circuit modules:
- Differential amplifier;
- Darlington´s amplifier;
- Stabilised voltage source;
- Operational amplifier with two types of negative feedback;
- Integrator and low pass filter with operational amplifier;
- Analog to Digital Converter stimulated by the harmonic testing signal superimposed on the DC signal;
- Amplitude and frequency modulator;
- Remote laboratory for experimental study and verification of more complicated circuit in the course of “Programmable logic arrays” is described in [10],[11].
- Course “Sensor systems” requires laboratory exercises giving students experience about differences among sensors of the same physical quantity realised by different technology. It allows using the same sample of the measured quantity for all sensors of that quantity. Differences among outputs from sensors of different technology for the same input physical quantity allow students demonstrate importance of metrological characterization of the measurement. The following virtual experimental workplaces are available for local and remote access of students:
- Sensors for measurement of illumination and optic gates with photovoltaic source;
- Strain gauge sensors realised by wire, foil and semiconductor technology;
- Sensors for the measurement of the object distance;
- Sensor systems for the measurement of water parameters.
- Access to the proposed VLs is permanently open and allows monitoring the activity of students enrolled in the course. Students’ monitoring and the on-line tests provide teachers with easy evaluation of students. Vice versa students’ questions and problems provide feedback for the laboratory designer how to improve stands. The whole idea of learning through the internet offers students first touch with electronics and instrumentation. Afterwards students will be able to better manipulate with real laboratory equipment and measured circuits.

IV. LABORATORY STANDS WITH THE REMOTE ACCESS

The common approach how to realize a virtual laboratory workplace is utilization of multifunction data acquisition boards (DAQ) installed directly on the laboratory server devoted for one group of experimental tasks. Such boards usually contain multiplexed up to 16 analog inputs that can be used for acquiring analog signals from tested modules and at least 2 analog outputs. They can substitute two generators. The programmable counters implemented on the board can be utilized as pulse generators or frequency meters. Simultaneously existing programmable digital inputs/outputs are available for the control of analog switches connecting more tested modules to the common DAQ.

A. Virtual instruments on the VLS

Instrumentations based on DAQ cards also require convenient software realizing data acquisition and presentation on graphical - user interface. Graphical interface for one VLS is designed in form of real instruments assembly with possibility to control them with knobs and to display acquired data.

Basic architecture of the realized laboratory for course “Electronics” is shown in Fig. 1. Circuits to be measured are listed in Chap.III. Laboratory hardware consists of two DAQ boards (PCI 60336 and PCI 6251) with block SCC-68 connecting five electronic circuits under test.

Virtual instruments utilized in the VLSs are:

➢ *Virtual oscilloscope*

- Visualized virtual oscilloscope allows controlling basic settings and functions:
- time base;
- voltage range;
- switching the inputs ON/OFF;
- triggering level;
- V-position;
- H- position;
- input channel coupling;
- AUTO button;

- RUN/STOP button.

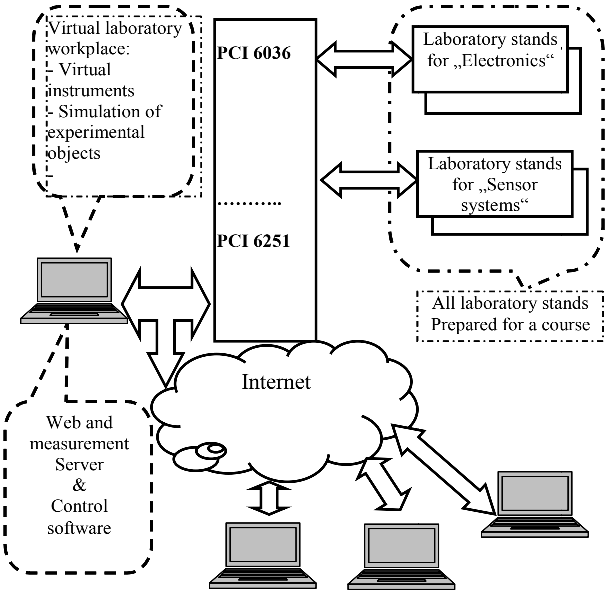

Fig. 1. Architecture of the proposed remote laboratory

➢ *Virtual generator*

Software representing virtual generator allows changing basic parameters:

- output waveform shape
- amplitude
- offset
- frequency
- superimposed noise

➢ *Virtual digital multimeter*

User interface representing virtual digital multimeter allows to select:

- measured quantity- current, voltage, frequency;
- the measuring mode (AC or DC) and its range.

➢ *Virtual power source*

User interface representing virtual power source allows:

- change supply voltage in symmetrical or single mode;
- change output current limitation.

➢ *Control of other signals, selection of measuring nodes*

Modification of the circuit components is performed by the analog multiplexer on the board of the tested circuit. Analog multiplexers are controlled by the digital outputs of DAQ which allows performing the circuit modifications. The changes of the connected inputs/outputs are displayed in the form of corresponding connection of virtual “measuring conductors” (Fig. 2).

The laboratory stand for testing operational amplifiers circuits consists of four independent circuits. The laboratory server using multiplexer allows changing four circuits with operational amplifier e.g. inverting, noninverting amplifier, integrator and rectifier (Fig. 3). Corresponding user interface is shown in Fig.2. Selection of feedback type is performed by changing index tab representing particular circuit. Values of the components in the feedback are selectable by enumerated ring control on the user interface.

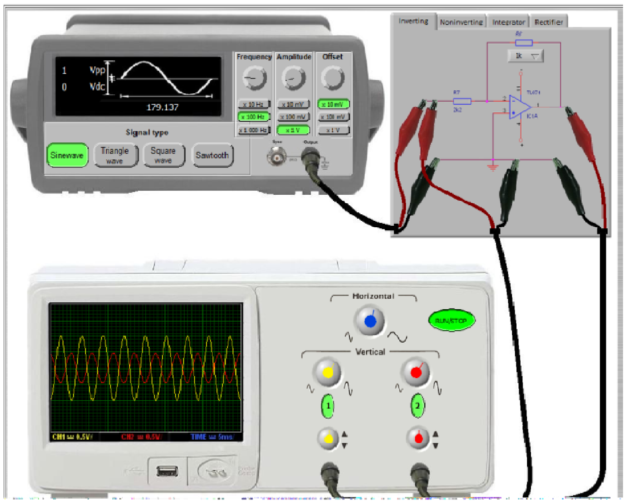

Fig. 2. User interface for measurement of four operational amplifier implementations

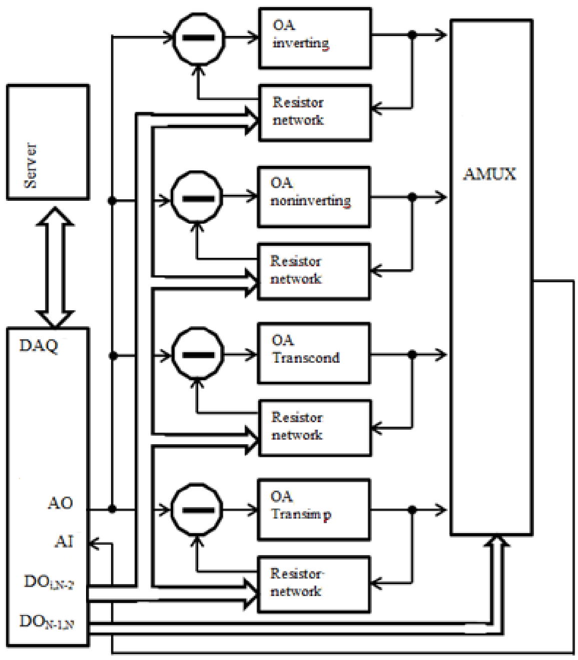

Fig. 3. Control among different types of feedback and amplifications of circuits with operational amplifier

Control of switches connected to the output of sensors with different technology for the same physical quantity at their inputs is the principal structure of experimental workplaces in the course “Sensor systems”. Stimulating signals could be generated by transducer of measured physical quantity controlled by the Analog outputs from DAQ. This possibility is reduced on the light and temperature generation by LED source and heater with known transfer characteristic. Reference values of other physical quantities taken from measured artefacts are measured from one sensor which is being taken as reference sensor. This laboratory task allows to evaluate uncertainty and other metrological parameters of all sensors installed on the laboratory stand.

B. Remote control of laboratory stands

LabVIEW programming environment allows to build web server for publishing on the Internet. The server publishes front panels of applications in the form of web pages and performs interactions among remote users and applications control. The web browser Explorer with installed plug-in Run-time engine by National Instruments is available for remote control by user. Distant clients are managed by the LabVIEW web server that ensures also transferring of the access among clients according the administrator’s rules. To decrease the requirements on hardware equipment and the dynamic sharing of DAQ boards was applied. The sharing means time multiplex of DAQ boards among running applications developed in LabVIEW, which is internally controlled by software semaphores (Fig.4.).

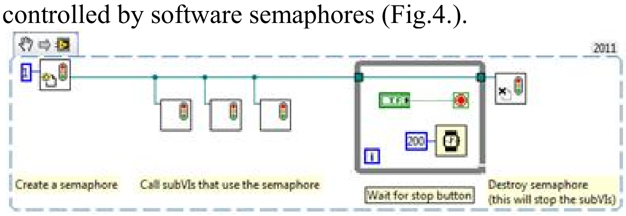

Fig. 4. Program for control of one VLS

The semaphore in LabVIEW is the effective way of creating a group of tasks virtually running in parallel on the same hardware. The authorized users are in queue with their requirement to perform the chosen exercise. The semaphore gives access to the *L*-th user and takes input data for control of selected workplace from its web page and starts the application. Application is running for only the necessary time to perform laboratory task required by the user. At the end of this session the acquired output data are transferred on the web page displaying the workplace. The acquired data could be downloaded from the each workplace by the user. This gives the user an additional possibility for performing a post-processing by various signal processing tools like Matlab, SIMULINK, e.g.

V. EXPERIENCES WITH VLS IN EDUCATION

Developed VLSs were utilized for two courses with predominance of the experimental work and were utilized both in local and remote control mode. Advantage of local control was immediate access to the subjects under tests. However the VLSs were equipped by virtual instruments displayed on the server’s monitor, the similarity with stand-alone instruments gave students sense of work in real laboratory. Another advantage of VLS is the elimination of frequent hardware malfunctions caused by inexperienced students.

The experience with the proposed laboratory exercises was tested by a group of 18 students which were able to compare it with the conventional laboratory stands in the course “Electronics”. The web page on the server contains a window available for students’ questions and comments to the supervising teacher.

Results of the enquiry by prepared questionnaireamong students enrolled in the trial phase led to these conclusions:

1. Students appreciated the availability of the laboratory anytime, from anywhere with Internet access.
2. The possibility to repeat at least some experiments by the real instruments and circuits students proposed as preferable complementary way how to come in touch with real circuit properties.
3. The appearance of instruments on the user interface was evaluated as quite good.
4. Students involved in the trial phase had no problems with getting access permission and connection to the VLS by web browser.
5. They appreciated the benefits of virtual laboratory stands as very high for understanding principal of the course.
6. Students were very satisfied with proposed virtual laboratory and recommended it to use in the other courses too.
7. Interviewed students proposed some user interface improvements and ideason how to extend prepared laboratory tasks.

VI. CONCLUSIONS

The virtual laboratories are useful tool for self-training of students in the basic courses which can be used easily in teaching without expensive equipment.The main advantage of the system is cost effectiveness and modularity using combination of common ready modules in LabVIEW and simple possibility to develop and modify software for control of any VLS. Proposed virtual laboratory is the last stage of the chain “theory – simulation – experiment”.

The system allows for monitoring of activities of students enrolled in the course. Results of monitoring and answers on short questionnaire allow teachers to evaluate students who use virtual laboratory and give new suggestions to improve the testing stand. The whole idea of learning through the Internet is to provide the first touch with electronics and instruments for students.

The additional advantage of the proposed virtual laboratory is that it is an example of virtual measuring network over wide area designed using hardware and software components representing the information and communication technology.

VII. ACKNOWLEDGMENT

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