

COMPUTER INTEGRATED LABORATORY FOR TEACHING ELECTRONICS AT UNDERGRADUATE LEVEL

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Abstract: There are several approaches to implementation of computer assisted laboratory for basic electronic education. Trying to keep the advantages of the available concepts such as classical individual work, remote access laboratory, virtual laboratory, and similar, a concept for a teaching laboratory for basic electronics at introductory undergraduate level is proposed. It allows virtual laboratory work, but at the same time keeps the physical experiment while substituting the majority of the instruments by virtual ones. The realization of a laboratory with the mentioned properties has one drawback, it is quite expensive, so the proposed solution uses low-cost acquisition hardware. The computer is used here practically in all phases of the work starting from the access and authorization, documentation, student-teacher interaction, measurement control, etc. Our results to be presented here are mostly related to the virtual instrumentation and the physical laboratory work.

Keywords: basic electronics, learning technologies, virtual labs.

INTRODUCTION

Introduction of computers into educational process is neither new nor an obsolete subject. In fact, thanks to several advanced new technologies it becomes more and more attractive, feasible, and affordable at the same time. That equally applies to ordinary educational process such as university teaching and to continuing education of engineering staff. Among the technologies that enabled blooming of the subject one should inevitably mention the development of the Internet. It brought us several new procedures referred to as e-learning, distance learning, remote learning, collaborative learning and similar. That, not only allowed for an easy and inexpensive access to the knowledge as such and better and faster student-teacher interaction, but introduced the possibility for new concepts such as virtual laboratories, mainly based on simulations.

In addition, several software packages, to mention only the LabVIEW (described in [1] and [2]) as an example, enabled development of what is now called virtual instrumentation that simplified completely 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 incomparably low price.

Typically, technically based education fields need to comprise not only theoretical knowledge and scientific background, but also practical learning units. Electrical and electronic engineering are probably the broadest and most dynamic engineering disciplines covering everything from sub-micron-scale transistors to national-scale power grids

and telecommunication networks. This is why most of the solutions offered in the literature for computer-assisted experimental work are related to electronics.

Looking for the concepts to be implemented, one must face several opportunities and probably as many obstacles. Among the most important is the fact that at the first year, the students' technical background is so limited that one cannot count on any familiarity with measuring instruments and circuit proto-boards. On the other side, the aspiration is to have as complex experiments as necessary, the limits being imposed by the curriculum goals. To tackle these obstacles practical presence of the students in the laboratory is necessary and, of course, help by a tutor present in the laboratory is indispensable.

The main attention here will be paid to the real experiments. In that way, the concept of Computer Integrated Laboratory (CIL) for electronics was developed. In this concept real experimental setup is used but based on virtual instrumentation. All the advantages of classical experiments are preserved at the lowest price. From the functionality point of view the experiments were designed to be as close as possible to the classical ones.

In this concept, the lecturer and the teaching assistant play an important role. Besides the tutoring in the laboratory, their major activities now include preparation of the software packages, modifying, upgrading, and updating the existing experiments, and continuous evaluation of the teaching and learning outcomes.

The concept is under development since the year 2004, and this is third incarnation of CIL for electronics [3].

In the following the CIL will be reviewed from conceptual, hardware and software point of view. Examples of experiments will be also described.

REVIEW OF THE SOLUTION

Basic electronics is taught as introductory course. That means that only basic electricity laboratory work was offered to the student previously. The goal of the laboratory work is to give possibility to the students to experimentally verify the theoretical lessons concurrently as they advance. That means that all students present in the laboratory within a week are doing basically the same experiment. Table I contains the complete list of the experiments that are implemented and conducted within current curriculum in CIL [4].

CIL utilizes benefits of computerized instruments. The expansion of low-cost personal computers in past three dec-

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ades induced the development of measurement and acquisition equipment. Most new implementations of legacy instruments like oscilloscopes, AVΩ-meters and circuit analyzers are fully computerized. New types of stand-alone instruments and measurement apparatus are equipped with adapted operating systems and acquisition software. Besides the stand-alone instruments with computer interface, there are number of acquisition modules that can be connected with PC using specific software. The complete measurement system consists of a PC, an acquisition module and software. The software is referred to as virtual instrument, and the whole concept as virtual instrumentation.

Table I

List of the laboratory experiments

Name	Short description
Operational amplifier	Static and dynamic transfer function, saturation waveforms
Single Stage Amplifier	Amplitude characteristics of common source and common drain MOSFET amplifiers
Negative Feedback	Influence of negative feedback on amplitude characteristic, input and output resistance of amplifier, noise and on nonlinear distortions
Oscillators	Frequency characteristic of Colpitts, Pierce and the Wien oscillator.
Audio frequency power amplifier	Characteristic of AB and B class power amplifiers
Full wave rectifier and voltage regulator	Full wave rectifier, capacitive filter, and voltage regulator waveforms and output characteristics

HARDWARE IMPLEMENTATION OF THE LABORATORY

The experiment setup consists of measuring unit and breadboards with circuits under experiment (Table I).

The measuring unit, in this case, was implemented using low-cost Analogue Discovery 2 multi-function module that allows measurement, visualization, generation, recording and control of mixed-signal circuits of all kinds [5]. The module has two differential acquisition channels with 1MΩ impedance, ±25V range, 14-bit resolution and 100MS/s sampling rate. The signal generation is supported through two channel arbitrary waveform generator with ±5V range, 14-bit resolution, and 100MS/s sampling rate. The module supports digital signal manipulation, too. External signals or devices under test (DUT) can be connected to the module using breadboard or BNC adapters, providing possibility of quick and easy reconfiguration of circuit topology and selection of connecting points, which is required in some exercises. Two programmable power supplies are used as DC voltage generators for power supply. Maximum DC output voltage is limited to ±5V. This voltage is adequate for power supply, polarization and measurement of static characteristics of semiconductor devices and properties of basic electronic circuits.

The breadboard which is unique for each experiment is

connected to measuring unit, i.e., Analogue Discovery 2 module (Fig. 1 and Fig. 2). The module's acquisition channels are connected to circuit using differential method. Differential method was used in all experiments, in order to decrease noise and increase the CMRR what becomes important when precise measurement of small voltage (or current) values is required. The measurement of currents can be performed only indirectly, by transforming current into voltage using shunt resistor.



Fig.1 - The breadboard with full-wave rectifier (left) and voltage regulator (integrated circuit in the upper middle position of the board). The measuring unit is connected via IDC connector, positioned at the right side of the board.

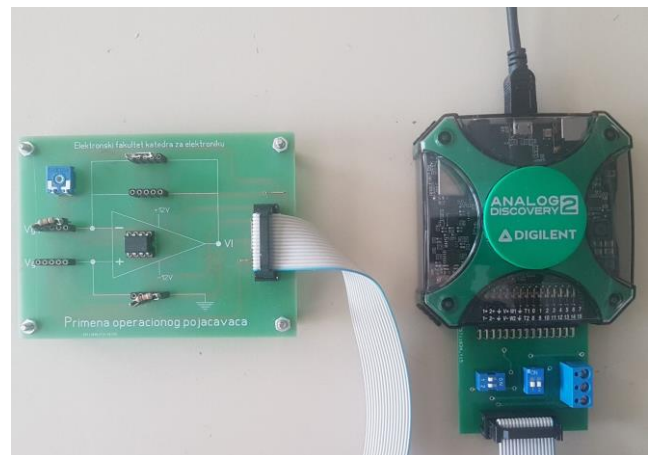


Fig.2 - Complete measuring setup. Analog Discovery 2 is connected with breadboard with integrated OPAMP.

VIRTUAL INSTRUMENTS

Virtual instruments are implemented using National Instruments LabVIEW developing environment, which provides for simple software realization and testing. Virtual instruments consist of device driver and application with graphic user interface.

Analog Discovery 2 is supported through the software development toolkit for programming with Python, C++, and LabVIEW (Fig 3.).

The user interface of the virtual instruments 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 measured values. All measured values are placed in a table, and after the measurement process in appropriate file.

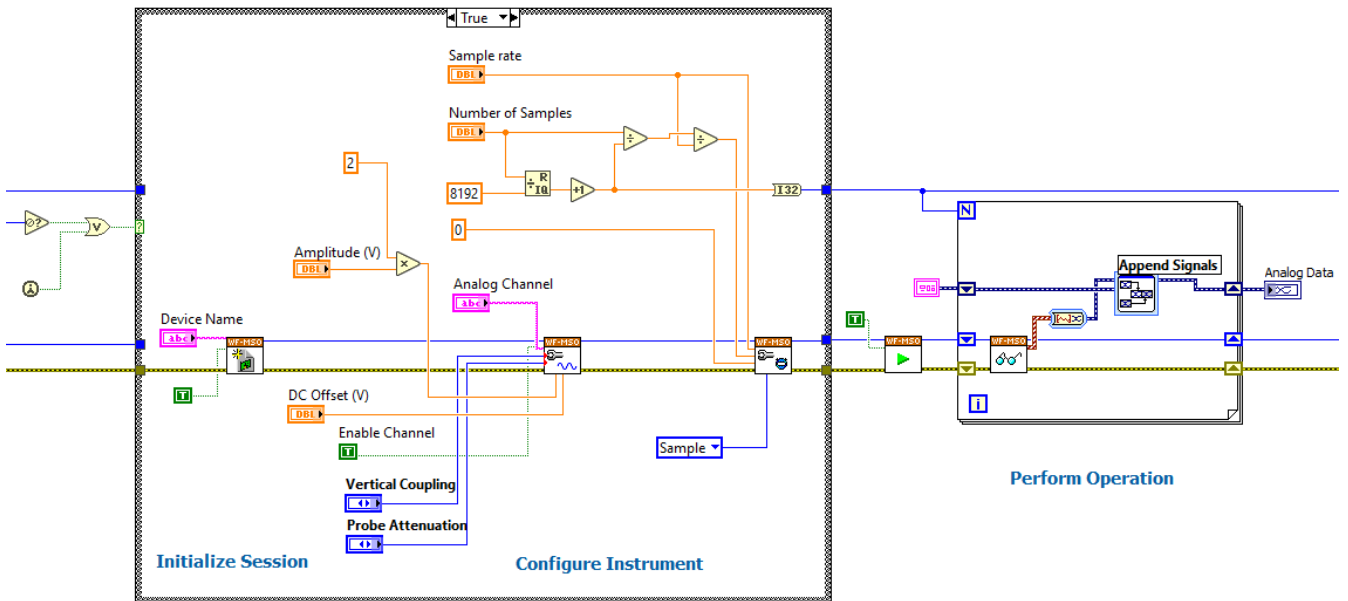


Fig.3 - Customized virtual instrument (VI) for Analog Discovery 2 acquisition control. This VI is nested in all virtual instruments that perform some type of voltage or current measurement. It provides precise acquisition control: sample rate, number of samples, coupling, attenuation, etc.

User interface also provides controls for data manipulation and saving measured values.

The laboratory integrates various virtual instruments that are implemented: scalar network analyzer, oscilloscope, spectrum analyzer and frequency meter. As illustration, operation of two virtual instruments will be described in detail.

Operational amplifier

There are several configurations of operational amplifier circuit implementation considered here: inverting and non-inverting amplifier, circuits for derivative computation and integration, summing and subtracting. Two waveform generators of the module were used as arbitrary waveform generators (sine, triangle and square) with fixed frequency and amplitude.

The phases of both generated signals can be changed from 0 to π radians, using visual controls within the graphic interface of the virtual instrument. Both, generated signals and signal acquired from tested circuit output are shown in the graphic of interface of the virtual instrument (Fig. 4).

The main window of the virtual instrument consists of two panels for adjusting the parameters of the input signals (signal generators v_{g1} and v_{g2}) and two oscilloscope panels for input and output signals (Fig 4).

The panels for adjusting the parameters of the input signals can define the waveform of the signal (sinusoidal, triangular and rectangular) and its phase. The phase of the signal is given in degrees and can be set with a potentiometer or entered as numerical data. The amplitudes of the input signals are set to the optimal values for individual applications of the operational amplifier. The generator (in the upper left part of the panel) is connected so as to excite the inverting input, while the generator (in the lower left part of the panel) excites the non-inverting input of the amplifier.

The oscilloscope panels show the waveforms of the signals from the generator that are fed to the circuit input (in the upper panel) and the signal at the circuit output (in the lower panel). The panels are synchronized.

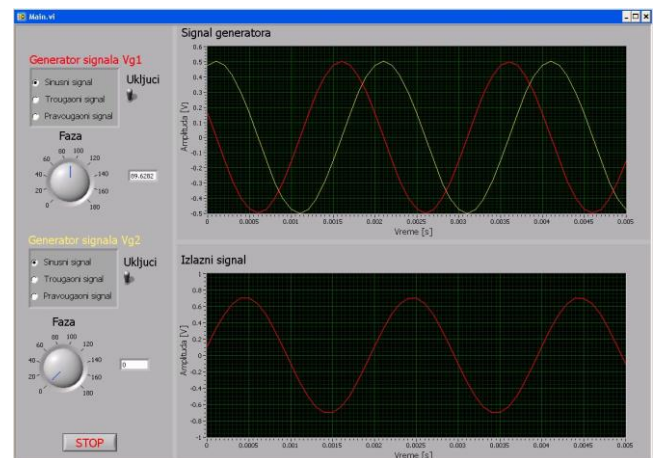


Fig.4 - Virtual instrument for OPAMP experiment. Upper oscilloscope shows input signals. Both signals have same amplitude and frequency, but different phases. The panels for adjusting the parameters of the input signals, located at the left side of user interface, can define the waveform of the signal (sinusoidal, triangular and rectangular) and its phase [4].

Full wave rectifier and voltage regulator

The virtual instrument allows insight into voltage waveforms at the output of the rectifier, capacitive filter and at the voltage regulator, current-voltage characteristics, and measuring DC and AC output voltage (Fig. 5). Desired circuit configuration can be selected using switches P1 and P2 on breadboard (Fig. 1). The input voltage is obtained from power grid, after proper transformation using separate insulation transformer.

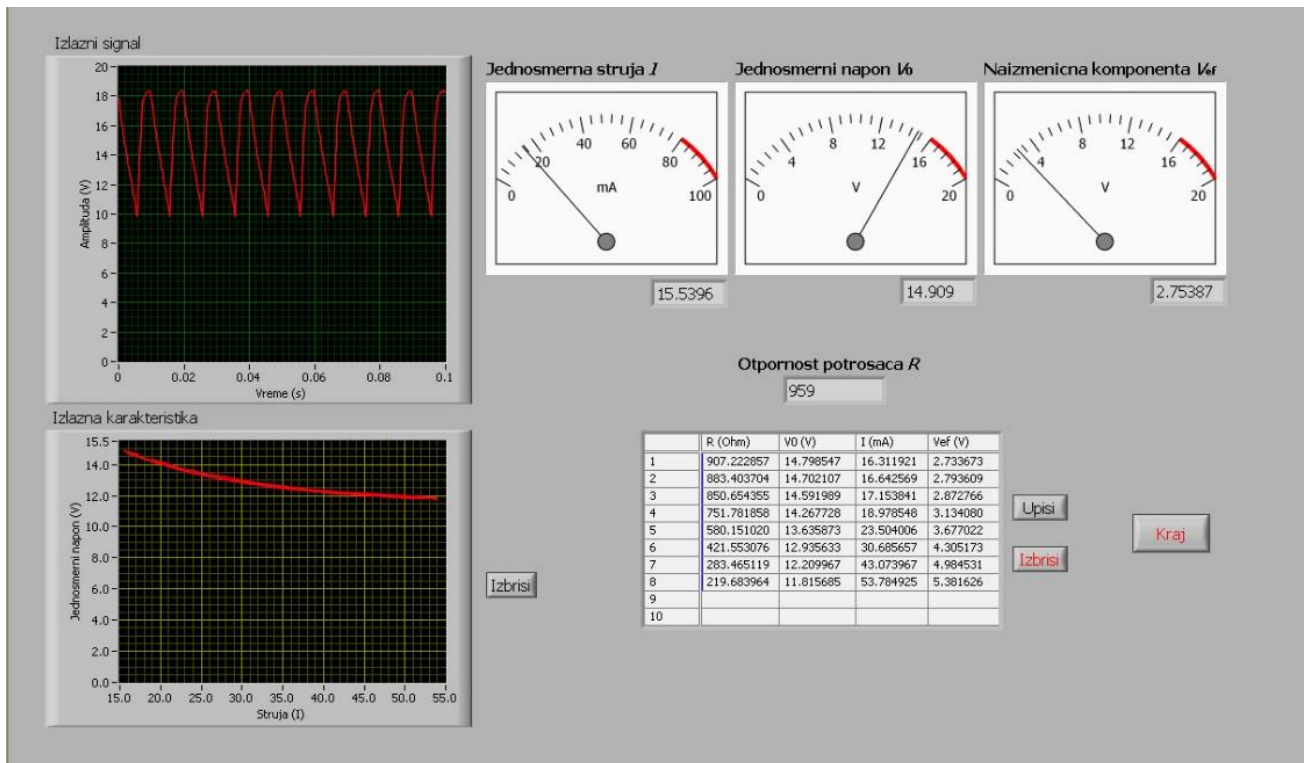


Fig.5 - Virtual instrument for full wave rectifier and voltage regulator experiment. Upper left oscilloscope shows output rectified/filtered/regulated voltage. Output characteristic – output voltage as function of load current – is shown below [4].

The voltage waveforms can be observed on the oscilloscope panel in the upper left corner of the virtual instrument.

The output DC voltage-current characteristic is shown on the panel in the lower left corner.

The values of DC current, DC voltage and AC voltage component are displayed on analog and numerical indicators in the upper right part of the main window. The measured value of load resistance is displayed numerically in the center of the window. All measured values can be entered in the table and saved for further offline analysis.

CONCLUSION

A description of the state of development of a system implementing computer in an electronic laboratory is given. It was successfully implemented to a graduate level basic electronics course. This is third version of the computer integrated laboratory for electronics, which is under development since 2004. This particular version is adopted according to the curriculum of the Basic electronics course. Six experiments are implemented within the laboratory.

The experiments are employed using low-cost multi-functional module, breadboards specific for each experiment and software part implemented as virtual instruments. This approach to laboratory practice allows students to con-

centrate on the properties of electronic circuits, while the measurement technique itself is pushed into the background.

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