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A Remotely Accessible and Configurable Electronics Laboratory Implementation by Using LabVIEW

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ABSTRACT: In this article, selected applications from the experiments included in undergraduate Electronics and Computer Education curriculum are transformed into remotely accessible and configurable manner. The experiment user interfaces and publishing over the internet is developed in LabVIEW. These experiments are suitable for online conduction where students are either in-class or laboratory on-campus and/or at home. In this work, four different remotely configurable experiment modules are designed and implemented. Remotely configurable facility in a predefined range is performed by using switches activated by DO terminals of a data acquisition card through a web-based application. In this way, students can select the desired experiment from the ones stored on the PCB, adjust the voltage applied to the input terminal of the circuit and change the circuit elements values by using telepresence methodology. Comput Appl Eng Educ 18: 709–720, 2010; View this article online at wileyonlinelibrary.com; DOI 10.1002/cae.20276

Keywords: remote lab; electronics education; instrument control; GPIB interface; LabVIEW

INTRODUCTION

In technical and vocational education, practice is also very important subject beside theoretical education. Most of the lecturers in technical education institutions all around the world were agreed that learning by practicing is more retention than learning by reading. That's why theoretical content must be supported by practicing in a properly equipped laboratory environment.

If the number of students in a class is more than the number of seats in a lab or if there is not enough equipments and devices for individual use of each student in a limited period to complete all the procedures in a lab sheet, this causes some problems. In addition, lack of teaching staff is also another important problem to give adequate technical support [1]. Current conventional solution for those kinds of problems in underdeveloped countries' universities is to divide the students into smaller groups. Author's solution in Technical Education Faculty of Marmara University is the same. This means that students can spend half of the actual time in a lab. Then practicing inadequately causes grow of inexperienced young generation with the lack of scientific skills and knowledge. And finally, rising cost of laboratory instruments is another reason to develop online labs. Those reasons have created a strong market for software based laboratory instruments to develop new virtual and remote laboratory applications [2].

There are mainly two approaches in literature for implementing online labs: the first one is Web based simulations or virtual labs and the second one is remote lab in which students are allowed to control instruments and conduct different experiments in a real lab [3,4]. In some universities, simulation based virtual laboratories in Multisim, Matlab, and SimQuick, etc. are developed to eliminate above-mentioned problems. But simulation programs cannot compensate real applications. That's why technical education institutions should develop remotely accessible real laboratories to find the best solution, which will conciliates the useful parts of the both approaches. The market and the user responses indicate that LabVIEW is one of the primary choices in designing control and analysis solutions virtually and/or remotely in the area of engineering technology and education [1,2,5–8]. LabVIEW enables the user to mix and match between real hardware components and virtual components to create a complete system

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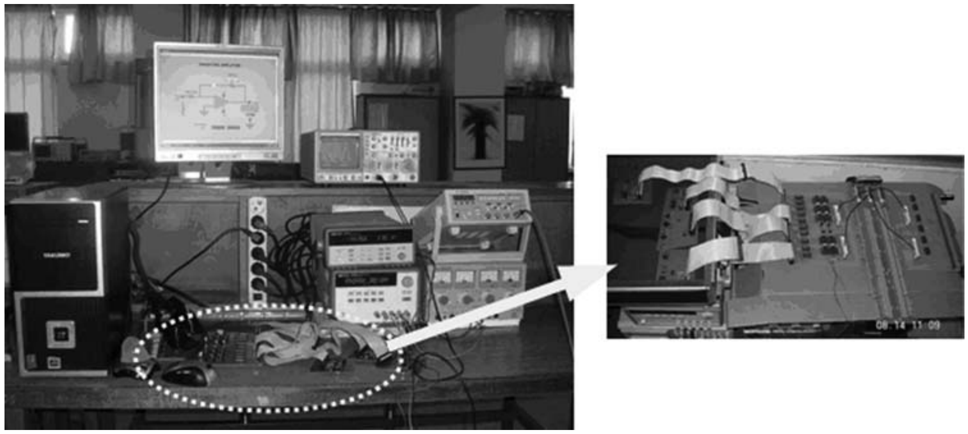

Figure 1 Remotely accessible and configurable electronics laboratory experimental setup [29].

[2]. So physical contact of the students with the real industrial instruments can be succeeded while performing electronics experiment remotely such as at home.

In this work, a conventional Electronics laboratory experiments are transformed into remotely accessible and configurable experiments by using PC-controlled instruments and LabVIEW graphical development platform. Developed Remotely Accessible and Configurable Laboratory (RACEL) is shown in Figure 1.

SIMILAR WORKS

Nowadays great efforts have been made in virtual or remote labs activities in engineering education and many proposals have been presented in the literature all over the world in conference proceedings and/or journals [1–8,9–18,19–22,23–28]

In previously presented articles about remote lab shows that they have some common techniques and features. There are mainly three topics that should be fulfilled and highlighted in a remote lab:

- Configurability.
- Software solution for web enabling.
- Curriculum.

Due to used methodology for above topics, articles differentiate from others. Even if their hardware and software solutions are similar, they differentiate from others about Curriculums, which makes them novel. For example, in Ref. [26] while Sensor and Signal conditioning subject is under consideration in Refs. [7,23] Signal processing subject is discussed.

In Ref. [1], development of remote laboratories is overviewed without any implementation. This article emphasizes the advantages and disadvantages of remote and real physical laboratories and used technologies in web-based solutions. It indicates that LabVIEW is one of the a few easiest programs that can be used in such an application.

Proposed and implemented systems in Refs. [2,5] are the most similar ones to the presented in this article in both technical and educational aspect. However, NI ELVIS workstation is integrated in the system described in Ref. [5]. With the help of this solution, students can have access to an array of instruments including a DMM, an osc, a function generator, and a variable power supply without any instrument control application VI's on the server side. This alleviates the developer's software work. Configurable circuit concept is achieved by using relays driven by software as used in RACEL. In RACEL quadruple bilateral switch IC is used to activate the switches. That IC is very small package and has low path impedance when it is ON state. Power dissipation of the device is also low. RACEL described in this article differentiates from the system described in Ref. [5] in point of hardware view. On the other hand, configurability feature is not available in Ref. [2]. In addition, covered curriculum in RACEL is more extensive than in Ref. [2].

GENERAL STRUCTURE OF THE SYSTEM AND IMPLEMENTATION

The implemented system mainly consists of two parts:

- Hardware.
- Software.

Hardware

Block scheme of the system is shown in Figure 2.

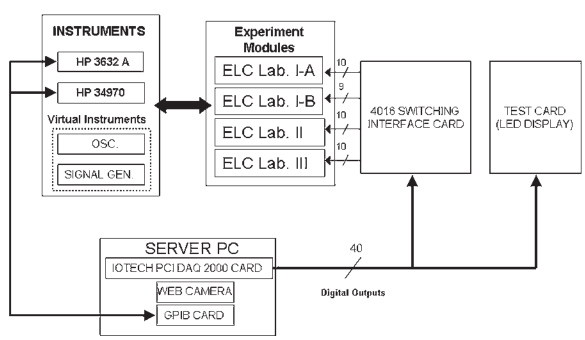

Figure 2 General view of the hardware components in RACEL.

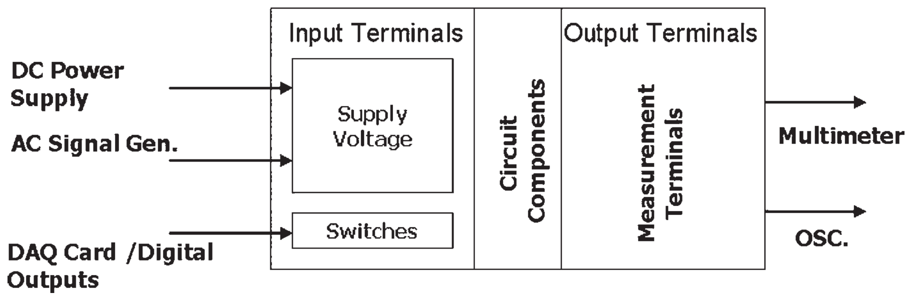

Figure 3 Remotely configurable experiment modules block scheme.

Remotely Configurable Experiment Modules. During the work, four experiment modules are designed. These modules are coded according to the related Electronics Curricula. For example, Diodes and its small-signal and large-signal applications are included in ELC211 Electronics I course content. That's why, the module having diodes and their application circuit on it is called as ELC Lab I. Each module has a group of input terminals, a group of output terminals and some electronic components required. The block scheme of the modules is shown in Figure 3.

Input Terminals. There are two different types of input: One of them is adjustable and/or fixed dc or ac source connection and the other is switch connection.

(a) *Supply Voltage*: IOTECH DAQ2000 Card's Wiring Terminal Board is preferred to use for fixed dc voltages such as 5 V or $\pm$12 V. On the other hand, Agilent HP 3632A DC power supply is used for user-adjustable voltage values. In some experiments such as rectifier circuits, an ac source is also required to perform the experiment. Thus there is no available PC-controlled signal generator in the Electronics laboratory in Marmara University, a virtual device is used and output signals are simulated in ac analysis.

(b) *Switches*: Each experiment module has $\sim$10 switches activated by Digital Outputs (DO) terminals of the IOTECH DAQ2000 Board in order to select experiment and/or add or remove a component such as adding a bypass capacitance in common emitter amplifier circuit.

To choose any experiment to conduct on any module, related switches must be set as listed in the columns where under the related experiment name. In all Tables, "0" means an open circuit and "1" means a closed circuit. Most of the switch positions are previously arranged by designer of the remote lab. Students are not allowed to change those switch positions via interface. In this way, incorrect connections such as short-circuited dc power supply are avoided. However, some switches indicated in Tables are free to turn ON or OFF state.

Output Terminals (Measurement Terminals). Each module has output terminals for measurement device connection. This connection allows the students to control, adjust, and monitor the experiment variables over the user interface. DC measurements can be performed by using Agilent HP 34970A Data Acquisition/Switch Unit. On the other hand, ac output signals are measured by Kenwood CS oscilloscope in which PC connectivity is not available. But, MultiSim simulation program is used to transfer the ac output signals for distant users to allow monitoring ac waveforms on the interface.

ELC I-A Experiment Module. Circuit diagram of the ELC I-A Experiment Module is shown in Figure 4. The conductible experiments are listed in the first row of Table 1.

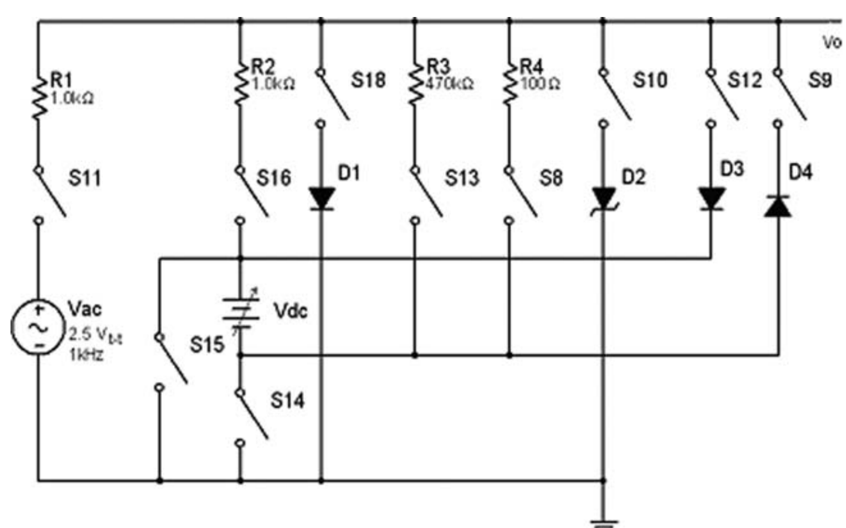

Figure 4 ELC I-A module circuit diagram.

Table 1 Experiment Selection Table for ELC I-A Module

	Experiments					
	Forward biased diode charact.	Reversed biased diode charact.	Forward biased zener diode charact.	Reversed biased zener diode charact.	Positive clipping circuit	Negative clipping circuit
Digital Outputs (switch positions)						
S8	0	0	0	1	0	0
S9	0	0	0	0	0	1
S10	0	0	1	1	0	0
S11	0	0	0	0	1	1
S12	0	0	0	0	1	0
S13	0	1	0	0	0	0
S14	1	0	1	0	1	0
S15	0	1	0	1	0	1
S16	1	0	1	0	0	0
S18	1	1	0	0	0	0

ELC I-B Experiment Module. Circuit diagram of the ELC I-B Experiment Module is shown in Figure 5. The conductible experiments are listed in the first row of Table 2.

As shown in circuit diagram in Figure 5, user can add or remove load resistance and filter capacitance (by changing S2, S3, S26, and S20 switches' positions) to monitor the effect on the ripple in rectifier circuit. The following approximation can be used to estimate the percent ripple:

$$\% \text{ ripple} = \frac{1}{2\sqrt{3}fRC} \times 100\%$$

where R is load resistance, C is filter capacitance, and f, frequency is 50 Hz for a half-wave rectifier and 100 Hz for a full-wave rectifier.

ELC II Experiment Module. Circuit diagram of the ELC II Experiment Module is shown in Figure 6. The conductible experiments are listed in the first row of Table 3.

As shown in Table 3, S19, S24, and S29 switches can be set either "0" or "1." When the switch S19 is set to "1," this removes signal generator's internal resistance. When the switch S24 is set to "1" emitter resistance R_E is bypassed. In this way,

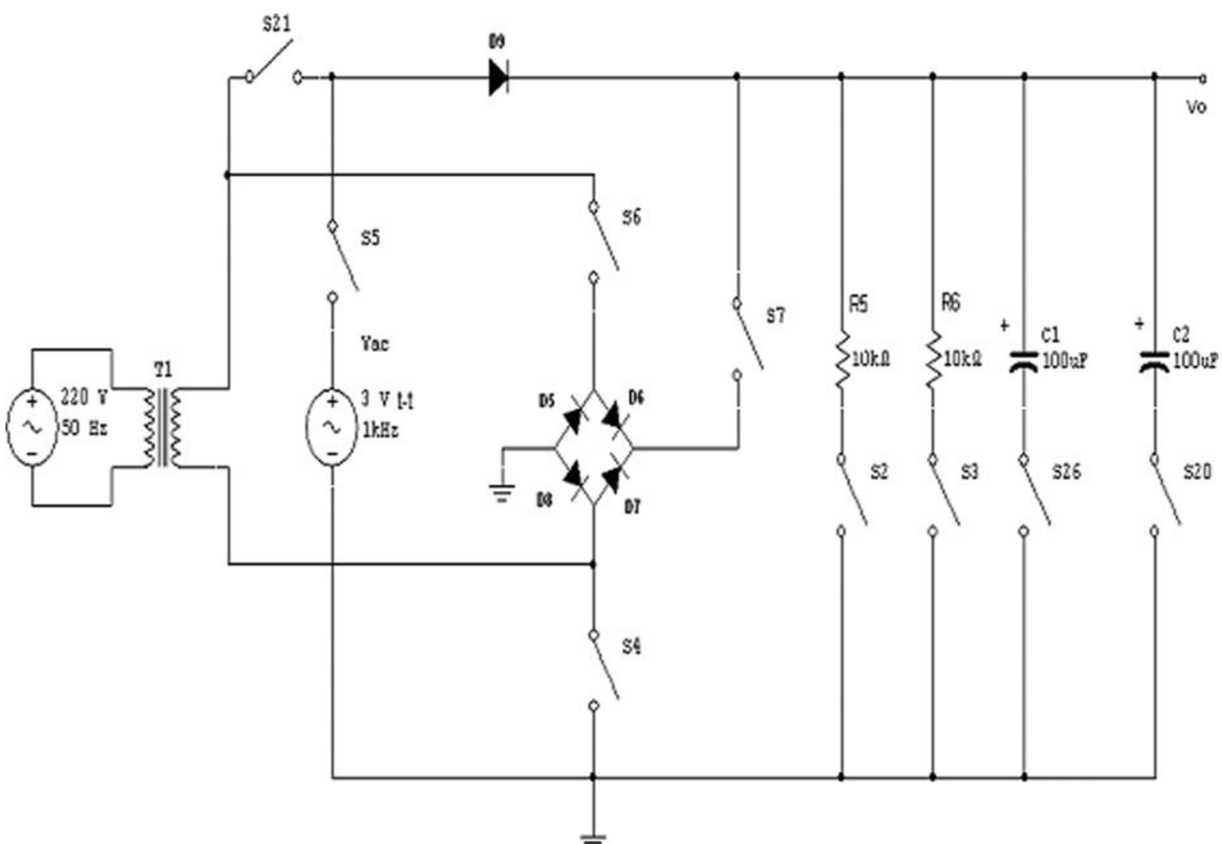

Figure 5 ELC I-B experiment module circuit diagram.

Table 2 Experiment Selection Table for ELC I-B Module

	Experiments		
	Halfwave rectifier		Full wave bridge rectifier
	Signal generator is used for ac source	Transformer is used for ac source	Transformer is used for ac source
Digital Outputs (switch positions)			
S2 (R5)		0/1	
S3 (R6)		0/1	
S4	0	1	0
S5	1	0	0
S6	0	0	1
S7	0	0	1
S20 (C2)		0/1	
S21	0	1	0
S26 (C1)		0/1	

the students can realize increase in amplifier's output signal. When the switch S29 is set to "1," a load resistance will be connected to the amplifier's output. This causes a decrease in gain.

ELC III Experiment Module. Circuit diagram of the ELC III Experiment Module is shown in Figure 7. The conductible experiments are listed in the first row of Table 4.

The user can adjust the feedback resistance according to the predefined values of 1, 2.2, and 4.7 K by setting one of the switches S33, S34 and S37. The students can realize the effect of the feedback resistance on the voltage gain in inverting and non-inverting configuration. An ideal inverting amplifier's voltage gain is determined by

$$A_V = -\frac{R_F}{R_1}$$

where R_1 is input resistance, R_F is the feedback resistor.

The voltage gain of an ideal non-inverting amplifier is determined by

$$A_V = 1 + \frac{R_F}{R_1}$$

Software

The system is generally based on client-server architecture. All processes are executed on the server side. There is no additional software required on the client computer side other than an internet access, a web browser, and LabVIEW Runtime Engine [1]. Web Publishing Tool is used to publish all experiments VI panels to World Wide Web for monitoring and control by the client side [23,24]. LabVIEW is also used in user interface design.

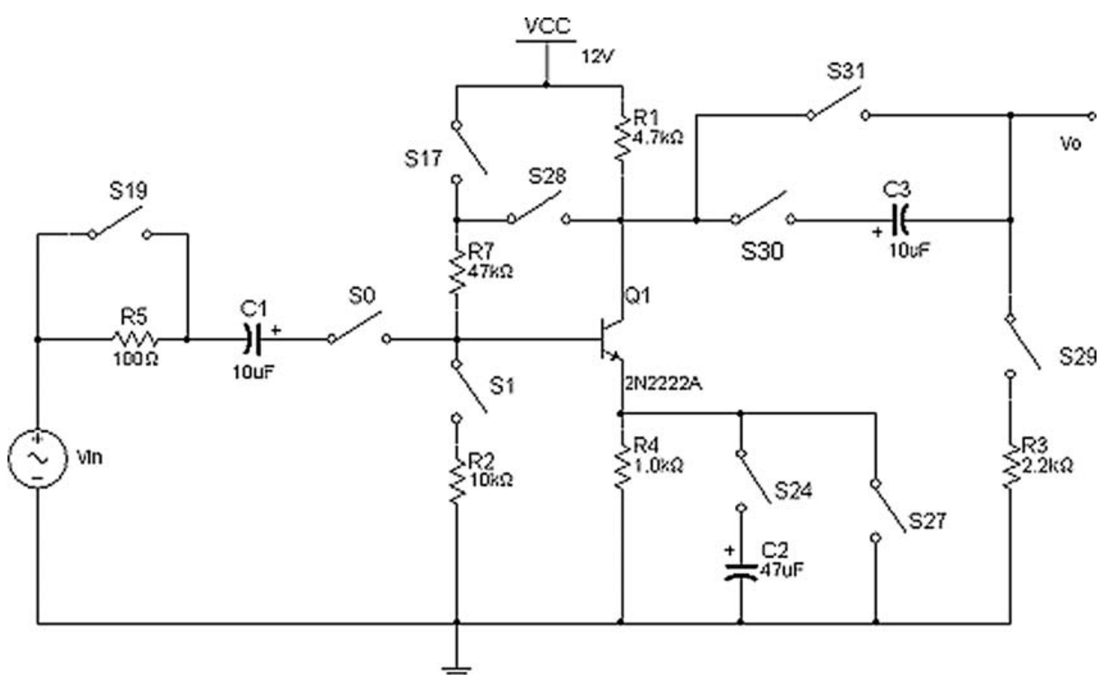

Figure 6 ELC II experiment module circuit diagram.

Table 3 Experiment Selection Table for ELC II Module

	Experiments			
	Base biasing	Voltage divider biasing	Collector feedback biasing	Common emitter amplifier
Digital Outputs (switch positions)				
S0	0	0	0	1
S1	0	1	0	1
S17	1	1	0	1
S19 (RS)	0	0	0	0/1
S24 (CE)	0	0	0	0/1
S27	1	0	0	0
S28	0	0	1	0
S29 (RL)	0	0	0	0/1
S30	0	0	0	1
S31	1	1	1	0

User Interface Design. In this work, as mentioned earlier National Instruments LabVIEW 7.1 has been used for all major programming procedures to complete the work. The page seen in Figure 8 is displayed before logging into the remote access laboratory. It is not possible to log into the laboratory environment unless the correct username and password is entered. If the username and the password are verified, the Selection page shown in Figure 9 can be accessed to login to desired laboratory environment among the ELC I, II, and III laboratory. Selecting the laboratory from the menu on the interface can be done using a mouse by double clicking or using a keyboard. Block diagram of the student login page in LabVIEW is shown in Figure 10.

When the user selects the desired laboratory environment and then the desired experiment name below it, the control panel related to the selected experiment will be displayed. Once a user accesses the laboratory, another user is prohibited to access the same experiment. The session can be closed anytime by the user or the lab session ends automatically after 10 min period.

As an Example Experiment: Non-Inverting Amplifier. In the experiment front panel shown in Figure 11, the input voltage is a DC that can be adjusted to any desired value between 0 and 10 V. Also the feedback resistance (R_F) can take one of the three predefined values as 1, 2.2, and 4.7 K. Thus, the effect of the feedback resistance on the output voltage or its benefit can be observed as mentioned earlier.

When the "APPLY" button is pressed as shown in Figure 12, HP 3632A power supply is set to the input voltage adjusted by slider (Vin Control in the block diagram shown in Fig. 12) on the user-interface. The output voltage is measured by HP34970A instrument.

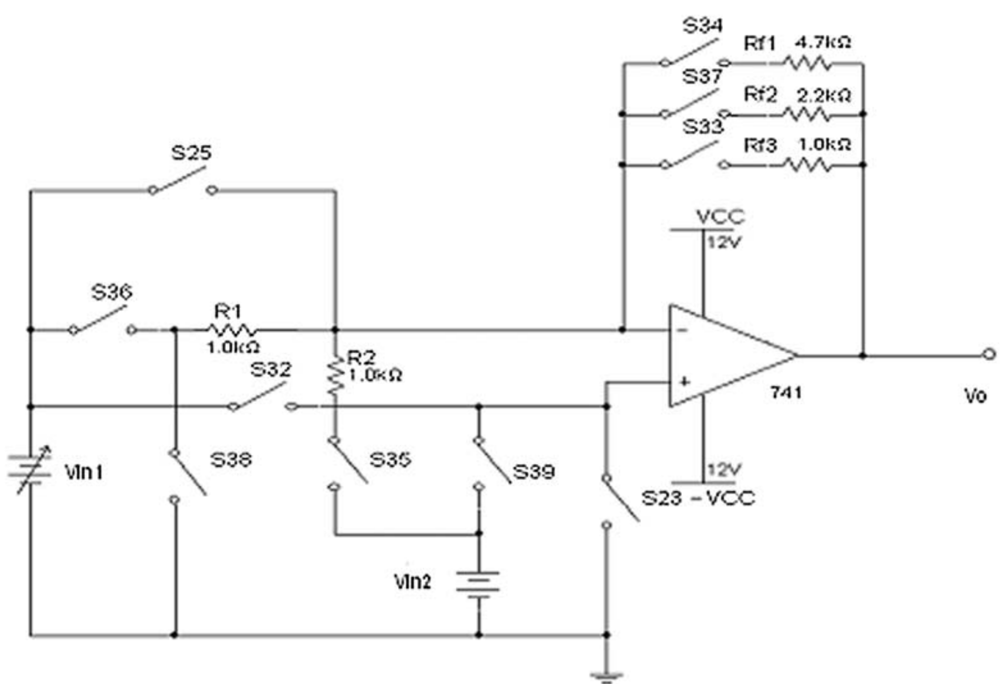

Figure 7 ELC III experiment module circuit diagram.

Table 4 Experiment Selection Table for ELC III Module

	Experiments			
	Inverting amplifier	Non-inverting amplifier	Summation circuit	Comparator circuit
Digital Outputs (switch positions)				
S23	1	0	1	0
S25	0	0	0	1
S32	0	1	0	0
S33 (RF3)	0/1	0/1	0/1	0
S34 (RF1)	0/1	0/1	0/1	0
S35	0	0	1	0
S36	1	0	1	0
S37 (RF2)	0/1	0/1	0/1	0
S38	0	1	0	0
S39	0	0	0	1

The most important point on the experiment front panels is that the switches on the interface must be closed before the ''UPDATE SWITCH'' button is pressed.

A USB camera is added to the system to let the students monitor the setup in the real lab simultaneously. After the ''MONITOR'' button is pressed an image panel will appear and display the real-time image of the setup. By monitoring the parameter changes and results on the user interface, students feel more certain about the experiments.

Web Interface. In this work, Web Publishing Tool of the LabVIEW application is used to transfer the experiments available on the internet environment. VI's, generated by this tool can be published to www. As a result of necessary adjustments, it is possible to publish using the address generated within the application. LabVIEW Run Time Engine is adequate to run the VI's available in the LabVIEW environment using a client PC web browser.

EXPERIMENT RESULTS

As an example experiment, non-inverting amplifier experiment is discussed in Table 5. While $R_F = 2.2$ K, the results are recorded on the table. It is possible to change the input voltage and the feedback resistance as well as the results can be monitored in this experiment.

STUDENT FEEDBACK

During the summer holiday of the school year 2007–2008, RACEL was introduced to the students who were completing their 24 days vocational summer training in the Electronics Laboratory of MUTEF. Then 22 students let to practice with RACEL. And finally, those students were asked to fill in a questionnaire combined five subscales with 22 statements as shown in Table 6. Results are also shown in Table 6 at the right hand columns. Student reaction to the RACEL looks positive according to the survey.

From these results, students' responses indicate that RACEL is easy to access, easy to use, and easy to learn how to use. Even if the worst-valued statement seems S.2, in fact it was caused by the usage of virtual IP. If IT center in the campus supplies and permits us to use real IPs, this negativity will disappear.

Statements between S.7 and S.11 indicated that disadvantages of the traditional method such as compulsory attendance

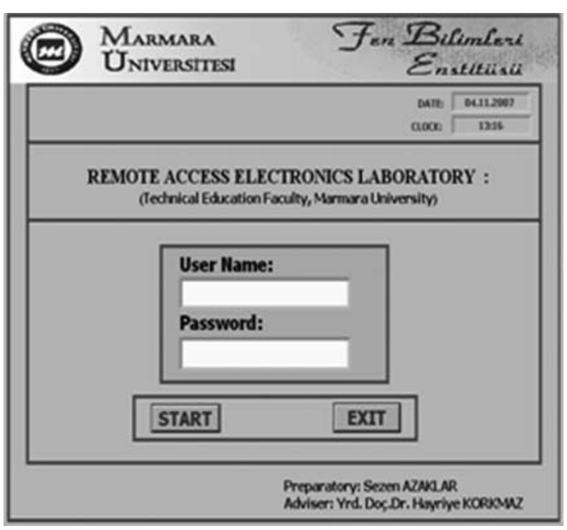

Figure 8 Login page front panel [29].

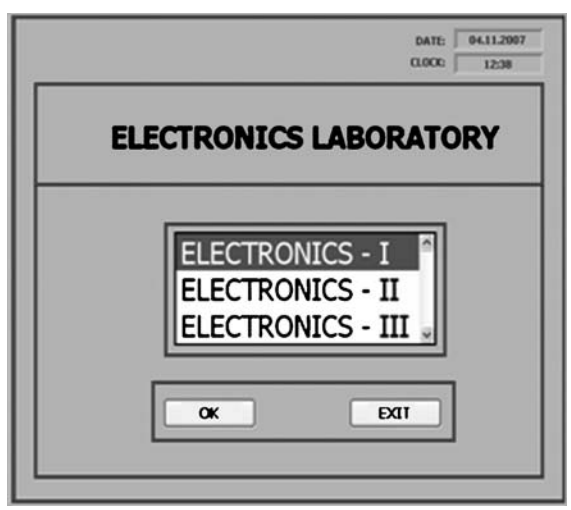

Figure 9 Laboratory selection page front panel [29].

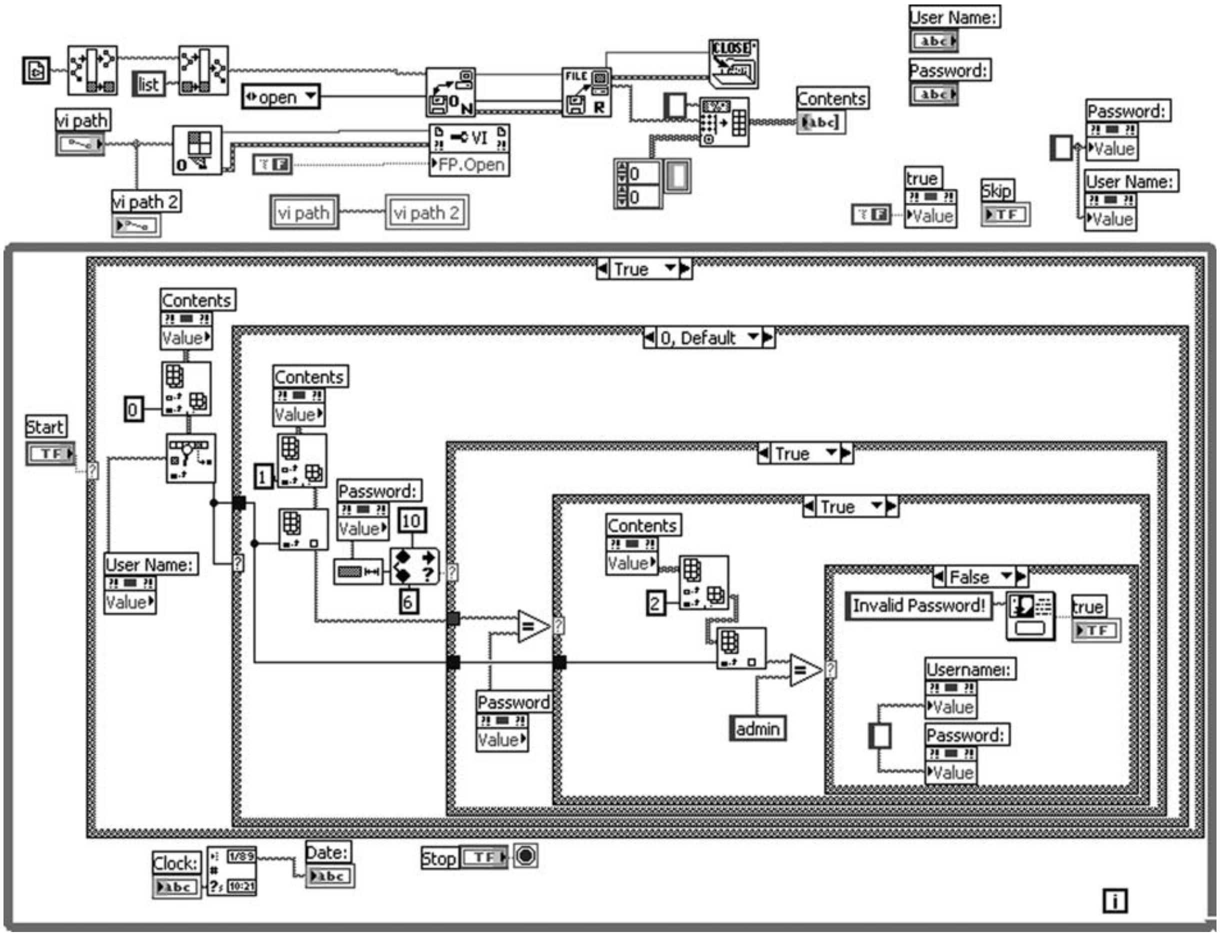

Figure 10 Block diagram of the student login page: password query [29].

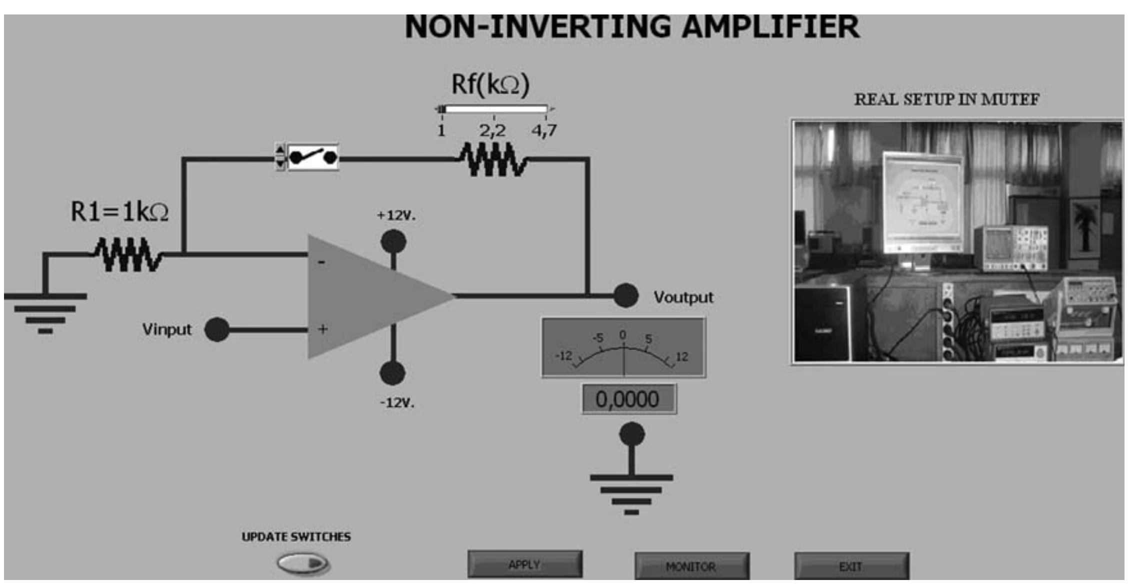

Figure 11 Non-inverting amplifier front panel in LabVIEW—User interface [29].

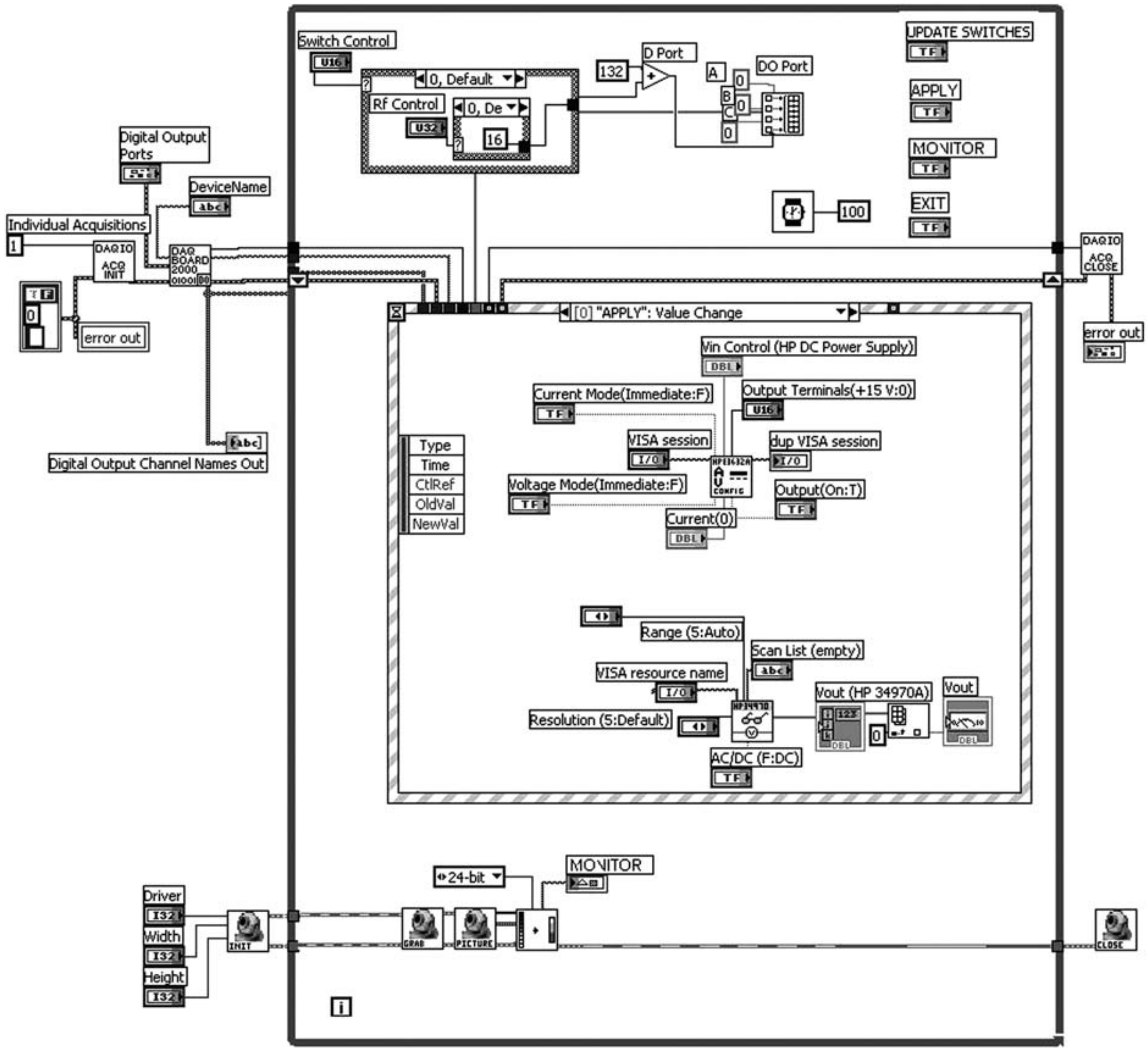

Figure 12 Block diagram of non-inverting amplifier experiment in LabVIEW [29].

Table 5 Non-Inverting Amplifier Experiment Results

	Measured values		Theoretical results (calculated values)
	By using a 4016 switching interface card	By using a hookup wire	$V_0 = (1 + (R_F/R_{in})) \times V_{in}$ $R_F = 2.2$ K, $R_{in} = 1$ K (fixed)
V_{in} (V)	V_{output} (V)	V_{output} (V)	V_{output} (V)
0.5	1.529	1.63	1.6
1	3.106	3.625	3.2
1.5	4.684	4.901	4.8
2	6.258	6.523	6.4
2.5	7.847	8.151	8
3	9.504	9.789	9.6
3.5	10.958	11.043	11.2
4	11.051	11.043	12.8
5	11.051	11.043	16

Table 6 Survey Statements and Associated Responses From the Students

		A	B	C	D	E
Access						
S.1	It is very easy to access in-campus and there is not any restriction	14	8	0	0	0
S.2	It is also very easy to access the RACEL from out of campus	2	6	10	0	4
User friendliness						
S.3	It is easy to use	20	2	0	0	0
S.4	It is easy and quick to learn how to use	14	8	0	0	0
S.5	Objects on the user interface are obvious and clear	14	8	0	0	0
S.6	Objects and displays are well symbolized as real ones	10	12	0	0	0
Self efficiency if you let to choose						
S.7	I prefer to complete the experiments traditionally in the lab with my group members	8	6	2	4	2
S.8	I prefer to complete the experiments by using RACEL	6	12	4	0	0
S.9	I prefer to use the two methods to take advantages of both methods	12	10	0	0	0
S.10	I believe that my personal skills will improve if I use RACEL	4	14	2	2	0
S.11	Participation of each student in a three-membered experiment group will not be equal in the real traditional laboratory environment	18	4	0	0	0
Functionality/configurability/reliability						
S.12	Input variables' range is enough to comprehend the subject	8	14	0	0	0
S.13	I can examine the circuit elements' effects separately which are the most effective on the output variable	14	2	2	4	0
S.14	I can observe the input and output variables numerically on the user interface	14	8	0	0	0
S.15	I can compare the input and output variables	12	8	2	0	0
S.16	I can observe the experiment results graphically	14	8	0	0	0
S.17	Experiments results for both methods are consistent	10	8	4	0	0
Learning and cognitive aspect after conducting the experiments by using RACEL						
S.18	This causes better understanding that in diode applications clipping level is directly related to the DC power supply's output value and its polarity	10	10	2	0	0
S.19	This causes better understanding about the effect of emitter bypass capacitance on gain in transistor amplifiers	10	12	0	0	0
S.20	This causes better understanding about the effect of load resistance on gain in transistor amplifiers	12	8	2	0	0
S.21	This causes better understanding about the effect of feedback resistance on gain in inverting and non-inverting amplifiers	12	8	2	0	0
S.22	This cause to comprehend the analog input and digital output concept deeply by using a data acquisition board in a real application	8	12	2	0	0

A, strongly agree; B, agree; C, neutral; D, disagree; E, strongly disagree.

to the lab sessions, participation differences of the group members, inadequate duration to complete the all experiment procedures can be compensated by using RACEL. Almost all students agreed that those two methods should be used together in a well-arranged and mixed programme.

Statements between S.12 and S.17 indicated that most of the students were satisfied by using the RACEL's user interface and they felt comfortable. Last statements between S.18 and S.22 also indicated that students strongly agree or agree that RACEL is an effective aid in learning some specific topics included in curriculum, which the instructor wanted to emphasize.

CONCLUSIONS

In this work, a real time remotely accessible and configurable environment is designed in order to support the practical activities of the students attending Electronics I, II, and III courses in the Department of Electronics-Computer Education of MUTEF. According to the students' opinion, RACEL seems to be able to solve the problems such as attendance, time limitation, and participation differences of the group members etc. faced in the traditional method and contribute to the student success.

The experiments in RACEL are fulfilled successively and discussed in three different conditions [29]. These are as follows:

- While the control is at server PC and the electronic switching circuit is used,
- While the control is at client PC and the electronic switching circuit is used,
- While the related switches are short circuited manually (using a hookup wire) instead of an electronic switching circuit.

When the measured and calculated values are compared, the experiment results are found to be coherent.

The students are not allowed to change the switch positions in designed environment. The student can only select the experiment name on the interface, make the adjustment, which are allowed in the design and monitor the results. Thus, undesirable conditions (such as short circuiting of the power supply) are avoided.

Each of the switching components used in this study act as if an $\sim 80-100\Omega$ serial resistance is added to the circuit. The measured values and the theoretical results will be more coherent provided that a switching component (the resistance close to 0 Ω) close to the ideal one is used.

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