Development of a Web-based Laboratory System for Distance Experiments on Basic Electronic Circuits

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Abstract: - In this paper, we implement a creative hybrid educational system for engineering experiments where web-based virtual laboratory systems and distance education systems are properly integrated. In the first stage, we designed client/server distributed environment and developed web-based virtual laboratory system for electronic circuit experiments. The proposed virtual laboratory system is composed of three important sessions and their management system: concept-learning session, virtual experiment session, assessment session. With the aid of the management system every session is organically tied up together to achieve maximum learning efficiency. In addition, every activity done during the virtual laboratory session are recorded on database and will be provided to the learners as the printout report included their own experimental information and results. With this new system structure, the learners can compare theoretical and experimental data; develop their capability in designing and analyzing the circuits; and make use of auxiliary educational tools for understanding complicated concepts.

In the second stage, we have implemented efficient and cost-effective distance laboratory systems for practicing electrical/electronic circuits, which can be used to eliminate the lack of reality occurred during virtual laboratory session. The use of simple and user-friendly design allows a large number of people to access our distance laboratory systems easily. Thus, self-guided advanced training is available even if many expensive types of equipment will not be provided in the on-campus laboratories. During distance laboratory session, the learners change the settings of the input signal and the values of circuit elements, observe the output waveform from the web camera, and obtain image information regarding their experimental results. The proposed virtual/distance laboratory systems can be used in stand-alone fashion, but to enhance learning efficiency we integrated them and developed a creative hybrid education system for engineering experiments. Our hybrid education system provides interactive learning environment and a new approach for the delivery of engineering experiments.

Key-Words: Web-based Virtual/Distance Laboratory System, Web-based Hardware Control Technologies, Multimedia Contents, and Java Applets

1 Introduction

Electronic experimental study is a very important component in engineering education. It not only acts as a bridge between theory and practice, but also solidifies the theoretical concepts presented in the classroom. In the classical approach, most of electronics experiments performed at real on-campus laboratories are accompanied by a complete manual, a detailed guideline for design and simulation steps, experiment procedures and a presentation of the technical report. Before the laboratory session, the learners should re-enforce basic concepts, prepare some design and simulation steps, and acquire a clear idea on what they should expect from the experimental work they will be carrying out in the laboratory. At the laboratory session, the learners are required to assemble the circuits, connect the equipment, make the measurements, compare the data to the expected behavior, and deliver a partial or complete report to the professor at the end of the session. This classical way of experimenting clearly has the following shortcomings.

- The classroom lectures or the handouts are generally not sufficient for the learners to be fully prepared for a hands-on experiment or to appreciate the significance of the previously explained theory in the experiment to be performed.
- When the learners are passive observers or a semi-active part of an experiment, they will understand neither the correspondence nor the difference between theory and practice.
- When practicing electrical/electronic circuits on virtual world, the learners feel the lack of reality. It is necessary to build bridge between virtual world and real world so that they can understand real experiment procedure easily during virtual laboratory session.

To cope with some difficulties we implement a creative hybrid educational system for engineering experiments where web-based virtual laboratory systems and distance education systems are properly integrated. We are focusing our initial efforts on electronic experiments for the reinforcement of undergraduate teaching, which is taken by most undergraduate engineering students.

In the first stage, we have implemented virtual laboratory system, which provides the learners with improved experimental methods. If the learners have access to the virtual laboratory system through signing up procedure, they can acquire the fundamental concepts on the related experiment and make a virtual experiment on basic electronic circuits according to the guided experiment procedures. Equipped with theoretical knowledge acquired by executing flash animations and Java applets, the learners can easily understand the important principles and the significance in the experiment to be performed. All of these activities will be carrying out in the virtual laboratory system by clicking the menu buttons in it and filling out some text fields to change the values of experimental components. Since this interactive virtual laboratory is implemented to describe the real on-campus laboratory, virtual experimental data similar to real experimental data can be obtained through the system. The proposed virtual laboratory system is composed of three important sessions and management system: Principle Study Sessions, Virtual Experiment Session, Assessment Session, and Management System. With the implementation of the proposed virtual laboratory system, it has become to intensify the work during the laboratory session and to provide the learners with better understanding of the significances related to the electronic experiments.

In the second stage, we have implemented an efficient and cost-effective distance laboratory system for practicing electrical/electronic circuits, which can be used to compensate the absence of reality, occurred during virtual laboratory session. The use of simple and user-friendly design allows a large number of people to access our distance laboratory systems easily. The learners in remote environment control many types of equipments in the distance laboratory system through web-based hardware technologies. During distance laboratory session, they change the settings of the input signal and the values of circuit elements, observe the output waveform from the web camera, and obtain moving image information regarding their experimental results. Thus, self-guided advanced training is available even if many expensive types of equipment will not be provided in the on-campus laboratories.

The proposed virtual/distance laboratory systems can be used in stand-alone fashion, but to enhance learning efficiency we integrated them and developed a creative hybrid educational system for engineering experiments. We developed communication system, prototype of control module, and control panel under graphic user interface environment to combine the virtual laboratory system with the distance laboratory system.

Our hybrid educational system provides interactive learning environment and a new approach for the delivery of engineering experiments. Every activity done during the virtual laboratory session is recorded on database and will be provided to them as a printout report form included their experimental information and results. The educators check the printout form turned in to estimate how well they understand the experimental contents and methods during virtual laboratory session. Finally, we have obtained several affirmative results such as reducing the total practicing hours and increasing learning efficiencies as well as faculty productivity. In Section 2, our virtual laboratory for practicing electronic circuits is described. In Section 3, our distance laboratory system and hybrid educational system are described. In Section 4, the conclusions are discussed.

2 Web-based Virtual Laboratory

2.1 Virtual Experiment Equipment

Since our virtual laboratory system is

implemented to describe the real on-campus laboratory, widely used experimental equipments such as oscilloscope, multimeter, function generator, and power supply etc. are implemented by Java applets.

All activities done in the virtual laboratory will be carrying out by clicking or dragging the mouse and filling out some text fields to change the values of experimental components. In addition, by previewing how to use some equipment on the Web the learners can reduce their waste time and labor during real laboratory session.

2.1.1 Virtual Analog Multimeter

Widely used multimeters can be divided into two types: digital and analog. Though digital type multimeter is more common, we implement an analog type multimeter for engineering educational purpose. As shown in Fig. 1 the implemented multimeter has two separate scales to avoid complicatedness. Ammeters and Voltmeters are read from left to right and have a linear scale. However, Ohmmeters are read from right to left and have a nonlinear scale.

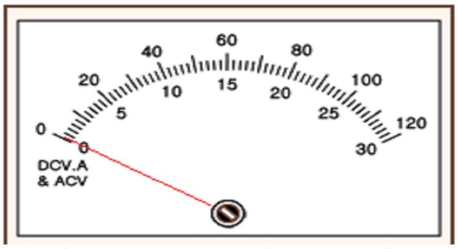


Fig. 1 DCV, A and ACV scales

The multimeter combines a voltmeter, ammeter, and ohmmeter into one package. On a multimeter, the range selector switch selects the function to be used by dragging the mouse to desired range and releasing.

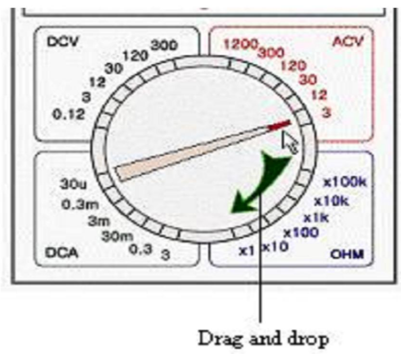


Fig. 2 Range selector switch

2.1.2 Virtual Function Generator

The virtual function generator is composed of four main parts: frequency adjustments by mouse dragging, waveform mode part, frequency adjustment by slide menu or choice box, and amplitude adjustment by dragging. Output frequency range of generated signals is 1Hz to 1MHz and amplitude range is 2V to 20 V peak-to peak.

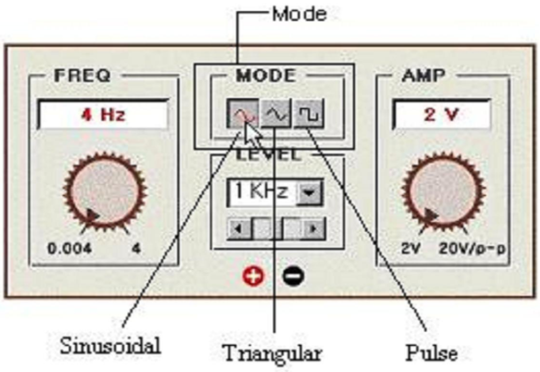


Fig. 3 Virtual Function generator

2.1.3 Virtual Oscilloscope

Oscilloscope is very important equipment in the area of engineering experiments. We implemented a virtual oscilloscope that allows signal voltages to be viewed on the Web, usually as a two-dimensional graph of one or more electrical voltages plotted as a function of time. Our virtual oscilloscope is implemented to describe typical commercial oscilloscope in view of some functions. It is not the same as commercial oscilloscope, but it is good enough to get educational effects in the area of engineering experiments. The virtual oscilloscope is composed of three main parts: oscilloscope body, control box, circuit box. Once the learners click on the button “CH1” or “CH2”, virtual marker and available marker position in the circuit box will be displayed together as shown in Fig. 4(a). If the markers are placed correctly on the circuit, its corresponding output waveforms will be displayed on the oscilloscope body. Clicking on the button “ZOOM” in the oscilloscope body, the learners can observe output waveforms in details on the separate window. Information that the markers have will be transferred when clicked on “ZOOM”. The Java source code makes the markers store frequencies, voltages, currents, phases associated with their positions in the circuit.

The detailed oscilloscope window is shown in Fig. 4(b), where several functions such as voltage, time adjustment, trigger control, cursor adjustment, summing. Furthermore, output waveforms can be stored, loaded, and printed out by clicking the buttons in the "STORE" box.

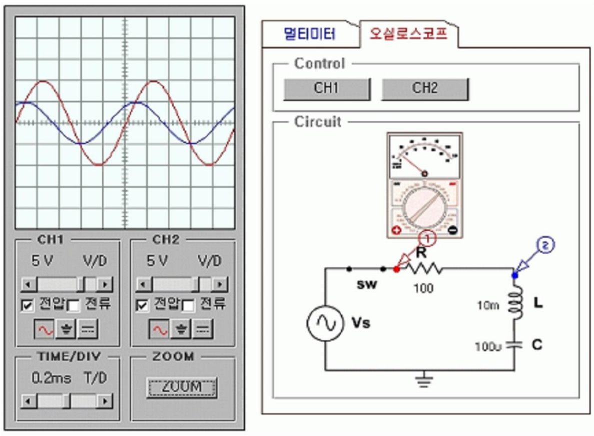


Fig. 4(a) Virtual oscilloscope and its structure

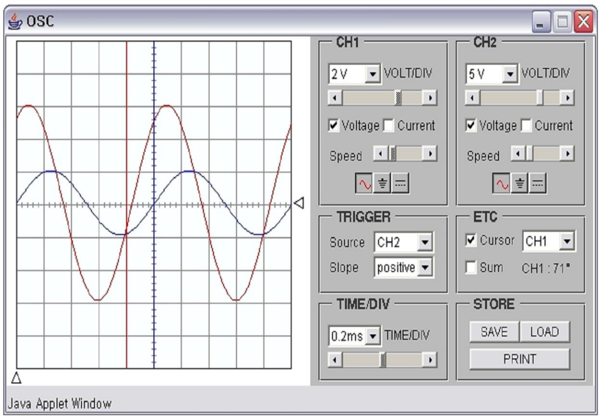


Fig. 4(b) A detailed window when clicked "ZOOM"

2.2 Virtual Laboratory for Electronic Circuits

The web-based virtual laboratory needs, in general, various interactive multimedia components such as Java Applets, Flash animations with useful educational effects. In order to achieve this goal, we suggest that our virtual laboratory include three important sessions and management system for effective experiments on the World Wide Web. The material of our virtual laboratory system is appropriate for advanced courses on electronic circuit experiments. Each course consists of 15 chapters and each chapter comprises the Principle Study Session to explain the concepts and theories of circuit operations, the Virtual Experiment Session to provide the learners with making virtual experiments on several electronic circuits. The Management System assigns the username and password to the eligible authorized persons and provides printout service for all information about the experiment done in the Virtual Experiment Session.

2.2.1 Principle Study Session

The Principal Study Session is responsible for making the learners understand the concepts and theories of the circuit operations included in each chapter. Interactive flash animations with creative and intuitive ideas for each subject lead the learners to understand them easily. For another example, Fig.5 shows an interactive Java Applet for understanding the important concepts of JFET characteristic curves. The learners can easily understand the related concepts to the JFET characteristic curves by increasing or decreasing V_{GG} by mouse clicking.

2.2.2 Virtual Experiment Session

The Virtual Experiment Session provides virtual experimental environment to the learners. Widely used experimental equipments such as oscilloscope, multimeter, function generator, and power supply etc. are implemented by Java Applets. During this session, the learners can build circuits for each subject, set the values for each circuit element, and measure voltages or currents etc. using several types of the virtual experimental equipment. When finishing the virtual experiment on the Web, they can print out all information related to their virtual experiments and submit it as their preliminary report to the educators in their on-campus laboratory classes.

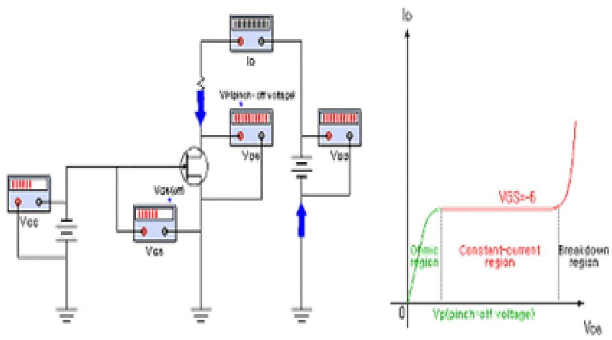
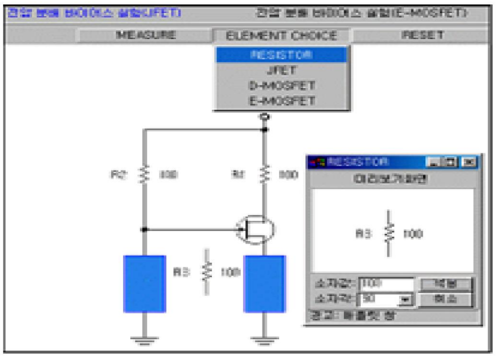


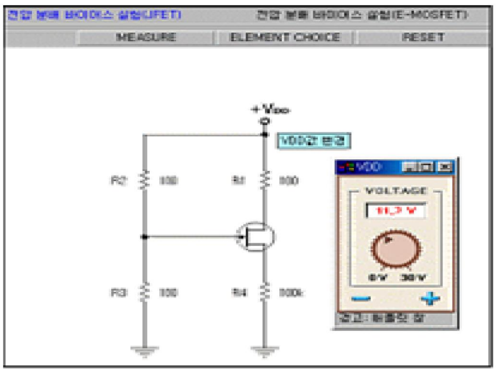
Fig. 5 Java applet for JFET characteristic curves

A virtual experiment is performed according to the following procedure: (1) Assembling and connecting the circuits (2) Applying input voltages (3) Making the output measurements (4) Transmitting experimental data to the database (5) Printing out the preliminary report as shown in Fig. 6(a)-(d). The learners build a given circuit by placing proper circuit elements from "ELEMENT CHOICE" menu. With this menu, the learner can select circuit elements and change their types or values. They can change the value of DC power supply by double-clicking the DC power supply symbol. In addition, they can insert a voltage and/or current markers into the circuit by using "MEASURE" menu. The learner can also measure several outputs for the various values of Vcc using the virtual oscilloscope.

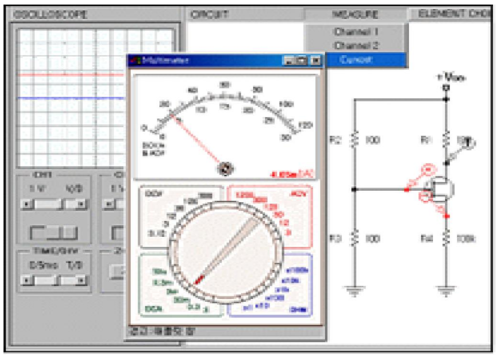
The virtual experiments are designed to be performed for the fixed structure with variable circuit parameters. Therefore, with the virtual experiment equipment, the learners make virtual experiments for the fixed circuit, but they can change circuit parameters (R, L, and C), values of voltage sources, and selection of outputs. Though the virtual experiments are not arbitrary, we can get enough educational purpose for electronic circuits. It is not always necessary to make virtual experiments for arbitrary circuits. What we need is to understand definitely for well-known basic electronic circuits.



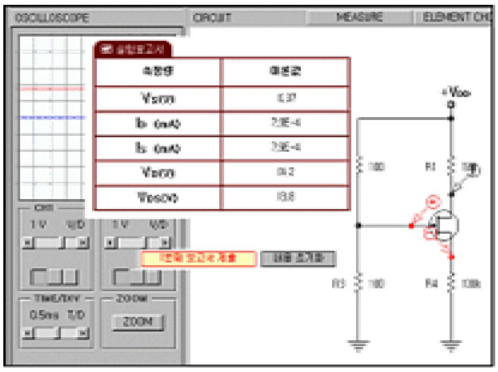
(a) Assembling and connecting a circuit



(b) Applying input voltages



(c) Making the output measurements



(d) Transmitting experimental data

Fig. 6 Procedure of making virtual experiments

2.2.3 Assessment Session

It is very important to provide the educators with useful information on experiments done in the virtual laboratory by which the educators evaluate how well the learners are doing. Every activity done during the virtual laboratory session is recorded on the database and will be provided to them as the printout form included their experimental information and results. The educators check out the submitted printout form to estimate how well the learners understand the overall experimental process. The management system supports communications between the educators and the learners in the ways mentioned above, and different setups for each learner. This assessment process is very essential to increase the learner's academic capability.

2.2.4 Management System

In the proposed virtual laboratory system, every activity occurred during the virtual laboratory session will be recorded on database and printed out as the preliminary report form. All of these can be achieved by the aid of the Management System. Professional

HTML Preprocessor (PHP) makes the database connectivity and the virtual laboratory environment is set up slightly differently for each learner. Our virtual laboratory system, based on client/server architecture, uses none of the commercial software package. Fig. 7 shows database connectivity of the Management System using PHP. Fig. 8 shows an input form that the learners fill out during virtual experiment session and Fig. 9 shows a preliminary report form to be printed out after making a virtual experiment during the virtual experiment session.

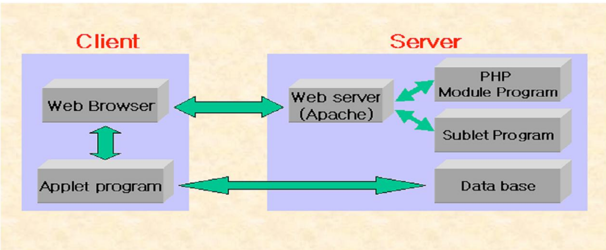


Fig.7 Database connectivity of the management system using PHP

In addition, in order to show the validity of our virtual laboratory system we investigated the damage rate of real experimental equipment during class and assessed student performance on the five quizzes for one semester. The students were divided into two groups: **G1**(Group1) not using the virtual laboratory system, **G2**(Group2) using the virtual laboratory system. The students also were asked to evaluate the virtual laboratory environment in terms of process effectiveness, degree of interactivity, and enjoyment. More specifically, for our virtual laboratory environment the students in Group 2 had to rate on a 5-point Likert scale their level of agreement with the following statements.

- The virtual laboratory system was effective in supporting my learning method.
- The virtual laboratory system provided me with the appropriate level of interactivity with the real experiment.
- I enjoyed using the virtual laboratory system to learn.

As shown in Table 1 we have obtained several affirmative effects such as reducing the damage rate of real experimental equipment, and increasing learning efficiency. The results of our survey show strong evidence of the superiority of the virtual laboratory environment over the classical on-campus laboratory environment. In addition, we can conclude that the virtual laboratory environment enables the learners to interact not only with the learning material but also with the educators.

Table 1. Between-group comparisons

	A	B	C	D	E
G1	25.4%	64.5%	N/A	N/A	N/A
G2	4.8%	81.4%	4.31%	4.01%	4.13%

A: Damage Rate of Real Equipment
B: Average Score of Five Quizzes
C: Process Effectiveness
D: Degree of Interactivity
E: Enjoyment
Scale: Strongly disagree 1 2 3 4 5 Strongly agree

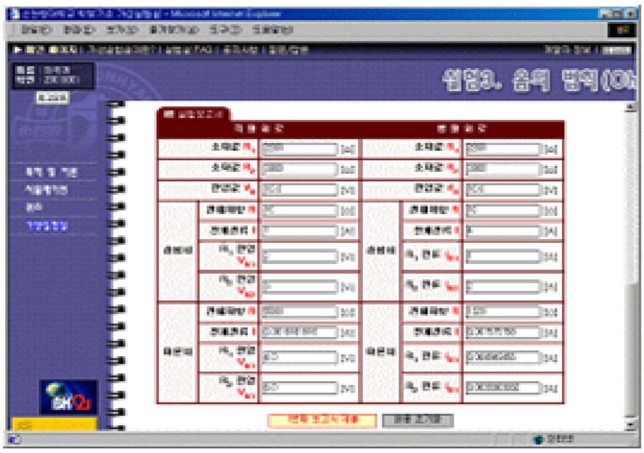


Fig. 8 An input form of virtual experiments

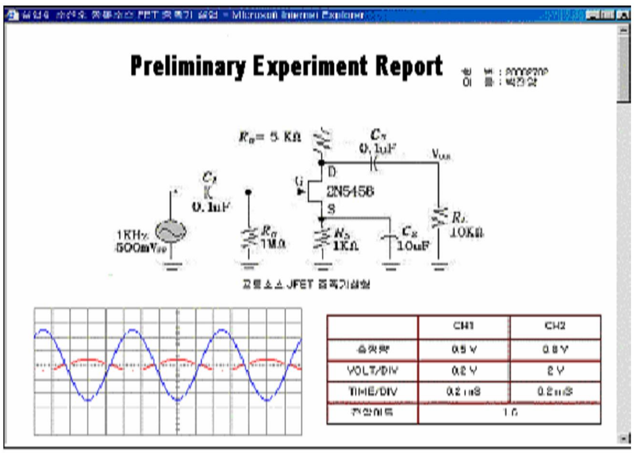


Fig. 9 A preliminary report form

3. Web-based Distance Laboratory

Web-based engineering laboratory systems are largely divided into virtual laboratory systems and distance laboratory systems. The web-based virtual laboratory systems provide virtual experimental environment similar to real experimental environment. Due to high cost of on-campus laboratories at the universities with a large number of students, much interest in the web-based virtual laboratory has been drawn. Since these interactive virtual laboratories are implemented to describe the real on-campus laboratory, the learners can obtain similar experimental experience through them. However, there are still some drawbacks: (1) the virtual laboratory environment lacks feeling of reality (2) it is very difficult for the virtual laboratory systems to describe the exact and precise operations of real experimental devices.

To cope with these drawbacks, we have implemented an efficient and cost-effective distance laboratory system for practicing electrical/electronic circuits, which can be used to compensate the absence of reality, occurred during virtual laboratory session. The use of simple and user-friendly design allows a large number of people to access our distance laboratory systems easily. The learners in remote environment control many types of equipments in the distance laboratory system through web-based hardware technologies. During distance laboratory session, they change the settings of the input signal and the values of circuit elements, observe the output waveform from the web camera, and obtain moving image information regarding their experimental results. Thus, self-guided advanced training is available even if many expensive types of equipment will not be provided in the on-campus laboratories.

3.1 Distance Laboratory for Electronic Circuit

3.1.1 Structure of Our Distance Laboratory

Our distance laboratory system is composed of Local Measurement System (LMS), Data Processing Server (DPS), and Remote Measurement Server (LMS). The operation of our distance laboratory system is largely divided into channel selection of Data Acquisition (DAQ) board and transmission of measured data. Once the learners have chosen the desired channel at the RMS, information on the selected channel will be transferred to the DPS and the LMS sequentially. The LMS with DAQ board starts measuring the experimental data and then makes the measured data transferred to the DPS and the RMS sequentially. Fig. 10 shows structure of the proposed web-based distance laboratory system and its related data flows.

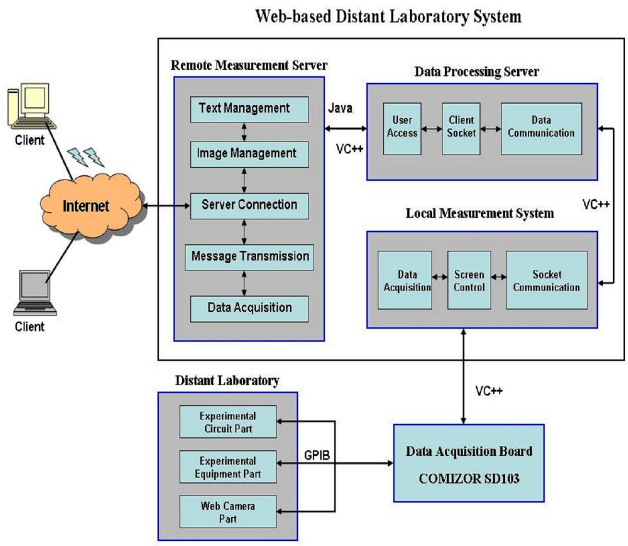


Fig. 10 Structure of the distance laboratory system

3.1.2 Local Measurement System (LMS)

LMS plays important roles to measure several experimental data from the distance laboratory and then transmit the data to the DPS. Many types of experimental equipment such as multimeters, function generators, oscilloscopes, and web cameras were set up for the learners in the distance laboratory. In addition, a GPIB controller card is installed to control experimental equipment properly through PCI bus. The LMS is designed to use a DAQ board (SD103, COMIZOR) in order to get the data measured in the distance laboratory. The LMS is composed of data acquisition module, screen control module, socket communication module. Brief descriptions of each module are as follows: the data acquisition module gets the data measured at every time interval from the DAQ board, stores the measured data in the buffer, and then transmits them to the DPS. The screen control module generates waveform images by using the array-type data transmitted from the DAQ board and displays them on the screen. Finally, the socket communication module stores the measured data in the buffer, changes their format according to the socket transmission method, and then transmits them to the DPS. Visual C++ is used for socket communication between the LMS and the DPS.

3.1.3 Data Processing Server (DPS)

DPS plays important roles to transmit the data obtained from the LMS to the RMS. The DSP is composed of client socket module, user access module, and data communication module. Brief descriptions of each module are as follows: the client socket module manages clients' access and transmits its information to the RMS. The user access/delete module stores user information when a user has access to the distance laboratory system and then transmits it to the RMS. Finally, the data communication module sends every user in the distance laboratory system the data transmitted from the LMS simultaneously. Visual C++ is used for data communication between the DPS and the RMS.

3.1.4 Remote Measurement Server (RMS)

We implemented RMS to provide every user in the distance laboratory with overall experiments in progress through the web camera. The RMS is composed of text/image management module, server connection module, message transmission module, and data acquisition module. Brief descriptions of each module are as follows: text/image management module analyses text and image information from the data transmitted from the DPS, stores them in the buffer, and displays the buffer on the screen. The server connection module enables the users to have access to the RMS by using predetermined server IP address and port number. Java codes in the RMS collaborate with the Visual C++ codes in the DPS to communicate with each other. The message module controls the RMS by transmitting control signals to the RMS. Finally, data acquisition module takes the measured data only out of the transmitted data stream and stores them in the screen output buffer.

3.2 Some Experiments for Electronic Circuits

Distance laboratory for electrical/electronic circuits is composed of three main parts: experimental circuit part, experimental equipment part, and web camera part. Through the web camera, the learners observe the circuits to be performed, experimental equipment such as multimeters, oscilloscopes, and function generators. The experimental circuit part is connected to the DAQ board to get experimental data and a GPIB controller card is installed to control experimental equipment properly through PCI bus. The web camera takes pictures the circuits to be performed and experimental equipment to offer the learners in real-time.

During measurements of the experimental circuits, the web camera takes the pictures and transfers to the learners by using socket communication programs. The socket program in the RMS side transfers the experimental data measured during a distance laboratory session to the socket program in the client side. The transferred data will be made as moving images and be viewed to the learners. Thus, without the presences in the real on-campus laboratory, the learners can conduct their distance experiments with the moving image viewed. Fig. 11 shows distance laboratory for electronic circuits.

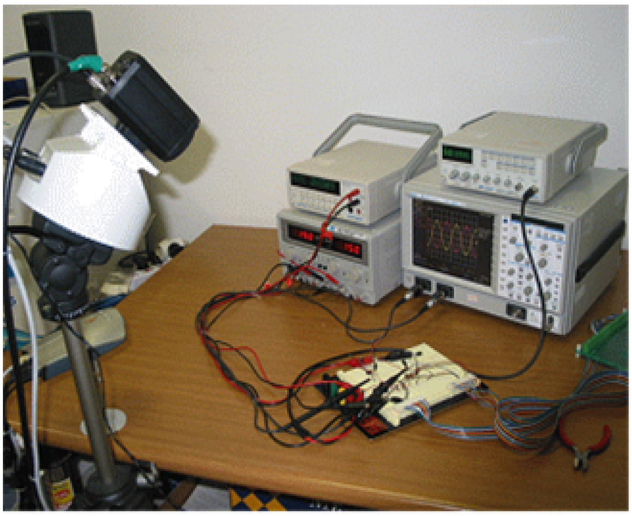


Fig. 11 Distance laboratory for electronic circuits

To make experiments in the distance laboratory for electrical/electronic circuits the learners need to sign in with their user IDs and passwords to the distance laboratory. Once signing in has been completed, they can observe the moving images of the circuits to be performed and experimental equipment. In addition, they can check out the real experimental results from the RMS and can change the channels they want to observe. Fig. 12-13 show distant experiments for the RLC series circuit and transistor amplifier, respectively. Note that a little time delay in data transmission is occurred from Fig. 12(c) and Fig. 12(d). In general, the more the time is occurred, the more channels the learners select. This problem can be solved if we design the distance laboratory system by connecting the commercial database.

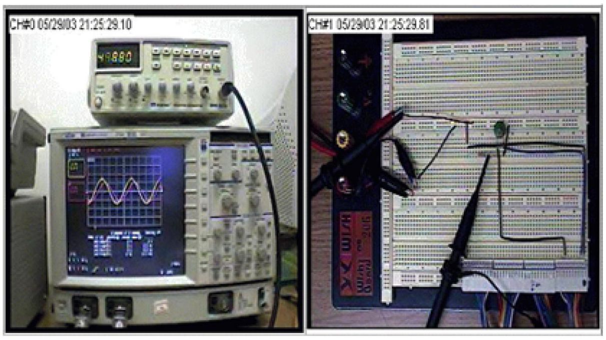


Fig. 12a Distance laboratory for RLC series circuit taken by the web camera

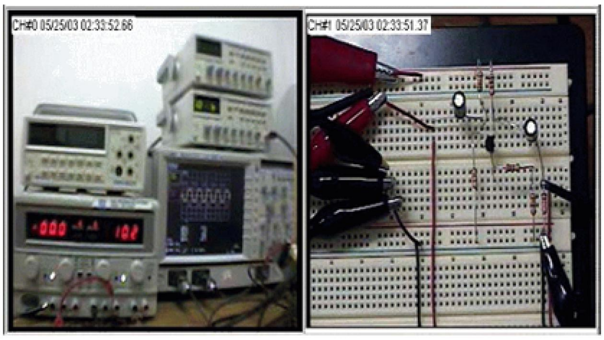


Fig.13a Distance experiment for transistor amplifier taken by the web camera

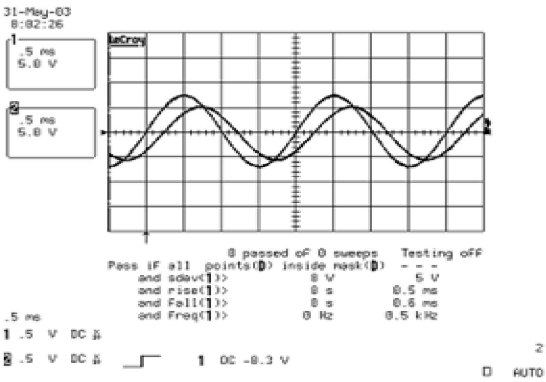


Fig. 12b Output waveforms for RLC series circuit measured by the oscilloscope

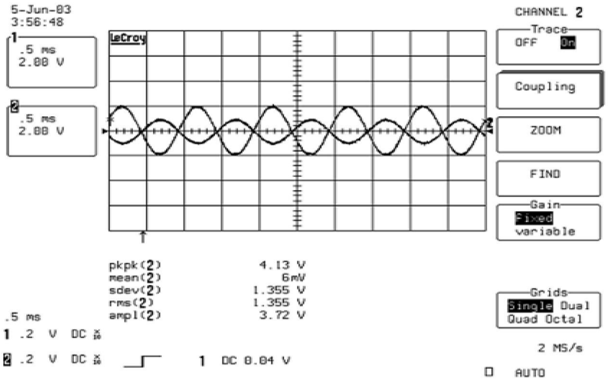


Fig.13b Output waveforms for transistor amplifier measured by an oscilloscope

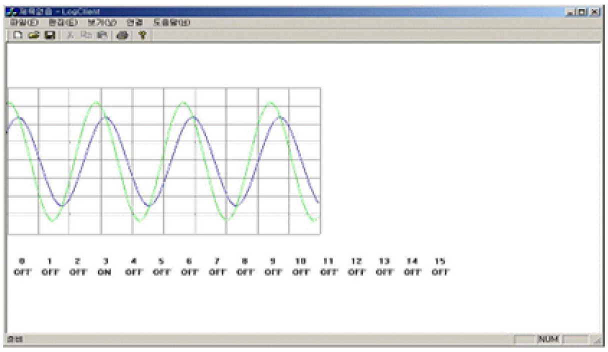


Fig.12c Output Waveforms measured by the LMS

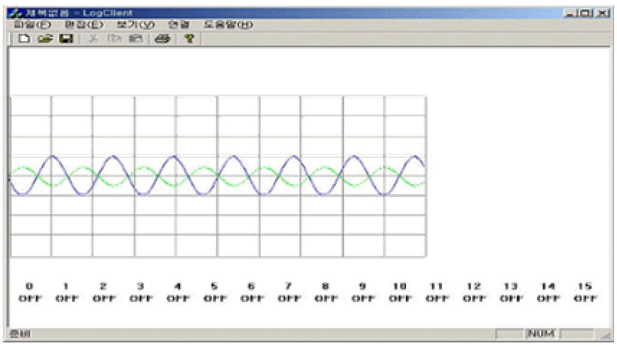


Fig. 13c Output waveforms measured by the LMS

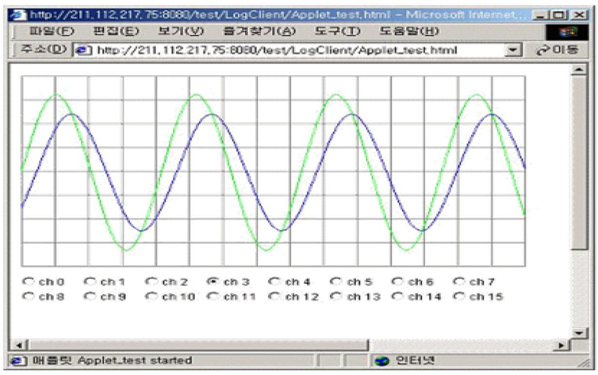


Fig.12d Output waveforms transferred to the RMS

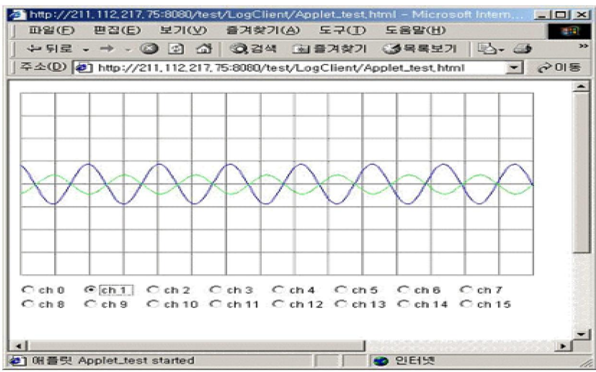


Fig. 13d Output waveforms transferred to the RMS

3.3 Integration of the Virtual and the Distance Laboratories

The proposed virtual/distance laboratory systems can be used in stand-alone fashion, but to enhance learning efficiency we integrated them and developed a creative hybrid educational system for engineering experiments. We developed communication system, prototype of control module, and control panel under graphic user interface environment to combine the virtual laboratory system with the distance laboratory system.

Through database connectivity using PHP, our hybrid educational system enables the learners to compare two experimental results from two different laboratories: the virtual laboratory and the distance laboratory. If many users have access to our distance laboratory system simultaneously, they will be getting the priority number associated with hardware control according to their access order to the distance laboratory system. The user with highest priority number makes experiments first, when the other users can only observe the overall experiments performed by the first user. Once the first user has completed the distance experiment, next turn is the second user.

The educators check the printout form turned in to estimate how well they understand the experimental contents and methods during virtual laboratory session. The distance laboratory system helps the learners improve feeling of reality and learning efficiency in the experiments of electrical/electronic circuits.

In addition, our hybrid educational system provides two courses and each course needs one semester. The implemented hybrid educational system can be used in stand-alone fashion, but using, as assistants of the real on-campus laboratory class will show more encouraging results.

4. Conclusions

An efficient virtual laboratory system with creative and interactive multimedia contents was implemented, which can be used to enhance the quality of education in the area of electrical/ electronic circuit experiments. In order to offer the learners virtual environment on the World Wide Web, various types of experimental equipment such as virtual oscilloscopes, virtual analog multimeters and virtual function generators was implemented. This new and innovative structure will be used for eliminating the difficulties of classical experimental system. With this new system structure, the learners can compare theoretical and experimental data; develop their capability in designing and analyzing the electrical/electronic circuits; and make use of auxiliary educational tool for understanding complicated concepts. In addition, we have obtained several affirmative effects such as reducing the damage rate of real experimental equipment, and increasing learning efficiency. The results of our survey show strong evidence of the superiority of the virtual laboratory environment over the classical on-campus laboratory environment. Therefore, we can conclude that our virtual laboratory system enables the learners to interact effectively not only with the learning material but also with the educators.

Furthermore, we have implemented efficient and cost-effective distance laboratory systems for practicing electrical/electronic circuits, which can be used to eliminate the lack of reality occurred during virtual laboratory session. Although main objective of our distance laboratory system is the reinforcement of experiment education on basic electronic circuits, it also can be extended to different engineering fields in similar methods. The use of simple and user-friendly design allows a large number of people to access our distance laboratory systems easily. Thus, self-guided advanced training is available even if many expensive types of equipment will not be provided in the on-campus laboratories. During distance laboratory session, the learners change the settings of the input signal and the values of circuit elements, observe the output waveform from the web camera, and obtain image information regarding their experimental results. The learners can go through a distance laboratory session at their own pace without requiring the presence and the assistance of a laboratory supervisor

The proposed virtual/distance laboratory systems can be used in stand-alone fashion, but to enhance learning efficiency we integrated them and developed a creative hybrid educational system, which makes two types of experiments for electrical/electronic circuits. Our hybrid educational system will be used for the teaching of undergraduate and postgraduate courses. In teaching, the possibility of anytime anywhere access allows undergraduate students who are not able to finish the real experiments to continue to work on the subject after the formal laboratory session on their own time through the Internet.

With the explosive growth of the World Wide Web, we can expect to see many of the key features of our hybrid educational environment be implemented on the Web more conveniently in the future, where they will be more universally accessible.

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