A Web-Based Electrical and Electronics Remote Wiring and Measurement Laboratory (*RwmLAB*) Instrument

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***Abstract*—This paper presents an instrument based on a new architecture called "Remote Wiring and Measurement Laboratory" (*RwmLAB*) acting as a local multicircuit board on a common distributed panel on the Internet. Matrix switching, data acquisition, data processing and analysis, and graphical unit interface enabled-devices characterize the *RwmLAB*. *RwmLAB* is intended to address real-time remote wiring of electrical and electronic circuits and real data acquisition over the Internet instead of using simulated data. This Web-based instrument allows for flexibility and the spontaneous delivery of laboratory material and ensures a global access to a worldwide audience.**

***Index Terms*—Analog–digital, emerging technologies, mixed signal processing, remote data acquisition, remote laboratory, remote wiring, virtual measurement system, web and internet.**

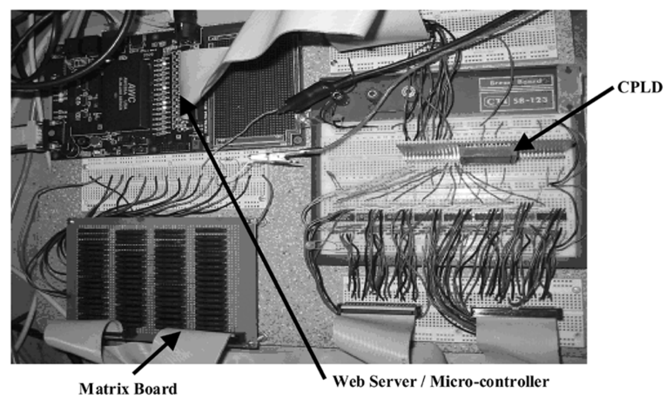

Fig. 1. Pictorial representation of the various components on the breadboard.

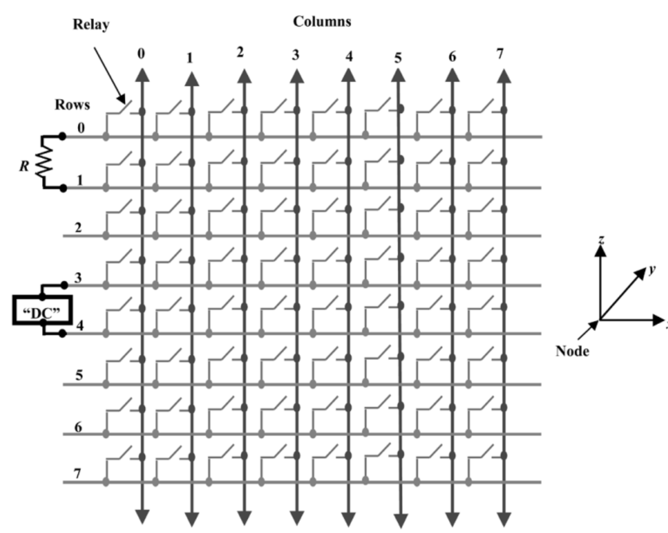

Fig. 2. 8×8 switching matrix network with examples of a resistor and a power supply ("dc") connected.

I. Introduction

The Web and Internet technology have been used for many instances of e-commerce, banking, video, and data on-demand [1], [2], etc. In [3], Fortino *et al.* showed a demand on service (MoD) delivery system that allows a user to access, retrieve, and control live systems and achieve data acquisition in distributed virtual instruments. Internet protocol has also been used to enable power meters for measurements [4]. Other very innovative Web-based architectures have been employed for collecting offline data, accessing real-time data, and for achieving data on demand. These Web-based architectures used expensive dedicated networks, several bus systems, and third-party protocols [5]–[8].

In the last few decades, computers have been used in the training of engineering students [9]. The last few years have seen the Web as an integral part of distance learning in many engineering courses. In the field of engineering, the Web has been used for analysis, design, and simulation of both electrical and electronics circuits. Some of the simulation software packages have been integrated into curricula and have contributed greatly to the training of engineering students.

Some Web applications such as "computer based training" (CBT) and "computer assisted learning" (CAL) have been developed to take over part of the teaching-learning process [9]. Such Web-based approaches still depend on simulation software packages. Large numbers of research papers has been published on CAL, and the effectiveness of such a learning method has been intensely debated: "no significant difference" versus "noticeable increase in performance." The real challenge is to provide innovative new ways of using the Web.

At the Electrical and Computer Engineering Department of Western Michigan University, a new Web-based hands-on real-time remote wiring and measurement laboratory instrument has been developed [10]. Students are physically able to wire up electrical and electronics circuits at the host laboratory site using

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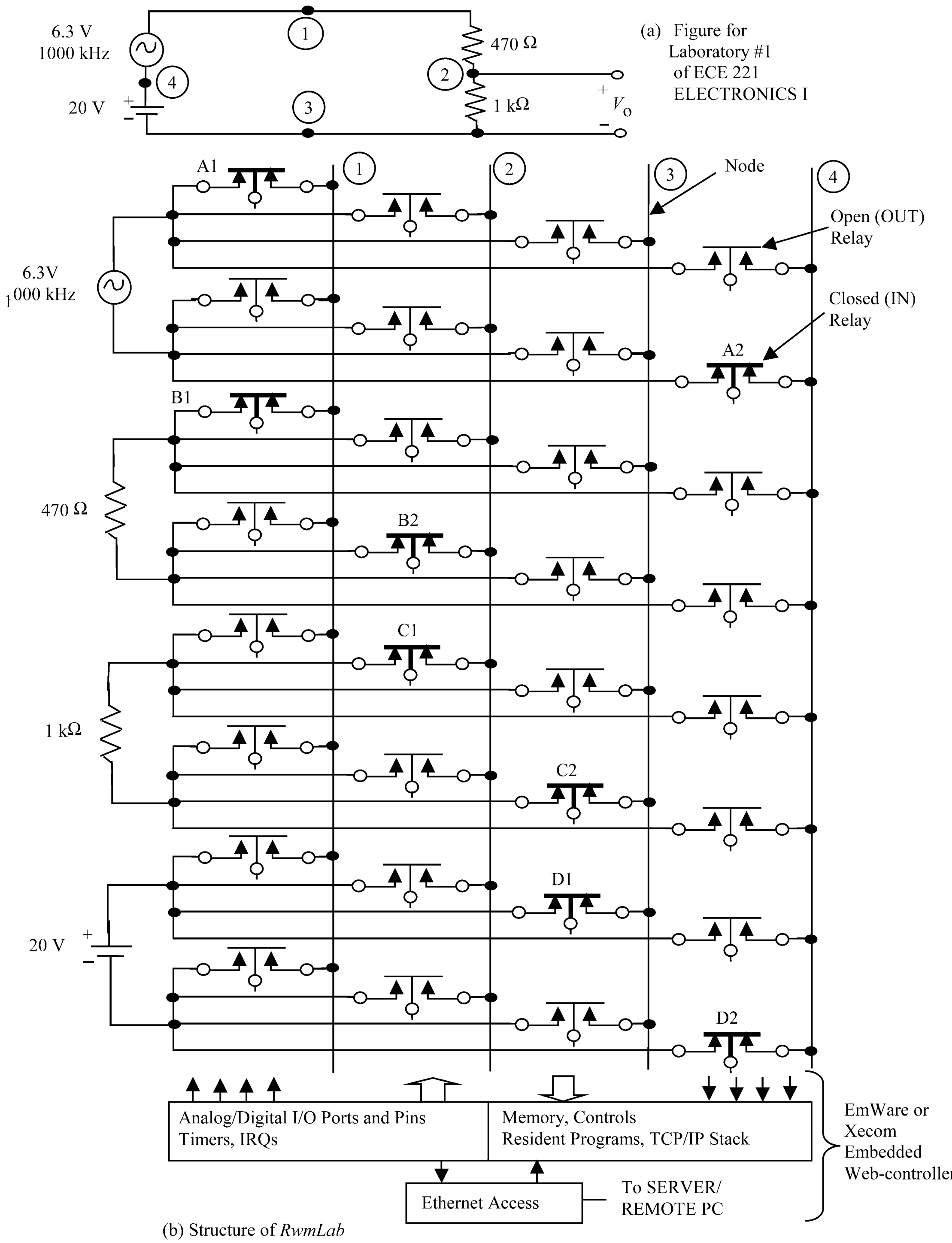

Fig. 3. Features of the *RwmLAB*.

Internet access and by means of a conventional circuit board. *RwmLAB* also allows students to remotely connect instruments and also change their settings. The data acquisition interface allows students to make measurements at the nodes. The data and waveforms collected at the nodes are made available on the Web. The *RwmLAB* interface is greatly simplified by using a graphical interface to allow the students to experience the frustrations and hands-on experiences of a real-world laboratory environment. In this paper, the design and construction of *RwmLAB* as a laboratory instrument is discussed.

II. Web-Based-Hardware-Software Hybrid Laboratory

A. Importance of Hardware-Software Laboratory

In most applied engineering courses such as in electrical and electronics circuit theory, diverse topics are covered in rapid succession. It is important that students grasp these concepts quickly. It has been documented by Mohan *et al* [11], [12] (projects sponsored by NSF) that it is a dangerous trend for universities to move away from hardware-based laboratories. Even though software simulations such as PSPICE (or other

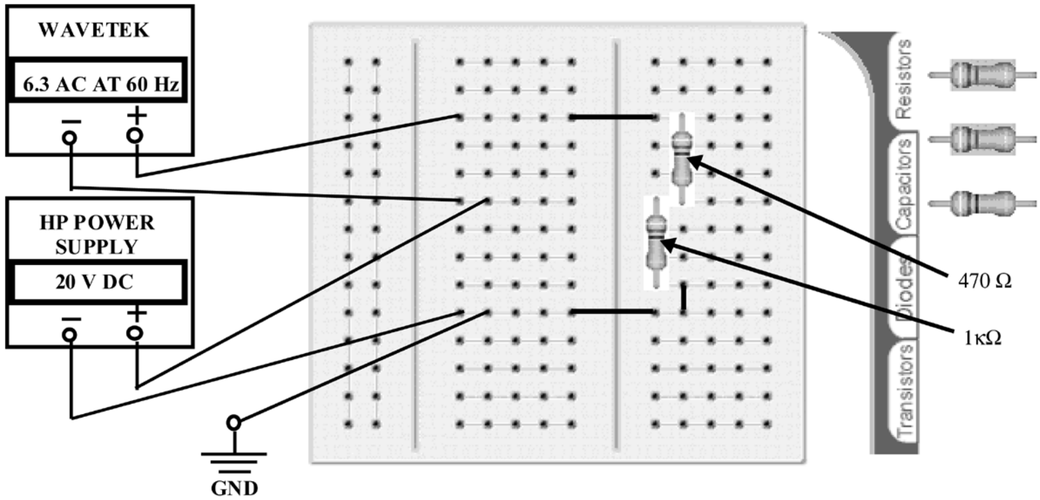

Fig. 4. "Virtual breadboard" with wired circuit of Fig. 3.

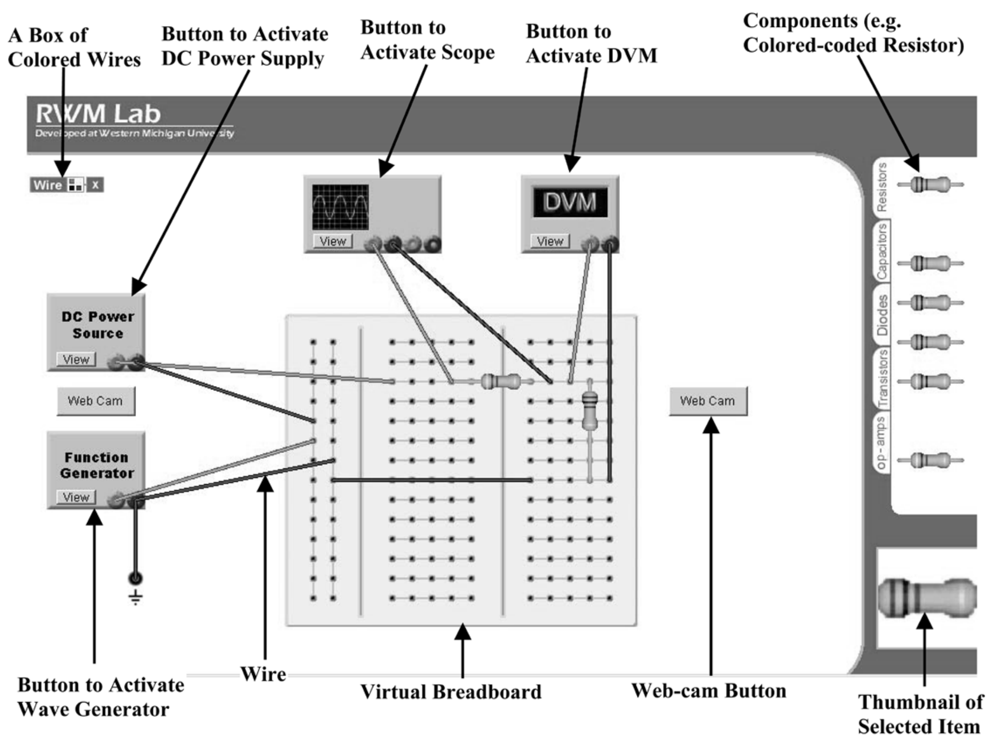

Fig. 5. Web capture of a wired circuit.

software tools) exercises are certainly helpful, Mohan *et al.* have shown that this is inadequate for students to comprehend these difficult concepts. Students become bored with simulations; such an approach fails to excite students. Furthermore, such simulations do not prepare them for "real-world" hands-on experience to design, build, test, or use real hardware.

B. Web-Based Laboratory Instrument

A graphical interface ("virtual breadboard") on the Web serves as the medium for a student to interact with the real laboratory components and instruments. The Web interface has components (the virtual resistors and virtual capacitors have values on them, and virtual transistors and diodes have type stamps on them), Web cam buttons, a box containing colored wires, and instruments that appear as buttons. The "virtual breadboard" allows a student to physically wire remotely an electrical/electronics circuit in the laboratory over the Internet. Real data and waveforms can be obtained instantly. This approach gives student a real-time hands-on experience in graphical mode. This is another tool to allow students to probe further what they are learning in lectures and in the laboratory. It is flexible, allows for spontaneous delivery of real data for learning and for laboratory verification, and it is another tool to enhance learning.

Some institutions do not have electrical and electronics laboratories. This Web-based hardware/software hybrid instrument can be an invaluable tool to these institutions because the instrument is globally accessible to a worldwide audience.

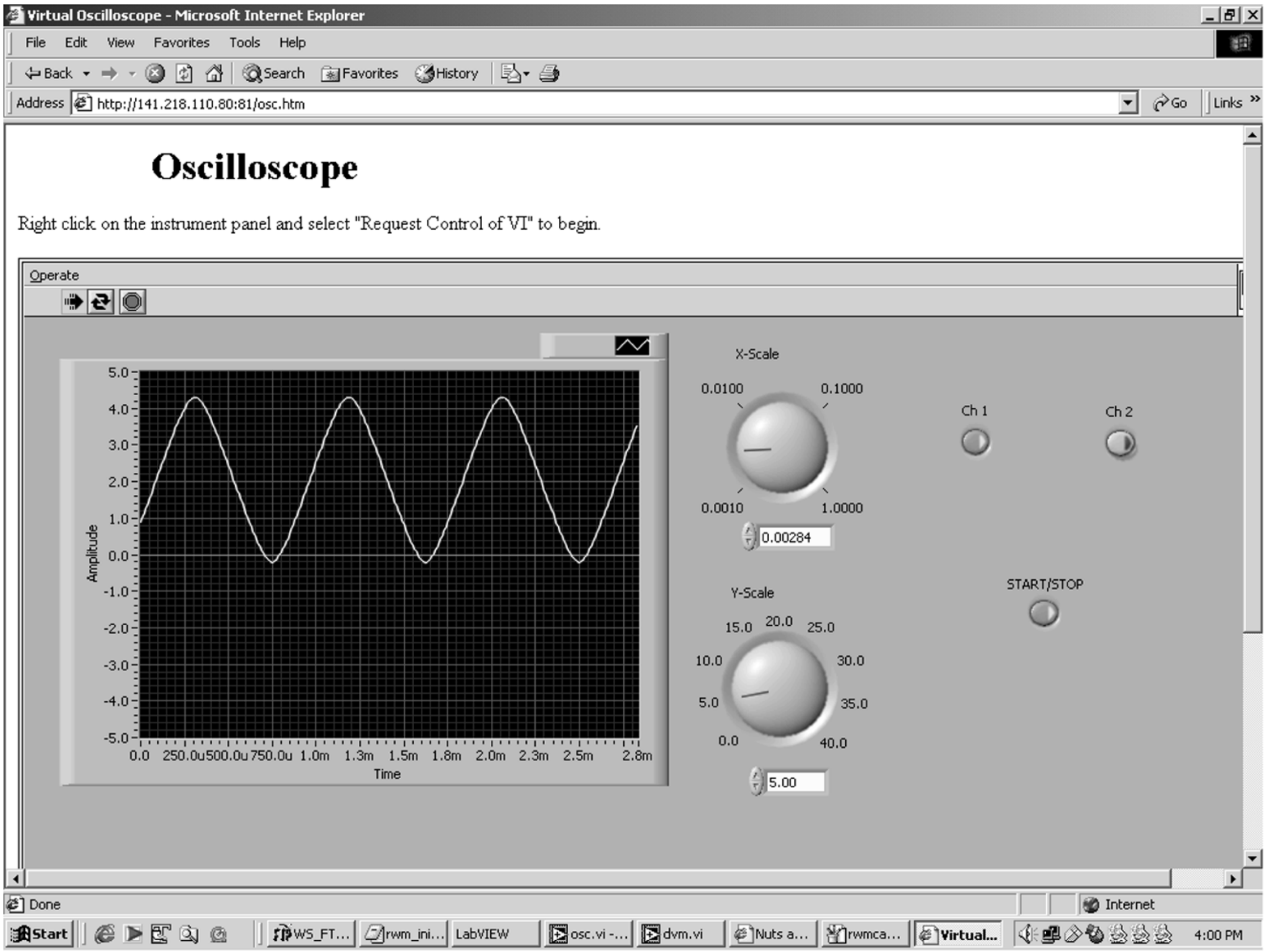

Fig. 6. Web capture of GPIB of scope control buttons and waveform.

III. Proposed Approach and Instrument

The *RwmLAB* consists of a matrix switching board (*Xecom's* [13] AWC86A) as the main controller with a Web-based server and a complex programmable logic device (CPLD). At the front-end of the AWC86A is a Web server and at the back-end is an AMD 40-MHz AM186ES-based microcontroller with SRAM and Flash memory. The AWC86A Web server incorporates a multitasking operating system and TCP/IP stacks with 10Base-T Ethernet access. The controller portion allows the setting and resetting of up to 16 dedicated transistor-transistor logic (TTL) signals that are connected to relays. A pictorial representation of the various components of the switching matrix board is shown in Fig. 1.

A switching matrix board is wired using standard electronic relay latch components and laid on a standard breadboard. Fig. 2 illustrates the 8×8 matrix used showing how components and instruments are connected. The matrix board is defined by rows in the x–y plane and columns on the z-axis. The format for defining the exact position of an instrument/component on the matrix board is shown in the equation at the bottom of the page The "!" represents the beginning of a comment line, the name of an instrument, or the name of a component. The "$Instrument/ComponentValue$" is used to either describe an instrument or the value of component. The "$Left\_Terminal$," "$Middle\_Terminal$," and "$Right\_Terminal$" define the x-, y-, and z-coordinates, respectively, of an instrument or component on the matrix board. Fig. 2 illustrates how components and instruments are connected.

Fig. 3 is an example showing the features of a portion of the matrix board. The CPLD is used to control the switching pattern of the relays. The setting and resetting of the matrix board relays are accomplished by the 16 dedicated TTL signals of the AWC86A controller through the CPLD. An Internet enabled embedded system software is to create a breadboard that appears like a standard "virtual breadboard" similar to those typically used in undergraduate electrical and electronics laborato-

$$! \mid Instrument/Component\,Value \mid Left\_Terminal \mid Middle\_Terminal \mid Right\_Terminal.$$

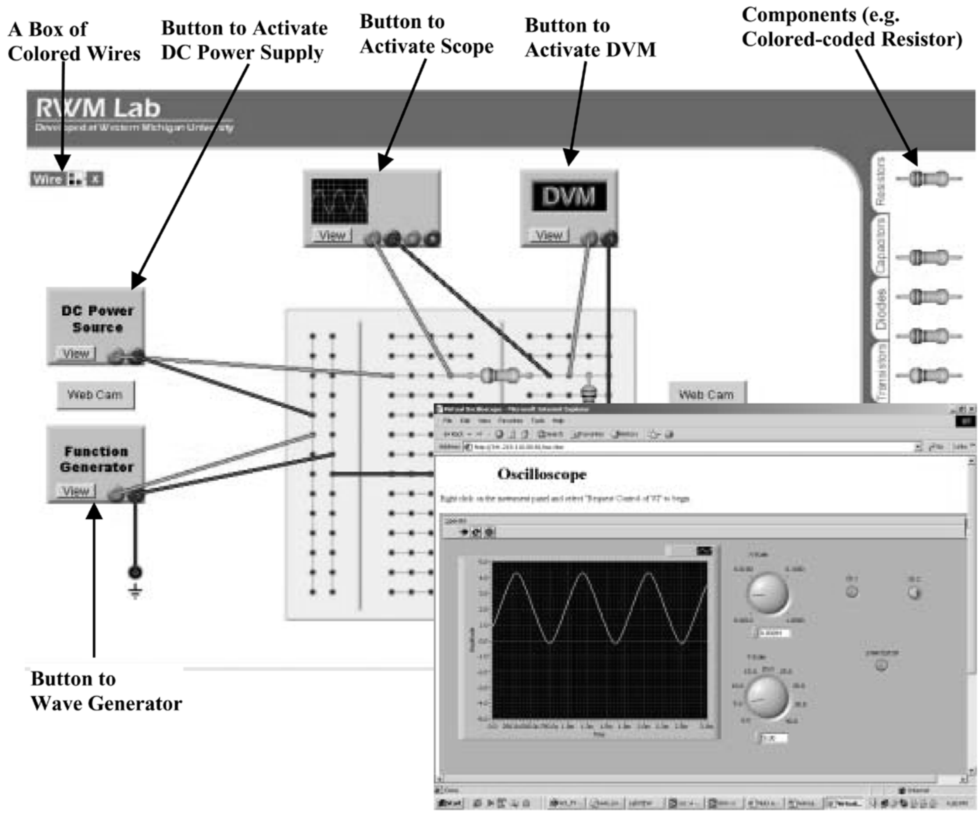

Fig. 7. Web capture of wired circuit and GPIB of scope control buttons and waveform.

ries. A pictorial representation of the various components available for the laboratory is also presented on the side of the screen. The instruments are represented by buttons. In some components, color-coded bands are displayed to indicate the appropriate values of the component. For example, resistors look like the actual color-coded resistors. For other components, a tool tip is used to display the appropriate value or perhaps display a data-sheet.

Fig. 4 shows a typical Web-based "virtual breadboard" with the wired circuit of Fig. 3. The user is able to drag any components around the virtual breadboard as desired to accomplish the necessary wiring. When the user completes the circuit and presses any of the instruments' buttons, the software analyzes the circuit to determine which hardware leads are connected together. These connections represent nodes. The software first sends a reset signal to clear all the physical relays. The software then sends a digital code associated with each lead/node combination sequentially through the hardware. The software running on this website sends a clear signal, and then sequentially sends the digital code associated with each lead/node combination through the dedicated TTL signals using a common gate interface (CGI) protocol. These signals are decoded by a CPLD and routed to appropriate relay latches. The latches in turn drive electronic LED-based relays. When a relay is set, it physically connects a leg of the component to a node. Any other components connected to that node are then also physically in the circuit.

All the software is done in HTML, JavaScript, Java, and in C language for the CGI interface. The HTML, JavaScript, and the Java reside on the Web server of the AWC86A, and the C language resides in the controller portion of the AWC86A. The AWC86A fully integrates the Web sever and the microcontroller.

IV. Results: Interactivity

The Web-based software, written in HTML, JavaScript, and Java, integrates the virtual breadboard, components, scope, digital voltmeter, power supplies, and waveform generator. Fig. 5 shows a Web capture of the circuit in Fig. 3. The power supply is represented by the "*DC*" button image and the waveform generator is by the "*AC*" button image. The circuit of Fig. 3 is wired on the virtual breadboard just like any student will do in a normal laboratory. The resistors also are color-coded. The power supply and the waveform generator are also connected in a similar fashion. If an instrument is double clicked, it will open as a separate window on the Web. This will allow the student to physically change the settings in real-time in the laboratory: All the equipment settings can be changed because they all use general purpose interface bus (GPIB) interface protocol. The student will also see simultaneous changes on the Web window. In addition to this, A Web cam can also be activated in the laboratory to open another Web window showing live the equipment and its reading changes. Fig. 6 is the scope display window that shows the waveform across the 470-Ω resistor. Fig. 7 combines windows for the circuit on the wired virtual breadboard and the scope display. At the present time the Web-based laboratory can be used for experiments with the following components: resistors, diodes, and transistors. The following equipment can also be used: digital multimeter, oscilloscope, power supplies, and

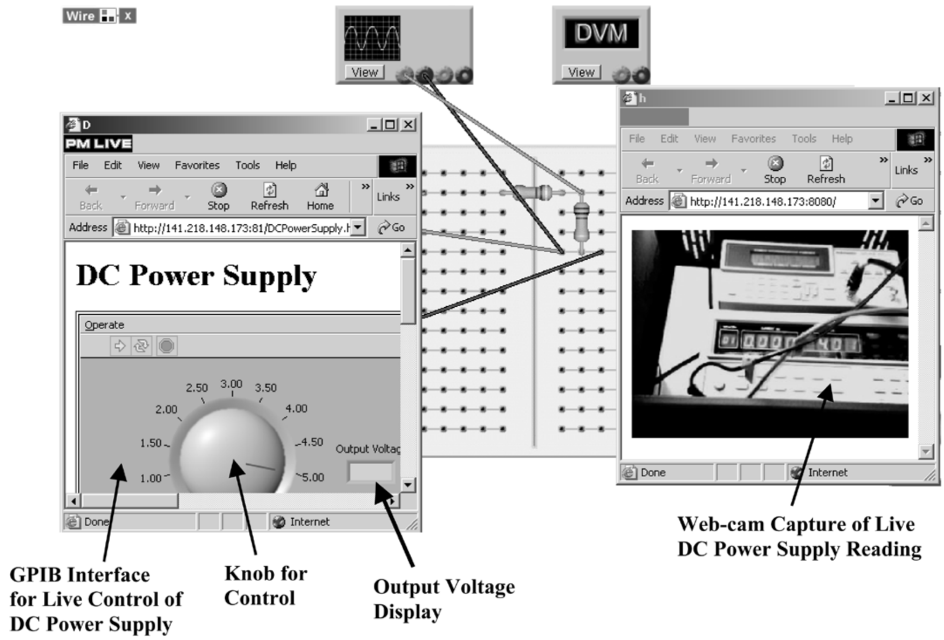

Fig. 8. GPIB controls and display, and live web cam capture of dc power supply instrument.

a waveform generator (sine, triangular, and rectangular waveforms with adjustable duty ratio).

A. Real-Time Physical Control of Real Instruments

All the instruments used in *RwmLAB* have a GPIB interface, and each instrument is fitted with a Web cam. The GPIB interface allows each instrument to be controlled from the Web and also shows the real-time reading of the instrument. There are four instruments: a digital multimeter, a digital oscilloscope, digital power supplies, and a digital waveform generator. Each instrument has its own IP address and with a Web update cycle of 8 s for all four instruments (including the Web cams) in the sequence: multimeter, 0–first second; oscilloscope, second–third second; power supplies, fourth–fifth; and waveform generator, sixth–seventh second. In this way, there is no interference of the updates of all four instruments if they are requested at the same time. An instrument reading and its Web cam are synchronously updated within 2 s. When an instrument is requested, a window pops up showing the GPIB controls for the instrument and the reading of the instrument (see Fig. 8). The reading of the instrument can be changed by the controls on the Web. A Web cam, when activated, will simultaneously show live the changes in the reading (or waveform) of the instrument. An instrument or a Web cam must be requested by clicking on it in the Web window. Although the *RwmLAB*, itself, cannot be configured by the students from the Web because of safety issues at the host laboratory, the student has the ability to configure component connections within the *RwmLab*. When an instrument or a Web cam button on the Web is clicked, a CGI-packet is sent to the host laboratory to reset all instruments, and to receive and assemble the Web wired circuit.

Clearly, the above mentioned Web-based hands-on real-time laboratory instrument has a lot of advantages over many previously Web-based laboratories. It provides interactivity through a Web browser window. Students may work from anywhere in the world as long as they have access to the Internet and a Web browser, and it provides similar frustrations as in a real-world laboratory environment. This approach forces the students to think before interacting with the system because an electrical or an electronics circuit must be wired correctly in order to obtain any useful results. This increases the chances of the learner going from "*surface learning to deep learning*" [9]. This in turn ensures long-term retention and absorption of the laboratory material.

V. Conclusion

The present instrument adapts existing, proven, and workable technologies to implement an electrical and electronics and power electronics laboratory instrument. The system works, and here, the intention is to use existing technologies to enhance active learning using the Internet. An added advantage is that the web now becomes a medium for active teaching and learning. The experience gained in developing this Web-based module has confirmed that a real stream of data can be obtained over that Internet without having to use simulated data.

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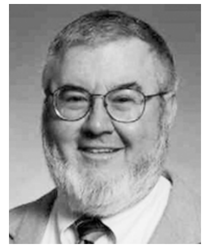

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Jon Fitzmaurice, photograph and biography not provided at the time of publication.

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