A World Wide Web Based Architecture for the Implementation of a Virtual Laboratory

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Abstract

The World Wide Web (WWW) has given to the universities the opportunity to create a virtual laboratory based in remote controlled instrumentation.

The solution proposed in this paper allows remote access to equipment, in such a way that hardly differentiates from using the same equipment when accomplishing real device measurements at laboratory.

An improved architecture simplifies the implementation of a Virtual Laboratory and it allows a more versatile and efficient environment aimed to reach distance learning.

1. Introduction

The omnipresence of Internet and the World Wide Web tools have made possible a global solution for distance learning. Web based tutorials for theoretical courses are widely used. An ideal learning environment must also provide a practical support. The need of an experimental laboratory, aimed to understand the concepts involved in electronic engineering, is evident in higher education. It is possible to devise a learning environment with a tightly coupled set of interactive tools that can serve today's students requirements in a effective way that combines theoretical an experimental aspects.

The simulation tools may be used as an accessory of a theoretical course. This kind of tools, although interesting, usually does not reach the same benefits than real equipment experimentation. On the other hand, a laboratory whose instrumentation is remotely accessible could be reachable. Web tools give the possibility to students of accessing measurement instrumentation by means of a visual environment. Obviously, this second approach seems to be the best method for carrying out an effective learning of electronic instrumentation. This meant experimenting on real equipment, is the best way to find out its operating mode.

The idea of using measurement instrumentation through Internet already has been successfully used [1] [2]. A remote laboratory should resolve an integrated environment for measuring on real devices at distance. The facility will allow students to access sophisticated electronic test and measurement equipment and allow them to carry out real measurements on them. Some remote laboratories and experiments that can be run remotely via a web interface are described in reference [3].

The solution proposed in this paper allows remote access to measuring equipment, in such a way that it hardly differentiates from in situ laboratory equipment operation. Therefore, this is a virtual laboratory, which allows the possibility of accomplishing real device measuring. All the developed applications are used directly via Web, so, they are easily accessed through a Web Browser (such as Netscape).

The outline of this paper is as follows: system architecture of the remote controlled instrumentation is presented in section 2. An improved architecture using a GPIB-LAN adapter is introduced in section 3. In section 4, the characteristics of our Virtual Laboratory

are introduced. Tutorial structure and content are discussed in Section 5. Finally, conclusions are summarized.

The present work is integrated in a context of collaboration with other European universities in the project RETWINE [4] (REmoTe Worldwide INstrumEnt).

2. The System Architecture

Our laboratory is equipped with instrumentation for semiconductor electrical characterization. Traditionally this equipment is used in situ and, because of physical space and number of available instruments, students access must be restricted. In the real instrument, the measuring set up is performed pushing buttons on their control panel and the measurement results are displayed on the instrument display.

Currently, we focus on developing a general methodology to control GPIB-Based instruments through Internet.

The different parts integrating the whole remote measurement system are:
- The measurement instruments with GPIB (General-Purpose Interface Bus) interface.
- A Personal Computer (PC) or Workstation (WS) running a Web Server application.
- A PC serving as the instrumentation controller (Instrumentation Server). It is equipped with a GPIB interface card and an Ethernet card.
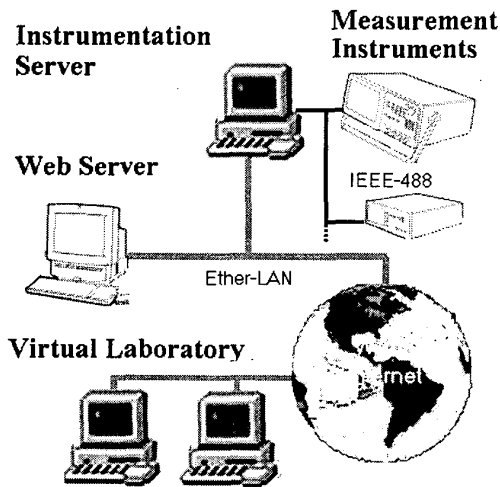

Figure 1 : Intrumentation Server Scheme

- The client computers, PC or WS, with Internet access.
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An schematic of this architecture is represented in Fig. 1.

Most of the measurement instruments used in test and characterization processes, in the domain of experimental physics an electronic engineering, support the SCPI (Standard Commands for Programmable Instruments) command structures defined in the standard IEEE-488.2 [5]. A maximum of 15 device loads can be connected to each bus to be remotely programmed from an external computer by using the GPIB interface. Several GPIB cards are commercially available for any kind of computer. In order to program the equipment from applications written in high level languages a set of libraries are also provided with the GPIB card.

The instrumentation server, in our case, is a PC serving as instrumentation controller, connected to a semiconductor parameter analyzer HP4145B and to a capacity meter HP4284A by means of a GPIB cable. In this typical GPIB configuration, a remote measurement process can be split in three steps. In the first one, the set up measuring conditions are programmed in the equipment, i.e. value of the voltage source, integration time period, number of measurements etc. In the second step the instrument receive a command of trigger to start the measure, and the values are stored in the same equipment. When all measurements have been done, the instrument sends a request of service to the instrumentation controller indicating that the measure process has finished. In the third step the measurement data are transferred from the equipment to the computer. The equipment programming is accomplished by means of commands sent through the GPIB interfaces. Based on the GPIB port number assigned to the instrument, the commands are transferred through the GPIB card and cable to the corresponding instrument, which interprets the commands ant takes appropriate actions, like set up initial condition, take a measurement, or send the measured data.

In addiction to control the instrumentation connected to the GPIB interface, the PC is equipped with an Ethernet card to be connected to the local area network (LAN). This connection provides the communication with the Internet world. This PC is running Microsoft Windows 98 and the application that really implements the instrumentation server is an C++ application developed to interface between the TCP

(Transfer Control Protocol) server and the library controlling the GPIB card. This application has a client-server structure with a particular port dedicated to their communication. The TCP server transmits information to or from the measurement instruments, coming from or directed to the user computer through de wide area network (WAN). The controller program has been developed in such a way that it is independent of the measurement instrument and also of the analysis or test nature to be performed. Their task is to keep on the data exchange between the LAN and the IEEE-488 interfaces. As the program executed in the controller is able to serve several users demands, directed to several measurement instruments, an appropriated name for the controller is instrumentation server.

The Web Server is implemented by using a PC running Red Hat [7] Linux 6.1 with the Apache HTTP (HyperText Transport Protocol) Server. The computer acting as Web server may cover various objectives. First of all, it provides web pages with information about the measurement system available from this server, and links to any other equipment included in the RETWINE network. Tutorials and technical descriptions of each instrument are also included. As a second task, this server has to verify the authenticity of the user. A password control is implemented to allow access to the measurement instrument. This server also implements a booking system to avoid the simultaneous access of several clients. Finally, it serves as a communication bridge for the information flow between the user and the measurement system. This communication, through the WAN, uses the resources offered by Internet. As in the case of the instrumentation server, the information flow, routing between the measurement instrument and the user, is independent of the instrument, this meant, generic for

any kind of characterization or test to be performed. The client/server software environment is shown in figure 2

Finally, in the user computer, it will be executed an application, supplied by the Web server, on an adequate client for the WWW as a browser is. That application has been developed in Java, in order to provide it a multiplatform characteristic.

3. An Improved Architecture

In the last years, Tektronix and other companies have announced a new GPIB-LAN adapter. This adapter features a GPIB interface, an Ethernet interface and a hardware implementing all the server functions performed by the instrumentation server. In this way, the instrumentation server can be eliminated from the architecture as shown in figure 3.
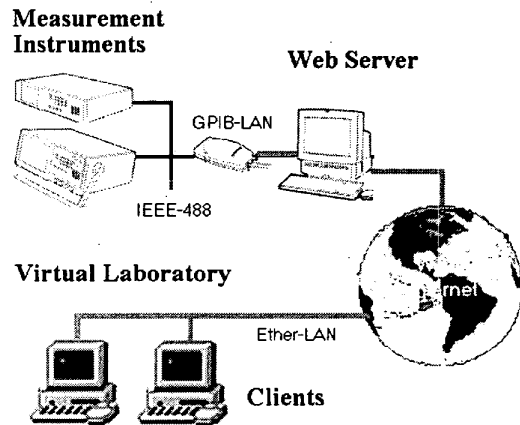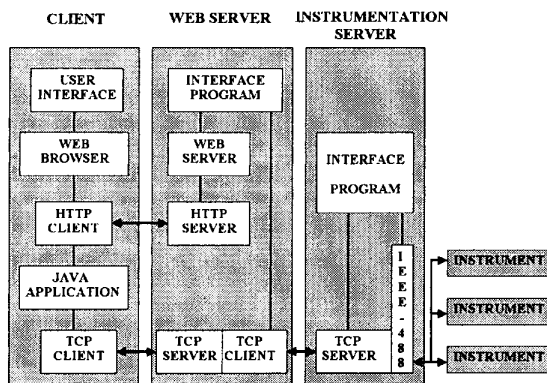

Figure 3 : Improved server architecture scheme

The advantage of this GPIB-LAN adapter is mainly economical, because the price is lower that a computer with a GPIB card. The adapter supports VXI-11 specifications defining a network instrument protocol based on RPC (Remote Procedure Call). Although libraries from C++ on Windows are available, in our case a set of Java classes has been developed in order to communicate the adapter with the Web server using the RPC protocol. Several procedures have been defined for the GPIB-LAN server performing all the steps needed to implement the measurement process. With this architecture the web server maintains the booking and authentication functions and it has also to

Figure 2. The client-server software environment

build the RPC packets according with the data flow sent by the client. This new software environment is represented schematically in figure 4
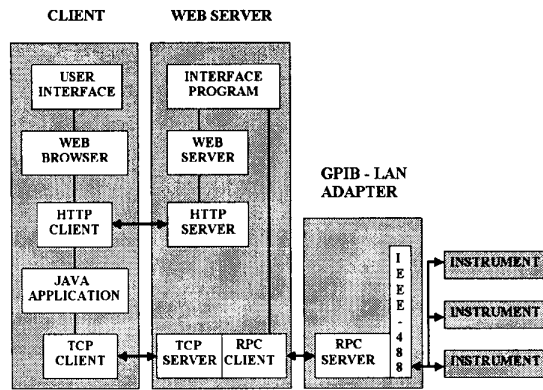

Figure 4. A new client-server software environment

4. Virtual laboratory

Our laboratory has incorporated to the Virtual instrumentation Laboratory a semiconductor parameter analyzer HP4145B and, recently, a LCR capacity meter HP4284A. For both instruments, our Web sever has pages providing a connection point with the remote measuring system.

The application executed from the browser contains the graphic interface, or virtual instrument, by mean of which the user performs the set of remote measurements. The interface consists in a graphic reproducing the front panel of the measure instrument. This panel usually contains buttons for the measurement setup. Pushing the buttons with the mouse, the user generates in the instrument the same effect that pushing it in the front panel of the physical instrument. In order to obtain this objective, we make use of the instrument programming command set: commands are generated by the application, and send to the instrument through the Web server and the instrumentation server, successively. The Fig. 5 and Fig 6 show an example of virtual instrument: the HP 4145B and the HP 4284A.

Besides the virtual instrument driver, user can accede to a web page set in which the technical characteristics of the equipment are detailed, as well as help pages allowing the user to learn about the measurement instrument use. In the following section it is shown an

example of this tutorial. These pages are dedicated to show with examples the most usual test and measurements performed with equipment.

On the other hand, devices to be evaluated are not accessible to the user, because they are located near the real measuring instrument. For this reason, audio and video communication facilities, between the user and the person in charge in the laboratory, has been added. Audio tools like NetMeeting allows the user to indicate the kind of fixture to be done. Also, a video-conference application will allows the user to observe images form the experimental system arrangement.
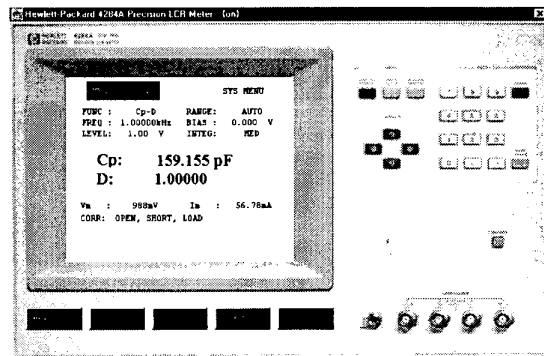

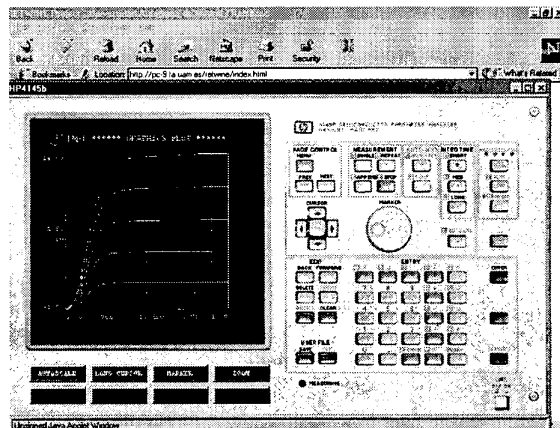**Figure 5: Virtual instrument (HP 4284A).**

Figure 6: Virtual instrument (HP 4145B) managed by the user from the browser.
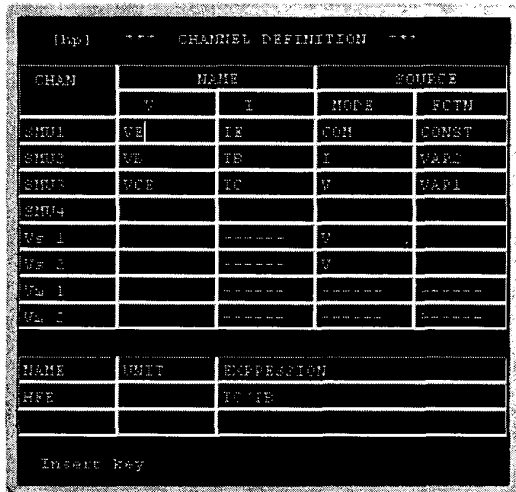
5. Basic Tutorial

In order to accomplish a practical experience, and to make easier the initial contact with the virtual instrumentation, a tutorial is available from the Web page http://www.ii.uam.es/retwine. In this way the first steps for the managing of the equipment, can be done.

The goal of this tutorial is to obtain the output characteristics of a NPN transistor, using the semiconductor parameter analyzer HP 4145B. It is assumed that the transistor is connected properly. Students should configure the measuring equipment following the steps indicated in the tutorial. A screen shows in each step the parameters to be introduced by the user. An example is shown in figure 7.

When all the steps have been completed, pushing the measure button, the measuring process starts. The data obtained in the remote instrument are collected and visualized in the selected format. For example, a plot of collector current IC versus collector to emitter voltage drop, VCE, with base current IB, as parameter will be displayed as can be seen in figure 8 This appearance is the same that could be observed by an user on the real instrument screen.

In order to know the effectiveness of the work performed, several students from the Universities involved in the project were invited to participate in a test session. For this test session we have developed a

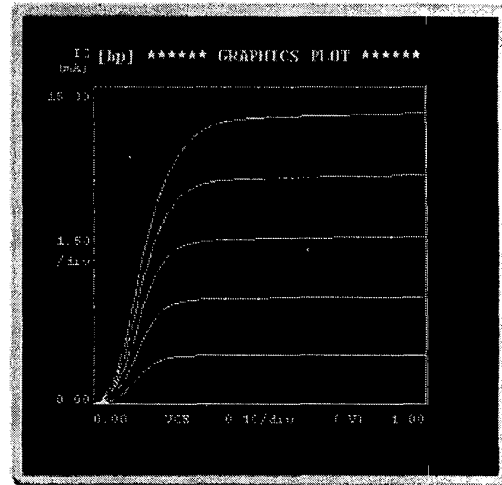**Figure 7: Parameter configuration screen**

Figure 8: A plot of the measured data in the screen of the virtual instrument.

feedback form. The students have indicated their opinion about the use of instrument (graphic user interface, intuitive approach, easy to use) an also about the tutorial, technical documentation and help pages.
The results showed the existence or minor technical problems that were solved. In general, we have obtained a very positive feedback from the students, especially the use of a tutorial like a tool for a quick learning of the instrument use was.

6. Conclusion

The electronic instrumentation shared through the Internet is the complement ideal for a Web based course. The remote access to instrumentation allows different users sharing an equipment from anywhere in the world.

The shared electronic instrumentation by means of the access in remote through the network has the following advantages:
- The remote learning of students without time restrictions or distance limitations.
- The use of expensive material to which students would not have access in a traditional laboratory.
- Sharing equipment between different university laboratories.

Finally, to emphasize the scalability of the system, being possible to add instrumentation in accordance with the necessities. It must be noted that this project, directed to educational institutions, may be extended to the electronics and telecommunications fields, where small or even medium industries can not assume the high costs derived from the acquisition and maintenance of this kind of instrumentation.

7. Acknowledgments

8. References

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