Session 2426

A Robust and Scalable Distance Laboratory Platform

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Abstract

To bring greater attention to the areas of science, engineering and technology, the University of Hartford has merged its colleges of engineering and technology to form the College of Engineering, Technology, and Architecture (CETA). It has also launched the construction of a new building to house the integrated science, engineering and technology programs (ISET). We are actively pursuing initiatives that create a greater level of synergy between the programs and strengthen the college and deliver better-qualified graduates to the workforce.

In response, the authors designed and have begun implementation of an automated laboratory test environment (ALTE). Users of ALTE can develop and remotely execute a variety of laboratory experiments over the Internet. Execution of the experiment hardware is controlled by a lab station personal computer (PC) linked directly to the device under test (DUT). Users first login to a management server that provides authentication and ensures that time has been reserved. It then re-directs their browser to the appropriate lab station for the experiment they are about to run. The management server also stores experiment procedures needed by students to perform the lab.

Introduction

To improve and innovate the way we reach our constituencies in higher education, many institutions have turned to distance education. Distance Education has manifested itself in a variety of ways within the forum of higher education. As technology has improved, a wide variety of delivery methodologies and pedagogues have emerged to deliver course material to students outside of the classroom. In the field of engineering and technology, we have faced significant hurdles in delivering laboratory content via a distance format. Providing a "hands on" laboratory experience for a student who is not on campus has been an ongoing challenge.

At the University of Hartford, Engineering and Technology programs have enjoyed a trend of sustained growth. Both graduate and undergraduate programs have experienced increasing enrollments, and as a result, this has severely limited "open-lab" availability. "Open-lab" has traditionally been a time when students can access the laboratories to finish lab assignments, makeup missed work, and get addition experience with the laboratory instrumentation. Our philosophy in creating ALTE was not to replace existing onsite laboratory experiences, but rather to supplement onsite laboratories with of a system to provide 24x7 access to the same laboratory experiments via the Internet. It is the aim of our system to allow users to run experiments that would be nearly identical to the laboratories that they would experience in the classroom or onsite laboratory.

Much of the early work that used the Internet to remotely deliver experiments began in 1998 with Esche and Chassapis.[1] It was followed by a series of work reported in 2000 by both Esche and Gurocak.[2,3,4] Each year, a growing body of work has appeared that has further validated both the technological viability of distance laboratories, and their effectiveness in delivering a worthwhile laboratory experience.[5,6,7,8,9,10]

The quality of the architectures and designs has steadily improved including the latest presented at the 2003 ASEE National Conference.[11,12,13,14,15,16] There is ample evidence that this form of experimentation delivers a valuable learning experience for students. Our objective was to build on previous efforts and develop a robust and scalable platform suitable for widespread implementation within CETA. We believe that ALTE is such a platform.

ALTE consists of three elements: a web-based application/database system that manages online access and lab station resources, testing protocols that run on multiple lab station PCs, and hardware/instrumentation that transmit signals and collect data from DUTs. Multiple lab stations, each with a dedicated mix of measurement equipment interface with the DUTs. Lab stations can be equipped with different equipment bundles such as Agilent (i.e. DMM, function generator, oscilloscope), National Instruments' Educational Laboratory Virtual Instrumentation Suite (ELVIS) and custom data acquisition or serial/parallel port interfaces for programmable devices.[17,18] At each lab station, the device under test (DUT) is connected to a pre-developed LabVIEW virtual instrument panel (VIP) that is the user interface to perform the experiment.

The management server and its attendant database control user authentication, accept reservations for access to experiments, store experimental procedures, re-direct users to the appropriate lab station and keep statistics on the system. The management server is capable of supporting a large number of lab stations. It is at the lab stations where the actual measurement equipment and DUTs are located.

Five parameters are automatically collected by the system to gage the extent of usage. All metrics are linked directly to the quantity of students who benefit from using it and include the number of:

- Laboratory experiments that run on the system.
- Courses that use ALTE experiments.
- Technology and engineering programs that use ALTE.
- Students who perform ALTE experiments
- Hours students spend on ALTE conducting experiments

The measurement process is automated using the server as the collection platform. ALTE tracks access by program, by course, by student and timestamps sessions. This ensures that data is consistently collected, and also yields more in depth statistics on the patterns of usage such as time of day, session length and levels of interactivity. Figure 1 shows a high-level view of ALTE's architecture including three different equipment bundles, lab stations and the management server. Figure 1 shows a high-level view of the architecture including three different equipment bundles, multiple lab stations and the management server.

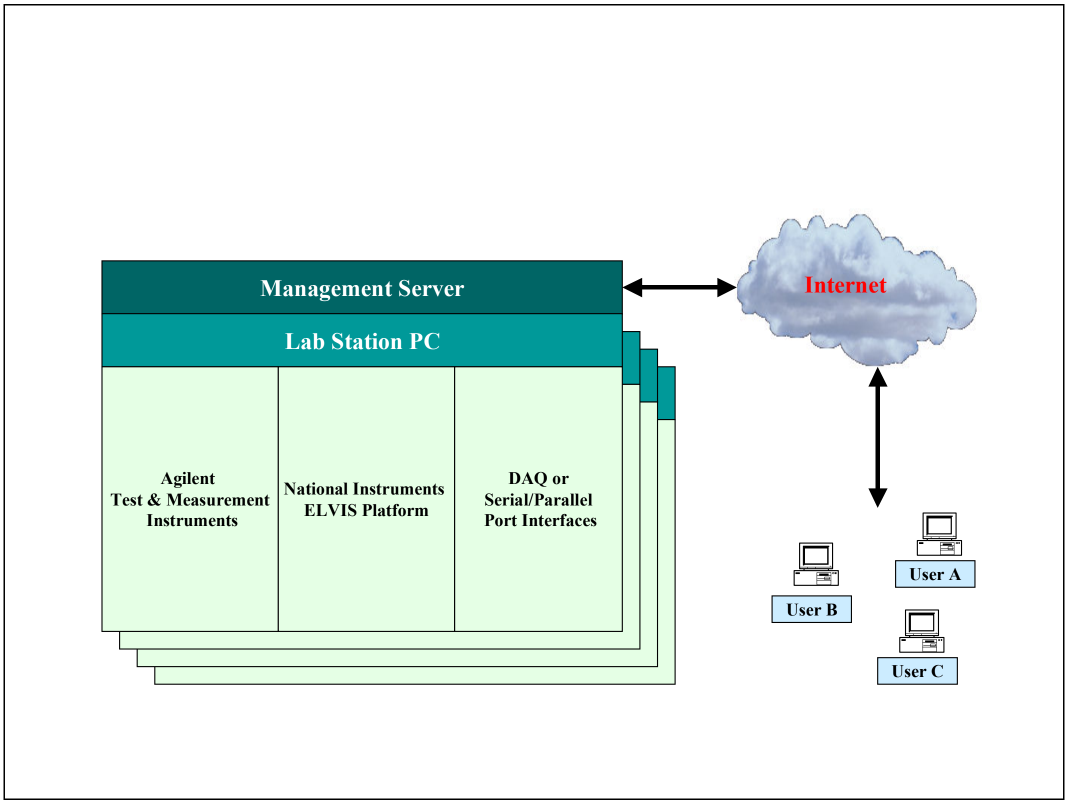

Figure 1 – High-level view of ALTE architecture.

The Management Server

The ALTE management server sits atop the system architecture. It provides login control, reservation processing and access to experimental procedures. The data store is provided by a MySQL database running on the same machine. The management server is capable of interfacing with multiple lab stations. When an experiment is launched, the management server re-directs the user to the appropriate lab station and the virtual instrument file needed for that experiment. ALTE is accessible by any authorized user over the Internet by navigating to its home page at http://alte.hartford.edu.

The operating system on the management server is MS Windows 2000 running IIS 5.0. A MySQL 4.1.1 database (with MyODBC Connector 3.51.06) is loaded on the management server. The web pages are written in ASP with Visual Basic Scripting (VBS) for "behind the page" processing. The VBS code was written so it could easily be converted to a Microsoft .NET framework in the future.

The ALTE website consists of two areas: public and private. All public pages are accessible to any visitor from the home page. A screen shot of the home page is shown in Figure 2. Some examples of public pages are ALTE Benefits, FAQs, Help and Site Index. Public pages are designed to be informational only, and visitors to these pages cannot perform any lab experiments.

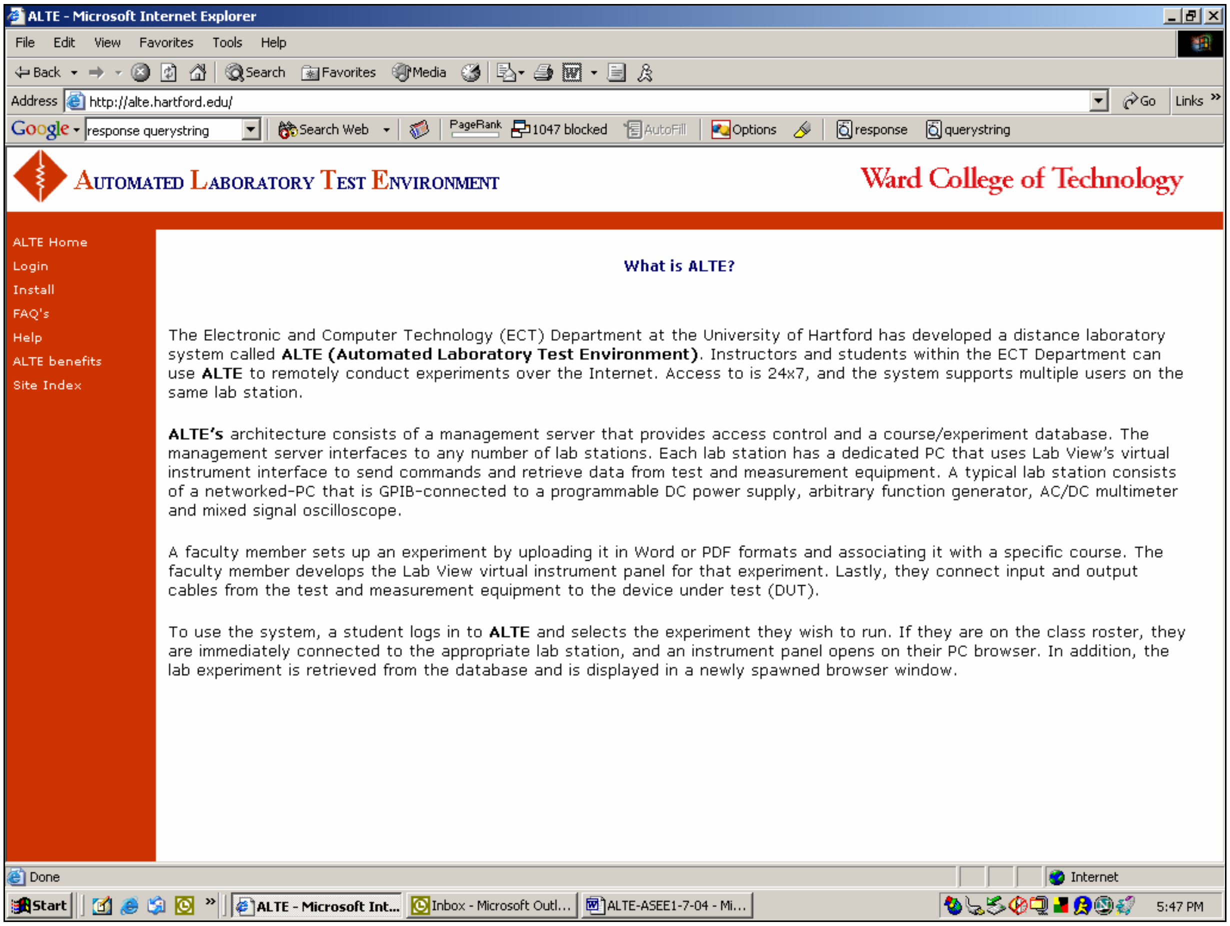

Figure 2 - Screen view of the ALTE home page.

The bulk of the management server's web pages are located on the private or member side. These pages are exclusive to authorized users (e.g. students, instructors, guests) and are reachable only with a valid username and password. ALTE recognizes four classes of users: Administrator, Instructor, Student and Guest. Once a user successfully logs in, they are directed to the services page appropriate for their role class.

An instructor self-manages his/her account profile, courses, experiments and students. An account profile contains their first and last name, organization, contact information and current password. Courses can be created, edited and viewed by an instructor, and must be entered before an experiment can be added. Likewise, experiments can be created, edited and viewed by an instructor. Each experiment is uniquely associated with a course set up previously. Instructors are also afforded a student's view of the system so they can test drive their experiments.

Each instructor is required to maintain a roster of students who are allowed to access experiments for their courses. In the future, we intend to integrate ALTE with either the University's Banner or Blackboard system. When complete, student rosters can be automatically synchronized anytime an instructor chooses. This will enable instructors to focus exclusively on developing experiments.

Administrative access is limited to a select few who have overall responsibility for ALTE. The primary duties of the administrator are to create/delete instructor accounts and associate lab station names with network IP addresses. Administrators are afforded an instructor's and a student's view of the system so they can troubleshoot and resolve issues that may be reported to them. Administrators can also set up guest accounts. These are used to provide demonstration experiments for users other than students. Some examples of guests are: industry partners, K-12 users and sponsors/patrons of the college. Figure 3 shows a screen shot of the administrative services screen.

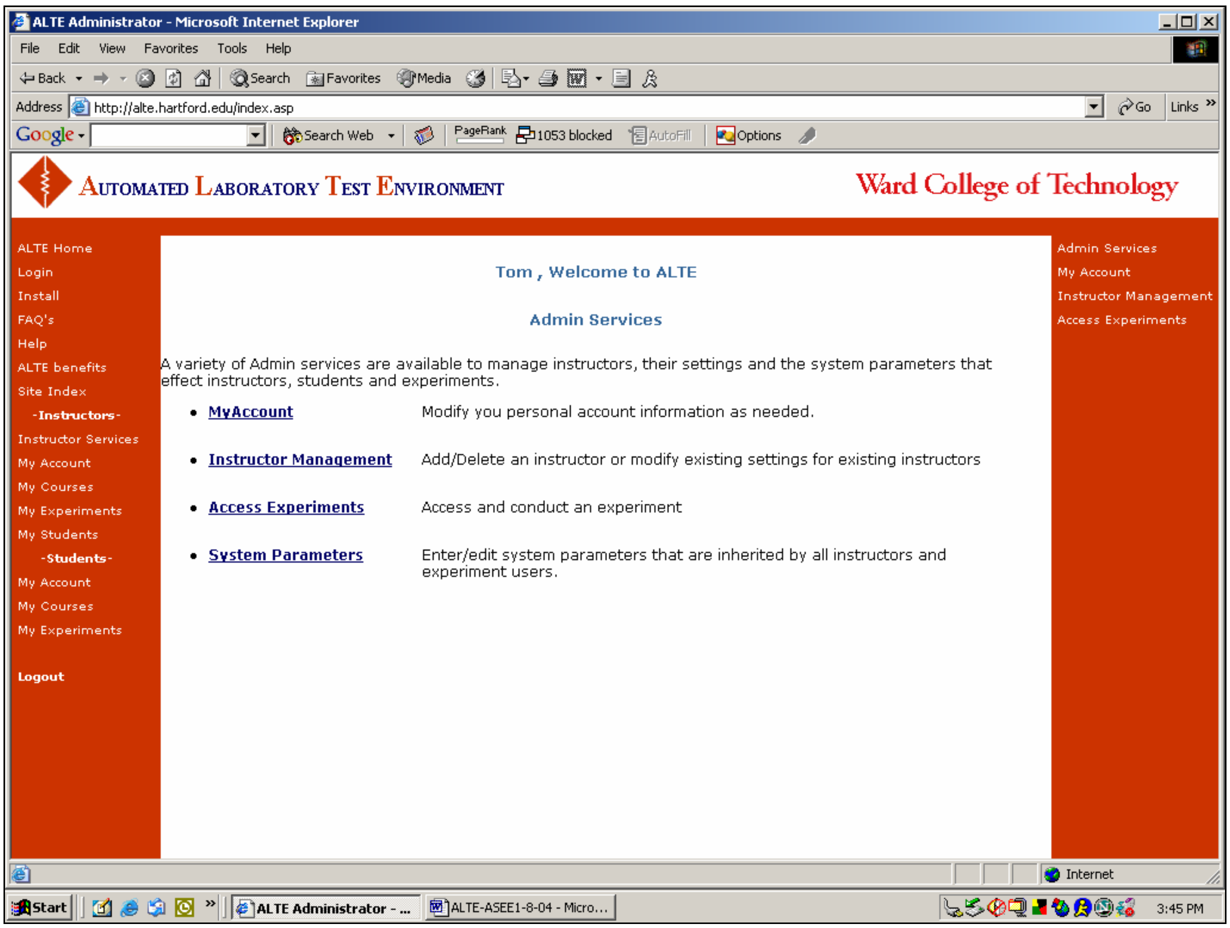

Figure 3 - Screen view of the admin services page.

The Lab Station

We chose LabVIEW by National Instruments for the measurement interface. When a user accesses an experiment, a new browser window is spawned and the lab procedure document is loaded. This document is similar to the handout for the current onsite experiment. At this time, there is little difference between the online and onsite procedures, but the two will likely diverge some as we go forward. Places where the student is required to take a measurement, observe a waveform, or control equipment must be clearly marked in the online procedure.

At the same time, a second browser window is spawned, and a pre-developed LabVIEW virtual instrument panel is opened. On this panel are all of the control settings and readouts the user needs to perform the experiment. The user now has three windows open on their desktop: the ALTE application screen, the online experiment procedure and the VIP. They can move back and forth as they work through the experiment.

The VIP is a graphic representation of the laboratory equipment being remotely controlled. Rather than using purely "software" instruments, we chose to use LabVIEW to access actual equipment and DUTs. The decision to use "live" equipments rather than virtual ones was a difficult one. We wanted to preserve as much of the laboratory experience as possible. Figure 4 shows a VIP screen for the Agilent 54622D mixed signal oscilloscope.

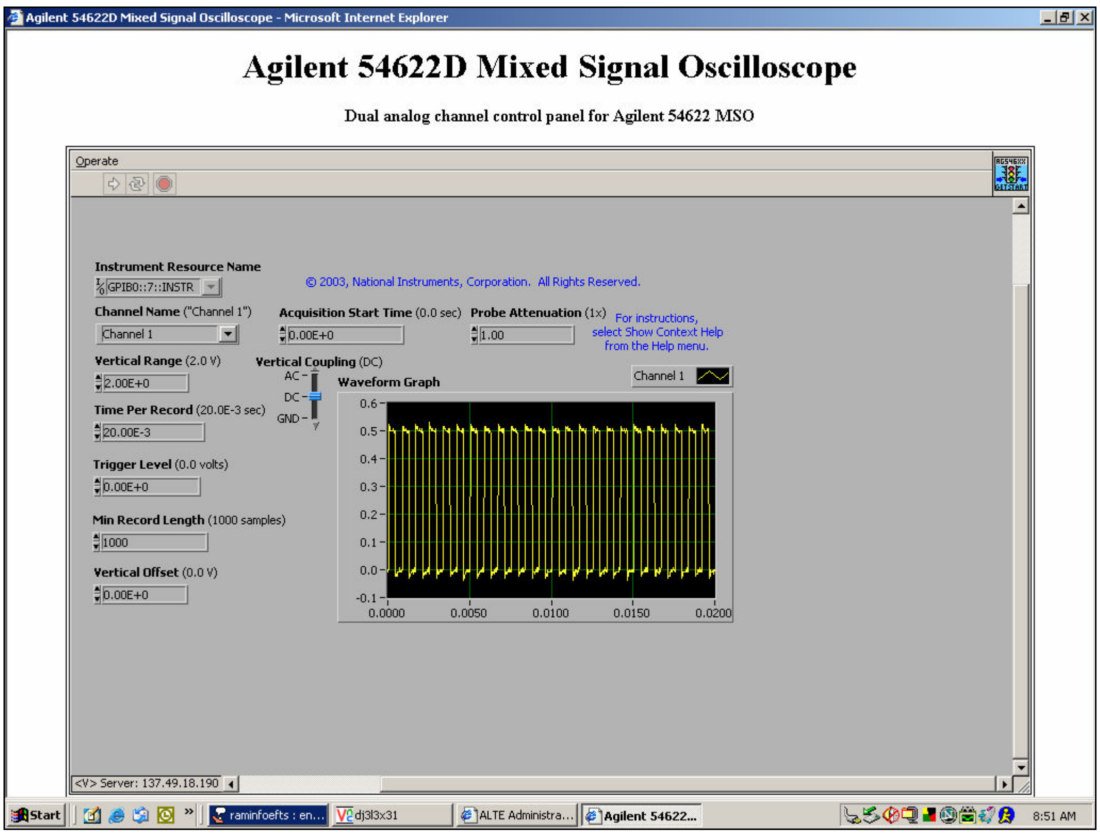

Figure 4 – Virtual instrument panel for an Agilent mixed signal oscilloscope.

Although we did not implement experiments that utilize purely virtual instruments, there is no limitation in the system that would prohibit this. As we expand our array of experiments, we expect to use a combination of both "live" and virtual instruments. It is often transparent to the user and in many cases may not affect the user's ability to accomplish the learning objectives.

The number of VIPs required to support a particular experiment varies. Some experiments require a single VIP, and student visits it during different parts of the experiment, changing test points or signal levels. Other experiments require multiple VIPs. Multiple VIPs are often used when students need to access different equipment during an experiment, e.g. changing input waveforms. Another example would be if a student had to observe an analog signal at one point and a digital signal in another.

VIP complexity can be managed by the instructor (or developer). In introductory courses where a students' experience level is limited, the VIP should allow limited access to equipment controls. For example, when observing a waveform on an oscilloscope, students may only need access to the time base, amplitude, and cursor controls. As they become more experienced, more of the measurement and control suite may be exposed.

Some of the frustration that students feel when they're unable to get equipment and breadboards to work properly can be eliminated. Using VIPs tailored to the skill level of the student (i.e. the number of knobs and buttons they can turn or push), the instructor has a simple way to manage the complexity of the experiment interface.

Test and Measurement Hardware

ALTE can accommodate a variety of test equipment and experiment configurations in the underlying lab stations. Figure 5 shows ALTE equipped with an Agilent lab station bundle including DMM, power supply, function generator and oscilloscope.

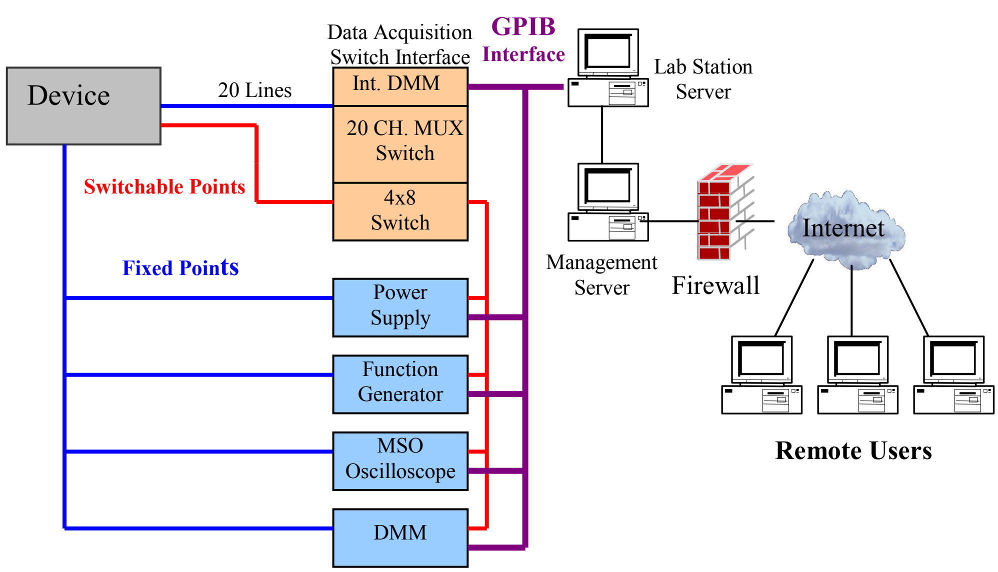

Figure 5 - ALTE test equipment bundle.

Simple experiments can be performed using only a DMM or National Instruments' ELVIS system. More complex experiments may require an arbitrary waveform generator, mixed signal oscilloscope with a multiplexed switching array. The standard suite of equipments we're currently using consists of an Agilent 54622D Mixed Signal Oscilloscope, Agilent 33120A Arbitrary Waveform Generator, Agilent E3631A Programmable Power Supply. We chose these instruments because they were GPIB addressable, mirrored our lab equipment and provided a high degree of functionality.

To access multiple test points on the DUT, we found the Agilent 34970A Data Acquisition Switch Unit/Controller very useful. It is a GPIB-controllable modular chassis with three slots that can be populated from eight available plug-ins. It also has a built-in 6.5 digit DMM. One plug-in we used was an Agilent 34904A 4x8 Channel Matrix Switch. In another instance, we used an Agilent 34901A 20-Channel Armature Multiplexer to dynamically access multiple test points on a DUT. It contains a four-by-eight, two-wire switch that can be re-configured dynamically by a VIP

The system is not limited to the test equipment described above. In the future, we plan to connect logic analyzers, spectrum analyzers and RF network analyzers to increase the variety of experiments available remotely.

Conclusions

The development of the first release of the ALTE platform is complete. It has been tested using several equipment bundles and performance has been excellent. We found the integration of the management server and the lab station to be a simple task, largely because of the built-in server inside LabVIEW 7.0. It contains a number of security and VIP control features that were useful.

Our current plans are to pilot test ALTE in Fall 2004 in two electronic courses. Two experiments in each course will be designated as “distance labs.” Students will be able to access these experiments 24x7 over a four-week period. Lab reports will be prepared using the same format at the onsite labs, and be graded using the same criteria. Afterwards, students will be asked to provide feedback on the distance labs by completing a survey. The results will be factored into our plans for the Spring 2005 semester and beyond. Over time, we expect that more courses and programs will begin to offer distance labs via the ALTE platform.

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Biographies

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