# The Development of Interactive Distance-Learning Laboratory for Teaching Digital Design in Electrical and Computer Engineering

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*Abstract* – **Distance education provides an avenue for students far from a university center to complete their degrees in a timely fashion. This paper describes a distance learning (DL) laboratory setting in which students at remote locations synchronously engage with an instructor and students at a university center and complete laboratory experiments in a digital design laboratory course offered by an ABET-accredited electrical and computer engineering program. The Polycom-based DL system supports two-way, real-time communication, which includes audio, video and lecture material, between multiple locations. The required DL equipment is described and the unique challenges faced by both students and faculty in this environment are discussed.**

*Index Terms* – Engineering distance education, Interactive distance learning studio

## INTRODUCTION

This paper is a reflection of our experience in developing, piloting, and delivering two interactive synchronous distance-learning (DL) labs at the University of West Florida (UWF). UWF offers ABET accredited programs in electrical engineering and computer engineering [1]. Numerous authors have investigated different distance learning environments [2-10]. UWF, with a student body of approximately 13,000, has its main campus location in Pensacola (PNS) but has a strong presence in areas to the east through its Emerald Coast branch campus locations. The largest of these branch campus areas is located in Fort Walton Beach (FWB) due in large part to the proximity of Eglin Air Force Base and associated contractor companies that require a highly skilled workforce. Many degree programs offer courses at UWF Emerald Coast locations (e.g., criminal justice, teacher education, hospitality management, computer science, etc.), but, due to a unique delivery method described in what follows, the engineering department offers a complete degree program, which includes all required laboratory courses.

Approximately eleven years ago and primarily due to the needs of the Air Force as well as supporting contractor companies, UWF began offering its electrical engineering and computer engineering program in Emerald Coast using a synchronous distance education model. At the outset, no faculty were located in FWB while at the present time, three full time engineering faculty out of the faculty body of eight are resident in Emerald Coast.

All lecture courses in the UWF engineering program are offered in an Interactive Distance Learning Studio (IDLS) and not in an increasingly common asynchronous, self-paced learning environment [11, 12, and 13]. The UWF [14] IDLS, which employs commercially available equipment from AMX [15], and Polycom [16], uses a dedicated Internet connection which reserves 3Mb/s for real-time audio and video and an additional 3Mb/s for data. In this setting, an instructor from either campus, with the help of facilitators at both locations, simultaneously delivers a lecture course to students in Pensacola and Emerald Coast. The real-time audio and video connection allows the faculty member to see, hear and interact with students at both ends with the same capability afforded to the students. Using a Tablet PC or a Wacom Cintiq 22HD, the data connection allows the instructor to present lecture notes via an electronic whiteboard or PowerPoint as well as to utilize engineering software through use of a commercially available projection system in both classrooms. The system also allows lecture audio and data to be recorded so that students can review lecture material at a later date.

While faculty lectures are presented to students in both locations, faculty at either end were responsible for teaching laboratory sections in their corresponding location in a traditional face-to-face setting. This required the acquisition of identical --and often costly-- laboratory resources at both locations and the necessity of offering two lab sections even if enrollment is low at either location. This exact situation presented itself many times especially in our upper level digital design lab which is required only for our computer engineering students. In addition, students taking the co-requisite labs of many classes don't have direct access in the lab to the professor on the "far" side who teaches the lecture portion of the class. This leaves the students talking the lab at the "far" side at a disadvantage. This situation sparked the idea of developing a distance-learning laboratory to alleviate these problems.

After securing funding though UWF's Instructional Technology Enhancement Projects (ITEP), the authors researched, acquired, and installed the necessary hardware and software to create an interactive distance-learning lab and piloted the offering of the digital design lab in such a setting. In this paper, we discuss the details of the lab setting and the challenges that students and faculty faced the first time this setting was utilized.

## DISTANCE LABORATORY SETTING

The authors established two interactive distance learning laboratories (one at Pensacola campus and the second at the Emerald Coast campus) that incorporate the latest in computer-aided design (CAD) software and allow students at one campus to interact with their professor and classmates at the "far" campus. The two interactive distance learning laboratories are hosted in the regular digital design labs at both ends and did not require extra lab space.

Like the distance learning classrooms we use to deliver lectures, the interactive distance learning laboratories are setup with video conferencing equipment that allows the students and professors on the "far" and "near" sides to interact in real time. In addition, the setup includes computers with the latest CAD software for designing and testing digital and electronic circuits. The computers are setup to allow remote access to the CAD software from any computer with an Internet connection. This, for example, will allow a student to connect to the host computer, design his/her circuit, simulate it, and discuss it with the professor without having to be physically in the lab.

The CAD/simulation software we decided to use is Multisim made by National Instruments, a pioneer company in circuit simulation and testing. In recent years there has been a shift towards a "bench-like" software that simulates in real-time the workplace of an electronic designer. Such software produces a computer-based model of circuits and uses virtual electronic instruments (function generators, oscilloscope, power supplies, voltmeters, etc.) to test these circuits. Multisim is considered by many to be the industry standard (Figure 1).
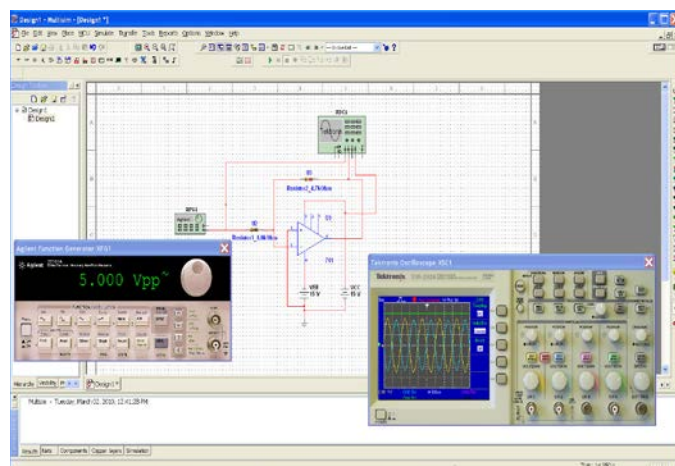


**Figure 1.** Screen capture of the Multisim software.

A detailed list of equipment for both labs is detailed in Table 1. As can be seen in Table 1, the total equipment coast including hardware and software was less than $58K (which includes a backup unit). Installation costs are not included since the authors installed the equipment themselves with the help of engineering students for whom this was a learning experience in hardware and software installation.

**Table 1.** Price list of acquired project items

| Item | Cost |
|---|---|
| HDX 9004 XLP Polycom with EagleEye Camera | $10,798 |
| HDX 9004 XLP Polycom | $3,500 |
| EagleEye Camera | $2,450 |
| Camera Mounting | $516 |
| HDX Ceiling Microphone Array | $1,718 |
| LG 55" HD TV with Wall Mount and Warranty | $11,574 |
| Bose Sound System/Amplifier | $1,594 |
| Cables, Wires, and Adapters | $2,429 |
| Wacom CINTIQ 21UX Interactive Pen Display | $9,996 |
| Ceiling Mount | $386 |
| Ploycom Touchscreen Control | $1,151 |
| Mobile TV Cart with Shelf | $788 |
| Dell Computer T7500 & OptiPlex 9010 | $4,617 |
| Misc Polycom Parts | $181 |
| Microsoft Surface RT Tablet | $988 |
| Microsoft Surface Pro Tablet | $1,422 |
| HD Projector | $3,558 |
| **Total** | **$57,666** |

Figure 2 shows the wiring diagram of all needed equipment in both labs. Each IDLS uses a Polycom HDX 9004 XLP system configured as shown in Figure 2 with two EagleEye HD cameras and two 55 inch HDTVs for students and instructor views. It uses a high fidelity Bose Sound System, one HDX ceiling microphone array to capture students' questions and one podium microphone for the instructor. The instructor's podium has a high-end computer connected to a Wacom CINTIQ 22HD Interactive Pen Display that can be used as a white board and/or to annotate lecture notes. The screen content is displayed on projectors at the two lab locations.

The equipment in the new labs is compatible with the different DLL settings at other UWF classrooms and has the capability to connect to multiple locations at once (the new system is capable of connecting up to 8 sites simultaneously). Figure 3, shows a screen capture of four simultaneous connections to four different locations. The left top corner shows an older version of Polycom 9001 system, the right top corner show the new Tandberg system, the bottom left corner shows a connection using a PC computer system using Telepresence m100 PC software from Polycom while the right bottom view is a Polycom 9004 system.

The new equipment also allows an instructor to teach his/her class/lab from his/her office or from anywhere in the world to multiple sites at the same time. Figure 4 and Figure 5, show one of the authors presenting lecture material to two different locations from his office's computer. The system can also be used as a multipoint videoconferencing system

for meetings/presentations and interaction between students and instructors.
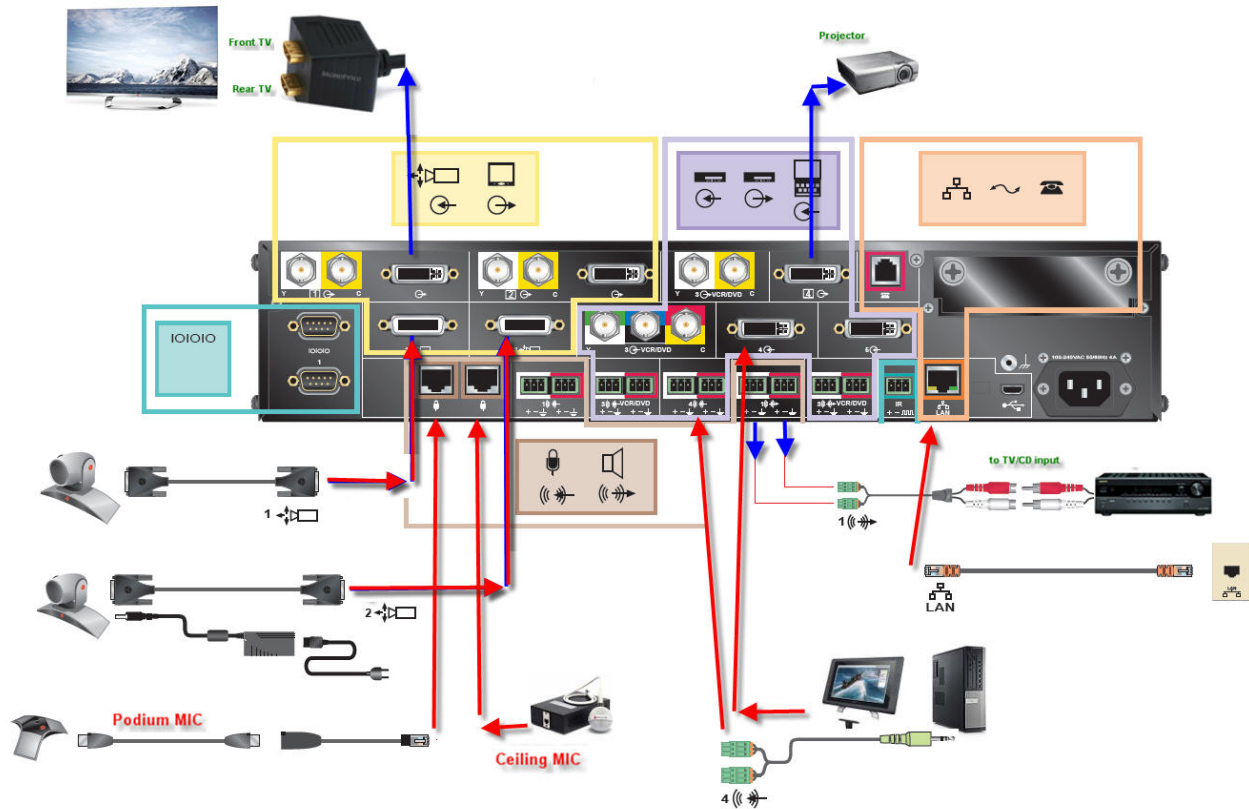


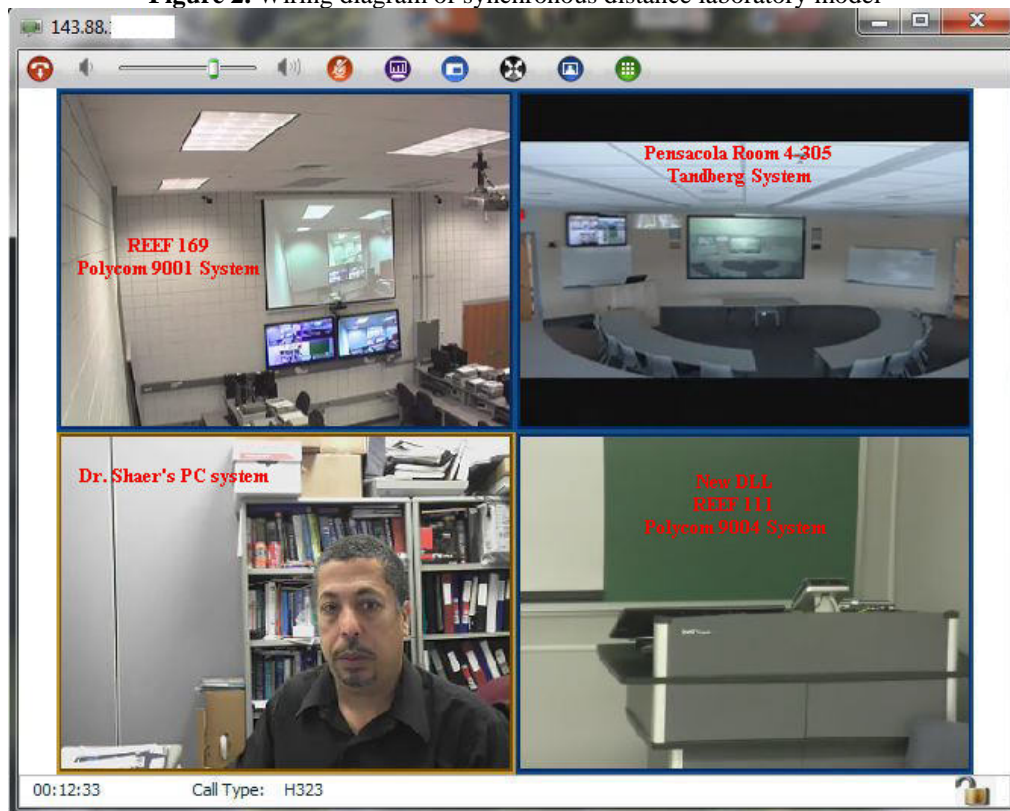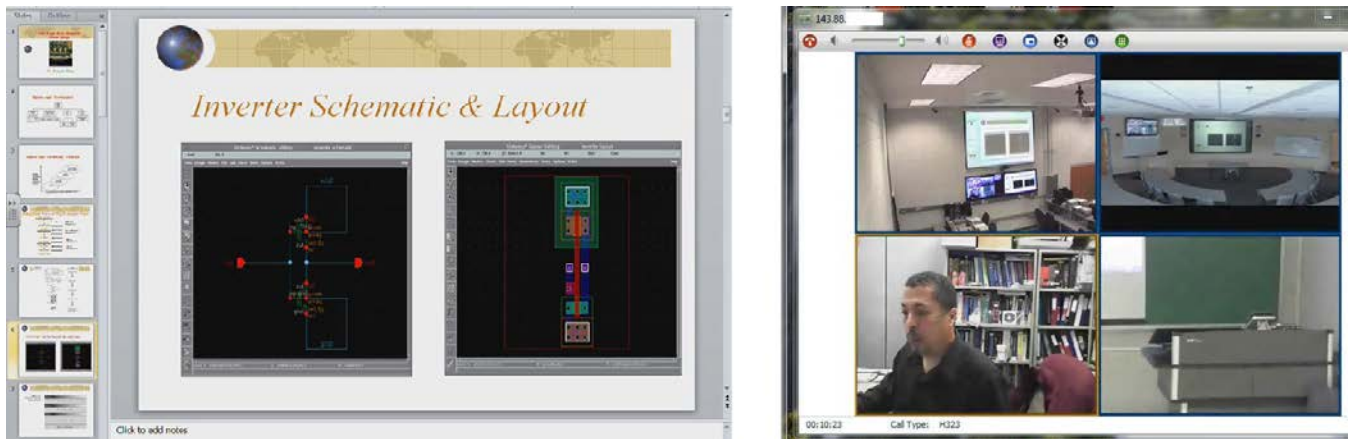**Figure 2.** Wiring diagram of synchronous distance laboratory model



**Figure 3.** Four Simultaneous Multipoint Connections

**Figure 4.** Office Presentation to Multiple Rooms


**Figure 5.** Students' View

## STUDENT LEARNING IMPACT

The digital design course (EEL4712) is required for all computer engineering students and is commonly taken as an elective by many electrical engineering students. Currently, the class is organized as 3 hours of lecture and 3 hours of lab every week. The advances in computer technology in the areas of computer software and hardware have paved the road for instant results for circuit simulations. The new CAD tools stimulate the senses with colorful, accurate circuit waveforms in graphical and tabular formats. No longer must the user enter hand-coded data for circuits or systems; a click of the computer mouse is all it takes to create a professional-looking schematic of a circuit or a block diagram of a system. The simulation is fast and the results are many times better than hand calculations could provide. Circuit simulation complements the laboratory environment, but cannot replace it entirely. Skills acquired in the laboratory allow the ECE students to examine circuits from a different viewpoint.

The digital course is reorganized into blocks of time when students can interact with the instructor in real-time as new material and concepts are presented and then work in small teams (typically two-student teams) to design, simulate, synthesize, and test digital circuits. Students are initially trained on the use of the equipment the first week of class. Hands-on learning, with adequate documentation, is often the best way to proceed. After the students can operate the equipment and the CAD tools, they start the design component. Working with the instructor and with their classmates, they learn how to do efficient circuit/system design on different levels of abstraction. The most effective way to complete this stage is by instructor-guided learning. When an instructor presents new material, students are able to download circuits and simulate them in real-time to have a better intuitive feeling of what is happening with the circuit than in cases where simulation was not performed. By the end of the course, students are able to design their own circuits, share their results with fellow students and give oral presentations.

The simulation, verification and testing of the designs will be done using the Electronics WorkBench/Multisim software and the Quarus II as CAD tools. Circuit simulation is a very powerful method for solving many types of complicated digital circuits and systems. The Electronics WorkBench software package offers easy-to-use graphical user interfaces and provides fantastic graphical output that rivals the best electronic bench equipment. Virtual instruments are cheap to own and operate and they never need service and calibration. Students enjoy simulating circuits without having to put up with the hassles of the physical networks and the vast number of interconnections that link everything together. This encourages students to experiment with circuit components, identify the

component's function and link each function to the characteristics of the circuit's response. The more time spent studying a topic from different viewpoints with various techniques, the better the topic will be understood.

### DISTANCE EDUCATION FACULTY-STUDENT CHALLENGES

While the above described synchronous distance education model is preferable to an asynchronous one, there are many challenges that are not present in a typical laboratory setting. The major challenges include the following:

- Students in the distant laboratory are only visible on large screen monitors located at the front (primarily for use by students) and rear (for use by faculty) of the DLL. As such, establishing a connection with students at the distant end and using their facial expressions for feedback during lecture to gauge understanding is extremely difficult. The lack of direct interaction between faculty and students at the distant end manifests itself in end of semester evaluations of the laboratory and instructor where the distant end typically has a less positive indication of the course and instructor when compared to the near end.
- Distant student lab reports are submitted electronically for grading using eLearning drop boxes by scanning a paper copy or by creating their work directly on a Tablet PC by utilizing Windows Journal, Microsoft Word or Microsoft OneNote. However, these electronic documents are much more time consuming to grade than paper copies.
- Interacting with distant students during office hours to clarify problems is challenging. While a telephone conversation or an email especially with a handwritten attachment created on a Tablet PC can be utilized, there is again a lack of personal interaction.
- It is almost impossible to debug a circuit wiring diagram or equipment malfunction over the distant site.

As a final comment, in general, the time spent on a one credit synchronous distance education lab for both the student and the faculty is more than a typical three credit lecture course. Faculty are cognizant of the additional effort and take this into account in terms of being more flexible than would typically be the case. However, the same recognition is not afforded to faculty in any distance education program at UWF.

### STUDENT LEARNING OUTCOME ASSESSMENT

The evaluation of the new DLL and its impact on student learning is a major element of this work. Assessment was conducted using an assortment of methods to provide immediate and long-term feedback. The following methods were used:

- *Student performance on course examinations*: This most fundamental measure of student performance provides immediate feedback to instructor to allow adjustment of instructional techniques using the interactive lab environment.
- *Student responses on course evaluations*: Standardized course evaluations were collected from students at the end of each semester for each course using the interactive lab. We focused on the responses to questions most clearly related to the new teaching environment. In addition to the standard questions on the form, we added additional questions designed specifically to assess the effectiveness of teaching in this interactive environment.
- *Student preparation for subsequent courses*: This assessment technique measures perhaps the most important aspect of how well the new instructional format educates students. By comparing the preparation level of students who have learned digital design in the new environment with that of students learning under traditional structure, the value of the interactive laboratory environment can be assessed.

In the first year of offering digital design over the new DLL laboratory, students' evaluations were very negative for several reasons. "Instructor does not have long hand to reach the distant site to move a wire or to adjust a function generator or a power supply or to debug a bad wire connection." This negative response was removed by hiring an undergraduate teaching assistant who is familiar with the equipment and has taken the course to be located at the distant site to be the hand of the instructor.

### SUMMARY

This paper has described the development, setting of distance-learning laboratory, and the challenges faced by faculty and students. The facilities currently utilized have been described, and the challenges faced by faculty and students have been noted.

It is expected that the previously noted challenges will be prominently noted by students as responses to the questionnaire. The student learning outcomes assessment, taking into account student location must still be completed. If student learning outcomes are relatively similar between both locations, then the UWF distance education delivery model will be validated. If the outcomes vary significantly among the two student populations, then serious discussion with all faculty will be required in order to fix deficiencies.

### REFERENCES

[1] University of West Florida, Department of Electrical and Computer Engineering. Available: http://ece.uwf.edu/

[2] Carnevale, D. 2000 "Turning Traditional Courses into Distance Education". Chron. High Educ., vol. 46: pp. A37-38.

[3] Mirakian, E. and L. Hale. 2007. "A Comparison of Online Instruction vs. Traditional Classroom Instruction in an Undergraduate Pharmacology Course", Proceeding of the 3rd Annual GRASP Symposium, Wichita State University, pp. 95-96.

[4] Blackwood H. and C. Trent. 1968. "A comparison of the effectiveness of face-to-face and remote teaching in communicating education information to adults." Manhattan: Kansas State University, Cooperative Extension Service. (ERIC Document Reproduction Service No. ED 028-324).

[5] Jaeger, M. 1995. "Science teacher education at a distance." The American Journal of Distance Education, vol. 9 no. 2, pp. 61-75.

[6] McCleary, I. D. and M. W. Egan. 1989. "Program design and evaluation: Two-way interactive television". The American Journal of Distance Education, vol. 3 no. 1, pp. 50-60.

[7] Molnar, A. R. 1997 "Computers in education: A brief history." Technology Horizons in Education Journal, vol. 24 no. 11, pp. 63-68.

[8] Souder, W. E. 1993. "The effectiveness of traditional vs. satellite delivery in three management of technology master's degree programs". The American Journal of Distance Education, vol. 7 no. 1, pp. 37-53.

[9] Thomerson, J. D. and C. L. Smith. 1996. "Student perceptions of the affective experiences encountered in distance learning courses." The American Journal of Distance Education, vol. 10 no. 3, pp. 37-48.

[10] Spooner, F. et al. 1999. "Student Rating of Instruction in distance learning and on-campus classes," J Educ Res. Vol 92, pp. 132-140.

[11] Blackboard Inc. Available: http://www.blackboard.com

[12] ANGEL's web-based teaching and learning tools. Available: http://www.angellearning.com

[13] Desire2Learn Incorporated, 1999-2009. Available: http://www.desire2learn.com

[14] Shaer, B. and A. Fuchs. 2008. "Work in Progress: Student Learning Outcomes in a Distance Education Setting" The 38th ASEE/IEEE Frontiers in Education Conference, pp. 12-13.

[15] AMX hardware and software solutions. Available: http://www.amx.com/

[16] Polycom, Available: http://www.polycom.com/

[17] Center for University Teaching, Learning, and Assessment (CUTLA). Available: http://uwf.edu/cutla/index.cfm