# An Innovative Approach for Implementing an Online Undergraduate Electrical Engineering Program for Community College Students

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## ABSTRACT

The demand for electrical engineers in the State of Maryland is projected to increase over the next few years with the Base Realignment and Closure (BRAC). This event is projected to bring new positions to the state, primarily in the Harford and Anne Arundel County areas. In an effort to provide additional educational opportunities, the Department of Electrical and Computer Engineering (ECE) at Morgan State University (MSU) developed an off-campus program at Harford Community College (HCC) leading to the Bachelors of Science degree in electrical engineering. The current undergraduate program in electrical engineering being offered at Morgan State University is accredited by the Accreditation Board for Engineering and Technology (ABET). This paper presents the steps taken by our department to provide students in the Harford county area with the ability to complete the second half of an Electrical Engineering program at their respective two year institution.

*Key words: Online Electrical Engineering courses, Engineering for Community College Students Teaching Online ECE laboratory courses*

## I. Introduction

The implementation of the federal government's Base Realignment and Closure Act (BRAC) of 2005 will result in the relocation of military agencies to Aberdeen Proving Ground (APG), Fort Meade, Fort Detrick, Andrews Air Force Base and the National Naval Medical Center. An estimated 28,000 positions will be moving to, or created at APG with more than 50% of them needing to be filled by new hires. The Army alone will add 3,400 new hires with 55% of them holding degrees in electrical/electronic engineering. The current employment trend indicates that over the next four years, Maryland will experience an increase of close to 60,000 new jobs, most of which will be high education, high technology jobs. The American Association of Engineering Societies (AAES) reports that based on 2005 to 2007 numbers, Maryland produces an average of 293 graduates with bachelor's degrees in electrical engineering annually. Students enrolled at HCC and Cecil Community College (CCG) that are interested in pursuing engineering as a transfer student, have to travel or relocate to Baltimore City (26 miles), Baltimore County (42 miles), Prince George's County (65 miles), or Newark Delaware (35 miles). Since ECE graduates are already in high demand, our university has made an immediate and strategic initiative to offer an Electrical Engineering degree program to the residents in the Hartford county area by delivering a combination of face-to-face (F2F) courses on the campus of HCC and online courses that will be offered directly from the campus of MSU.

Trends in higher education for the past 10 years have shown that enrollments in online courses or online degree programs have been growing substantially faster than overall higher education enrollment. A survey of online learning conducted in 2009 by the Sloan Consortium indicated that enrollment in one or more online courses reached 4.6 million students in 2008 [1]

The 17 percent growth rate for online enrollments is significantly higher than the 1.2 percent growth rate of the overall higher education student population during the same time period [2]. The authors of the survey entitled, "Learning on Demand: Online Education in the United States, 2009″ [1] conclude their report by stating that "online enrollments in U.S. higher education show no signs of slowing." One discipline that has lagged behind all others in the development and delivery of online education is engineering. While close to 320 engineering schools in the USA have received accreditation from the Accreditation Board for Engineering and Technology (ABET) for their undergraduate programs, only a handful of those offer engineering programs that are completely online at the graduate and/or undergraduate level. The trend has started to change lately, and every year more and more engineering programs are adding an online component to their regular curriculum. The main obstacle is the fact that most engineering curriculums require a very intensive hands-on laboratory component that is very hard to implement and deliver completely online because of the cost involved in setting up laboratory equipment for each online student.

Currently, only a handful of institutions offer a completely online Bachelor of Science (BS) engineering degree program. They are listed in Table I. The majority of the universities that offer an online engineering curriculum indicate to their students that their online program is separate and different from their regular on campus program. Some universities on the other hand make no differentiation between their online and their on campus degree programs. One way universities are assuring that their online engineering degree programs are as valuable as their on campus programs is by using various types of technologies to increase and enhance the learning experience of their online students. Over the past four years, we have been investigating the use of inexpensive, highly portable instrumentation to facilitate our lab requirements. Our approach is slightly different from the other two universities that offer a BS degree in electrical engineering (EE) because we are able to utilize a new technology, the "Mobile Studio IOBoard™" developed at Rensselaer Polytechnic Institute (RPI) to implement the laboratory and design components of our undergraduate courses. We also supplement our online courses with lecture captures of our regular on campus courses using the Panopto Focus™ software. Finally, we use the Adobe Connect™ software to allow online students to demonstrate their projects and laboratory assignments to their instructors from another location.

Table I: ECE Program Catalog Description

| University Offering Online Program | B.S. Degree Program Offered Online |
|---|---|
| University of North Dakota | Chemical, Civil, Electrical, and Mechanical Engineering |
| The State University of New York (SUNY): Binghamton, Buffalo, and Stony Brooke campuses | Electrical Engineering |

## II. Online EE Program Development

The mission of the Department of Electrical and Computer Engineering is to provide a high quality engineering education to a diverse population ranging from those who would otherwise not pursue higher education to those seeking advanced degrees. As a result of the new enabling technology, a partial online program targeted toward completing the second two years of an undergraduate electrical engineering degree is being piloted at our institution. In this paper, we detail the curriculum changes, how the formats of both laboratory and non-laboratory courses were modified. A two plus two approach avoids the frustration associated with an institution wide conversion of all required courses to fulfill graduation requirements. By adopting this approach, only a few select courses outside of the program inventory need to be addressed and the proper resources can be applied in a satisfactory manner. The current plus two program requires 65 credits of courses consisting of 18 credits of lab augmented core courses, 15 credits of non-lab based core courses, 12 of 21 credits of elective courses, and 20 credits of non-electrical courses. The proposed program expansion will allow students to be able to take electrical engineering courses while continuing to work at the military facilities near Aberdeen and other locations around the state. Our proposed program was implemented with the assumption that the added accessibility, affordability, flexibility of this approach will increase the number of students who enter and complete electrical engineering programs at Morgan and choose careers with the government and government contractors.

The Bachelor's of Science degree in electrical engineering at MSU is accredited by the Accreditation Board for Engineering and Technology (ABET). Since the proposed changes to the new program at HCC will not impact the curriculum, it will not require a separate accreditation process. The students that take classes away from the Baltimore campus will have access to the resources in Baltimore and equivalent resources at their home campus. A cooperative agreement between MSU and HCC has been negotiated in order to lease space from HCC to accommodate faculty and staff offices, classroom instruction and hand-on laboratory experiences. As member of the MSU community, students in Harford County will have remote access to electronic library resources that are available to students in Baltimore. These electronic resources are primarily research databases and electronic publications.

Table II: ECE Program Catalog Description

**The Major in Electrical Engineering**

The Department of Electrical and Computer Engineering provides its students the opportunity to apply mathematical and physical concepts to engineering problems early in the curriculum, through laboratory and design experiences. The Department has been following the philosophy of design across the curriculum for some time. In addition to the strong design experience integrated throughout the required courses, the electives offer students the opportunity to enhance their skills with additional open-ended problem solving. These problems are broad-based, incorporating knowledge from specialty areas of communications systems, signal processing, microwave systems, solid state electronics, controls and automation, and computer engineering. The computer engineering emphasis is a special component of the electrical engineering (EE) program, where the Department offers a concentration in this area within its EE program. This rounds out the program by providing the necessary tools to meet the demands of the information age.

**Requirements for the B.S.E.E. Degree**

A minimum of 132 credit hours is required of students pursuing the Bachelor of Science Degree in Electrical Engineering. These credit hours are distributed as follows:

| | | |
|---|---|---|
| General Education Requirements | | 48 or 49 |
| University Requirements | | 2 |
| Mathematics and Science Requirements | | 24 |
| Electrical Engineering Core Requirements | | 43 |
| Electives <u>or</u> Concentration Requirements | | <u>15</u> |
| | Total: | 132 or 133 |

The curriculum for the students in Harford County will be the same as our current students. The catalog description shown in Table II will not undergo any changes. Based on the existing articulation agreement between HCC and MSU, we anticipate that the transfer students will have completed most of the courses in the first two years at HCC. The admissions process and criteria will be the same for all transfer students, including those who opt to take courses in Harford County. There is an existing articulation agreement with Harford Community College, which lists these requirements. The learning outcomes for students in the program are based on the requirements for accreditation. These program learning outcomes are assessed in all departmental courses and results are used for program improvement. Similar processes will be implemented in the courses taught in Harford County. The curriculum sequence for the transfer students from Harford County is shown in Table III. The additional courses that will be offered by MSU in Harford County, for the last two years of the program have been marked with an asterisk. A subset of the EEGR4XX will be offered each academic year, based on student interest and faculty expertise. None of the courses in the curriculum are new courses. The engineering and non-engineering courses marked with an asterisk will be offered on the campus of HCC or other locations in Harford County, using the traditional F2F format based on the minimum enrollment requirement of at least 12 students.

Table III: Curriculum Sequence for HCC students

| | FIRST YEAR: First Semester | Credits | | FIRST YEAR: Second Semester | Credits |
|---|---|---|---|---|---|
| CHEM 110 | GENERAL CHEMISTRY + Lab | 5 | PHYS 205 | PHYSICS I + Lab | 5 |
| MATH 241 | CALCULUS I | 4 | MATH 242 | CALCULUS II | 4 |
| ENGL 101 | FRESHMAN COMPOSITION I | 3 | *ENGL 102 | FRESHMAN COMPOSITION II | 3 |
| HIST 101/105 | HISTORY I | 3 | HIST 102/106 | HISTORY II | 3 |
| ORIE 104 | INTRO TO ENGR I | 1 | EEGR 105 | INTRO TO ELEC ENGR | 3 |
| PHEC XXX | PHYSICAL ED | 1 | | | |
| **TOTAL** | | **17** | **TOTAL** | | **18** |
| | | | | | |
| | SECOND YEAR: First Semester | Credits | | SECOND YEAR: Second Semester | Credits |
| PHYS 206 | PHYSICS II + Lab | 5 | MATH 243 | CALCULUS III | 4 |
| MATH 340 | DIFFERENTIAL EQUATIONS | 3 | EEGR 221 | SIGNALS & SYSTEMS | 4 |
| EEGR 202 | ELECTRIC CIRCUITS | 4 | *EEGR 215 | ELECTRONIC MAT & DEV | 4 |
| EEGR 203 | INTRO TO ELECTRICAL LAB | 1 | EEGR 211 | INTRO TO DIGITAL LOGIC | 3 |
| EEGR 161[1] | OBJ ORIENT PROG FOR ENGR | 3 | HUMA 201 | INTRO TO HUMANITIES I | 3 |
| *HEED 100 | HEALTH EDUCATION | 2 | | | |
| **TOTAL** | | **18** | **TOTAL** | | **18** |
| | | | | | |
| | THIRD YEAR: First Semester | Credits | | THIRD YEAR: Second Semester | Credits |
| *EEGR 305 | ELECTROMAGNETICS | 4 | *MATH 331 | APPLIED PROB & STAT | 3 |
| *EEGR 322 | DISCRETE SYSTEMS | 3 | *EEGR 390 | PRINCIPLES OF DESIGN | 2 |
| *EEGR 317 | ELECTRONIC CIRCUITS | 4 | *IEGR 305 | THERMODYNAMICS | 3 |
| *APPR XXX[2] | APPROVED ELECTIVE/EEGR243 | 3 | *EEGR 4XX[4] | ECE ELECTIVE*** | 3 |
| *HUMA 202 | INTRO TO HUMANITIES II | 3 | *ECON 211 | ECONOMICS (MACRO) | 3 |
| **TOTAL** | | **17** | **TOTAL** | | **14** |
| | | | | | |
| | | | | | |
| | FOURTH YEAR: First Semester | Credits | | FOURTH YEAR: Second Semester | Credits |
| *EEGR 490 | SR. DESIGN PROJECT I | 1 | *EEGR 491 | SR. DESIGN PROJECT II | 2 |
| *EEGR 400 | INTRO TO PROFESSIONAL PRACTICE | 1 | *EEGR 4XX[4] | ECE ELECTIVE*** | 3 |
| *EEGR 4XX[4] | ECE ELECTIVE*** | 3 | *HIST 350 | INTRO TO BLACK DIASPORA | 3 |
| *EEGR 4XX[4] | ECE ELECTIVE*** | 3 | PHIL 109 | INTRODUCTION TO LOGIC | 3 |
| *CEGR 304 | ENGINEERING MECHANICS | 4 | *HUMA XXX | HUMANITIES ELECTIVE | 3 |
| *BIOL 101 | BIOLOGY | 4 | | | |
| **TOTAL** | | **16** | **TOTAL** | | **14** |
| | | | | | |
| | | | | TOTAL CREDIT HOURS | 132 |

## III. Online Course Development

### Phase I- Pedagogy and Implementation of Online EE Courses

The development of the our online ECE courses discussed in this paper started about 12 years ago with the addition of web-based course supplements for the regular courses[3],[4]. The web-based course supplements consisted of additional course materials such as PowerPoint slides, animations, short video, and other website links that were there to help the regular students understand the course material better. The F2F courses were converted to asynchronous online courses over a two year period from 2010 to 2011. We started evaluating various hardware and software technologies that would make the course experience of online students as close as possible to the regular students. We had to carefully evaluate the advantages and disadvantages of synchronous and asynchronous modes of content delivery for our online students. All courses were required to conform to "The 2008 – 2010 Quality Matters$^{TM}$ (QM) Rubric" [5]. This rubric outlines many of the practices that are generally accepted for teaching engineering courses and includes some items that are critical for an online student's success [6],[7]. The rubric assigns points to several aspects of an online course to ensure a student's success. Any MSU course that is converted to an online course cannot be offered to students until it meets and passes the grading scale set by the instructor of the "Online Course Design Workshop" course. This is done to ensure that all online courses meet the minimum course development standard to assure the success of the students who will be enrolled in it. Samples of the different components of the rubric used to evaluate all online courses at our university are shown in Table IV [5].

Table IV. Components of a Quality Matters$^{TM}$ Rubric [5]

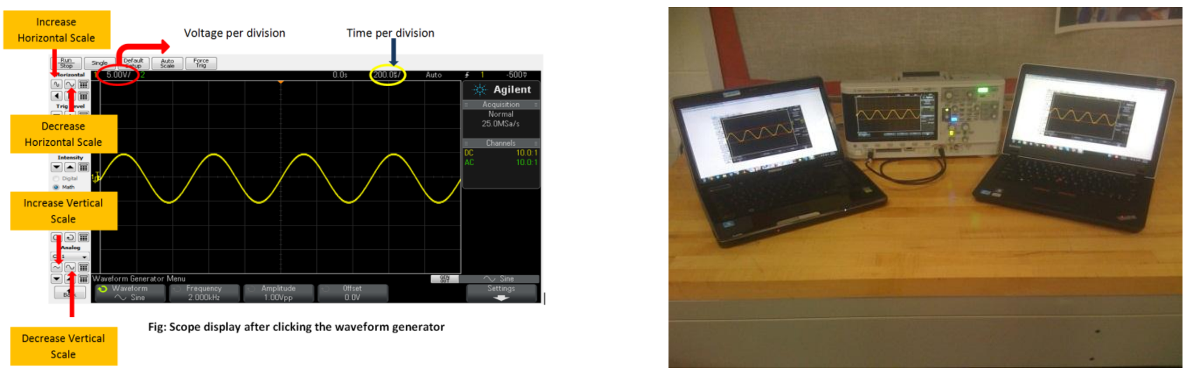
| COMPONENTS OF A QM RUBRIC |
|---|
| 1. Course Overview and Introduction: Ensure that all instructions for students are easy to find including establishing expectations for the course and how to use the modules developed for the course. |
| 2. Learning Objectives: Students are provided measurable learning objectives for each module and information on how to meet the objectives. |
| 3. Assessment and Measurement: The course assessment must be aligned with the course objectives and at a level appropriate for the course. Grading criteria must be explicitly stated. |
| 4. Instructional Materials: Course materials must allow students to meet the course and module objectives. |
| 5. Learner Interaction and Engagement: Interactions that occur between the student and the teacher must foster interaction between course participants and instructors. |
| 6. Course Technology: The tools and media must support student learning and be accessible to students. Students must have access to all tools and instructions must be provided on how to use these resources. |
| 7. Learner Support: Students must be aware of technical, academic and student support services available for the course and at the university. |
| 8. Accessibility: The course should be accessible by all students and provide alternate means of access. |

**Phase II- Pedagogy and Implementation of Online EE laboratory Courses**

Although ECE students had access to web based supplementary course there were always required to come to the ECE laboratory rooms and use the laboratory equipment to design, build, test and demonstrate their projects and laboratory experiments to the course instructor. This changed four years ago, when our university joined the Mobile Studio project that was funded by a five year NSF grant at RPI. The addition of the Mobile Studio IOBoard$^{TM}$ allowed us to redesign our regular and laboratory ECE courses in such a way that the students can now conduct the majority of their design and laboratory experiments outside of the ECE laboratories. The faculty at our institution worked with peers at other institutions involved in the Mobile Studio project to redesign various laboratory and design experiments so that they can be completed by the students using the Mobile Studio IOBoard$^{TM}$. The key issue that we had to address was the fact that the Mobile Studio IOBoard$^{TM}$ is limited to very low voltages (plus or minus 4 Volts) because it draws its power from the USB port of the laptop it is connected to. This implied that laboratory experiments that required a "Power Supply" or "Function Generator" with more than 5 volts had to be redesigned in such a way that the overall concept of the experiments could still be understood by the students. The instructors involved in the Mobile Studio project at the various institutions worked together very closely so that they all followed a very sound pedagogy to deliver the educational content using the Mobile Studio IOBoard$^{TM}$ technology. Various papers on the use of the Mobile Studio IOBoard$^{TM}$ technology and pedagogy have been published by the various members of the Mobile Studio project at several conferences [8],[9],[10],[11],[12].

One question that has constantly been raised with the exclusive use of the Mobile Studio IOBoard$^{TM}$ to conduct laboratory experiments online is whether students have acquired enough laboratory skills to easily transition and start using regular function generators and oscilloscopes found in most ECE laboratories. The focus of this paper is to show how we utilized the new Agilent X-Series Oscilloscopes with integrated Function Generators, that have the optional local area network (LAN) connection modules, to allow students to control every feature of the oscilloscopes remotely using a web browser on their personal computer (PC). Agilent X-Series Oscilloscopes provide the user a virtual front panel that looks and operates the same way as the real front panel of the scopes with the same associated keys and knobs. This implies that students who are conducting ECE laboratory experiments online will have access to the same type of equipment that is used by the students enrolled in the F2F laboratory courses. We proceeded to develop laboratory experiments that can be conducted completely online using the Agilent X-Series Oscilloscopes. We tested the new laboratory experiments using undergraduate students who conducted the experiments completely online.

The approach we took in converting the F2F laboratory experiments into online laboratory experiments is to make sure that the outcomes of both types of laboratory experiment were the same. We also wanted to find out whether students who completed the online laboratory experiments had the same confidence level in using the laboratory equipment as those who participated in the F2F laboratory courses. Until now, we had no means of directly evaluating whether students who conduct laboratory experiments online using the Mobile Studio IOBoard$^{TM}$ can transition smoothly and be able to use comfortably the regular Oscilloscopes and Function Generators found in the F2F laboratory. By using the Agilent X-Series Oscilloscopes with integrated Function Generators for both the online and F2F laboratory experiments, we were able to evaluate and compare the performance of the students enrolled in both types of courses. Fig. 1(a) shows the interface of the virtual instrumentation as seen by the online student. It should be noted that each icon on the virtual instrument represents an actual button in the real instrument. Therefore, an online student that understands the functionality of an icon on the virtual instrument should be able to utilize the same button on the real instrument. The captions in the orange boxes are added inside the laboratory instructions to make it easier for the online students to understand the functionality of each icon. Fig.1(b) shows the view on the screen of two laptop computers that are remotely connected to the real instrument using the Internet. Notice that the waveforms on the screen of the laptops are exactly the same as those seen on the real instrument. Fig 1(b) proves that two or more students can use the same equipment online to work together as “lab partners” to complete their laboratory assignments.




(a) (b)

Figure 1(a): Virtual instrumentation interface seen by online students. (b) Sample view from laptops of two online students that can use the same Agilent equipment remotely at the same time .

Table IV shows the pedagogy we used to convert a RC filter laboratory experiment that is designed for a F2F laboratory to one that can be conducted completely online using the same equipment. The picture on the right of Fig. 2 illustrates one of the results of the “RC Time Constant Evaluation” laboratory experiment conducted by an online student. After the students complete Part I of the laboratory experiment using the Agilent oscilloscopes, we except them to be able to build their own RC circuit using the Mobile Studio Board in Part II of the lab. We designed part I of the laboratory experiments for the online students to make sure that they first understand the concept discussed in the theory section of the course. We then expect the online students to design and build a new circuit in part II that replicates the results of the original experiment. We plan to conduct additional laboratory experiments in the Spring 2012 semester with two or more online students working together as laboratory partners. We have currently designed two additional laboratory experiments that can be conducted completely online using the Agilent X-Series Oscilloscopes with integrated Function Generators. The first online laboratory experiment deals with evaluating the cut-off frequency of an unknown filter circuit (low pass or high pass) by taking different measurements. The online students are then required to build their own filter circuit and test its performance by taking measurements using their Mobile Studio IOBoard$^{TM}$. The second online laboratory experiment deals with evaluating the performance of various Operational Amplifier circuits by first taking different measurements, and then building their own amplifier circuit using their Mobile Studio IOBoard$^{TM}$.

Table IV: Sample laboratory experiment for Online (Web) ECE students

EEGR 203-WEB - Introduction to Electrical Lab — Dr. Yacob Astatke

Lab 7-WEB – RC Time Constant Evaluation

The Time Constant of a circuit is the time response of the circuit when a step voltage or signal is firstly applied. The time constant of a circuit solely depends upon the reactive components either capacitive or inductive, that is connected to the circuit. When an increasing DC voltage is applied to a discharged Capacitor the capacitor draws a charging current and "charges up". On the other hand, when the voltage is reduced, the capacitor discharges in the opposite direction. The time it takes for the capacitor to charge or discharge to a percentage of its maximum supply voltage is called its Time Constant ($\tau$). The time ($5\tau$) is time taken for the capacitor to fully charge or discharge, etc...

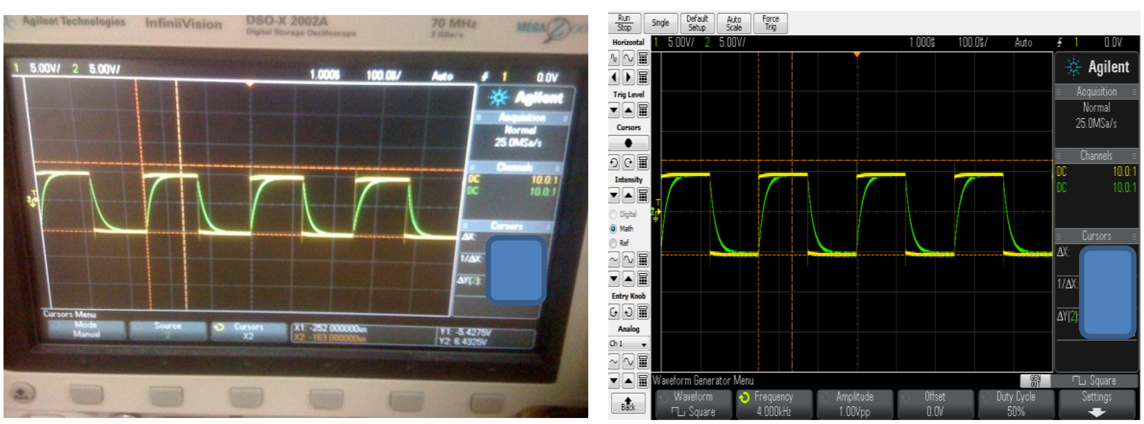
**Part I- Determine the time constant of the RC circuit in Fig 2**

The **Agilent X-Series Oscilloscopes** with integrated Function Generators located in the laboratory is connected to an **unknown RC** circuit**. T**he input and output signals of the RC circuit are shown in Fig. 2(a). The Voltage input (Vs) is a Square wave 1V peak to peak signal, which acts as a switch. The **capacitor value is C=0.01µF**. **Note:** 1V peak to peak is scaled to 10.0V peak to peak on the oscilloscope (Refer to Page 13 of the operation manual).

**Step 1: Connect** to the oscilloscope through the internet to access the display of the output voltage signal from the RC circuit on the **virtual scope**. Follow the procedure in the online student's version of the operation manual on how to connect to the oscilloscope remotely. Your screen should look like the one shown in fig 2(b).

**Step 2:** Determine how long it takes for the capacitor to fully charge or discharge by comparing the input and output waveforms. In other words, find out the time it takes for the capacitor voltage to reach steady state period (Refer to Fig 2(a)). You can do this by **measuring the time on the x – axis using cursors** (Refer to pages 9 -14 of the operation manual). You can put two cursors as shown in Figure 2(a) and 2(b) and read the values in row labeled "Δx" to find the time difference. This area is shaded in both Figure 2(a) and 2(b).

**Step 3:** Use the time you measured in "Δx" to compute the time constant of your circuit. Don't forget that this time is equal to ($5\tau$).




(a) (b)

Figure 2a: Output of unknown RC circuit connected to physical Agilent Equipment**.** (b) Output of unknown RC circuit as seen through the virtual instrumentation connected to physical Agilent Equipment

**PART II Design and build your own RC Circuit**

**Step 1:** Build an RC circuit with the resistor that you estimated in step 4 of Part I. Recall that the capacitor value is 0.01µF and the voltage input is a 1V peak to peak square wave signal.

**Step 2: Connect the circuit to the <u>Mobile Studio IOBoard</u>** to display the input voltage (Vs) and the voltage across the capacitor (Vc). From the display, **determine the time constant** of the **new circuit**. Recall that Vs should be maintained as 1V peak to peak (corresponds to 10V peak to peak on the oscilloscope).

**Step 3:** Compare the time constant in Part II to the one in Part I. Explain any similarities and differences, etc…

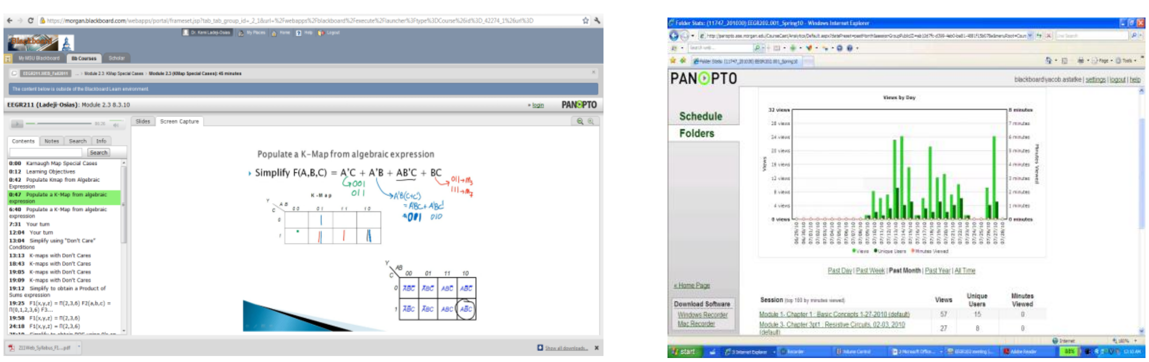
### Phase III- Pedagogy and Implementation of non-EE Online Courses

Our department worked in collaboration with other departments throughout the university to develop and deliver online courses listed in Table III that are not offered by our department. For example, the online version of the CEGR 304 Engineering Mechanics course has already been developed and certified by a faculty member from the Civil Engineering department, and piloted during the summer of the 2011. The IEGR 305 Engineering Thermodynamics course is under development by a faculty member from the Industrial Engineering department. Some of the non-engineering general education courses already have web version completed and certified. The other courses will be developed in collaboration with the appropriate departments. If an online version of the non-engineering course is not available, we plan to offer the course as a F2F course to the community college students .

## IV. Course Delivery and Testing

### Phase I -Implementation of the Panopto Focus™ Lecture Capture technology

All core 200 level and 300 level ECE courses have been converted to online versions, and have been piloted with our regular students during the past two years. We are now ready to offer these courses to transfer students from community colleges. One of the important requirements in the design of our online courses was the evaluation and final choice of hardware and software technologies that would make the course experience of online students as close as possible to the regular students. We had to carefully evaluate the advantages and disadvantages of synchronous and asynchronous modes of content delivery for our online students. Since our goal was to offer the online ECE courses to students from within the United States or abroad, we decided to use a tool that can offer both synchronous and asynchronous course contents to the online student. We decided to use the "Panopto Focus™ " software which was available on campus. We used the Panopto Focus™ software to capture and record a synchronized version of the text (using PowerPoint), audio, and video from the daily lectures of the face-to-face ECE courses. This allowed the online students to follow the lectures and class discussions that occur in the regular courses at their own pace and time. A screen capture of a digital logic lecture recording is shown in Fig. 3.



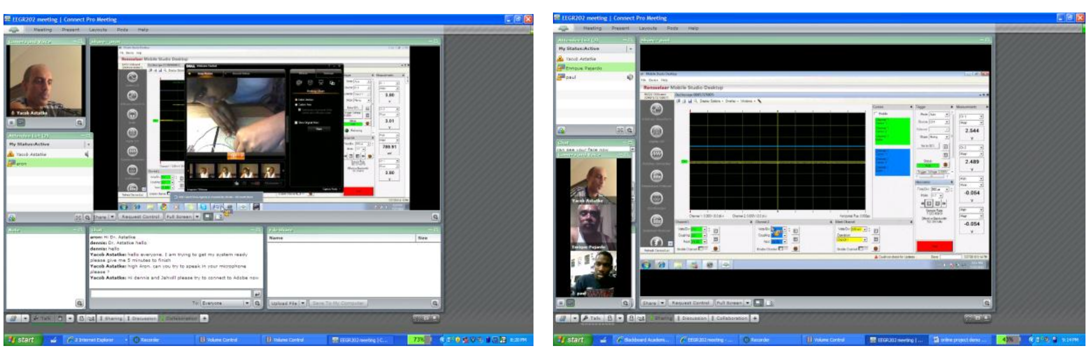

(a) (b)

Figure 3(a): Panopto Focus™ lecture recording for digital logic course. (b): Panopto Focus™ lecture recording monthly usage in circuits lab course.

The different time stamps on the left indicate that the students can access any part of the lecture recording by forwarding and rewinding the lesson. This allows the students to focus on a specific section of the lecture without the need to go through the whole recording. The picture on the right shows the monthly statistics on the usage of the various lecture recordings. The online lectures can be watched over the internet using streaming technology, or can be downloaded as podcasts. The only option that is not available to the online students while they are watching the streaming or podcast versions of the regular course lectures is the ability to ask questions of the course instructors in real time. This however does not prevent the online students from asking their questions at some other time using email, chat rooms, or over the telephone.

**Phase II- Online Presentation of EE Laboratory Projects**

Although the first and second phases of the implementation of our online courses added more flexibility to our regular students, they were still required to come to the campus and use the ECE laboratories in order to demonstrate their design projects or laboratory experiments to their course instructors. We decided to use Adobe Connect™ video conferencing software in order to allow the students to complete their project and laboratory experiment demonstrations without physically being present on our campus. The Adobe Connect™ software allowed the course instructor to schedule an online project or laboratory experiment demonstration time with the students. This required both the students and the instructor to have access to laptops with audio/video cameras so that they can conduct the video conferencing more efficiently. Although we encountered some technical difficulties while trying to set-up the video cameras with the laptops and the Adobe Connect™ software, we were successful in proving that the students could actually conduct a project demonstration completely online from various off-campus locations. The online ECE project demonstrations were successfully conducted for the EEGR 202 Electric Circuits course in the Summer of 2010, while the instructor was in Troy, New York, and the students were in New York City, NY and in Baltimore, Maryland. The following sections present the screen captures and other results that demonstrate the implementation of our first two ECE online courses. The screen captures shown in Fig.4(a), (b) show how the instructor and the students were able to conduct the complete laboratory demonstration online. Note that in Fig. 4(b), other students can follow the demonstrations of their classmates while they wait for their turns.

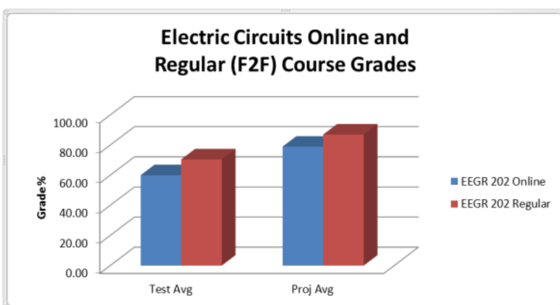


(a) (b)

Figure 4 (a): Student making changes to his circuit and showing the results to the instructor
(b) Other students following online demonstrations of laboratory experiments by their classmate.

## V. Course Results

The results of our completely online and hybrid (face-to-face and online) courses are very encouraging although they suggest that more work needs to be done to make our online courses as effective and reliable as our regular courses. Figure 5(a) shows the grade comparison between 25 students enrolled in the regular (F2F) Electric Circuits course and 6 students enrolled in the online version of the same course during the summer of 2010. The main issue facing online ECE courses is the learning curve required to use the various technologies for the first time, especially to complete their laboratory and design experiments on their own. We have attempted to improve our offerings by adding enough written documentation such as user manuals and troubleshooting tips on the Mobile Studio boards, the Panopto Focus and the Adobe Connect software packages. Although the online students always have a difficult time completing their first laboratory assignment, their confidence level increases with each laboratory experiment and they are usually able to successfully complete the remaining laboratory and design project experiments in the online courses with less difficulty. We have learned from the experiences of our online courses and have taken additional steps to improve current and future online ECE courses offered at our institutions. We have already developed several additional training and teaching materials that clearly explain how to use the Mobile Studio IOBoards™ to future online students. We also constantly test and evaluate new and improved online laboratory experiments using the F2F students enrolled in other ECE courses. The ECE course instructors have also recorded lectures additional ECE courses using the Panopto Focus™ software. This implies that students taking the online ECE courses in the future will have access to additional lecture notes, example and homework problems, test and quiz solutions that were given in the previous semesters. Fig. 5(b) shows a student conducting an experiment using the Mobile Studio IOBoards™. Note the comparison in size with his set-up, and the rack behind him that is currently used by the F2F students to conduct their laboratory experiments.



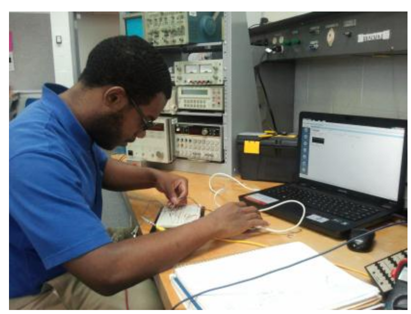



Figure 5(a): Grade comparison between F2F and Online students enrolled in Electric Circuits . (b) ECE Student using the Mobile Studio IOBoard™.

The other issue that we have to address is the approach used for administering exams to future online students. The students enrolled in the pilot online ECE courses are usually given the same projects, homework assignments, and tests as the students enrolled in the F2F courses. They are given the exams on campus because they currently are local students from the Baltimore area. This will not be a requirement for future online students from community colleges and other states because we plan to form partnerships with test centers or learning centers to allow them to take their exams from other locations. This approach is currently used by most programs that offer online courses to their students.

## VI. Conclusion

The impact of the online ECE courses on our F2F students has been very positive. The availability of the online courses have allowed our F2F students to complete more ECE courses over the summer, resulting in synchronizing larger cohorts of upper class students. The online ECE courses have also started attracting more transfer students owing to the flexibility offered to those who cannot assume a full time schedule or attend classes during the conventional primetime hours. We take special care before enrolling students in our online courses, by assessing a student's ability to work independently and whether or not they have reasonable expectations of the degree of time management and persistence needed to satisfactorily complete their coursework online.

One of the key research questions that we plan to answer during the Spring 2012 and Fall 2012 semesters is to evaluate whether students will be able to transition smoothly from using the Agilent X-Series Oscilloscopes remotely to using them in the F2F classroom based only on their experience and the instructions given in the online course. We also plan to design laboratory experiments that can remotely be conducted by multiple students from multiple locations using the same oscilloscope. We plan to use video conferencing software such as Adobe Connect to facilitate the collaboration between the students. If this is successful, it implies that we will able to replicate the discussion and collaboration that occurs when two or more students complete a laboratory experiment in the F2F course. Note that although we conducted all of our experiments using the Agilent X-Series Oscilloscopes, we are sure that the same experiments can be conducted with other types of oscilloscopes as long as they have the remote LAN access built in. We also plan to evaluate other portable ECE laboratory kits such as the Digilent "Electronics Explorer™" [13] and National Instrument (NI) myDAQ™ [14] boards to evaluate their performances and compare them to the Mobile Studio IOBoards™ .

Although both the Mobile Studio technology, and the Adobe Connect™ software have previously been used separately by other institutions for similar applications, to the best of our knowledge no other higher education institution in the United States has combined both technologies to offer ECE undergraduate courses completely online. This new approach represents a major paradigm shift in the way higher education institutions should think when delivering Electrical Engineering education. We hope that it will open the door to many students who are candidates for joining the science, technology, engineering and mathematics workforce such as, current and new personnel relocating to new military bases, mid-career employees, and ex-military personnel because they typically require the opportunity to continue to earn a living while pursuing their education and are most often unable to relocate to college campuses for the two to three years required to complete the requisite courses for a Bachelor's degree. Online education is here to stay, therefore we hope that engineering schools nationwide can follow the path set by the other disciplines [15].

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