Computer/Electrical Engineering Transfer Program Cost-Effective Laboratory Facility

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Abstract

The constant evolution of the Computer Engineering and Electrical Engineering curriculum has necessitated a downward migration of basic engineering-content courses into the freshman and sophomore years. This has presented a challenge to two-year institutions in regard to articulation of content-rich introductory engineering courses, having equivalent breadth and depth to the university-level courses. This is especially true regarding courses involving both lecture and lab experience, in which the problem of integration of technically-current sophisticated laboratory equipment becomes a major concern.

Montgomery College, in Rockville, Maryland, working in close cooperation with the University of Maryland, College Park, our major transfer-to institution, has established a comprehensive EE/CE laboratory facility. This facility provides the freshman/sophomore students with a laboratory experience fully equivalent to the UMCP requirements, so that direct transfer into the junior year is the normal sequence. Montgomery College is the only community college in Maryland that offers this option. Other in-state transferees must take a lab course at UMCP prior to attaining junior status.

The laboratory equipment, facility layout, lab experiments, simulation support and course coordination form a seamless sequence of digital and analog experiences. The focus is on providing a learning experience combining phased-level-complexity industry-level equipment and useful/leveraged experiments, with a high-writing-content professional report as the product.

This session will provide a brief but comprehensive overview of the design of the course, the objectives and outcomes, the facility and equipment, the laboratory experiments, and the report generation. Several elements will be featured:

Each experiment requires designing from an engineering specification, utilizing traditional approaches; a complete simulation, utilizing PSPICE $_{tm}$; breadboarding of the circuit; testing of circuit performance compared to specification; and preparation of an industry-standard format technical report

During the course, students learn PSPICE $_{tm}$, both digital and analog functions, in a progressive manner as the experiment complexity increases.

In a similar manner, students perform testing of circuits using a planned progression of increasingly complex equipment, and develop the ability to generate their reports in-process during their lab work. This is made possible by the design of each MC laboratory station, which is based on a Pentium processor running windows-based simulations, windows-based test equipment and windows-based word. There is no need for use of a 488 bus, et.al. that requires learning complex equipment control sequences, which the limited course time will not permit.

I. Introduction

Montgomery College, located in the Maryland suburbs of Washington DC, is the largest Community College in the State of Maryland, with three Campuses and approximately 22,000 full-time-equivalent students. MC (as it is known) offers a broad spectrum of transfer, career and continuing education programs, both on-site and web-based. The engineering transfer program is on-site at the Rockville Campus and transfers approximately 60 to 65 engineering students per year. Although MC offers a broad range of engineering science programs in Aerospace, Biological Resources, Chemical, Civil, Mechanical, Nuclear, and Fire Protection; the predominant disciplines are Electrical and Computer Engineering. The 15 mile proximity of the University of Maryland College Park makes this the most popular transfer institution, although numbers of students have transferred to and graduated from MIT, Stanford, Cal Tech., Cornell, Purdue, Johns Hopkins, Rensselaer, and Virginia Tech. It was as a result of the major renovation of the EE/CpE program at UMCP three years ago, that three courses typically found in the upper level curriculum of most institutions were reprogrammed to the sophomore year. These courses were Analog Circuit Design Fundamentals (204), Digital Circuit Design Fundamentals (244), and Digital/Analog Circuits Design Laboratory (206). MC engineering faculty responded with a corresponding, fully transferable set of courses, the first two being lecture format, and the last (206) being a lab-only course. As a result of both state system coordination and the preponderance of students attending UMCP, it is not surprising that MC and UMCP faculty communicate regularly regarding curriculum, and some elements of the approach taken in this implementation were inspired by Wes Lawson of the UMCP EE Department. The problem facing MC was that none of the existing physics labs could provide the level of complexity and sophistication required of the 206 course topics. A lab design, driven by the new transfer requirements as well as future expansion of the fundamentals curriculum was required, and fast !

II. Laboratory and Course Design Philosophy

The design of what is now termed the Fundamental and Digital Circuits Laboratory course was driven by the traditional dual constraints of current (and future) technical legitimacy coupled with financial and physical space limitations. Space first. – The easy approach of converting a classroom was immediately discarded, as MC has expanded its offerings and classrooms were already at a premium. Next, existing non-physics laboratories were surveyed, but the exploding Biology program at MC had first priority on any available space. The options were limited to the existing Physics labs. Upon embarking on a critical evaluation of departmental space usage priorities, a situation familiar to many readers emerged. The general physics lab in Science East-308, while still supporting full classes, had become the repository of “carts full” of equipment and experiments accumulated over many of the 50 years of history of MC. A surprisingly large percentage of this equipment had been superceded, but never surplused. After a major "evaluation" effort by the department, the vast majority of equipment was removed and an area of approximately 20x28 feet was recovered, and was designated for the planned matrix of 16 stations.

The technical requirements of the lab, now the focus, were driven by faculty vision, course requirements and transferability constraints. As its primary objective, this lab course was envisioned as the capstone of the MC Engineering transfer sequence in that the actual "engineering design process" was to be the focus of the course, with the individual labs representative of potential design challenges (with scope and complexity commensurate with the students' current level). It was deemed essential to introduce the students to this "real world" engineering experience as early in their academic career as their capability allowed as an "career interest grabber". A second objective of this approach was to "encourage" the students to call upon a broad range of previous course(s) experience(s) to successfully complete each weekly design challenge. The final objective of the course was to maximize the opportunity for the students to have an early "hands on" experience with actual industry-standard components, equipment and software.

The curriculum offering sequence of the lab course follows the completion of Physics 262 (Electricity and Magnetism) and is concurrent with Math-282 (Differential Equations). The EE sequence was structured with the digital course (244) as a prerequisite for the lab (206), with the analog course (204) as a co-requisite (or prerequisite) with the lab. This concept allowed the lab syllabus to be structured in three phases: a brief introductory phase where the emphasis was to be on introduction and use of PSPICE $_{tm}$ and extensions of oscilloscope techniques. This was followed by the body of the course, which was divided into two parts, the first focusing on digital design and the second on analog design. While representing a slight departure from traditional approaches, it is believed that the learning sequence was improved while the scope of material addressed was essentially preserved, permitting full transferability.

III. Course Content Approach

The overall approach for the course was that of a deliberate, planned growth in complexity of each of the "objectives" areas. These areas include the following:

1. Lab experiment specification elements, highlighting the key design requirements of each circuit/topic area, and requiring application of previously learned design techniques.
2. Digital design, phased in complexity by topic area in the 244 digital design course, from simple timing and counter generator designs to algorithmic state machines.
3. Analog design, phased with the 204 course, from simple dc networks, through operational amplifier summers, integrators and differentiators.
4. Simulation capabilities, from drawing circuits to creating frequency sweeps of filter responses.
5. Equipment operation/application, including the proper use of analog, digital, and PC-integrated measurement systems.
6. Report generation, utilizing industry-standard format, focusing on "per cent error" from required specification parameters, and increasing the weight placed upon "analysis of results".

Beginning with the format of the Labs themselves, all labs are structured with a pre-lab requirement (homework before the lab period) which specifies the circuit design requirement, the simulation requirements, helpful references to previous course text chapters and handouts provided. This is followed by the lab experiment proper, (performed during lab time) requiring build, debug, and test of the circuit, and obtaining proper annotated print-outs of the results. The experiment closes with questions regarding the experiment and the requirement to create the typed standard-format report.

Digital design begins with designing a 555 timer with a specific period and duty cycle, followed by an asynchronous counter. Other experiments include the following circuit designs: SOP/POS circuit, Adder/Subtractor (one bit & four bit), array logic, and encryption sequence detector,

Analog design includes ac nodal analysis (analysis only), thevenin & norton equivalents, passive filter design, operational amplifier design, and intro to complex waveforms.

Simulation capabilities include circuit schematics, initial conditions and transient analysis options, source programming (amplitude, frequency, sweeps), PROBE formatting, cursor measurements and schematic and simulation "porting" to reports.

Equipment operation includes analog, digital and integrated oscilloscope displays of analog and digital signals and integrated logic analyzer display of digital signals, including formatting and "porting" to reports.

Report generation includes utilization of Windows-based WORD_{tm} word-processing software, windows- interfaced $\text{PSPICE}_{\text{tm}}$ and windows-interfaced digital storage oscilloscope / logic analyzer software.

IV. Course Phasing

Phase one, consisting of three labs, begins with a self-study intro to simple PSPICE $_{\text{tm}}$ commands, and drawings using the required text[1], and the simulation software included with the text, together with and immediate hands-on exercise in oscilloscope techniques, based upon utilizing the equipment[2] and processes from the previous Physics E&M course. (Also, students are already familiar with PC operation and the use of Windows, and word and spreadsheet programs.) The following two labs continue the tutorial to complete both a simple dc circuit and ac circuit and introduce the PROBE function, complemented by breadboard build and test of both circuits. This is followed by a lab lecture and hands-on introduction to printing digital oscilloscopes[3,4].

In phase two of the course, the digital designs are implemented and a lecture on the use of the integrated digital storage oscilloscope / logic analyzer[5] is presented. By the end of this phase, the students have developed a rudimentary capability in simulation techniques, and the use of digitally-interfaced equipment.

In phase three of the course, the analog designs are implemented. The experiments are phased such that the course "tracks" the co-requisite analog course, and the operational amplifier experiment is completed concurrent with the analog course completion. The complex waveform activity is the last topic covered and is completed with hands-on exercises utilizing a Fourier-series software tutorial on the lab PC's.

V. Laboratory Facility Design

With the technical requirements established, the design of the lab proceeded. An individual student work station was the basic element, and the objective was to have one station per student, rather than the conventional multi-student position. This decision was shaped by the three basic elements of the faculty "vision". First, the concept of learning, implementing, and most importantly, internalizing the "engineering design process" is a highly personal discipline, and as such requires repetitive reinforcement in multiple situations to become inculcated. Second, "encouraging" recollection of previous work places in perspective the initially disparate subtopics of the preparatory courses and evolves a coherence and inter-relatedness perspective essential to linking these "basics" into a "body of knowledge" at this level. Third, students become familiar with "every facet" and step necessary to actually create a working circuit, and thereby experience the exceptional positive reinforcement that comes from being able to say "I did it !". This is not to say that discussions and comparisons among the students are prohibited, but instead are encouraged - but only after making their own significant efforts toward the problem. This environment places an additional burden on the instructor to both be involved with each student's individual progress and to "threshold" the degree of sharing. Recognition of this requirement was critical in determining the number of stations in the lab; limiting it to sixteen, maximum.

The student work station required space, components and equipment to be within the accepted human factors radii and focus angles, necessitating a careful layout of the station. Unfortunately, the ideal bench space was limited by the available facility, so that 72x30 inch benches were used rather than the 96x36 that we had preferred. While we gladly accepted the cost savings, the space constraint proved to be not prohibitive, especially when the PC keyboard was mounted under the bench on a slide-out. Each station was equipped with a Compaq Desk-Pro Pentium processor. Each station was equipped with a digital/analog trainer[6], which provided several cost savings. First, each trainer provided a fully adjustable Sin/Square/Sawtooth signal generator (1 to 100kHz), together with fixed +5VDC and +/- 12VDC, and variable +/-1 to 20VAC power supplies. Second, included in the trainer were a multimeter and a set of basic hand tools. The Tektronix 2213A analog oscilloscope for each station was shared with the Physics courses as it was used only for the first two experiments before phasing to the Tektronics TDS-320 digital oscilloscope for each station, acquired as used equipment. The final phase of the station resulted in a cost-driven decision to allocate one PC-integrated Link Instruments Series 28464 Digital Storage Oscilloscope / Logic Analyzer to each two stations. The PC containing the DSO/LA was mounted on the strong, technician-built shelf above the bench, as were the TDS's and the displays. (They just fit!) Each student was allocated a "Tray" of a breadboard and wiring kit for their use during the course. After class these trays were stored in a shelf area at the rear of the lab. All components were provided to the students, and required 3-6x6 plastic parts cabinets for storage. The layout of the station is shown in Photographs #1 and #2, the lab area is shown in photograph #3, and the tray, storage and parts area is shown in photograph #4

Photograph #1: Two Lab Stations (Second PC on Floor)

Photograph #2 Lab Stations w/Logic Analyzer Probes, TDS, Simulation and Report

Photograph #3: Laboratory

Photograph #4: Tray, Storage and Parts Area

VI. Approximate Cost for the Laboratory

The approximate cost for the sixteen stations, and the common equipment and components required to support the lab is summarized as follows: (Note: Two year old + prices)

Station:	
Compaq PC - w/Parashare 95 16 port daisy chain (Windows supported)	$ 1,700
Elenco Electronics Trainer XK-550	300
Tektronics 2213A (used)	650
Tektronics TDS 320 (used)	1666
Link Instruments 28464 DSO /LA (New) - (1/2 of approximately $ 4000)	2,000
Bench, et.al	500
Per Station	$ 6,816
Sixteen Stations	$ 109,056
Common:	
Printers (Hewlett Packard Laser 2500) (2 @ $500)	$ 1,000
Array programmers (2 @ $ 2000)	4,000
Testers (Digital devices, Analog Op-Amps, RLC) (6 @ $ 500)	3,000
Parts/breadboards/wires/cabinets/trays/shelves	3,000
Subtotal:	$ 11,000
Laboratory Total	$ 120,056

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