

# Development of Competent VLSI and Microelectronics Curricula in a New Undergraduate Program

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## ABSTRACT

The new Undergraduate Electrical Engineering program at the Alabama A & M University offers *three options*. These are: (1) *General Electrical Engineering*, (2) *Computer Engineering*, and (3) *Microelectronics and VLSI*. Each of these options offered by the Department of Electrical Engineering has earned accreditation under the **ABET EAC EC 2000** Criteria effective 1999. The *General Electrical Engineering* program is very much identical to most standard curricula that are followed in the programs offered by other schools. The content of the courses in the *Microelectronics and VLSI* option is adjudged by the global competitiveness. There are *six* courses that distinguish this option from the usual *General Electrical Engineering* option. The rest of the courses are identical to the *General Electrical Engineering* option. Out of these *six* courses *three* are titled as *VLSI Design and Testing* with sequential order. One of them is offered at the junior level and the other two courses are offered at the senior level. Then two (*Semiconductor Engineering*, *Integrated Circuit Engineering* or *Analog Circuit Design and Analysis II*) of the remaining three courses are mandatory for the students of all *three options*. Thus, they constitute junior level requirements. The last course is designated as the *advanced integrated circuit engineering* offered exclusively for the senior level students in this option. The purpose of each of these courses and the contents are reviewed, evaluated, and justified to meet the career needs of the students. Also these *six* courses in this option are also addressed to keep continuation or smooth transition at the junior level from the sophomore level as it is done for the *General Electrical Engineering* program. The students in the *Microelectronics and VLSI* option are employed with attractive salaries and are receiving attractions from other intra-discipline requirements for the job.

## INTRODUCTION

The new Electrical Engineering program established at the Alabama A & M University (AAMU) in 1996 offers three options at the Undergraduate level. These options are: (1) *General Electrical Engineering*, (2) *Computer Engineering*, and (3) *VLSI and Microelectronics*. Each of these programs is **ABET EAC EC-2000** accredited. The Department is constantly growing since its first commencement in May 1999. Till to date 36 students graduated in these three options and successfully employed with various organizations. A few of them are currently attending Graduate programs elsewhere. The enrollment is consistently increasing, and gradually the *VLSI and Microelectronics* option is becoming both popular and familiar for professional growth of the prospective students. The City of Huntsville in Alabama is projected to be one of the Microelectronics cities in the nation by 2008. Therefore, this program is anticipated with sustained flowing students and thereby expected continued growth.

At present there is no *VLSI and Microelectronics* laboratory available on campus for hands-on training of the students. However, in this option the first batch comprising of *five* students graduated in May 2001. Each of these students is employed and pursuing career growth. In the next batch with *six* students in the same option are scheduled to Graduate in May 2002. Both these batches of students were provided hands-on laboratory training at the University of Massachusetts (UMass) – Lowell campus in the Summer of 2000 and 2001, respectively. For this hands-on training financial support was obtained. The REU (Research Education for the Undergraduates) funded during 2000 was provided by the National Science Foundation (NSF). During 2001 the total funding was arranged through the Army Missile Command (AMCOM). Any remaining balance was supported by the University.

The construction of the new **School of Engineering and Technology building** is progressing. This building will have a dedicated *VLSI and Microelectronics* laboratory comprising of about **2500-sq. ft. class 10,000** clean room. This laboratory will be used primarily to train the Undergraduate students that are useful in the Government Laboratories, Industries, Autonomous Bodies, and etc. organizations. Since the Electrical Engineering program is in the infancy stage it is designed to establish with the *state-of-the-art* instrumentation utilizing current Faculty strength and available resources. The Faculty members are actively involved in organizing and establishing such a laboratory and orient toward practical training of the students as they have substantial exposure in the industrial environment. This new laboratory is envisioned as a *state-of-the-art* installation of the essential instruments.

There are *eight* courses designed and developed altogether in the *VLSI and Microelectronics* option. They are: Semiconductor Engineering (**EE305**), Integrated Circuit Engineering (**EE430**), Advanced Integrated Circuit Engineering (**EE431**), and three courses in sequence bearing title with numerical order as VLSI Design and Testing (**EE350**, **EE451**, and **EE452**), and Engineering Analysis and Design in VLSI and Microelectronics (**EE470** and **EE471**). The first *six* courses carry 3-credit hours each and the last *two* courses carry 2-credit hours each. Thus, a total of 22 credit hours are required for a student choosing this option. Students who do not complete the entire sequence package of the courses in the *VLSI and*

*Microelectronics* option must meet the criteria of the *General Electrical Engineering* Program. Therefore, there is a room for the students to maneuvering the curricula with the *General Electrical Engineering* option who lose the sequence or desire not to continue in the *VLSI and Microelectronics* program without jeopardizing credit hours or semesters.

As part of the competitive strategy in a minority institution (Alabama A & M University is a land grant institution and a part of the Historically Black Colleges and Universities, HBCU) and to become relevant to the regional support with the graduates the *VLSI and Microelectronics* option is geared toward a national milestone. To satisfy this option effectively, a state-of-the-art laboratory is being built in the new **School of Engineering and Technology** building. It is expected that this laboratory will be functioning during the Fall 2003 for full-scale in-house training of the prospective students.

The purpose of the *VLSI and Microelectronics* option is to develop a competitive program at the Undergraduate level emphasizing silicon technology in conjunction with other emerging parallel technologies. Also the program is initiated to have a national recognition for the minority students through the hands-on training in this area of technology. The courses that are developed serve extensive in-depth profiling of the state-of-the-art technology.

## **BACKGROUND OF THE PROGRAM**

The Alabama A & M University is a land-grant institution, established in 1890's to serve the needs of the minority population of the State of Alabama. During the 1970's, the University entered into a lawsuit to acquire the necessary funds to carry out its land-grant mission. In 1995, the court order authorized the University to establish two new engineering programs, one in **Electrical Engineering** and another in **Mechanical Engineering**. The Electrical and Mechanical programs became a part of a larger legal desegregation law suit resolution in the civil case CV 83-M-1676. This situation brought to AAMU both challenge and unique opportunity to develop *VLSI and Microelectronics* option in the Department of Electrical Engineering.

The Electrical Engineering program offers BS degree. In addition to the *general electrical engineering* version, the program offers options in *VLSI and microelectronics* and *computer engineering*. The Department began offering courses in the optional areas in the fall of 1999. Starting with the recruitment of just six students in 1996, the Electrical Engineering Department has grown to over 180 undergraduate majors. During the same period, the faculty has grown from two to seven. Three classes of students have graduated from the program. The **ABET EAC EC-2000** accreditation was granted to the Department of Electrical Engineering in August 2001. Additionally, the State has provided funds to build a structure to house the entire **School of Engineering and Technology**. The 86,000 square foot building is scheduled to be completed in the Fall 2003. At that time, AAMU's students will have access to a **2,500-sq. ft. class 10,000 clean room** where these experiences will be obtained.

Although Faculty members at AAMU have the necessary experience and expertise to offer courses in the option area of *VLSI and Microelectronics*, laboratories and other practical

infrastructure components of the program have not yet been developed. During the summer of 1999, the Department of Electrical Engineering of AAMU entered into an agreement with the UMass - Lowell to provide laboratory experiences for students in the *VLSI and Microelectronics* option.

During the summer of 2000, students in this option were allowed to participate in a full-time (comprising of 120 hours of laboratory, 40 hours of lecture, and 40 hours of industrial field trip for the entire Summer Session) laboratory course at UMass – Lowell. The course provided hands-on experiences at every level of integrated circuits processing. As noted earlier the Electrical Engineering program at UMass - Lowell has a well-equipped laboratory that is suited for this purpose. The course provided hands-on experiences at every level of integrated circuits processing. Typically in a Semester approximately a total of 40 hours are spent for the lecture for a 3-credit hour course. It also provided visits to local integrated circuit manufacturing companies in the Lowell-Boston area. This experience was funded via NSF-REU grant. In the same way during the Summer 2001, students in this option were allowed to participate in a full-time (comprising of 120 hours of laboratory, 40 hours of lecture, and 40 hours of industrial field trip for the entire Summer Session) laboratory course at UMass – Lowell. Thus, the course provided hands-on experience at every level of integrated circuits processing. Typically in a Semester approximately a total of 40 hours are spent for the lecture for a 3-credit hour course. It also provided visits to local integrated circuit manufacturing companies in the Lowell-Boston area. The financial support was gathered from AMCOM and various scattered sources on campus to manage the student support.

Out of *ten* students enrolled in the *VLSI and Microelectronics* option in Fall 1999, *five* participated in the program with the UMass-Lowell in the summer 2000. In the same way *twelve* students enrolled in the *VLSI and Microelectronics* option in Fall 2000, *six* participated in the program with UMass-Lowell. These students took semiconductor (EE305) and microelectronics (EE350) courses throughout their junior year and were in the process of entering their senior year of study during this program. Unfortunately, there were no laboratory experiences to accompany the courses at AAMU. Working with the National Science Foundation and AAMU, the UMass – Lowell agreed to enroll these students in an intensive course, VLSI Fabrication (**EE16.470**). This course was substituted for VLSI Design and Testing III (**EE 452**) at Alabama A & M University. Based on the size of the sophomore class, it is estimated that the participation in this program is gradually increasing.

Although the Electrical Engineering program at AAMU does not have fabrication, characterization, and testing laboratory the Department continues to identify ways to support this option at least until the installation of the new clean room. This period includes the hands-on training period at UMass – Lowell during Summer 2003. In order to equip the program in the Department of Electrical Engineering the software tool, *L-Edit Pro*, has been procured from the **Tanner Tools Corporation**. This tool supports layout and verification of the complex integrated circuits. It contains a layout editor, a design rule checker, standard cell place and route, a CMOS library, and a macro library. The software supports the three VLSI Design and Testing courses and the senior project course for the students in this option. All

students participating with the program in the summer will have had experience with these simulation tools prior to going to UMass - Lowell.

The Faculty members of the Department works closely with several local organizations but not limited to: MEMS Optical, and the fabrication facilities of NASA, and the Army (AMCOM). Negotiation with NASA for shared use of their fabrication facilities has continued for the past several years. Unfortunately students have been unable to utilize those facilities, as it is not directed toward student usage. Representatives of MEMS Optical proposed senior projects and invited students to work in their facilities during 2000-2001 academic year. Unfortunately, the organization had production goals to meet, while the Department needed a teaching facility. In any event, the support of MEMS Optical has been critical to the success of the program thus far.

### **FACILITY AT THE UNIVERSITY OF MASSACHUSETTS - LOWELL**

The laboratory at the UMass - Lowell has a long history of success in the *VLSI and Microelectronics* technology. The list of the instruments acquired for the fabrication and characterization laboratories (distributed instructional processing laboratory, DSIPL) include photoresist spinner, soft baker, mask aligner, wet and dry etching facilities, hard baker, stripper, wafer saw, wafer scribe, heated and non-heated baths, diffusion furnace, alloying furnace, oxide furnace, junction depth sectioner, I-V (current-voltage) curve tracer, C-V (capacitance-voltage) station, film thickness measurer, ellipsometer, four-probe resistivity measurer, wafer prober, scanning electron microscopes, optical microscopes, image shearing microscopes, thin film evaporator and sputter coating unit, wire-bonder, shear and pull tester, ion implanter, etc. In addition to these instrumentation facilities *Cadence design and analysis software* is currently available there, which is similar to what AAMU has procured from *Tanner Tools*. The DSIPL was founded in 1986 although the laboratory was first established in 1984 at the UMass - Lowell. The funding was provided then and the support continued by several local industries including the State of Massachusetts.

The same course (**EE16.470**) at the UMass - Lowell will be enrolled during the summers of 2002 and 2003 by the students of AAMU. These students will spend *twenty-four hours per week* in fabrication, characterization, and testing laboratory obtaining experience that will be substituted for one of the three VLSI Design and Testing courses (that is **EE452**). A separate report will be procured from the students after completing a competitive applied project in addition to their regular ancillary laboratory work. Like summer 2000 and summer 2001 experience will consist of the following laboratory facilities: *fabrication and processing, characterization, testing, and reverse engineering of the existing microelectronic end-products*. To support the planned programs of 2002 and 2003 necessary proposals have been submitted. These proposals seek necessary funds to continue and formalize this collaborative relationship to benefit the students in the **VLSI and Microelectronics** option at AAMU until the laboratory facility is established at the new School of Engineering and Technology building in Fall 2003.

## LABORATORY DEVELOPMENT

It may be noted profoundly that the financial support of **BOEING** is very helpful to build the infrastructure of the VLSI and Microelectronics laboratory. It was announced during the groundbreaking ceremony in November 2001. This support money will be used toward the procurement of the initial instruments such as oxidation furnaces, wire bonding unit, lithography facility, mask aligned tooling, hood and furniture, etc. The funding to support the characterization and testing instruments have been forwarded to other organizations noting the support of BOEING to AAMU's new VLSI and Microelectronics laboratory. These instruments include vacuum coating system, variable field Hall effect measurements and cryogenic platforms, C-V plotter, impedance analyzers, deep-level transient spectrometer (DLTS), I-V measurement set-up (low to high current), multipurpose electrometers, high performance digital multi-meters (DMM), sensitive sourcemeter, nano-volt preamplifier, lock-in amplifier, etc. Nevertheless, these instruments are emphasized as essential to provide immediate training with a target of gradual independent program in the nation. This intention allows the students to have a strong in-house training and the current program at the UMass - Lowell will eventually be discontinued. Of course this will coincide with the establishment of the new Engineering and Technology building by Fall 2003.

## STATE-OF-THE-ART CURRICULA

The task of designing an innovative non-duplicative curriculum for the *VLSI and Microelectronics* option is a challenge. Also it is an opportunity to elevate design and testing oriented laboratory facility to execute such a program option for the prospective students desiring state-of-the-art training. The task was initially viewed as a multi-year project with a goal to erect a competitive engineering program that requires **ABET EAC EC-2000**. In fact, the accreditation was achieved within a reasonable amount of time. At present AAMU's Electrical Engineering program is publicized as an ABET accredited program. This publicity has enhanced the enrollment.

With the present Faculty strength the content of each course is structured while the course of UMass – Lowell has been taken the way it is there. Apart from the two required courses (EE305 and EE430) at AAMU for all three options, there are four regular courses and two back-to-back design and analysis oriented courses exclusively for the VLSI and Microelectronics option students. However, the back-to-back design and analysis courses (EE470 and EE471) are required for all the three-option students but need not be related to *VLSI and Microelectronics* projects for *General Electrical Engineering* and *Computer Engineering* options. The summary content of the required (by all three options) courses are as follows: (1) EE305: physical electronics and basics concepts of junction devices (unipolar and bipolar) and integrated circuits, etc., and (2) EE430: class of amplifiers, amplifier circuits, designs of various amplifiers, amplifier circuit simulation, etc.

The remaining *four* regular courses actually constitute the VLSI and Microelectronics option with one of them is credited to the students for the course taken at UMass – Lowell. The course at UMass – Lowell is entitled *VLSI fabrication* (EE16.470). This course involves

hands-on laboratory practices including lectures. It is credited as EE452 at AAMU for the students in the *VLSI and Microelectronics* option. The summary content of the other three courses at AAMU may be provided as the (1) EE350: fundamental principles, introduction to CMOS VLSI technology, basic logic circuits, etc., (3) EE431: discrete and integrated devices, physics and technology of multi-junction devices, etc., and (2) EE451: instrumentation, measurement techniques, data acquisition and analysis, characterization and testing methods, semiconductor point defects and crystallography, compound semiconductors, technologies of single crystals and polycrystals, etc.

The two back-to-back design and analysis courses include projects. While taking these two courses during the final year, a student has to pick up a project related to *VLSI and Microelectronics* area. This single project may have several sub projects. The entire project is expected to be completed during two consecutive semesters (Fall and Spring).

Till to date each of the aforementioned courses have been offered more than once. Each time these courses offered the content got restructured through the filtered sequence of delivering the lectures. There is a great deal of refinement in these courses. The associated problems assigned to the students as home work or asked in the periodic tests were synchronized according to the materials covered in sequence. In the future there is a scope of revising the content.

## **CONCLUSIONS**

A program option in the new Department of Electrical Engineering at AAMU has been developed. The courses and laboratory practices developed in this option are nationally outstanding and serve the purposes of the organizations requiring such fresh skills. The new state-of-the-art laboratory is under construction with the help of the funding from the State of Alabama, BOEING, and other national and local resources. This laboratory will be housed in the new School of Engineering and Technology Building in Fall 2003.

## **ACKNOWLEDGMENT**

It is author's pleasure to thank Mrs. Sanjida Khanam for her interest and intellectual support in this work, and Dr. A. A. Mobasher (Department of Mechanical Engineering, AAMU) for extending help in various ways during the preparation of the manuscript. Special thanks are extended to Drs. V. T. Montgomery, A. J. Bond, V. R. Goteti, K. B. Cook, and K. Heidary (all from the Department of Electrical Engineering, AAMU) for their constant suggestions to improve the *VLSI and Microelectronics* option program.