Addressing the Future: Development of an Electrical Engineering Curriculum

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Abstract

The Electrical Engineering program at the Milwaukee School of Engineering (MSOE) has implemented a major revision of its curriculum for the purpose of assuring course content consistent with both present technological changes and long-term technology trends. In addition, the curriculum places an increased emphasis on developing the professional skills of our graduates.

Curriculum modifications include a greater focus on microprocessor based systems, interfacing, signal processing, and material science. Core electrical engineering topics are introduced during the freshman year and include both lecture and laboratory experiences. The curriculum has retained its broad range of content topics and its traditional strong design and laboratory focus.

The curriculum changes are intended to provide the breadth and depth of technical knowledge and the professional skills that will enable our graduates to: enter industry with immediate productivity, pursue changing career opportunities, adjust to life-long technological changes, and pursue graduate school studies.

I. Introduction

After satisfying all requirements associated with our last ABET EAC evaluation visit based on EC2000, the faculty of the Electrical Engineering program at the Milwaukee School of Engineering (MSOE) made the decision to thoroughly review and revise the EE curriculum. At the time the curriculum had opportunities for improvement as evidenced by both faculty and student feedback. While none of the known problems were major by themselves, the total accumulation was viewed as a significant impediment that hindered student learning. In addition, the passage of time requires periodic readdressing of the question of what should be the content and structure of a forward-looking curriculum.

Curriculum modifications had been continuously made over quite a few years for the purpose of addressing various problems as they arose. However, that approach has its limits as our constituencies' needs change. In addition to solving the intended problem modifications often introduced difficulties. Examples are:

- Changing from requiring an elementary introduction to computers plus a single C programming course to requiring two programming courses in C/C++. The two new courses were separated by a one year gap because of the available schedule slots in the curriculum.
- Courses or course sequences became unintentional "weed-out" courses
- Course sequences became somewhat lacking in continuity
- Some courses ended up being poorly placed in the curriculum.

What must also be mentioned is that the incoming students have changed over the years in their background and attitudes. The curriculum must adjust to the change in the students, especially during the first academic year. A common complaint had been "I came for Electrical Engineering and have been here for almost a full year and have yet to get any experience as to what the field is all about." The traditional answer of "be patient" has not proven to be very satisfactory.

II. Looking Forward

The questions that we believed needed to be answered in reforming our curriculum is what should the traits, characteristics, knowledge base, and skills be for our graduates when they initiate their career and what will serve them as an underpinning for long term success? These questions must specifically be answered in the context of long-term international events and trends, such as globalization[1, 2, 3], and be answered taking into account fundamental trends in technology[4], such as nanotechnology[5], and MEMS.

The answers we provided are that graduates still need technical skills that reflect the current state of technology, but looking forward, looking towards what is coming, not at what is fading away. However, graduates also ever more strongly need well-developed professional skills (communication, teamwork, analysis, etc.) to accommodate the rapid career changes that appear inevitable for most, if not all, engineers.

The primary focus of this paper is on the course curriculum content development. Other aspects of the electrical engineering program are still in active development and are or will be the topic of other papers[6, 7, 8]. As a result of extensive discussions, one stark conclusion formed by the program faculty leadership is that *a relevant and proper education must have a very strong non-technical component*.

The curriculum was developed with EC2000 as a background guideline. The EE program has a mission statement, educational objectives and program outcomes. These relate to each other in critical ways:

- Mission Statement – paints a picture of what the program ideally wishes to do and is attempting to actually accomplish
- Objectives – the qualities and possibilities of our graduates as they pursue their careers, with a particular emphasis on the first few years since that is the time period where our influence is most keenly felt by the graduates
- Outcomes – the belief is that if the desired outcomes can be instilled in the graduates, then achieving the objectives becomes a very real and strong possibility.

The course content is only one factor relating to the outcomes. Essentially, a series of courses does not a program make. Rather, all the tangible and intangible factors that form the connection between students and the program and university are as real in developing the student as are the courses.

III. Process Essentials

Before engaging in the detailed curriculum reform, the faculty made three fundamental decisions. The first decision was that we would begin with a clean slate; any existing course had to go through the same process of "earning" a spot as a new course. Actually, the discussions started in the context of content and knowledge that should be in the curriculum. References to existing courses and course numbers were discouraged. The second decision was that we would proceed with a top-down process, decide on the "big-picture" before any discussions of the details. The third decision was that the entire program faculty would vote on all proposed courses and basic content.

Committees were formed to discuss and make recommendations regarding the basic areas of technology that comprise electrical engineering. After a few initial skirmishes, which could be interpreted as territorial arguments, the most surprising (and perhaps unbelievable) thing that happened is that all final decisions regarding course content and topics were unanimous, with one exception where one negative vote was cast on a specific proposal.

The program's constituencies were consulted throughout the entire process. As the curriculum took shape, on numerous occasions students groups were asked to comment on the results. Also, input was solicited from the program's Industrial Advisory Committee. At semiannual meetings the committee actively reviewed the progress made and between meetings provided advice on specific issues via email.

IV. Course Curriculum Guidelines and Limits

There is a strong tendency to stuff 10 pounds of content into a 5 pound curriculum bag. Such "mission creep," seemingly inevitable when incremental changes are made, is equally tempting during a complete curriculum review. A program faculty with diverse backgrounds and viewpoints tends to define what is important in the education of students in the context of their own interests and experience. While both the interests and experience are of value, they do not inherently answer the question of what is necessary for the student, especially when considering what is needed for future career viability. Hence, it was critical to begin the process of curriculum development with some clearly defined guidelines and limits.

Course Curriculum Development Guidelines:

1. A 4-year curriculum is simply insufficient for students to learn everything that is desirable for them to know.
2. The curriculum will not attempt to include everything
3. Only the most critical content must be included in the curriculum
4. The curriculum must provide the base for life-long learning
5. The curriculum will continue to be broadly based

Rapidly changing technologies require universities to, above all, teach students how to learn. It is not possible to prepare for a lifetime of knowledge, but at best only for a lifetime of adjusting to change.

Engineering Accreditation Commission program criteria for electrical engineering programs state "*The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program*."[9] This criterion influenced the decision to include guideline number five.

Central to the guidelines is that rapid changes in technology assure that students will always have gaps in desirable knowledge at the time of graduation. No matter how long the formal educational process, there is always more to learn. That additional learning, in the end, must occur after the student graduates. Hence, the dictum of preparing students for life-long learning is central to curriculum changes. The purpose of the curriculum is to form a foundation for further learning, as well as preparing students for the technologies of the present.

Curriculum Development Limits - maxima:

1. total number of credits in the curriculum – 194-195 quarter credits
2. number of courses per quarter – 5 courses
3. number of credits per quarter – 17 credits
4. number of experimental laboratories per quarter - 3 laboratories

The primary focus is not on the number of courses taught or amount of content covered, but rather the focus is on learning. It is the understanding and using of knowledge that defines the graduate. The limits did result in the elimination or the absence of topics and content favored by some faculty. A key aspect of the adoption of the new curriculum was the willingness of the entire faculty to adhere to these guidelines and limits. Individual teaching and topic preferences were not a significant factor in the final decision making process. The result is a curriculum that is both current and looks to the future.

V. New Curriculum Description

The new curriculum was developed by the entire EE faculty with additional input from related academic programs, the EE Industrial Advisory Committee, MSOE administrative leaders, and, above all, based on student feedback that had been gathered over a lengthy period of time. The results of the changes and characteristics of the new curriculum, effective for incoming freshmen for the fall of 2004, are summarized as follows:

1. Freshman year: Every quarter of the freshman year has an electrical engineering course, beginning with *Introduction to Electrical Engineering*. Subsequent courses are an *Introduction to Computer Programming* and the first circuits course. The programming course is microprocessor-based (using a custom-designed Atmel-based experiment board) and specifically focuses on the interaction between programming and various hardware peripherals, as opposed to "action" on a computer screen only. The credit load in terms of credits and laboratories increases after the fall quarter. We believe it is necessary to

include a consideration of the transition of living away from home and in a very different academic environment as part of the "load" for the first quarter.

2. Circuit course sequence: A laboratory was included in the first two of the three course sequence. Student's lack of familiarity with real electrical components and concepts is a significant problem in their ability to understand circuit theory.
3. Most significant new required EE courses:
    a. Dynamic Systems – the course has an interdisciplinary flavor and serves as a prerequisite to a course in Control Systems. It covers some of the material from Dynamics (an ME course) that was dropped from the curriculum.
    b. Systems Interfacing – one of the most fundamental long term trends is the higher level of integration used in design. There is a major increase in the use of specialized integrated circuits and design at the system or subsystem level.
    c. Digital Signal Processing – the dominance of digital signals and the need to process such signals make this course essential. This course will precede the traditional continuous-time signal processing course.
    d. Electromagnetic (EM) Waves – with the advent of wireless technology, the critical importance of electromagnetic compatibility (EMC), and the critical nature of signal integrity, we have returned to a two-course EM sequence.
4. Other significant changes:
    a. Material Science – we dropped a second quarter of general chemistry in favor of a course with a chemistry-focus on Material Science. This course, in conjunction with the remaining chemistry course, Modern Physics, and Physics of Electronics provides a background for understanding developments in the material sciences.
    b. Technical Electives – like in many academic programs the past listed electives reflected the interests of the faculty and in many cases were seldom offered. A new series of electives will be defined that will be offered once each year and will be a logical extension of the key EE topic areas developed in the junior year.
    c. Linear Algebra – this course was added to enhance the math skills of our students and as an essential course for all who had plans for graduate school. We have found that valuable course time is otherwise too often used for explaining mathematical operations students should be more familiar with. It replaces a course in Vector Calculus.
5. Senior Design: The essentials of the academic year-long team project were retained. What has been or is being added is a greater integration of non-technical topics into team discussions with the academic advisor and outside speakers. The topics relate to aspects of business, communication, and domestic and international economic trends.

The entire new curriculum is shown in the attached Appendix. One central understanding the entire faculty had to wrestle with is that the absence of a given topic did not mean it was unimportant. A long list of topics that are important to know can readily be generated. The curriculum content and courses chosen simply were more important for our program than the topics not chosen. Further, some topics that were not included in the required topic list will appear among the technical electives.

The curriculum changes of the freshman year also specifically addressed the issue of retention. We believe it is critical to "get hold" of our students as early in their academic career as possible and foster the building of bonds with their fellow classmates, the faculty, and the advisors. An additional key desire is to instill in the students the standards that define academic success. We have found relying on other departments to do this meets with limited effectiveness. Hence, only if the faculty of the EE program has the necessary contact and interaction with the students can this be accomplished. Since the new curriculum was implemented in the fall of 2004, no data on retention exists at this time.

As can be seen from the course listing in the Appendix, the curriculum has retained its traditional emphasis on including associated course laboratories and integrating a major design focus. We have found that this combination strongly reinforces the theory of the lecture and enhances student understanding.

VI. Conclusion

The curriculum of the EE program has been thoroughly reviewed and revised with an emphasis on achieving student academic success and maintaining a depth and breadth that represents the EE profession. The curriculum reflects the technical currency of the field and its future directions.

The curriculum has retained its broad range of content topics and its traditional strong design and laboratory focus. Further, these emphases will prepare graduates for industry and graduate school studies.

The curriculum is an acknowledgment that graduates have the responsibility to understand that a four-year curriculum provides the beginning of a path of life-long learning.

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Biographical Information

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Dr. Stephen Williams is Associate Professor of Electrical Engineering and Computer Science at the Milwaukee School of Engineering (MSOE). He received the Ph.D. degree from the University of Missouri in 1990 and has 20 years of experience across the corporate, government, and university sectors. He is a registered Professional Engineer in Wisconsin. He teaches courses in control systems, electronic design, and electromechanics.

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OWE PETERSEN
Dr. Petersen is Interim Department Chair and Professor of Electrical Engineering and Computer Science at the Milwaukee School of Engineering (MSOE). He is a former Member of Technical Staff at AT&T Bell Labs and received his Ph.D. degrees from the University of Pennsylvania in 1971. He is a Senior Member of the IEEE and an ABET EAC program evaluator in Electrical Engineering.

Appendix

BACHELOR OF SCIENCE IN
ELECTRICAL ENGINEERING
Model Full-Time Track

Version 15.0
02/08/04

		-------------QUARTER---------		
FRESHMAN YEAR		**1**	**2**	**3**
EE-100	Intro to Electrical Engineering	1-2-2		
MA-136	Calculus for Engineers I	4-0-4		
EN-131	Composition	3-0-3		
MS-221	Microeconomics	3-0-3		
HU-100	Contemporary Issues	3-0-3		
OR-100	Freshman Orientation[1]	1-0-0		
EE-1910	Intro to Computer Programming		3-3-4	
MA-137	Calculus for Engineers II		4-0-4	
EN-132	Technical Composition		3-0-3	
CH-200	Chemistry I		3-2-4	
EG-1260	Engineering Graphics – Visualization		0-2-1	
EE-2050	Linear Circuits – Steady State I			3-2-4
MA-231	Calculus for Engineers III			4-0-4
PH-110	Physics of Mechanics			3-2-4
EN-241	Speech			2-2-3
EG-1270	Engineering Graphics – CAD			0-2-1
	TOTALS	**15-2-15**	**13-7-16**	**12-8-16**
SOPHOMORE YEAR		**4**	**5**	**6**
EE-2060	Linear Circuits – Steady State II	3-3-4		
EE-2920	Embedded Systems	3-2-4		
MA-235	Differential Equations for Engineers	4-0-4		
PH-230	Physics of Electricity & Magnetism	3-3-4		
EE-2070	Linear Circuits – Transients		3-0-3	
EE-290	Digital Logic Circuits		3-3-4	
MA-232	Calculus for Engineers IV		3-0-3	
PH-220	Physics of Heat, Wave Motion & Optics		3-3-4	
ME-255	Engineering Statics		3-0-3	
CS-2510	Intro to Object Oriented Programming			2-2-3
EE-2930	Systems Interfacing			2-2-3
MA-383	Linear Algebra			3-0-3
PH-250	Modern Physics			3-3-4
ME-354	Thermodynamics & Heat Transfer			3-0-3
	TOTALS	**13-8-16**	**15-6-17**	**13-7-16**

[1] Transfer students who have completed 36 quarter credits or 24 semester credits will be waived from OR-100 but will be required to complete OR-301 Transfer Student Orientation.

JUNIOR YEAR		QUARTER 7	QUARTER 8	QUARTER 9
EE-3050	Dynamic Systems	3-0-3		
EE-310	Analog Electronics I	3-3-4		
MA-262	Probability and Statistics	3-0-3		
PH-360	Physics of Electronics	3-3-4		
IE-423	Engineering Economy	3-0-3		
EE-311	Analog Electronics II		3-3-4	
EE-320	Electric & Magnetic Fields		4-0-4	
EE-3220	Digital Signal Processing		3-2-4	
EE-3720	Control Systems		3-3-4	
GE-300	Career & Professional Guidance		0-2-1	
EE-303	Signal Analysis			4-0-4
EE-3210	Electromagnetic Waves			2-2-3
EE-340	Electromechanical Energy Conversion			3-3-4
CH-3650	Material Science			2-2-3
Elective	HU/SS Elective[2]			3-0-3
	TOTALS	**15-6-17**	**13-10-17**	**14-7-17**

SENIOR YEAR		10	11	12
EE-407	Senior Design Project I	3-0-3		
EE-392	Digital System Design	3-2-4		
EE-4020	Principles of Communications	3-2-4		
Electives	Electives (one Technical, one HU/SS)[2]	6-0-6		
EE-408	Senior Design Project II		2-3-3	
SS-461	Organizational Psychology		3-0-3	
Electives	Electives (two Technical, one HU/SS)[2]		9-0-9	
EE-409	Senior Design Project III			2-3-3
HU-432	Ethics for Professional Managers & Engineers			3-0-3
Electives	Electives (one Technical, two HU/SS)[2]			9-0-9
	TOTALS	**15-4-17**	**14-3-15**	**14-3-15**

[2] The 27 credits of elective subjects in the Electrical Engineering program must be taken as follows:

- 15 required credits of Humanities and Social Science (HU/SS) electives. Of these 15 credits, 6 must be taken in the Humanities area (HU), 6 must be taken in the Social Sciences area (SS), and the remaining 3 must be taken in either the Humanities or the Social Sciences.
- 12 credits of Technical Electives from the approved program elective list.

All Technical Electives must be at the 300 or 400 level.

Engineering Technology courses may not used to satisfy any Electrical Engineering program requirements

Students in Air Force ROTC may make the following course substitutions: the course combination AF-400/401 for SS-455 (HU/SS elective), AF-402 for a Technical Elective, and the course sequence AF-300/301/302 for both EE-3210 and SS-461. Additional AF courses cannot be used to satisfy any Electrical Engineering requirements.

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