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Innovation in Engineering Education: Reshaping the Electrical Engineering Curriculum

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Abstract: *Research on engineering education curriculum and coming up with a structure that will allow electrical and computer engineering students to be introduced to the first circuit course and digital logic design at the freshman level is of great significance. Allowing students in these fields to be introduced to the electrical/computer engineering courses at the freshman level and with the just needed calculus and differential equation knowledge will allow those students to take more advance courses early in the junior and the senior levels. Research will be conducted to show that there are many schools up to this date that are still introducing the circuit classes at the second and the third year level and these schools are offering the advance electrical/computer engineering courses mostly late in the senior year. The proposed change in the electrical/computer engineering curriculum will shift the offering of the circuit classes to the freshman level allowing a less tense electrical/computer engineering advance courses later at the junior/senior level. This shifting of the curriculum will demand a change in the curriculum structure of the circuit courses. By doing that, this change will allow the students to learn and get introduced to more courses in the ever developing field and yet give them an edge and make them better prepared to enter the practical field.*

Keywords: *Electrical Engineering Curriculum, Computer Engineering Curriculum, Circuit Classes, Early Circuits, More Advanced Courses at Junior/Senior Level*

1. INTRODUCTION

There has been significant research in the area of curriculum development and instruction. Visions for a new century engineering education have been discussed [1]. With the advancement of new research areas in the areas of engineering in general and electrical and computer engineering in particular, new methods of engineering curriculum changes and instruction was discussed [2]. Although technology is an essential element in the engineering curriculum, but a holistic approach to engineering curriculum and instruction was introduced [3]. Teaching for quality learning was of most importance at many universities and the question of what the student should learn was emphasized [4]. As new technologies and new research areas are evolving continuously, the question of what the engineers should know as they go into the practice field becomes demanded immediate answers [5]. The quest for reform in engineering education and reshaping the engineering curriculum was evident in trying to adapt engineering curriculum to the twenty first century [6,7].

The paper will establish the need of the proposed change and the method of reshaping the electrical/computer engineering curriculum will be explained. The benefits of this change will be illustrated to

2. DATA GATHERING

In most engineering schools that offer electrical and engineering programs, the circuit course sequence is usually offered at a time where high level calculus and differential equation material is introduced. Table 1 shows a list of many electrical/computer engineering schools along with the semester where the circuit classes sequence is offered. This study was done for the academic year of 2016-2017 and data was obtained from the institution's websites. The electrical/computer engineering of sample universities was looked at.

Table-1. *Engineering Schools and Current Circuit Courses Offerings*

Name of University/ College	Course	Pre-Requisite For Course	Term Given
Georgia Tech University	ECE 2040: Circuit Analysis I	PHYS 2212/2232 (Introductory Physics I/ II) [min C] and MATH 2403*/2413*/24X3 (Differential Equations,) [min C]* Prerequisites indicated with an asterisk may be taken concurrently with ECE2040	Sophomore 1st Semester (Fall, Spring)
Clemson University	ECE 2020 Electric Circuits I	Pre-requisite: Sophomore 1st Semester -PHYS 2210 (Physics with calculus II) with a C or better.	Sophomore 1st Semester (Fall, Spring)
MIT	6.002 Circuits and Electronics	Prerequisite: Physics II (GIR); *Co-requisite:* 18.03 (Calculus II (GIR)) *or* 2.087 (Physics I (GIR)) AP level physics course in electricity and magnetism. You must know basic calculus and linear algebra and have some background in differential equations.	Sophomore 1st Semester (Fall, Spring)
University of SC (USC)	ELCT 221: *Circuits*	Pre-requisite – ELCT 101 (Electrical and Electronics Engineering), *ELCT 102 (Electrical Science) and MATH 142* (Calculus I & II)	Sophomore 1st Semester (Fall, Spring)
North Carolina A & T	ECEN 200. Electric Circuit Analysis	MATH 131, PHYS 241, PHYS 251, MATH 132, MATH 431	Sophomore 1st Semester (Fall, Spring)
Florida A & M	Electronic Devices and Circuits	Prerequisite: MAC 2312 (Calculus II) Co-requisites: MAC 2313 (Calculus III) and PHY 2049 (General Physics II w/Lab) C for FSU student or PHY 2049PHY 2049L (General Physics II w/Lab) for FAMU students	Sophomore 1st Semester (Fall, Spring)
Cal Tech	EE 44 - Circuits and Systems	Prerequisites: Phys1, should be taken concurrently with Math II and Physics II.	Sophomore 1st Semester (Fall, Spring)
Cornell	ECE 2100 Introduction to Circuits for Electrical and Computer Engineers	MATH 1910 (Calculus for Engineers), Physics 1112 (Physics I-Mechanics), Math 1920 (Multivariable Calculus for Engineers), Physics 2213 (Physics II-Electromagnetism), Math 2930 (Differential Equations for Engineers)	Sophomore 1st Semester (Fall, Spring)
Columbia University	ELEN E3201 Circuit analysis	Circuits I, Circuits II, Physics I	Sophomore 1st Semester (Fall, Spring)
Hampton University	EGR218 Circuit Analysis I	MAT151 Calculus I PHY203 Intro. to Physics I MAT152 Calculus II PHY204 Intro. to Physics II MAT260 Diff. Equations Prerequisites: a grade of C or better in MATH 212. Pre- or co-requisite: PHYS 232N.	Sophomore 1st Semester (Fall, Spring
Tennessee State University	Engr_2000 Circuits I	MATH 1910- Calculus I, MATH 1920 – Calculus II, PHYS 2110 – Physics I, PHYS 2111 – Physics II, MATH 2110 – Differential Equations	Sophomore 1st Semester (Fall, Spring)
Jackson State University	EN 220 Circuit Theory I	MATH 241 Calculus, MATH 242 Calculus II,	Sophomore 1st Semester (Fall, Spring)
Montgomery College	ENEE 207 Electric Circuits,	MATH 181 Calculus I (MATF), PHYS 262 General Physics II, MATH 182 Calculus II, MATH 282 - Differential Equations	Sophomore 2nd Semester (Fall, Spring)

It can be seen in Table-1 that

1. All the Circuit courses are offered during the sophomore year
2. Differential calculus is required for most cases

3. The least prerequisite is Calculus II and Physics II that are offered during the second semester freshman year

3. The Current State of the Curriculum and the Courses

The goal of this paper is to show the need for shifting up one semester the offering of the first circuit course and also to show why and how it is done. It has been demonstrated using Table-1 that the circuit course first part is offered at the first semester sophomore year or later in some school. Let us now look at the structure and contents of the circuit courses that are always offered using a single textbook.

The classical textbook used for the two circuit courses has the content as seen in Table-2. The typical circuits/electronics sequence is also given in Figure-1

Table-2: *The Classical Circuits Textbook Content*

Typical List of Subjects Covered in the Circuits Course Sequence	
❖Chapter 1. Circuit Variables	❖ Chapter 10. Sinusoidal Steady-State Power Calculations
❖Chapter 2. Circuit Elements	❖ Chapter 11. Balanced Three-Phase Circuits
❖Chapter 3. Simple Resistive Circuits	❖ Chapter 12. Introduction to the Laplace Transform
❖Chapter 4. Techniques of Circuit Analysis	❖ Chapter 13. The Laplace Transform in Circuit Analysis
❖Chapter 5. The Operational Amplifier	❖ Chapter 14. Introduction to Frequency-Selective Circuits
❖Chapter 6. Inductors, Capacitors, and Mutual Inductance	❖ Chapter 15. Active Filter Circuits
❖Chapter 7. Response of First-Order RL and RC Circuits	❖ Chapter 16. Fourier Series
❖Chapter 8. Natural and Step Responses of RLC Circuits.	❖ Chapter 17. The Fourier Transform.
❖Chapter 9. Sinusoidal Steady-State Analysis	

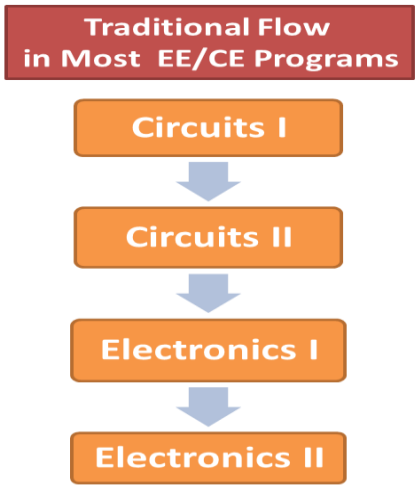


Figure-1. *A Typical Circuits/Electronics Course Sequence*

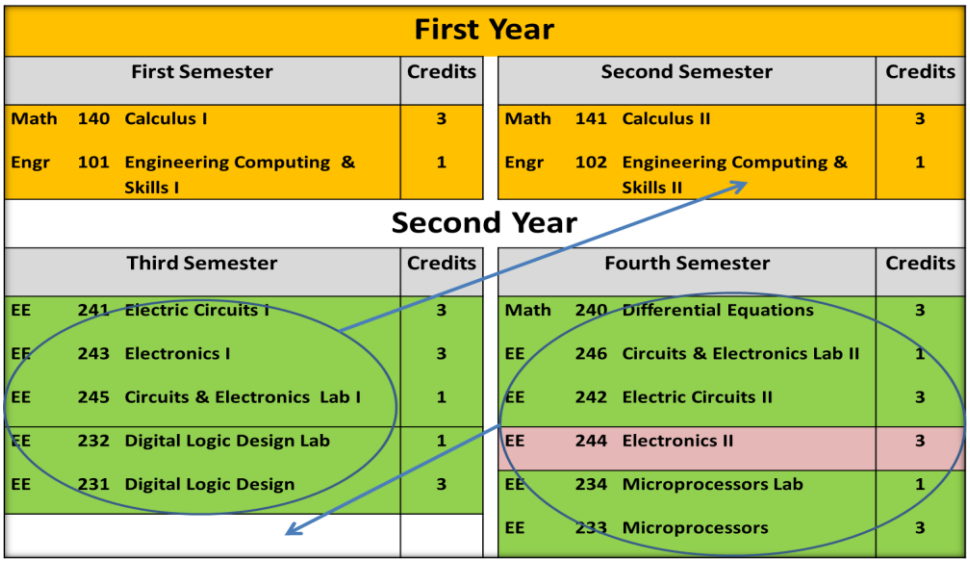
Currently and in all schools, chapters 1 through 8 are the contents of Circuit I and the chapters, 9 through 17 are the contents of the Circuits II course. Chapters 7 and 8 are the two chapters that are so important to the electrical and computer engineer and to fully grasp this content, students need advance calculus to include differential equations. This is why the Circuits I course is always given at least during the first semester sophomore year.

4. The Proposed Change

Taking a closer look at the Table-2, you can see that chapters 1 through 8 are always taken to be the content of the first circuit course. Differential Equations is a subject that chapters 7 and 8 heavily depend on. Chapters 1 through 6 and then 9 through 11 all require basic first semester calculus and knowledge of basic complex numbers that students usually take in high school.

Arranging the contents as seen in Table-2 by grouping chapters 1 through 6 and 9 through 11 and making them the content for the Circuit I course will work and students with the first calculus course can take Circuits I at the second semester freshman year. Chapters 7 through 8 and 12 through 17 can be group together and be made the content of Circuits II that can be taken the following semester.

Following this process, the offering of Circuits I can be moved to the freshman year second semester along with calculus II. The digital logic design course can also be offered at this level for there is no need for any calculus based math course at this stage. Electronics I can also be taken along with the Circuits I if the school is interested in applying the project based learning module where more than one course can be integrated and taught together. Figure-2 shows how a typical first year curriculum may look like.



First Year					
First Semester		Credits	Second Semester		Credits
Math 140	Calculus I	3	Math 141	Calculus II	3
Engr 101	Engineering Computing & Skills I	1	Engr 102	Engineering Computing & Skills II	1
Second Year					
Third Semester		Credits	Fourth Semester		Credits
EE 241	Electric Circuits I	3	Math 240	Differential Equations	3
EE 243	Electronics I	3	EE 246	Circuits & Electronics Lab II	1
EE 245	Circuits & Electronics Lab I	1	EE 242	Electric Circuits II	3
EE 232	Digital Logic Design Lab	1	EE 244	Electronics II	3
EE 231	Digital Logic Design	3	EE 234	Microprocessors Lab	1
			EE 233	Microprocessors	3

Figure-2. *Typical Part of First Year Electrical/Computer Engineering Curriculum*

5. CONCLUSION

The need to undertake the proposed changes to the electrical/computer engineering curriculum was established by data gathering on many universities of different ranks. Many other universities share the same theme of offering the first course in circuit analysis during the sophomore year. Assuming that students will take their first circuit course during the first semester of the sophomore year, they will complete the second circuit course by the end of the 4th semester. It is also not unusual that the schools will offer the electronics courses and the digital logic course afterward. By arranging the content of the classical circuit textbook that is always used for both the two courses, we will be able to change the content of the first circuit course and aligned it with calculus I. With this change, the offering of circuits I can be shifted easily to the second semester of the freshman year where it can be taken with the digital logic course at the same time. Furthermore, electronics I can be taken alongside with circuits 1 as an integrated course module while the two courses with their labs are taught together during extended-hours period.

This shifting of courses of at least one semester will allow curriculum designers to be able to fit more advanced courses in the electrical/computer engineering area and thereby, putting our engineering graduate at a greater advantage in being more prepared to tackle a wider range of the many ever evolving electrical and computer engineering disciplines.

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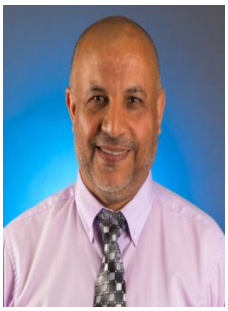

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