On the Development and Teaching of an Analog Mixed Signal-Based Curriculum with Emphasis in Design and Testing Techniques at Prairie View A&M University

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Abstract

We developed an analog mixed signal-based curriculum at Prairie View A&M University (PVAMU). The objective is to meet the demanded need of industry such as Texas Instruments, Motorola, and other semiconductor, electronics and communication industries by training students in this new area. The intensive exposure of the students to state-of-the-art mixed signal semiconductor electronics testing and design equipment, technologies, softwares and techniques prepares the students to be highly productive once they graduate. Therefore, less time is spent in coming up to speed in the work place. This curriculum development is for the training of highly talented students in the area of analog mixed signals (AMS) with emphasis in design and testing techniques. Three new courses and a new laboratory course have been developed, two at the undergraduate level including the laboratory course (Analog Mixed Signal Testing Techniques I & II, and Analog Mixed Signal Testing Techniques Lab); and the other at the graduate level (Advanced Analog Mixed Signal Testing Techniques). These courses complement the rich curriculum presently offered in the department of electrical engineering at PVAMU. A new AMS laboratory has also been developed to support both instruction and research. This helps to create an academic instructional and research infrastructure for mixed signal-based projects and research in the areas of testing.

Introduction

PVAMU attaches much importance to the training of students like any other university to meet the needs of future technology trends. As a result of the technology growth shown in the area of mixed signals, it has become one of the areas we placed much emphasis to develop curriculum and the necessary infrastructure for. This has necessitated the development of new courses, an instructional and research laboratory in the general area of analog mixed signal testing and design [1,2].

Within the semiconductor industry, analog mixed signal circuits and systems are growing rapidly and command a large share of the communication systems market. This is not only true in the state of Texas or nationally, but also worldwide. The problem is that it has become increasingly difficult to find qualified engineers to fill the necessary job positions needed to produce the analog mixed signal products. It is particularly true in the areas of analog mixed signal design

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and testing. This is a big threat to the leadership position that these industries like Texas Instruments, Inc. currently enjoys and to the future existence of the companies in maintaining that leadership position. As part of the objectives of this program in trying to fill this gap, four courses have been developed in the area of mixed signal design and testing techniques including a laboratory course to support the courses.

Four new courses and a new laboratory course have been developed, three at the undergraduate level including the laboratory course (Analog Mixed Signal Testing Techniques I & II, and Analog Mixed Signal Testing Techniques Lab); and the other at the graduate level (Advanced Analog Mixed Signal Testing Techniques) [1,2]. These courses complement the rich curriculum presently offered in the department of electrical engineering at PVAMU. A new AMS laboratory has also been developed to support both instruction and research. This helps to create an academic instructional and research infrastructure for mixed signal-based projects in the areas of testing.

These courses are taught both at the undergraduate and graduate levels respectively. To accomplish these new emphases at Prairie View A&M University, a new Analog Mixed Signal laboratory with emphasis in design and testing has been developed to support the newly developed curriculum. This now helps PVAMU to attract high caliber students to the program and to continue with its mission of educating young talented men and women who will eventually be the future employees of the semiconductor industry such as TI, and also to develop the Analog Mixed Signal component of the Electrical Engineering Department infrastructure.

The Developed Curriculum and Analog Mixed Signal Courses

PVAMU Electrical Engineering department has identified the need and opportunity for an Analog Mixed Signal (AMS) emphasis in design and testing. The proposed Analog Mixed Signal design and testing techniques, without question, tend to meet the needs of both industry and academia because of the acute shortage of skilled qualified engineers. In meeting the industry's need for well trained entry level Analog Mixed Signal design and test product engineers, the PVAMU AMS curriculum has now included the mixed signal courses as shown in Table I.

The Green color shows the University core courses. The Pink color shows the MATH and Science courses. The Dark Red color shows the Analog Mixed Signal courses. The Red color shows the engineering support courses. The Teal color shows the Digital courses. The modification and the introduction of new courses will help give the students a high-tech curriculum. Table I shows the flow of the suggested emphasis for the major in electrical engineering in Analog Mixed Signals. The newly developed course descriptions, prerequisites, and corequisites recommended for the AMS curriculum are discussed in the next Section.

Table I

Suggested Curriculum for the Major in Electrical Engineering with Emphasis in Analog Mixed Signal Design and Testing 1998-2001

FRESHMAN YEAR

First Semester	Hours	Second Semester	Hours
CIID 0110 General Studies	0	ENGL 1143 Technical Writing	3
ENGL 1123 Freshman Composition	3	MATH 2024 Calculus	4
MATH 1124 Calculus I	4	CHEM 1043 General Chemistry II	3
CHEM 1033 General Chemistry I	3	CHEM 1021 Inorganic Chemistry Lab	1
CHEM 1011 General Chemistry Lab 1	1	PHYS 2013 Engineering Physics I	3
MCEG 1213 Creative Engineering I	3	PHYS 2511 General Physics Lab I	1
SPCH 1003 Fundamentals of Speech	3	ELEG 1043 Computer Applications in Engineering	3
Total	**17**	**Total**	**18**

SOPHOMORE YEAR

First Semester	Hours	Second Semester	Hours
MATH 2043 Differential Equations	3	MATH 4173 Advanced Math for Engineers	3
MATH 3023 Probability & Statistics	3	ELEG 2023 Network Theory I	3
PHYS 2023 Engineering Physics II	3	ELEG 3033 Physical Electronics	3
PHYS 2511 General Physics Lab I	1	ELEG 3011 Circuits Lab	1
CVEG 2454 Statics and Dynamics	4	MCEG 2013 Thermodynamics	3
HIST 1313 The U.S. to 1876	3	HIST 1323 The U.S. 1876 to Present	3
Total	**17**	**Total**	**16**

JUNIOR YEAR

First Semester	Hours	Second Semester	Hours
ELEG 3013 Network Theory II	3	ELEG 3023 Signals and Systems	3
ELEG 3063 Logic Circuits	3	ELEG 3043 Electronics I	3
ELEG 3021 Logic Circuits Lab	1	ELEG 4011 Electronics Lab	1
CHEG 3003 Engineering Economy	3	ELEG 4013 Energy Conversion	3
POSC 1113 American Government I	3	POSC 1123 American Government II	3
Humanities/Social Science Elective	3	Humanities/Social Science Elective	3
Total	**16**	**Total**	**16**

SENIOR YEAR

First Semester	Hours	Second Semester	Hours
ELEG 4043 Electronics II	3	ELEG 4073 Control Systems	3
ELEG 4303 Digital Design	3	ELEG 4483 Senior Design Project II	3
ELEG 4003 Communication Theory	3	ELEG 4033 Electromagnetic Field Theory	1
ELEG 4473 Senior Design Project I	3	*Electrical Engineering Lab (Elective) (ELEG 3041 Micro. Proc. & Charc. Lab.	3
Humanities/Social Science Elective	3	*Technical Elective (ELEG 4XXX)	3
Technical Elective(ELEG 4053 (DSP)	3	*Technical Elective (ELEG 4263) - VLSI	3
Total	**18**	**Total**	**16**

The Proposed New Courses

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The undergraduate and graduate courses developed to update the curriculum are as follows:

ELEG 4273 Analog and Mixed Signal Techniques I
ELEG 4283 Analog and Mixed Signal Techniques II
ELEG 4291 Mixed Signal Testing Techniques Lab
ELEG 5xxx Advanced Mixed Signal Techniques

The 4XXX level courses are taught at the senior undergraduate level while the 5XXX level course is taught at the graduate level. First year graduate students can also take 4XXX level courses especially transfer or new students to the Mixed Signal curriculum. A more detailed description of these courses follows in the next Sections.

Detailed Descriptions of the Newly Developed Courses

Course: ELEG 4273-001-Analog & Mixed Signal Techniques (3-0) Credit 3 Sem. Hrs.
Prerequisite: ELEG 3043 Electronics I and ELEG 3063 Logic Circuits
Co requisite: ELEG 4003 Communication Systems
Text: Burns and Roberts, *"Introduction to Mixed-Signal Test and Measurement"*, Oxford Univ. Press, New York, Nov. 2000.

Additional Course References:

A. Hastings, *"The Art of Analog Layout",* Internal Manuscript, Texas Instruments, 1999.
P.Gray and R. Meyer, *"Analysis and Design of Analog Integrated Circuits",* 3rd Ed., John Wiley & Sons, Inc.1993.
Ismail and Fiez, *"Analog VLSI: Signal and Information Processing",* McGraw Hill, Inc., 1994.
Digital Signal Processing Principles, Algorithms, and Applications, 3rd ed., by John G. Proakis and Dimitris G. Manolakis; Prentice Hall, 1996.
References at the back of the chapters in the Text for the class.

Course Description: ELEG 4273 (3-0) Credit 3 Semester Hours. Overview of analog and digital logic circuits, mixed signal circuits and systems, mixed signal test specification process, DC and parametric measurements, tester hardware, DSP-based testing, simulation and design techniques, power management circuits and systems[3].

Goals: The goals of this course are to develop the application, implementation and techniques necessary for the design, testing and measurement of analog mixed signal circuits and systems. The course is intended to provide the necessary skills and concepts for the student to become a well accomplished analog mixed signal test and measurement engineer. It is the goal of the course to help the student to produce hardware and software that will be used by any analog mixed signal test equipment such as automatic test equipment (ATE). Digital signal processing design and testing concepts, techniques and approaches to various communication engineering systems using among other techniques frequency and time domain methods will be explored. Applications and implementations to various areas of AMS communications systems such as

PMP issues, Wireless, xDSL will be explored. IC layout and design issues relating to AMS testing will also be discussed.

Course Outcomes for Students: Upon completing this course, the student is expected to:

- Understand Analog and Mixed-Signal Testing Techniques.
- Be able to apply and implement the techniques necessary for the design, testing and measurement of analog mixed signal circuits and systems especially, in the areas of DC and Parametric Measurements, Measurement Accuracy, Sampling Theory, DSP-Based Testing and Analog Channel Measurements.
- Understand and be knowledgeable with most of the hardwares and softwares that can be used in analog mixed signal testing such as automatic test equipment (ATE), LabView™, etc.

Topics Covered in the Course[3]:

- Introduction.
- Overview of Mixed-Signal Testing
- The Test Specification Process.
- DC and Parametric Measurements.
- Measurement Accuracy.
- Tester Hardware
- Sampling Theory
- DSP-Based Testing
- Analog Channel Measurements
- Projects.

Course Projects: Students are expected to select a project topic, propose the nature of the problem to be solved and this requires the approval of the professor. There will be a required report on the project that must be handed in to the professor and presented to the class at the conclusion of the semester.

The Other Courses Developed in the Analog Mixed Signal Curriculum

The other courses are similar to the ELEG 4273 in terms of the format as described above. For brevity, we are only stating the description of the courses in this Section of the paper. If anyone is interested to know more, please do not hesitate to contact the author. These other courses are:

Course: ELEG 4283 Analog and Mixed Signal Techniques II (3-0) Credit 3 semester hours.

Course Description: This course covers **s**ampled channel testing, Focused calibrations, DAC Testing, ADC Testing, DIB Design, and Design for Test (DfT). IC layout and design issues relating to AMS testing. Data Analysis, Test Economics , Special Topics in Mixed Signal Systems and Projects. The prerequisite is ELEG 4273-Analog Mixed Signal Techniques I.

Course: ELEG 4291 Analog and Mixed Signal Techniques Lab (0-3) Credit 1 semester hour.

Course Description for ELEG 4291: This laboratory course covers Mixed Signal Measurements, Mixed Signal Parameter Measurements, Signal Sourcing Techniques, Signal Capturing Techniques, Frequency Domain Measurements, DSP- based testing, DAC testing, ADC Testing, Template test and Analog Circuit Review. Co requisite: ELEG 4273 Analog Mixed Signal Techniques I^3.

This course provides hands-on experience in the expanding areas of microelectronics and communication industries. The students learn the practical aspects of mixed signal-based and DSP-based testing. The students also learn software and hardware development tools necessary for mixed signal and DSP-based testing.

Course: GNEG 5193-021 - Advanced Analog Mixed Signal Techniques (3-0) Credit 3 semester hours. This is the graduate course developed for the continuation of this mixed signal curriculum.

Course Description: Advanced areas of analog mixed signals. Advanced testing and analysis techniques of various analog mixed signal (AMS) integrated circuits and systems. Wavelets and Wavelet Transforms and their applications to mixed signal testing issues. Advanced Considerations in the issues involved in the layout and design of analog ICs. Students will be expected to research and present various topics of interests in class. Projects are expected from the students at the end of the semester. Other special topics of interest will be covered especially as they relate to Data Converter and Power Management Product (PMP) issues. Lab sessions will be combined with lectures in this course as deemed necessary by the professor. Prerequisite: ELEG 4283 Analog and Mixed Signal Techniques II, Graduate Standing or permission of Instructor.

Goals: The goals of this course are to develop the application, implementation and techniques necessary for the design, testing and measurement of analog mixed signal circuits and systems. The course is intended to provide the necessary advanced skills and concepts for the student to become a well accomplished analog mixed signal test and measurement engineer. It is the goal of the course to help the student to produce hardware and software that will be used by any analog mixed signal test equipment such as automatic test equipment (ATE). Advanced Digital signal processing design and testing concepts, techniques and approaches to various mixed signal systems using among other techniques, frequency and time domain methods will be explored. Applications and implementations to various areas of AMS communications systems such as Data Converter & PMP issues, Wireless, xDSL will be explored. IC layout and design issues relating to AMS testing will also be discussed.

Course Outcomes for Students: Upon completing this course, the student is expected to:

- Understand Analog and Mixed-Signal Testing Techniques.
- Be able to apply and implement the techniques necessary for the design, testing and measurement of analog mixed signal circuits and systems especially, in the areas of sampled channel testing, focused calibrations, DAC and ADC testing, DIB design, design for test (DfT), IC layout and design issues relating to AMS testing, data analysis, test economics and PMP issues.

- Understand Wavelets and Wavelet Transform-Based testing of Mixed Signal Systems.
- Understand and be knowledgeable with the hardwares and softwares that can be used by most analog mixed signal test equipment such as automatic test equipment (ATE).
- Be knowledgeable with digital signal processing design and testing concepts.

Topics Covered include the following:
Introduction, Overview of Mixed-Signal Testing, Wavelet and Wavelet Transform Techniques, Application of Wavelet and Wavelet Transform Techniques to Mixed Signal Testing, Advanced Digital Signal Processing applied to mixed signal testing, Wavelet-based DAC Testing, Wavelet-based ADC Testing, DIB Design, Design for Test (DfT), IC layout and design issues relating to AMS testing, Data Analysis, Test Economics, Special Topics in Mixed Signal Systems and Projects.

Selected Course Projects

In all the courses described in this paper, there are course projects associated with them. We have listed some of them in this section for the reader. It should be noted that the level of difficulty is based on the standing of the student whether undergraduate or graduate student.

Project Topic List
Wavelet-Based Smart Scheme for Mixed Signal System Testing
Study of Wavelet-Based and FFT-based testing of Mixed Signal Systems Applied to Communication Systems
Study of Wavelet-Based and FFT-Based testing of Mixed Signal Systems as Applied to Communication Systems
Testing of Radiation Effects on Mixed Signal Systems
The Effects of Radiation on an Analog-to-Digital Converter
Effects of Radiation on Communication Systems, Using Wavelets to Analyze Error Effects.
Modeling and testing Substrate Noise in RF and Mixed –Signal ICs.
Designing the testing model and the Testing of Mixed Signal Systems such as ADC and DAC with the intent of minimizing the limitations of the current converters. Wavelet Transform should be used to Analyze Error Effects On the Mixed Signal Systems.
Design and Analysis of a Full Bridge Zero Voltage Switch DA-DC Converter Mixed Signal System.
Characterization and Testing of a DAC Using LabView.
Design , Implementation, Testing and Analysis of an Analog-To-Digital Converter.
Design , Implementation, Testing and Analysis of a Flash Analog-To-Digital Converter.
Design and Implementation of a Discrete Multitone Transmission (DMT) System: A Modeling and Simulation Technique.
Design, Testing and Implementation of DAC.
Design , Implementation, Testing and Analysis of an Analog-To-Digital Converter.
Modeling, Simulation and Testing of a Mixed Signal System Using LabView.
Design, development and testing of a low-cost solution OP Amp Function Generator.
Gain Characterization of BiCMOS internally compensated OP Amp: Quantification of the

Radiation and temperature induced variation of Gain.
Mixed-Signal ATE Optimization Program Development
Mixed-Signal Three-digit DOT graph Counter for Sub-Audible Frequencies.
Design, development and testing of a Mixed-Signal communication System that Guards Outside Interference and Minimizes Noise.
Designing the testing model and the Testing of Mixed Signal Systems such as ADC and DAC with the intent of minimizing the limitations of the current converters. Wavelet Transform should be used to Analyze Error Effects On the Mixed Signal Systems.
LM741 Op Amp Testing of all Spec-based Parameters: A Manual and Simulation-Based Testing Technique.
8-Bit ADC Design and Testing
LM 555 Timer Design & Testing Analysis
Mixed Signal System (DAC) Characteristics Testing - A Manual and Simulation-Based Testing Technique.

Impact to the PVAMU and Students

- Educational training of students through student research and hands on experiments that uses AMS technologies and techniques.
- Attracting more students especially minority students to the field of AMS, and Communications by providing support for their training.
- Enhancing the electrical engineering curriculum in the study of AMS and their application to communication systems and signal processing.
- To provide avenues for collaboration with other research laboratories within the university and industry.
- To expose students to real industrial experience by serving as interns with industry.

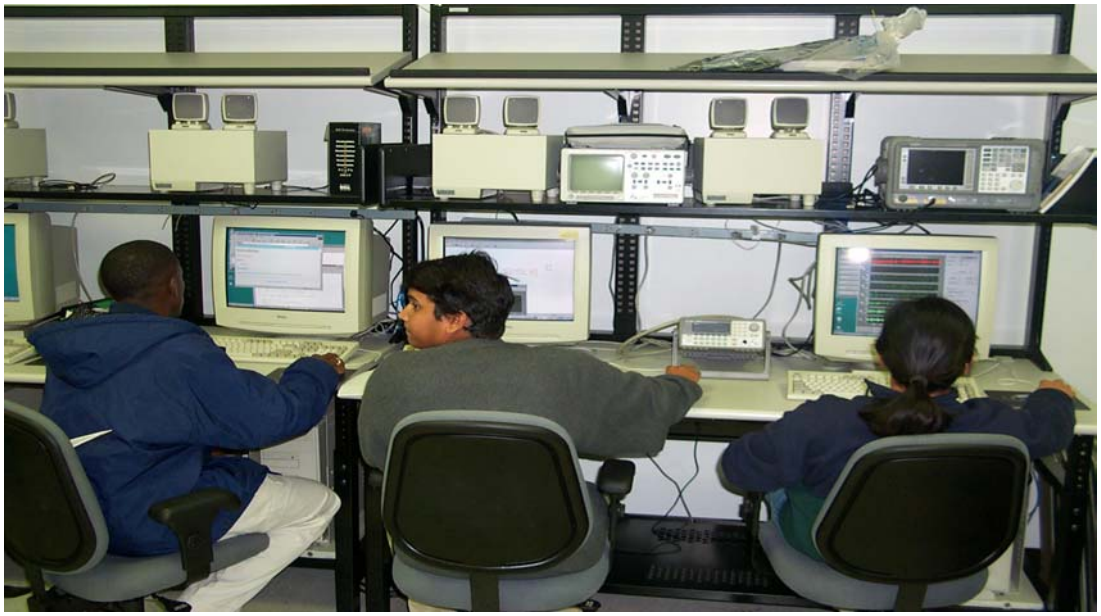

Figure1: Students working in the newly developed Analog Mixed Signal Laboratory

Summary and Conclusion

In summary, we have discussed the development of an analog mixed signal-based curriculum at Prairie View A&M University (PVAMU). The curriculum is currently meeting its objectives as planned by training students in this new area. The intensive exposure of the students to state-of-the-art mixed signal semiconductor electronics testing and design equipment, technologies, softwares and techniques have help to prepare the students to be highly productive once they graduate. Therefore, less time is now spent in coming up to speed in the work place. This curriculum development has help the semiconductor industries to increase their hiring of PVAMU students especially, those with this highly demanding skill in the area of analog mixed signals (AMS) with emphasis in design and testing techniques.

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