Advanced DSP for Undergraduates at a Small University*

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Abstract

Many universities offer a fundamentals of digital signal processing (DSP) course at the undergraduate level. Some large universities also offer advanced DSP courses. However, very few small universities offer advanced DSP courses to undergraduates. Oklahoma Christian University (OC) has developed a new curriculum that allows for an undergraduate student wishing to emphasize DSP to take three courses in this area. The first course is a fundamentals of DSP course. Advanced topics in real-time DSP systems design are covered in the second course. Adaptive signal processing is covered in the third course. All three courses rely on the use of Texas Instruments (TI) DSP devices in the laboratory.

Motivation

Emphasis in the electrical engineering field has shifted significantly to the design of digital systems. Also, systems being designed are increasingly complex [1]. In their paper, Lee and Messerschmitt describe "designers" as those who will likely have a BS or MS degree and will be designing digital systems composed of a mixture of hardware and software. They also state "As design tools increasingly take care of routine design tasks, there is less value added by routine design decisions, and more value added by overall system architecture, complexity management, and, most of all, relating the needs of the application to the design." They also describe that both software and hardware engineering are becoming concerned with "source code control, interactive debugging, data structures, compilation techniques, and programming language semantics."

These changes have had an impact on electrical engineering (EE) education. A shift is being made from emphasizing continuous-time linear time-invariant systems to discrete-time linear time-invariant systems [1], [2], [3], [4], [5], [6], [7]. Because of the emphasis on discrete-time systems, the use of digital signal processing (DSP) is becoming more wide spread. There are several institutions that are introducing DSP at the sophomore level [3], [4]. Even more common are institutions that have incorporated "real-time" DSP courses. These courses usually present DSP fundamentals along with a laboratory component that uses an evaluation board that contains a DSP device [8], [9], [10], [11]. Simple assembly and/or C programming techniques are used to run a system in real-time on the DSP board. Less frequent are institutions that bring real-time system design techniques to the undergraduate curriculum [12].

This paper describes an undergraduate curriculum at a small university designed to produce graduates with a BS degree who will be equipped to be designers mentioned earlier. This curriculum allows students to take emphasis courses in DSP which contain advanced topics. A small university can be considered as one with fewer that 2000 total students and fewer than 200 in engineering.

The next section describes the EE curriculum at Oklahoma Christian University and the three courses offered in DSP. The following section describes how OC designed the curriculum that

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would allow students to emphasize a particular area like DSP.

EE Curriculum

One of the main goals of the EE Department at OC has been "to produce students who are immediately productive in industry." To achieve this goal the department has striven to have a curriculum that is not only broad but has enough depth in specialized areas to allow students to be immediately productive. This is not to say that the curriculum is a "technology" curriculum. However, many of the tools and techniques used in the curriculum are found in industry. This curriculum is also ABET accredited.

Figure 1 shows a flow diagram of the engineering courses. The solid lines show prerequisites and the dashed lines show corequisites. Note that the last digit in the course number indicates the number of credit hours for the course. All courses must be taken by the students with the exception of the electives in the dashed box. Of these electives the students must take four courses.

Students that attend OC must take 16 credit hours of Bible courses. Because of this requirement there are more courses necessary for a degree at OC than at other universities. Therefore, the flow diagram is designed to have students graduate in 4-½ years.

Topics that are prerequisites for the DSP courses include:

- Math: calculus, differential equations, linear algebra, probability
- Programming: C++, assembly
- Discrete and Continuous-time Systems: time and frequency domain analysis of discrete and continuous-time systems, Fourier transform, Z-transform, sampling, frequency response, digital filters, state-space analysis
- Digital Circuits
- Stochastic processes: stationarity, correlation, types of processes, power spectral density, response of linear systems

As seen in figure 1, DSP is an emphasis area, meaning there are three courses offered in this area. DSP I is taken by all EE students. It is a three credit hour course with two hours of lecture and three hours of laboratory.

The theory content of DSP I is:

- Implementation of discrete-time systems
- DSP device architecture and programming
- Finite word length effects
- FIR/IIR digital filter design
- Multirate DSP
- Power spectrum estimation
- Linear prediction and optimal filtering

In the laboratory the TMS320C31 DSK has been used with the book by Rulph Chassaing [13]. Code Composer Studio (CCS), Code Explorer and the TI code generation tools are used to develop code for the DSK. Also, exercises using MATLAB/Simulink are used to simulate DSP systems and process data in real-time. This has been a very successful laboratory.

New exercises for this laboratory are currently being developed. These exercises will have similar content as previously used but will be based on the TMS320C6000 series of DSP chips. This change is being made for several reasons. First, the functionality of the C6x chips will allow experiments to be performed that are not possible on the C31 DSK. Second, the later courses will be using the C6x chips and thus it will allow a cohesive flow between courses. Third, Texas Instruments, as well as third parties and publishers, are giving much support and attention to the C6x. At the present there is not as much support in teaching tools for the C6x but this is quickly changing. One book is already available and is being considered for use [14].

DSP II will be offered for the first time in the Fall of 2001. This course will be concerned with real-time system design in the context of DSP systems. It is a four credit hour course with three hours of lecture and three hours of laboratory. Topics for the course will include:

- Real-time system development: requirements, context diagrams, data flow diagrams, state-transition diagrams, entity

relationship diagrams, design techniques, real-time operating systems
- DSP processor architecture and systems: TMS320C6000 architecture, pipeline architecture, development boards
- DSP programming: PC development tools, assembly/C programming, optimization techniques, host-target communication, I/O, host interface

Laboratory assignments will be based on the use of CCS and DSP/BIOS II. Some of the components of these tools that will be incorporated into the exercises are:

- Basics, compiling, loading, project management
- Breakpoints, probe points, file I/O
- Graph window, profiling, host interface
- Spawning and controlling tasks and data I/O
- Real-time scheduling analysis, load analysis
- Queues, semaphores and mailboxes

Two books being considered for DSP II are [15], [16].

Topics for DSP III are based on adaptive signal processing. This course has been taught in the past as a Special Topics course and will be offered in a revised form for the first time in the Spring 2002. The book for the course has been [17]. It is a three credit hour course with three hours of lecture. Assignments outside the lecture will utilize material learned in DSP I and DSP II.

Topics for the course include:

- Stationary processes and models
- Eigenanalysis
- Kalman filtering
- Method of steepest descent
- LMS and RLS
- Introduction to non-linear adaptive filters

Implementation at a Small University

When developing a curriculum the first thing to consider is available resources. At OC the resources and restrictions are:

- 5 Mechanical Engineering (ME) Professors
- 5 EE professors
- Support for Math, Science and General Education courses
- Maximum of 145 total credit hours for and EE degree
- 60 credit hours for general education courses (including 16 hours for Bible)

With 60 hours for general education there would only be 85 hours for engineering courses. This clearly would not be enough. Several courses in general education were substituted with engineering courses. After all substitutions, only 45 credits were needed to meet the general education requirements of the university. This left 100 hours to work with. The final number of hours required for an EE degree is 140.

The number of faculty in engineering is a problem. In fact, the five in each department was a minimum for previous ABET requirements. To alleviate this problem, the first two years of the ME and EE curricula are identical (within one or two classes). This left enough teaching hours to offer the courses seen in figure 1.

Breadth and depth of topics in the curriculum is a concern. Breadth is achieved through the math, science, and engineering science course. Courses chosen in these areas give the breadth necessary for students to be good engineers. This area is one of the biggest struggles since there are always more topics that seem like they should be in the curriculum than can be handled in the available hours. Compromises have to be made. Considering students going to industry and graduate school as well as the number of available hours, OC chose the courses seen in figure 1. The main compromise made was to require only two physics courses instead of the traditional three. Only time and the next ABET review will determine if that was a wise choice.

In order to provide depth in topics OC has decided to have emphasis areas in the electives. Because of the number of available faculty the number of areas of emphasis is restricted to four: DSP, Communications, Electronics and Computers. There is a danger in having depth in specialized areas at a university with few faculty.

The danger is that the curriculum can be faculty dependent. If a faculty member who teaches in a specialized area leaves the university then the emphasis area runs the risk of being dropped from the curriculum unless a suitable faculty member can be found.

Because of the number of students in the program (about 150) and the number of faculty, many of the engineering courses are only offered once a year. This is not too much of a problem for students who pass all their classes. However, for those that must repeat courses it could cause some delay in graduation.

Conclusion

A curriculum that allows students to study advanced topics in DSP at a small university is possible. In designing the curriculum compromises must be made. Through judicious choices of courses, topics and number of hours, a curriculum can be developed that will produce graduates that are "immediately productive in industry" and prepared for graduate school.

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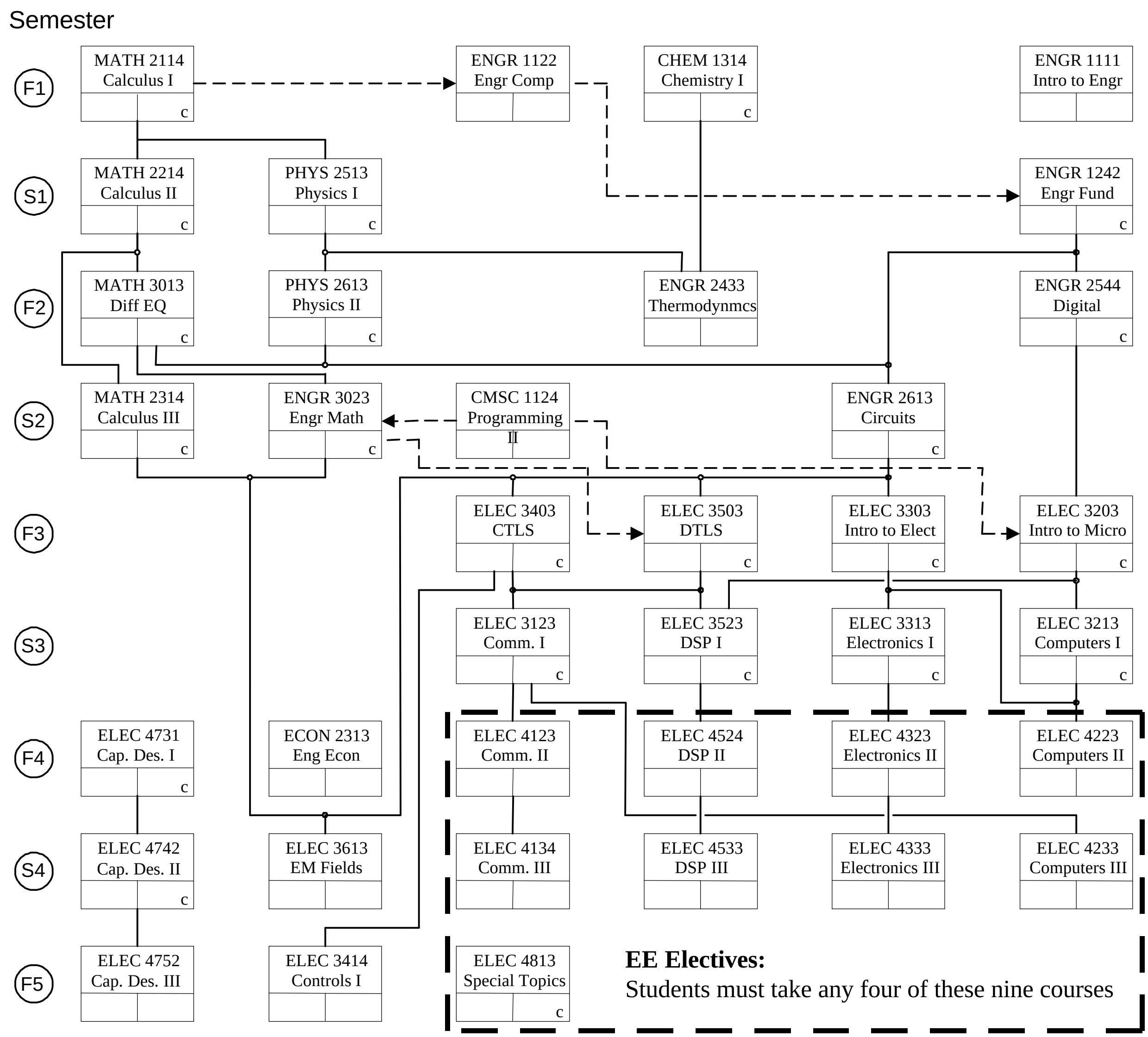

Figure 1: Electrical Engineering Course Flow Diagram