2006-871: THREADING TOPICS AND CREATING COURSE LINKAGE AMONG COURSES AND CURRICULAR AREAS

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Threading Topics and Creating Course Linkage Among Courses and Curricular Areas

Abstract - Electrical engineering technology (EET) programs have curriculum course sequences that create 'silos' of courses that appear independent to the students that take them. Students come to believe that the disciplines (analog, power, digital, communication, etc.) within EET have little in common or are remotely related. A FM receiver project for a junior level EET course in electronic communication has created a curricular linkage to two sophomore courses, one in RF and power electronics and the other in digital microcontrollers.

Introduction

The traditional model for teaching is comprised of curriculum course sequences that create vertical 'silos' where each topic is fully developed before going on to the next topic. This compartmentalized sequence of courses builds a solid conceptual foundation for the students [1, 2]. However, each course is treated as a separate body of knowledge creating an environment where the student sees no connection between different disciplines[3]. As the student progresses through the program, they may only get exposure to cross discipline courses in upper division electives or design courses. The traditional approach is flawed in that it tends to result in inadequate synthesis of basic concepts, poor retention of fundamental material between learning and application, and low motivation for learning fundamental materials[2]. It is essential that students should be made fully aware of what electrical engineering is all about and in what kind of problems electrical engineers are involved early in their academic studies[1].

Unless the curriculum helps the students integrate material across the courses, they have difficulty seeing how the material studied in one silo of courses connects to another silo[4]. Core courses are rarely interrelated, so no cohesive picture emerges as a student progresses through the curriculum. Curriculum content and flow is critical to the success of the student and their education[3,5]. The acquisition and retention of a true understanding of fundamental concepts and the relationship among the concepts is the hardest and least understood part in the educational process. Integrated problem-based learning scenarios that link across courses are crucial[1,4].

One of the biggest challenges has been, and still is, the integration of topics. Major curricular change is difficult to accomplish[6]. Major change requires that the entire faculty become involved. One such example is the creation and implementation of a spiral curriculum. The curriculum is spiral in that it revisits the concepts periodically with increasing sophistication throughout the curriculum[2]. The FM receiver project of this paper highlights the importance of connection within the disciplines without the major undertaking of completely revamping the entire curriculum.

The FM receiver project addresses problems such as lack of student motivation, poor retention, segment learning, and the lack of integration. The FM receiver project created for the junior year electronic communications course, while not a new idea or project for this type of course, serves as a vehicle to integrate the digital/microcontroller course sequence with the analog course sequence. For the electronics communications course, the FM receiver is designed, built and tested. The receiver utilizes a power audio amplifier that was built and tested during a prerequisite sophomore level analog power electronics course. In a required sophomore level digital/microcontroller course, the students design a project to digitally enter a radio frequency on a numeric keypad to control the FM receiver. The VCO used in this exercise is the same one utilized in the junior level FM receiver project creating a direct link to the junior level project. Implementation of a digitally controlled tuner adds extra credit points to the FM receiver project. Significant extra credit can be added by implementing additional features such as channel presets or memory functions, scanning and/or seeking channels, etc.

The project creates a thread across the analog course and digital microcontroller course sequences tying the curriculum together and crossing course discipline boundaries. The students realize that the study of electrical engineering technology crosses many curricular disciplines and that it is not possible to be ‘analog electronics’ or ‘digital electronics’ only.

FM Receiver Project

In a required junior level electronics communications course, a FM radio receiver is designed, built and tested. This receiver project is designed to illustrate all components of a communication system using a systems approach to the subject manner. The lecture content of the course details the blocks that make of the communication system, while the laboratory part of the course allow the hands-on design, building and testing of those block. The system is a superheterodyne receiver that constitutes 95% of receivers used worldwide, including broadcast radio, broadcast TV, cell phone communication systems, wireless LANs and satellite communications. A block diagram is shown in figure 1.

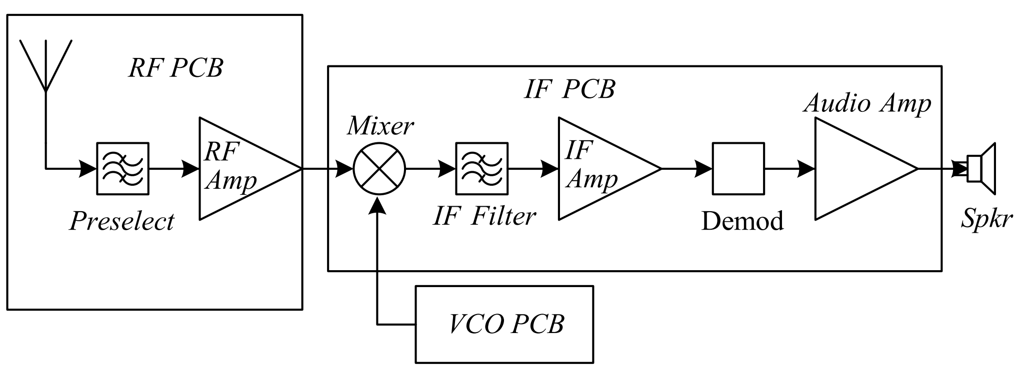

Figure1. Basic block diagram of the superheterodyne FM receiver system.

The receiver project is studied throughout the course and built block by block and totally integrated by the end of the semester. As indicated in figure 1, there are three main printed circuit board (PCB) blocks containing sub-blocks. The receiver requires a power audio amplifier to drive the speaker and listen to the output. Without the audio amplifier, the project is considered to be non-functional and the student will lose points on the project. The receiver project contains no information regarding the audio amplifier on how to build or test it. This is prerequisite knowledge from the sophomore level power electronics course.

The voltage controller oscillator (VCO) part of the receiver is used to tune in the frequency that is received by the project. The basic design of the VCO is to manually adjust a potentiometer to change the tuning voltage of the VCO, which in turn adjusts the VCO output frequency. This change in the VCO frequency is what ultimately changes the 'channel' that is heard on the radio receiver. A photograph of the three main PCBs block are shown in figure 2. The bottom PCB is the VCO system with the manual tuning voltage adjust at the lower left of the PCB. An electrical jumper was provided to help facilitate alternative tuning methods, such as the digital control. The middle PCB is the IF block system and the IC on the far right of the board is the location provided for the audio amplifier. For this photo, and IC is in place, but no biasing is shown.

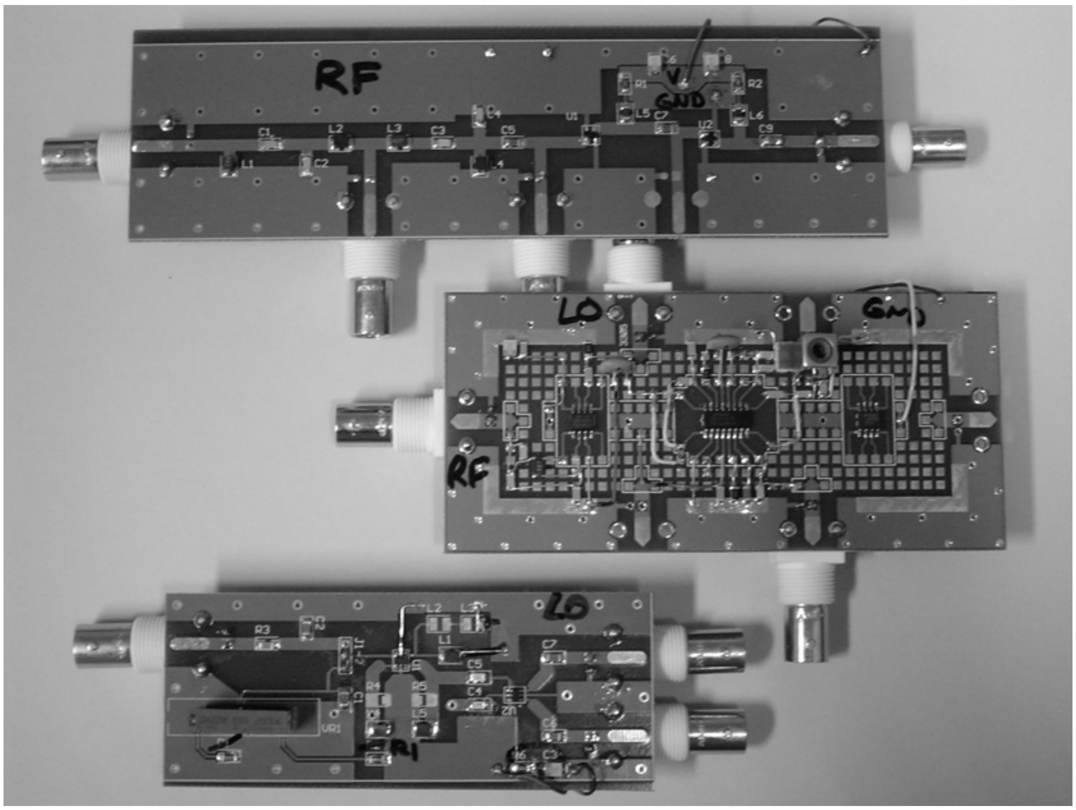

Figure 2. Picture of the FM receiver project. Top is the RF amplifier PCB, middle is the IF PCB, and bottom is the VCO PCB.

Extra credit on the project can be achieved by replacing the manually adjusted VCO tuning voltage with a digitally controlled tuning voltage. The VCO block has been studied and tested previously, so the student is aware of the requirements to tune the frequency. No information is given to the student on how to implement the digital control and no restrictions are given either. It should be noted that extra credit can only be obtained, if the project is working completely and that the students have worked in such a way to provide themselves with the time to accomplish the extra credit task. There are twelve extra credit options that the students can select from.

The audio amplifier is a required block of the receiver and its operation is a requirement of the project. The digital tuning of the VCO is an option. The students are required to implement these blocks (as well as any of the 11 other options) based on prior knowledge obtained in previous required courses. This helps create a cross threading of information between the 'silos' of EET courses.

Audio Amplifier

Students initially see the audio amplifier in a first semester freshmen course in an electronics project course, in which the students build a 1W audio amplifier using a simple integrated circuit (IC). There is no expectation, at this point, that they understand *why* the elements of the circuit are present, only that they can implement a given schematic. The students then measure voltage, gain, distortion, and power. Also included are a series of listening experiments to determine the effects of signal amplitude, frequency, wave shape, and the frequency response of the loudspeaker. Finally, students connect their personal listening device to the amplifiers and loudspeakers. From this first exposure to audio amplifiers, students gain an understanding of *why* they are necessary, a confidence that they can build and test an amplifier, a familiarization with fundamental audio parameters, how each is measured, and the impact each has on what is heard.

A more rigorous iteration of audio power amplifiers is presented in a required sophomore level semester course on Power Electronics. The last four weeks of this course are dedicated to the operation, analysis, and design of class B audio amplifiers implemented with both ICs and a combination of op amps and MOSFETs. The section opens with lectures covering the audio principles necessary to control the desired volume at the listener, account for the effects of distance, loudspeaker sensitivity, program content, and input signal level to derive the parameters of the required amplifier. The analysis and design of a low power (<10 W) audio amplifier is covered. Class B audio amplifier analysis and design (10 W to 500 W) are taught next. This includes the characteristics of MOSFETs in a linear application, how to parallel linear MOSFETs, design of a high voltage amplifier, implementation of the full composite amplifier, and finally, the design of current limiting and thermal protection.

A series of three-hour laboratory periods are dedicated to verifying the audio amplifier theory presented in class. The first laboratory is largely an extension of the experiment performed in the freshmen projects course mentioned above. A 40 W class B amplifier with current limiting is built and tested during the next two weeks.

Microcontroller Based Digital Tuner

In a required sophomore level embedded microcontroller course, the students design a digitally controlled system that generates an output voltage utilizing a numerical keypad and 7-segment displays. This digital tuner project utilizes a digital to analog converter (DAC) to provide the input to a voltage-controlled oscillator (VCO) that is used to tune the FM receiver.

This digital tuner project, with respect to embedded microcontrollers, is the primary vehicle to teach digital to analog converters, a fundamental topic in the digital course sequence. The microcontroller will provide the digital value required to produce the appropriate analog value necessary to control the voltage-controlled oscillator of the FM receiver. The FM receiver project provides the design parameters for the microcontroller-based project. The students learn how the design parameters influence the requirements of the DAC. The digital tuner project provides a platform to explore how the number of data bits and the reference voltage influence the actual output voltage from the DAC versus the desired values in a real world system.

In the microcontroller course, students are taught to read individual digits from a numerical keypad, and then are taught to acquire several digits and combine them to form a multi-digit number. There is also a requirement to display the information on 7-segment displays. This serves as a teaching example to introduce the concept of timer interrupts and how to implement them in a project. The digital tuner project serves to reinforce these early concepts and provides another example of how the concepts can be used. The repetitive uses of these core concepts in multiple examples aids the students in assimilating the information which leads to true learning.

The digital tuner project creates a direct link between the digital microcontroller course and the future communication course. The project highlights the importance of analog electronics for "digital" people and emphasizes the importance of digital microcontrollers to the "analog" folks. Besides highlighting the importance of these courses, the project builds the motivation of the students. The students that are more interested in analog courses are motivated in the digital course by the project. The students that are more interested in digital courses will be motivated in the communication course knowing that they can implement a microcontroller based tuner. The projects break down the barriers between disciplines and create a thread through the curriculum that integrates the courses. The digital tuner project requires the students to apply previously covered information and serves as a vehicle to introduce and teach new concepts while creating a direct link to the junior level communications course.

Conclusions

Teachers can become frustrated when teaching required courses as some students become bored and uninterested. A project immediately engages the students in exciting and interesting electronics (the reason they selected this major in the first place)[3]. This project creates an environment where a student interested in digital and power electronics can relate directly to a communications project. This relationship serves to build motivation in the digital student and gets them involved in the communications project. The same is true for a student only interested in power electronics. The student has an opportunity to demonstrate the skills they acquired in previous courses and build a power amplifier to be used with the receiver.

The results of the FM receiver project were mixed. The incorporation of the audio amplifier was 100% successful. This was expected as the receiver operation required an audio amplifier a basic component and without this amplifier, the project would not operate. The incorporation of the digital control to the FM receiver was a high valued extra credit option and was only attempted by those who completed the project at an accelerated pace. For the 2005 fall semester, five groups of a possible 26 attempted this option. Of the five groups, two were successful, two were 50% successful and one completely unsuccessful. Overall, only a total of fifteen groups attempted any extra credit efforts at this level.

The students in the sophomore power analog course can reliably build and test audio power amplifiers, but lack some knowledge about the details of the circuits. As typical for technology students, laboratory performance is better than comprehension of circuit theory. Each student takes a practical exam where they are required to change several key parameters of their amplifier and to demonstrate its full power performance. The second half of the final exam has been used to assess student learning about audio power amplifiers.

The students taking the introductory microcontroller course found the project enjoyable and recommended continuing this project in the future. The project increased the student motivation in the course and expanded the possible uses for microcontrollers in solving electrical engineering problems.

The project creates a thread across the analog course and digital course sequences. This thread ties the curriculum together across multiple disciplines. The students realize that the study of electronics requires the intermixing of digital electronics with power analog and communication electronics. A continuation and refinement of all the projects and threading of topics will be ongoing.

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