

## AN ON-LINE DSP COURSE FOR PRACTICING ENGINEERS

*D.V. Anderson, T.P. Barnwell, M.H. Hayes III,  
J.R. Jackson, R.W. Schafer, D.B. Williams*

*J.D. Echard*

Georgia Institute of Technology  
Center for Signal and Image Processing  
School of Electrical and Computer Engineering  
Atlanta, GA 30332–0250  
USA

Texas Instruments, Inc.  
12203 Southwest Frwy, MS 722  
Stafford, TX 77251–1443  
USA

### ABSTRACT

With the rapid increase in applications of DSP and the fact that, until recently, most DSP education has been at the graduate level, many users of DSP microprocessors find they have an insufficient background in DSP theory and design. At Georgia Tech we are delivering an on-line continuing education course that is targeted at these engineers. The 12-week course is comprised of three interconnected tracks in DSP system theory, real-time implementation principles, and laboratory assignments with MATLAB and the latest fixed-point TI DSP chips. The course was designed after an extensive needs analysis performed by Texas Instruments training specialists. It is intended specifically to provide a full semester's course in a way that is adapted to the schedules and circumstances of practicing engineers. In this paper we describe both the content of the course and the technology for delivering it on-line.

### 1. INTRODUCTION

Universities are developing very good curricula in digital signal processing (DSP) for undergraduate students with courses in DSP theory, implementation, and applications. The DSP semiconductor industry is doing a good job training engineers in the field on their DSP software and hardware tools through workshops and seminars. The missing link is that engineers already in the workforce need to learn DSP theory and how to implement this theory on real-time DSP processors.

The rapid advancement of technology experienced over recent decades makes it difficult for engineers to keep themselves abreast of the current technology. This is especially true with DSP. DSP is now pervasive. It is used in everything from disk drives and cell phones to automobiles and stereo equipment. However, until recently, DSP was only taught in the graduate curric-

ula of most universities and many practicing engineers have never been exposed to DSP. Many of these engineers now find themselves working on products that use DSP microprocessors. Recently, representatives at Texas Instruments, Inc., a leading producer of DSP microprocessors, presented this problem of how to train practicing engineers the basics of DSP and the implementation of DSP algorithms to educators at the Georgia Institute of Technology. The results of this collaboration are described within this paper.

Corporate training is becoming a multi-billion dollar business and many universities are feeling pressure to become more involved through continuing education and/or distance learning programs. Although a few schools have had such programs for years, educating practicing engineers is a new activity for many universities. In addition, the landscape of distance learning and continuing education has changed dramatically in the last few years; particularly, as the Internet has become a viable delivery mechanism.

Traditional university involvement in corporate training or continuing education has been mostly through short courses or video courses. Short courses are usually offered over several days at the university campus. They can be effective but may also disrupt an engineer's work schedule and, since the course is often offered in a remote location, there may be the added inconvenience and increased cost of travel. Video courses, unless delivered real-time over dedicated satellite or network connections, provide very little interactivity. Internet-based education shows promise in many respects:

- materials may be delivered either synchronously or asynchronously;
- multiple modes of presentation are available;
- many types of interactivity are possible;
- world-wide delivery may be possible;

- and delivery costs may be reduced.

There are, of course, problems with Internet-based delivery, and many of them will be discussed in the body of the paper.

The need for and difficulty in educating employees is not new and is evident in many engineering disciplines as well as in business, computer science, and a host of other specialties. This paper only discusses how the problem was addressed at Georgia Institute of Technology in the area of DSP through the development of a particular Internet-based course.

## 2. NEEDS ANALYSIS

### 2.1. Target Audience

The first consideration in developing the course was the intended audience. The input of associates at TI was invaluable in assessing both the make-up and needs of the intended audience. The target audience would be electrical engineers with bachelors or Masters degrees who are already working in the industry with little or no knowledge of DSP and some work experience with processors and C-language programming. Thus, the target audience typically consists of people with engineering degrees who know how to program and are often involved with the design of a DSP microprocessor based product. These engineers may find that they need DSP knowledge for their work but they do not usually have the luxury of returning to school to obtain this expertise. The engineers in the target audience are likely to be implementing DSP algorithms but not designing them.

### 2.2. Survey Results

Engineers at TI DSP seminars in the Southeast were asked to fill out a survey on DSP continuing education. The surveys were taken at the Atlanta, GA; Huntsville, AL; and Tampa, FL seminars. Out of 64 participants, 34 engineers filled out the surveys stating that they had interest in a continuing education course, 3 participants said they had no interest, and 27 did not fill out the survey. Most of these engineers were people who wanted to know more about DSP but had very little real-world design experience with DSPs.

Some of the highlights of the survey results were

- The majority of respondents (59%) were interested in Internet-based instruction,
- People overwhelmingly chose to have DSP tools at home (85%) with assistance from a lab instructor via the Internet, phone, or email.

- Topics that respondents showed the most interest in were

Discrete-time signal processing—	
sampling and aliasing	74%
Filters—FIR and IIR	85%
$z$ -transforms	65%
Spectrum analysis	65%
Understanding current DSP	
hardware and design issues	65%
Fixed-point processing techniques	68%
Interfacing issues	76%
Implementing real-time operating	
systems	85%
Code testing techniques	65%

## 3. STRUCTURE OF RESULTING COURSE

The course curriculum was then determined based on the target audience and its needs. In a typical university course, there is a great emphasis on the underlying theory, with applications being presented primarily to motivate the theory. This approach attempts to provide a broad base of understanding that the students can apply to solving new DSP problems. A single semester length course in DSP is insufficient to supply that level of understanding, and an in-depth coverage of a few topics would leave many topics untouched. In addition, the students in this course wanted topics not usually covered in a university DSP theory course, such as fixed-point signal representations and quantization effects, fixed-point filter implementation, and real-time DSP microprocessor programming. Therefore, the guiding philosophy in designing the course curriculum was to provide a foundation in DSP theory and real-time implementation that could be built upon later. Thus, the course was designed to introduce the theory and implementation of basic algorithms in a fixed-point environment. It includes enough practical applications to get the students started and enough theory so that they could understand whatever else they may need to learn through individual study. Advanced topics are mentioned but not covered in depth.

The goal of the course is to teach basic DSP theory as well as principles specific to the implementation of DSP algorithms on a fixed-point processor. The course length is designed to be roughly equivalent to a one-semester university course. It is delivered asynchronously over the Internet as described below and it takes about 12 weeks to complete. Due to the breadth of the material covered, students may gain a firm foundation in basic DSP principles and learn skills needed to implement DSP algorithms but they will not be expected to become experts in the field. However, it is

expected that the background is sufficient so that the students can effectively continue individual study in areas of concentration.

The material itself is divided into short modules, each consisting of a streaming media presentation, homework problems, and occasional supplemental material or on-line self-tests. Topics covered in the course are divided into three main areas addressing the following topics:

- Learning basic DSP concepts
  - sampling and quantization
  - linear, time-invariant (LTI) system theory
  - convolution and difference equations
  - filters and filter structures
  - z-transforms
  - basic Fourier analysis and frequency response
  - system response and characterization
  - fixed-point DSP issues
- Gaining experience in implementing DSP algorithms
  - basic DSP microprocessor architecture
  - an overview of the TMS320c62x fixed point DSP architecture
  - algorithm simulation and verification
  - C-language algorithm implementation
  - buffering, threading, code organization
  - optimization
- Becoming acquainted with the Texas Instruments TMS320c6x DSP architecture and development tools
  - C-compiler and assembler
  - real-time kernel
  - debugging
  - profiling
  - libraries and intrinsics

The characteristics of this course are defined not just by its content, but by the material that had to be left out. Among the topics that are *not* covered are:

- hardware design
- different DSP platform comparisons
- extensive optimization details
- peripheral configuration/communication
- most advanced DSP theory issues

### 3.1. Curriculum Organization

The target audience also influenced the presentation and organization of the course material. Since the amount of material to cover was great and since the students were located all over the United States and overseas, the course was developed as an Internet-based course. Since the course was aimed at engineers with full-time employment, it was desirable to break the course into short modules that could be completed in a relatively short amount of time. Each module consists of a short (5-15 minute) streaming media presentation, homework problems, and on-line self-test problems.

The short modules have many additional benefits for both the students and those who maintain the course. Students can pick and choose to study only those topics with which they are not familiar. It is easier to produce or modify a short module than a long one and topics can be updated by simply replacing a short module rather than editing a long lecture. When viewing a streaming presentation over a slow or unreliable connection the likelihood of successfully viewing the entire presentation is greatly increased for short presentations. It may also be possible to download the entire presentation prior to viewing. Finally, the short modules keep the student's attention more easily than a longer lecture, with more frequent reinforcement of the concepts via the homework and self-test questions.

### 3.2. Laboratory Exercises

Another important aspect of the curriculum was the need for “hands-on” experience. Learning is greatly accelerated by the application of the principles learned. This need was addressed by having weekly laboratory exercises that the students perform on a hardware DSP development kit. The laboratory exercises were designed to complement the material covered in the lecture modules.

## 4. METHOD FOR DELIVERY

The options available for Internet delivery of educational material are vast. Some of the possibilities considered for this course included:

1. HTML only,
2. HTML synchronized with audio,
3. HTML with audio and Flash animation,
4. Streaming video only,
5. Streaming video synchronized with an HTML presentation, and

6. Streaming video, Flash animation, HTML slides, Java enhanced pages, etc.

For slow Internet connections the first three methods are preferred. Over a modem, the poor quality of a sustained video stream often makes it more distracting than useful. Option 1, the straight HTML based presentation, can be effective, but it is difficult to design pages that convey enough information in an engaging manner. Also, it is unlikely to meet students' expectations for taking a university course. Option 2, HTML synchronized with audio, is used by various on-line training establishments but the authors of this paper found it to be somewhat less engaging than desired. Some on-line training web sites such as TechOnline ([www.techonline.com](http://www.techonline.com)) use professional speakers to record scripts prepared by academics. This approach increases the quality of HTML with audio but, because of the increased cost and preparation time, it is was not a practical option at Georgia Tech. Option 3, HTML with audio and animation, results in presentations that can be streamed over low capacity connections and yet remain fairly engaging. The primary difficulty with this option is that the production time is very large to produce a quality presentation.

For faster Internet connections video becomes viable. However, for high-quality video even LAN connections can have problems when competing network traffic causes intermittent congestion. Option 4 entails sending an entire filmed lecture over the network as video. Because of the high resolution needed to convey written information, this method is impractical for general Internet delivery. Option 5, streaming video synchronized with an HTML presentation, makes it possible to use smaller, lower-bandwidth video to show the presenter or supplemental information while using the HTML to convey all written information. Option 6, has a little of everything. When prepared with judgment, this type of presentation may be the most effective at conveying information and providing interactivity. However, it must necessarily require the most effort during production. Estimated time for production of detailed presentations having the components of Option 6 is 100+ hours for every hour of presentation.

The list of 6 options above is not comprehensive but it does demonstrate the trade-offs in designing a presentation that is high quality, easy to produce, and deliverable over the Internet. For the on-line DSP course Option 5 was used and tools, collectively named *inFusion*, were developed to decrease the production time by automatically putting the presentation together with synchronized slides. After creating slides, typically using PowerPoint or L<sup>A</sup>T<sub>E</sub>X, instructors would save the slides into a PostScript file. As shown in Figure

1, *inFusion* would display the slides while the instructor gave his presentation. Then, the software would save the slides and compressed video together into a streaming presentation. For the instructors, recording of the lectures took little more time than what was required to present the material.

The presentations use a small video showing a head-shot of the presenter designed to capture the wandering eye and keep the student's attention on the presentation. Large slides are used to convey written information; and simple animations are achieved by timed slide transitions. A screen shot of the resulting presentation is shown in Figure 2.

#### 4.1. The Bandwidth Hurdle

Even with small, compressed video (about 150x100 pixels) at 10 frames per second, the required capacity is too large for slower Internet connections. To address this problem a hybrid delivery method was used. The hybrid method involves sending the students copies of a CD-ROM that contains the lecture presentations (the video, HTML, and graphics). Then the course organization is provided via a web page that links to each student's CD-ROM drive on their computer. The web page is created using WebCT ([www.webct.com](http://www.webct.com)), a web course tool that permits each student to log in and keeps track of individual information, accesses, and statistics. WebCT also provides the tool to control access to the students' CD-ROM drives. This arrangement permits the viewing of high-bandwidth, high-quality presentations in a web browser while keeping control of the course from a central location using a low-bandwidth connection.

#### 4.2. Web Organization

In addition to the presentations, some other course characteristics were considered essential; these included interaction between students, a method for evaluating students' understanding, and student login. This functionality was also provided via the WebCT environment.

#### 4.3. Student Interaction

Students need feedback in the learning process. They also need answers to their specific questions. For these reasons, delivering an Internet-based course must have a means of two-way communication. For the DSP course students used the WebCT bulletin board to post questions and/or comments to each other and to the instructor. The bulletin board was monitored by a professor as well as by graduate students in DSP, represen-

tatives of Texas Instruments, and continuing education department personnel. When questions on the bulletin board were not easily answerable in writing they were handled by telephone.

The amount of discussion on the bulletin board far exceeded that of a similar course offered on campus using WebCT. It seems that when the students are not located near each other there is a greater demand for computer-assisted interaction among students and for individual attention. This need seems to directly contradict the belief by some that Internet-based education is completely scalable.

## 5. COURSE PREPARATION

The professors involved in preparing the on-line DSP course found that the preparation time required far exceeded the preparation time required for a traditional course. Filming and course preparation is very time consuming and, even with tools that dramatically reduce the effort needed to prepare the modules, it takes a tremendous amount of time and resources.

## 6. CONCLUSION

Georgia Tech has developed an Internet-based course on the fundamentals of DSP and the implementation of DSP algorithms. The course was developed with the cooperation and support of Texas Instruments, Inc., and it features lecture modules by professors in the Georgia Tech Center for Signal and Image Processing; laboratory exercises using the TMS320c62x platform; and on-line feedback, testing, and exercises.

Many universities are under pressure from within and without to develop on-line courses. The belief by many is that this is a simple transcription from one medium to another. Our experience has shown us that Internet-based education is dramatically different from traditional courses or even from traditional distance education courses. In particular, the amount of work in preparing an effective on-line course exceeds all other continuing education and distance education courses that we have developed at Georgia Tech. In addition, the delivery of an on-line course must consist of more than simply giving out the address to a web site. If anything, on-line students require more individual attention than traditional classroom students, especially if they are involved in hands-on learning projects. However, we are convinced that the benefits of on-line education, in many cases, justify the increased cost. Finally, we believe that Internet-based education will continue to grow, especially in the area of corporate training. As this field expands we must work closely with

industry and individual engineers and professionals to ascertain their needs and prepare materials accordingly.

The short course “DSP for Practicing Engineers” was first offered beginning in February 2000, to 50 students. It has also been offered to 30 students beginning in June 2000, and the third offering begins in September 2000. Information about this course can be found at [www.ece.gatech.edu/streaming/dspppe.html](http://www.ece.gatech.edu/streaming/dspppe.html). Further information about streaming media courses and software tool development at Georgia Tech can be found at [www.ece.gatech.edu/streaming](http://www.ece.gatech.edu/streaming). In particular, a beta version of the production tool *inFusion* can be found at [www.ece.gatech.edu/streaming/infusion.html](http://www.ece.gatech.edu/streaming/infusion.html).

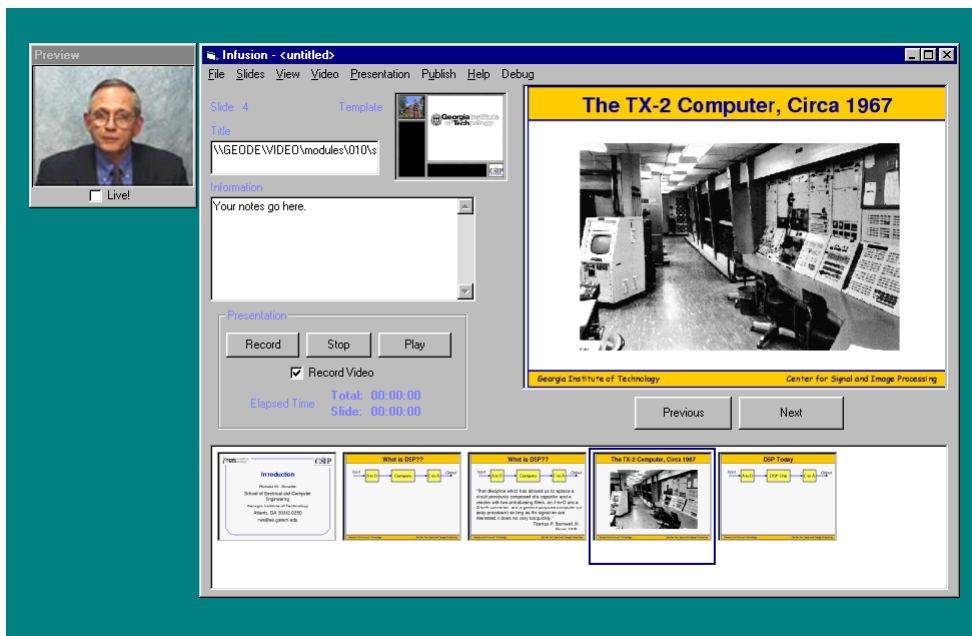


Figure 1: Screenshot of *inFusion* being used to record a lecture module.

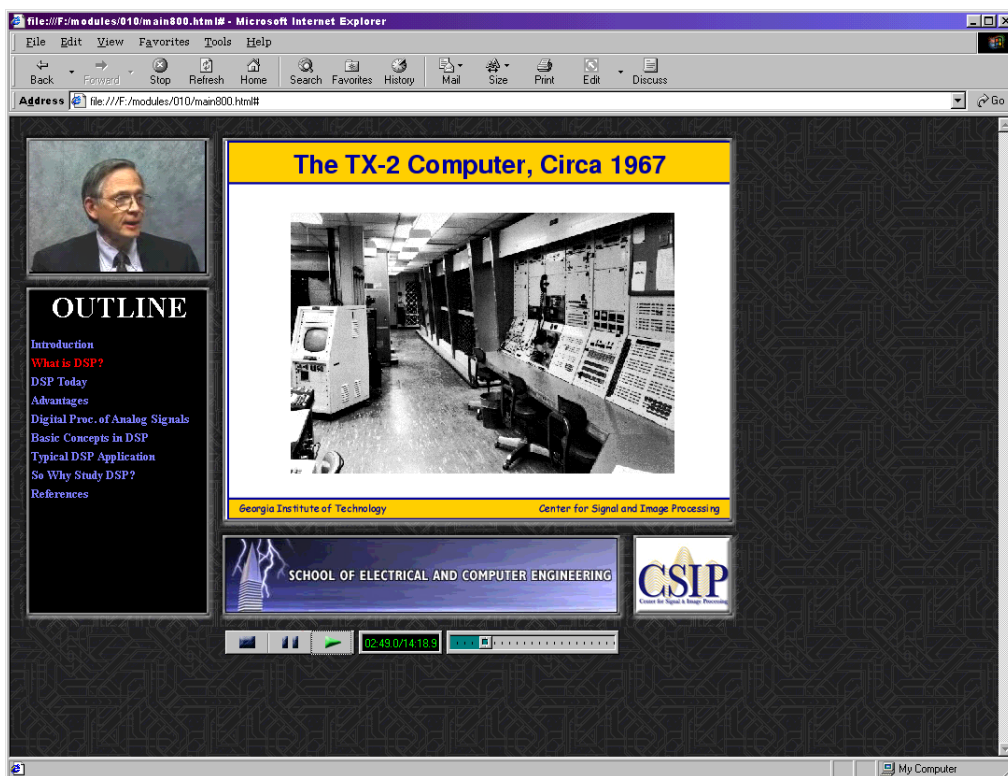


Figure 2: The resulting lecture module as displayed by a web browser.