Use of the Texas Instruments DSP Starter Kit (DSK) in Electrical Engineering Education

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Abstract

Texas Instruments produces a cost-efficient Digital Signal Processor (DSP) system packaged as the DSP Starter Kit (DSK). This system provides all the hardware and software necessary to develop and to test a wide variety of signal processing applications. Faculty members within TTU ECE regularly assign projects using this equipment to students taking courses in Digital Signal Processing, Project Laboratories, Telecommunications, and Networks as well as those working on master's theses and doctoral dissertations.

The DSK environment allows students to implement a variety of solutions to problems in signal filtering, data transmission, encoding, encryption, modulation, demodulation and compression. The DSK comes with the interface circuits necessary for capturing and reproducing analog audio signals and a variety of modulated waveforms. The embedded DSP can effectively process, analyze, adjust and reproduce the digital signal representations necessary to realize most modern communication methods. The Code Composer Studio, which is included in the DSK system, provides a highly effective software development environment for developing and debugging signal processing algorithms in C language.

Additionally, Matlab's Simulink can be used to communicate with the DSP. Simulink is block diagram-based and offers an easy graphical user interface to program the DSP. In addition, it offers many predefined blocks, e.g. to design digital filters. As part of the Digital Signal Processing course, the TI DSK is regularly used for week- and semester-long projects. Through these projects, students gain practical experience using the hardware and software tools, learn to solve problem statements independently, research literature, and familiarize themselves with state-of-the-art engineering tools. They are also more interested in the mathematical framework and theory related to digital signal processing if they feel that it helps them with their projects.

Texas Instruments DSK

Texas Instruments produces a low-cost alternative for beginning one's investigation of digital signal processors (DSPs), the DSP Starter Kit (DSK). The kit retails for $395, and significant educational discounts and donations are often available. As the TI DSP product line continues to develop, the exact device offerings on the available DSKs will change. However, the basic marketing approach has been in use by TI for many years.

TIs DSKs provide one of their higher-end DSP devices with sufficient off-chip peripherals to render it a practical test bed for a wide variety of applications. Typically, the DSP device itself has only a modest amount of RAM and no non-volatile storage, so the DSK adds SDRAM, FLASH, and a socket for a PROM. TI's family of DSPs do not tend to have on-chip analog-to-digital or digital-to-analog conversion, so the DSK includes these devices, suitable for audio applications. The DSK provides the requisite power supply, as well as all physical hardware necessary to connect the DSK to a Windows™ workstation.

The key to the timely, successful completion of any software-intensive project is the development system, and C / C++ language source-level debugging, direct debugger access to memory, variables and registers, and efficient project management, compilation, and image downloading are required. The software environment produced by TI for the DSP product lines is Code Composer Studio (CCS), and the DSK ships with a mostly functional version of CCS. It also ships with libraries which facilitate successful interface with the peripherals.

Our students can check a DSK and PC out of the stockroom, install the software, power the board, and run the traditional introductory "Hello world" example to make the LED blink on the board within a few hours. It has been done many dozens of times.

Matlab's Simulink

Matlab is a software tool which allows a "programmer" to determine and visualize a variety of mathematical relationships within data sets. The "language" used within Matlab is very intuitive and does not have nearly the degree of constraints a language like C does. In addition, various toolboxes are available that provide very sophisticated algorithms as simple predefined functions with specified input and output parameters. Examples for such functions are filter design algorithms, predictive coding, the capability to read and write WAV-formatted audio files, image processing tools, and neural networks, to just name a few. These powerful ready-to-use functions allow the user to evaluate the strengths and weaknesses of different approaches without the hassle of having to implement them first. Also, students can test approaches they have not understood well enough to implement and can then decide from the results whether they are worth further investigation. The task of reading in a CD-quality WAV file, bandlimiting it to the frequency band used for telephone communications, and saving it as another WAV-file can be accomplished in about 5 lines of code.

Matlab provides a graphical user interface (GUI) called Simulink, which allows a programmer to use a library of predefined blocks, drag-and-drop, and simple graphical interconnection to build a desired system. Again, a large library of predefined blocks allows the student to model sophisticated systems in a short time period. Simulink offers software oscilloscopes, spectrum analyzers and storage to easily monitor input, output, and intermediate signals.

Simulink was introduced as an event-driven, block-based simulation environment within Matlab, but it can also be made to generate C code. Simulink also offers a very powerful tool to work with the TI DSK; it can generate C code specifically intended for use with the TI DSK hardware. Simulink will establish the peripheral devices, memory structure, etc, in a fashion which will allow the code to be loaded into a CCS project, compiled and linked without further manipulation by a C programmer. This allows a non-programmer with little detailed knowledge of the DSP registers and peripherals to implement complex algorithms without writing a single line in Matlab or C.

Student Class Projects

A number of classes use the TI DSK and / or Simulink as platforms on which to develop projects. These classes include the very practical EE undergraduate laboratories, as well as more theoretical advanced electives and graduate courses in digital signal processing and communications.

The EE undergraduate laboratory third semester uses the TI DSKs as the core of communication systems, demonstrating modulation techniques including amplitude shift keying (ASK), quadrature phase shift keying (QPSK), frequency shift keying (FSK) and quadrature amplitude modulation (QAM). Separate lab teams of about 4 students each will design and implement both the transmitter and the receiver end of such a communication link. The DSK provides all of the hardware necessary to produce the analog waveforms to be introduced into the communication channel by the transmitter. It also provides all the hardware necessary for the receiver to capture and process that analog waveform and to reproduce the data stream indicated by the transmitter. Other even more advanced DSP projects are frequently undertaken in the two senior design lab courses.

Many senior electives and graduate courses are appropriate places for the DSKs to be used for class projects. Electrical Engineering classes include Telecom Networks, Digital Signal Processing, Advanced Telecommunications, Adaptive Pattern Recognition, Image Processing, Modern Communication Circuits, Computer Vision, and Statistical Theory of Communications. Within these elective classes, the TI DSK has been used for a variety of short- and long- term projects. Implementation of filtering, encoding, compression and reformatting of data streams are frequently assigned to students within the context of that course material.

Digital Signal Processing Course

Only one combined senior / graduate elective is offered by the Department of Electrical and Computer Engineering at Texas Tech University to teach Digital Signal Processing. Since discrete-time signals and systems have not been treated in any previous core undergraduate course, this course is the only opportunity to provide many theoretical concepts with respect to sampling, discrete transforms, and system properties and design procedures. Students who enroll for this course, however, expect to learn about digital signal processor hardware and how to program it. Due to time limitations, it is impossible to teach both aspects thoroughly. Here, the TI DSK together with the Simulink interface and CCS provide a handy kit for students to gain practical experience at a rich enough level to maintain their interest without losing sight of the problem statement.

In groups of up to 3, students get to choose a project such as adaptive filtering, speech coding, speaker recognition, equalization of a communications channel, or building an audio equalizer. Using independent study, they learn about the techniques applied to solve their problem, simulate it in software, and then implement it on the DSK. Typically, students choose to use the Simulink interface to communicate with the DSK when doing it for the first time. Simulink provides an analog-to-digital-converter (ADC) input interface block and digital-to-analog-converter (DAC) output interface block that facilitates communication with the DSK. Figure 1 shows a very simple Simulink model that samples an input signal present at the analog jack at 8 kHz, filters it, and sends it to the analog output jack. The ADC and DAC blocks take care of configuring the hardware correctly without further programming. To filter the signal, the "fdatool" (filter design and analysis tool) block allows the programmer to specify the filter characteristics through a graphical user interface (GUI) and calculates the filter coefficients, as shown in Figure 2. Students are able to perform this simple filtering implementation at the end of the second week of classes. The facility of experimenting with different filter parameters and listening to the results keeps them excited about their project and interested in learning more about the hardware. Although an easy-to-use tool that provides quick results, the code generated by Simulink for the DSK is not very efficient. Therefore, students use CCS during the second half of the semester to generate their own efficient C / C++ programs. At this stage, they need to learn more about the hardware and how to set it up correctly.

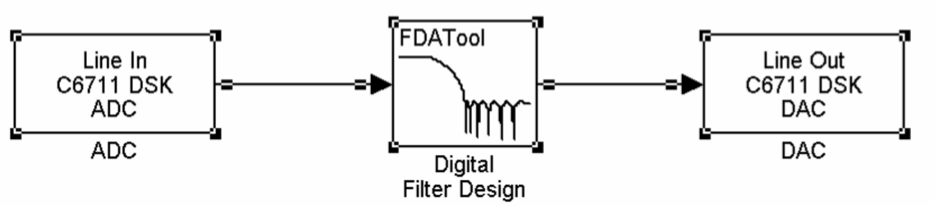

Figure 1. Filtering a Signal Using Simulink

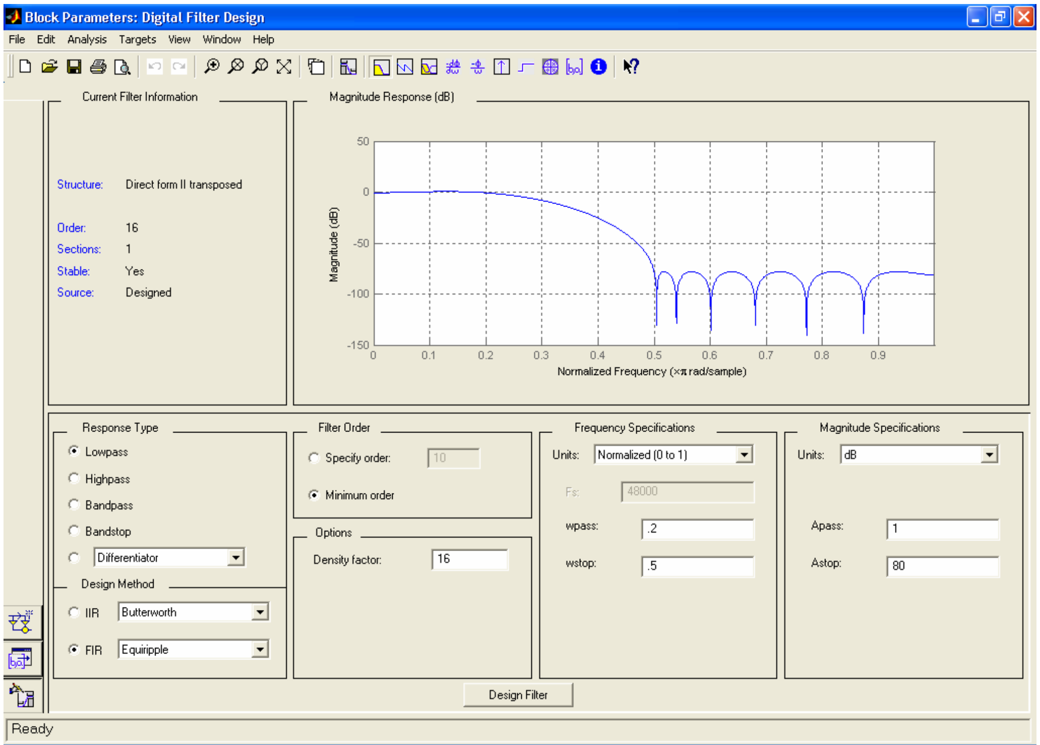

Figure 2. Simulink GUI to Specify Filter Parameters

While working on their projects, students learn the theoretical background material in class. Being able to relate theory to practice, students better understand the mathematical concepts presented in class, and they exhibit strong interest in the class projects. Interest in DSP is so high that the course is one of the very few ECE electives taught every year. The course consistently has 30-40 students. The course always receives excellent student teaching evaluations and students regularly ask for an advanced DSP course to be offered by the department in the comment section of the evaluation form.

Student Research Projects

Several undergraduate and graduate students have been or are now performing research implementations using the TI DSKs. Current research projects applying the TI DSK include cosine modulated filter banks [7], biomedical signal processing, image compression and representation [6], and blind source deconvolution. Master's theses in adaptive filter banks [3] and biorthogonal filter banks [4] have been completed. Figure 3 shows a Simulink screen taken in demonstrating an almost-completed Master's level research project [5] in cosine-modulated filter banks. Figure 4 shows the CCS screen when the same project is loaded onto the DSK.

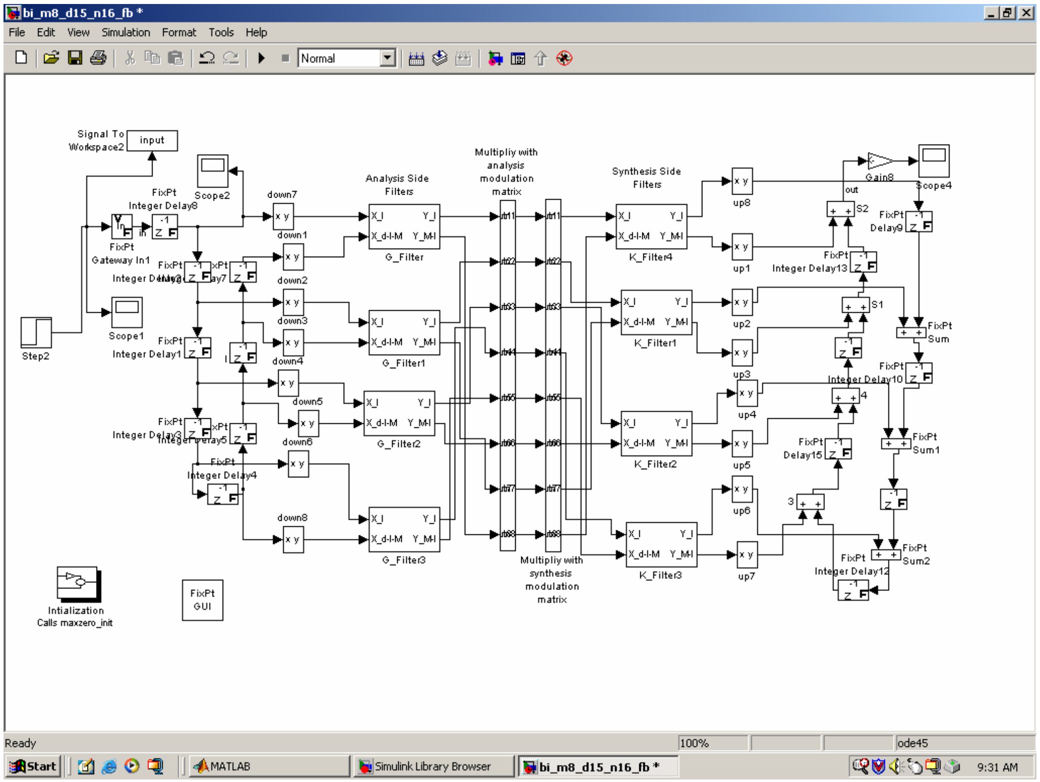

Figure 3. Simulink Representation of Cosine-Modulated Filter Bank [5]

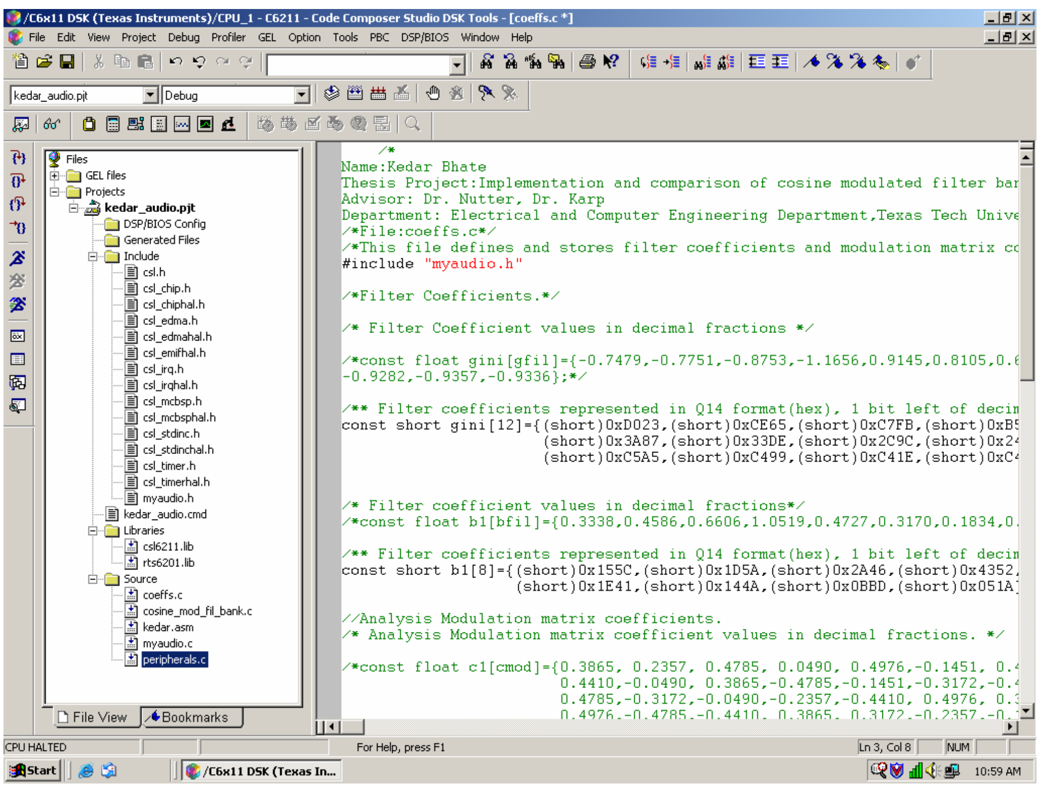

Figure 4. Code Composer Studio Presentation of Cosine-Modulated Filter Bank [5]

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