AC 2008-2575: USING REAL-TIME DSP TO ENHANCE STUDENT RETENTION AND ENGINEERING OUTREACH EFFORTS

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Using Real-time DSP to Enhance Student Retention and Engineering Outreach Efforts

Abstract

In recent years, the authors have described various classroom-proven DSP teaching tools that have helped motivate students and faculty to implement real-time DSP-based systems to enhance education. These efforts have emphasized the theme that DSP is much more than just a collection of theories and problem solving techniques, and that hands-on experience with hardware is extremely beneficial for both mastering concepts and retaining students. In addition to facilitating the education of numerous engineers and engineering students, these tools have also allowed us to reach out into our local communities and encourage future college students to consider studying engineering. This paper describes some of our real-time DSP-based community outreach efforts, and more traditional engineering courses, that have been facilitated by tools such as winDSK6 and the DTMF decoder/power switch box.

1 INTRODUCTION

Digital signal processing (DSP) is a topic that is covered in some way in nearly every undergraduate ECE program. While there are many fine texts available,[1–4] many educators and authors have recognized the need for more interactive learning and the use of demonstrations for this important subject.[5–8] Since the late 1990's, the authors have been suggesting and providing proven DSP teaching methodologies, hardware and software solutions, and DSP tools that have helped motivate students and faculty to implement real-time DSP-based systems to improve education in signal processing and related topics.[9–18] These efforts have emphasized the fact that DSP is much more than just a collection of theories and problem solving techniques, and that hands-on experience with real-time hardware is extremely beneficial; it helps students master various DSP concepts and improves student retention rates. Using real-time DSP as the catalyst, students can be more easily motivated to explore and implement a wide variety of DSP topics in an environment in which they are limited only by their imagination. This educational process can be greatly enhanced through the use of real-time demonstration programs such as winDSK and winDSK6.[9,10,16,19]

In addition to facilitating the education of numerous engineers and engineering students, these same tools have allowed us to reach out into our local communities to spark the interest of future college students and encourage them to consider studying engineering. This paper expands on an abbreviated description contained in a paper accepted for presentation at the 2008 IEEE ICASSP conference.[20]

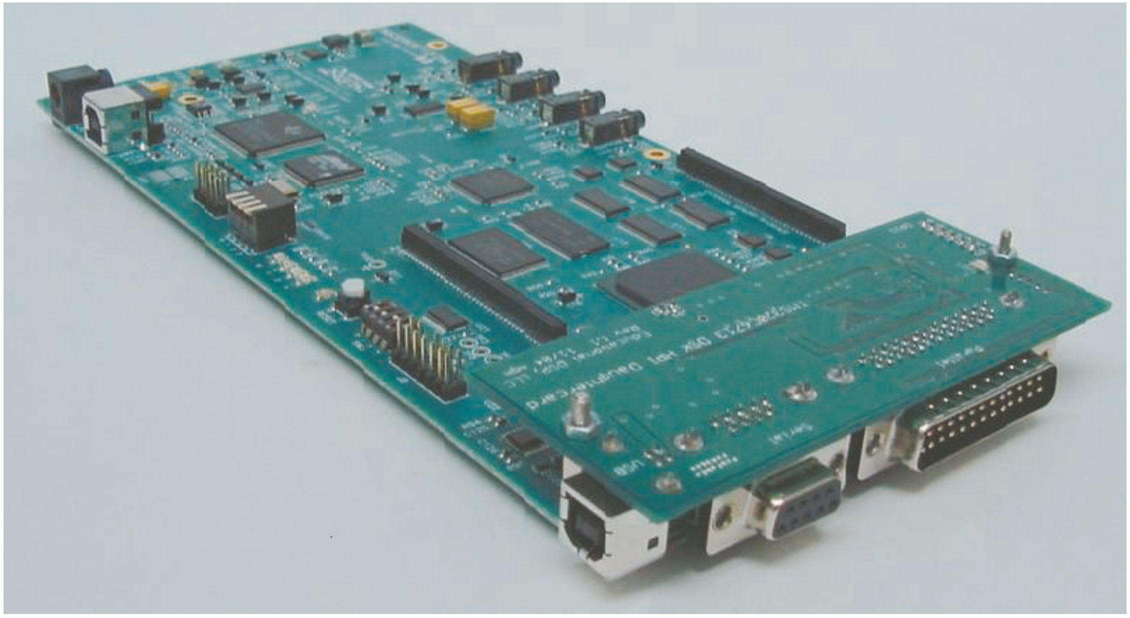


Figure 1: The TI TMS320C6713 DSK with an attached eDSP host port interface (HPI) daughtercard. The daughtercard allows for simultaneous connection to at host PC via USB, RS-232, and parallel port.

2 winDSK6 DSP Software

In order to allow for a wide variety of real-time demonstrations, we developed a software package tailored to the TMS320C6711 and TMS320C6713 DSK (**D**SP **S**tarter **K**it). The 6713 DSK is shown in Fig. 1. After several years of experience with our original winDSK program for the TMS320C31 DSK, the new winDSK6 software package is greatly improved and more capable, and takes full advantage of the higher performance DSKs. The winDSK6 program is a Windows Vista/XP/2000 application that provides an intuitive graphical user interface (GUI), and ensures that the first experience with the DSK is a positive and motivating one. This software makes the DSK hardware much more accessible to new users, and facilitates easy-to-use, ready-made classroom and laboratory demonstrations. For simplicity, all application software and DSK code is embedded in the executable file. A help file provides a section on each demonstration that discusses the theory and operation of the application, and context-specific help is available on each application control. To eliminate the requirement to have the Code Composer Studio (CCS) compiler and development tools installed on the demonstration machine, a completely new DSK driver was developed that runs under the Windows Vista/XP/2000 operating system[*]. The winDSK6 program, written in C++, encapsulates the DSK's physical and logical interface to the host computer. The applications that form the basis of winDSK6 have evolved over time and experience, with the authors' needs in the classroom and laboratory being the motivating force behind the new capabilities in the current version; the latest version can be freely downloaded from.[19] Individual applications are all dialog-based, and perform a similar sequence of operations, shown next, to execute an application program.

[*]Operation under Windows Vista has not been thoroughly tested as of the submission date of this paper.

1. Reset and reboot the DSK
2. Download the application software
3. Locate the shared memory block and initialize any data to synchronize the host computer and the DSK
4. Run the DSK application

This sequence occurs upon selecting an application with a mouse click; to the user it appears to occur instantaneously. Once the application is running, communication via the shared memory block is used to control the DSK application's behavior in response to user input via the dialog window displayed on the host computer. This gives users real-time interactivity and immediate feedback when changes are made on the host computer.

The winDSK6 demonstration applications highlight a number of signal processing operations. Nearly all applications require only the basic DSK hardware to operate. Applications include a DSK Settings button that allows for the control of codec functions (such as sampling rate) in real-time while the application is running on the DSK. As shown in Fig. 2, the available applications include talk-thru, K-P String plucking algorithm, notch filter, guitar synthesizer, audio effects, graphic equalizer, vocoder, several filters, a multi-mode digital communication transmitter, oscilloscope/spectrum analyzer, multi-channel signal and/or arbitrary waveform generator, and a DTMF (dual tone multi frequency) generator.

Of the many subprograms and lower-level GUIs in winDSK6, two of the most appreciated by teachers of DSP are commDSK and commFSK, which have been described in more detail at previous ASEE conferences.[21,22] The former allows full control of digital modulation schemes such as BPSK, QPSK, 8-PSK, 8-QAM, and 16-QAM, and the latter allows full control of variations on the FSK digital modulation scheme.

Selecting the commDSK option from the winDSK6 user interface launches the commDSK application and brings up the window shown in Figure 3. Selecting the commFSK option from the winDSK6 user interface launches the commFSK application and brings up the window shown in Figure 4. These programs greatly ease teaching and demonstrating various digital communications topics.

The authors have also developed various hardware "add-ons" for the DSK that make it even more capable for teaching DSP to students and for outreach activities;[15,17,18] see[23] for more details. A newly designed device to control external power relays via DSP is described next.

3 DTMF decoder and switch box

Most readers are familiar with DTMF sounds from their telephone keypad. The addition of additional external hardware in the form of a DTMF-based controller and power switching device, shown in Fig. 5, allows for more than just algorithms to be implemented in real-time. When using

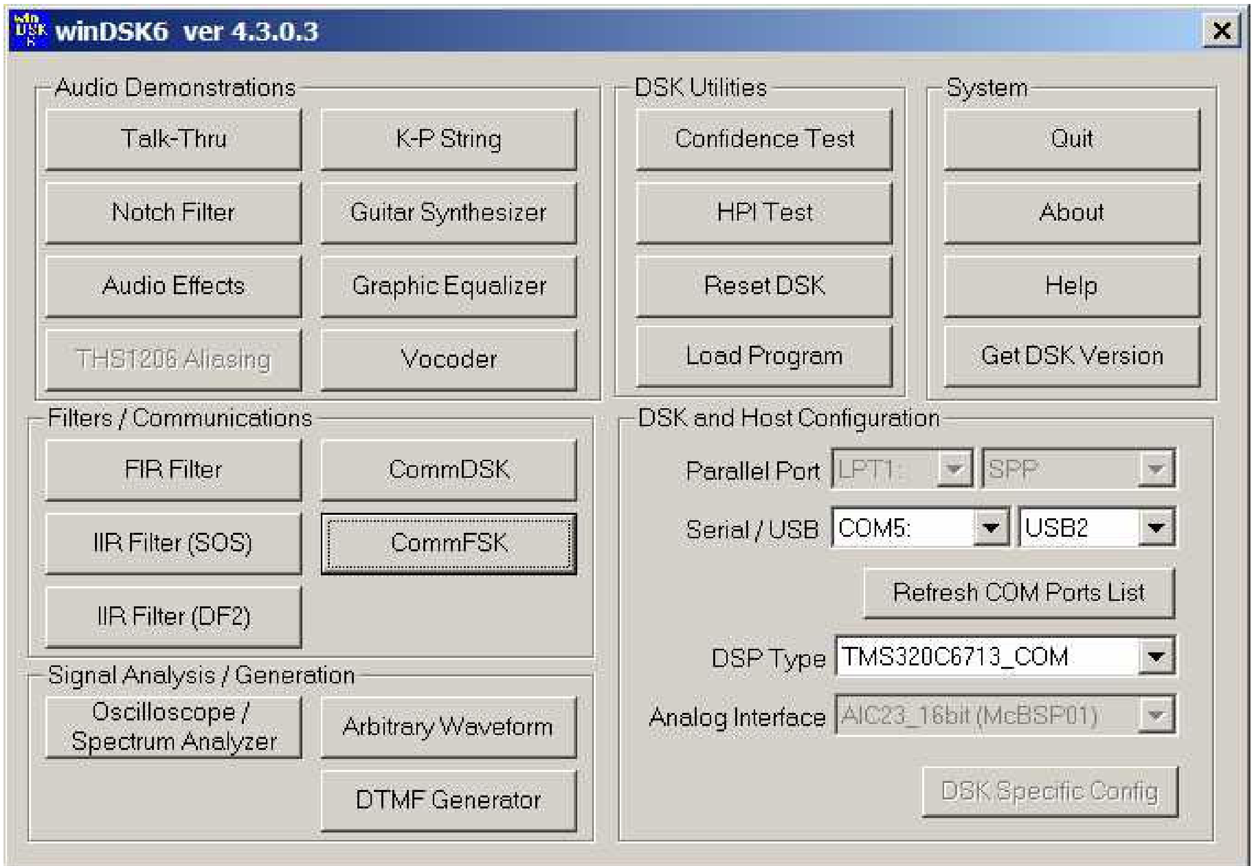


Figure 2: The main winDSK6 user interface for use with the C6711 or C6713 DSK from Texas Instruments.

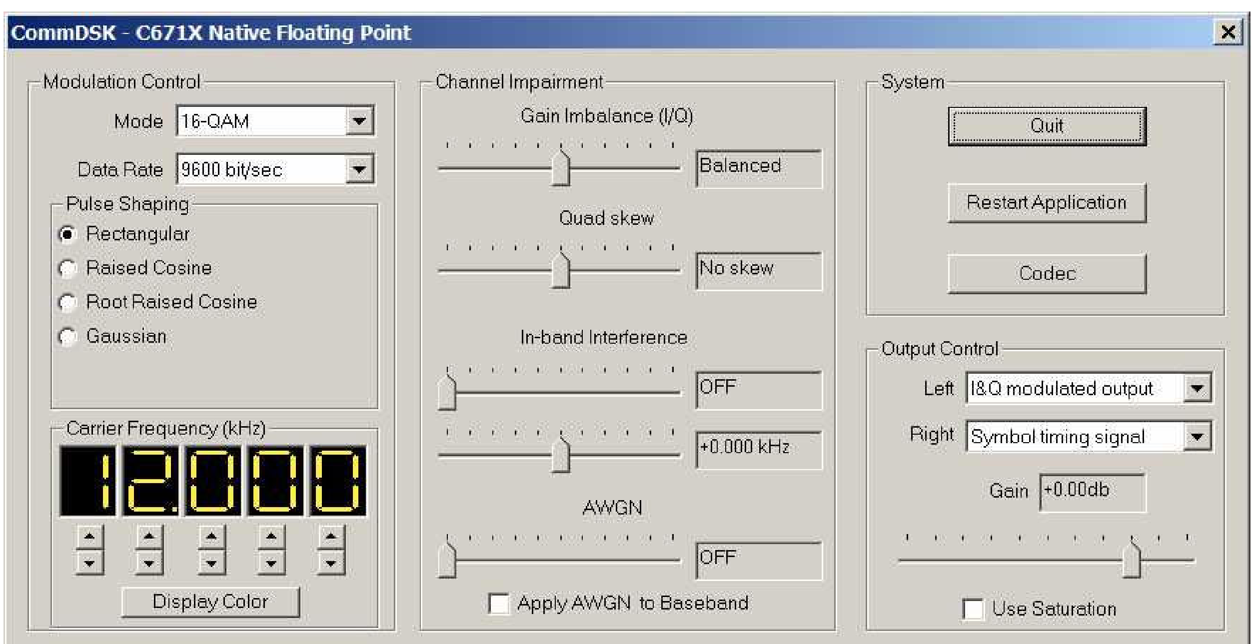


Figure 3: The commDSK user interface.

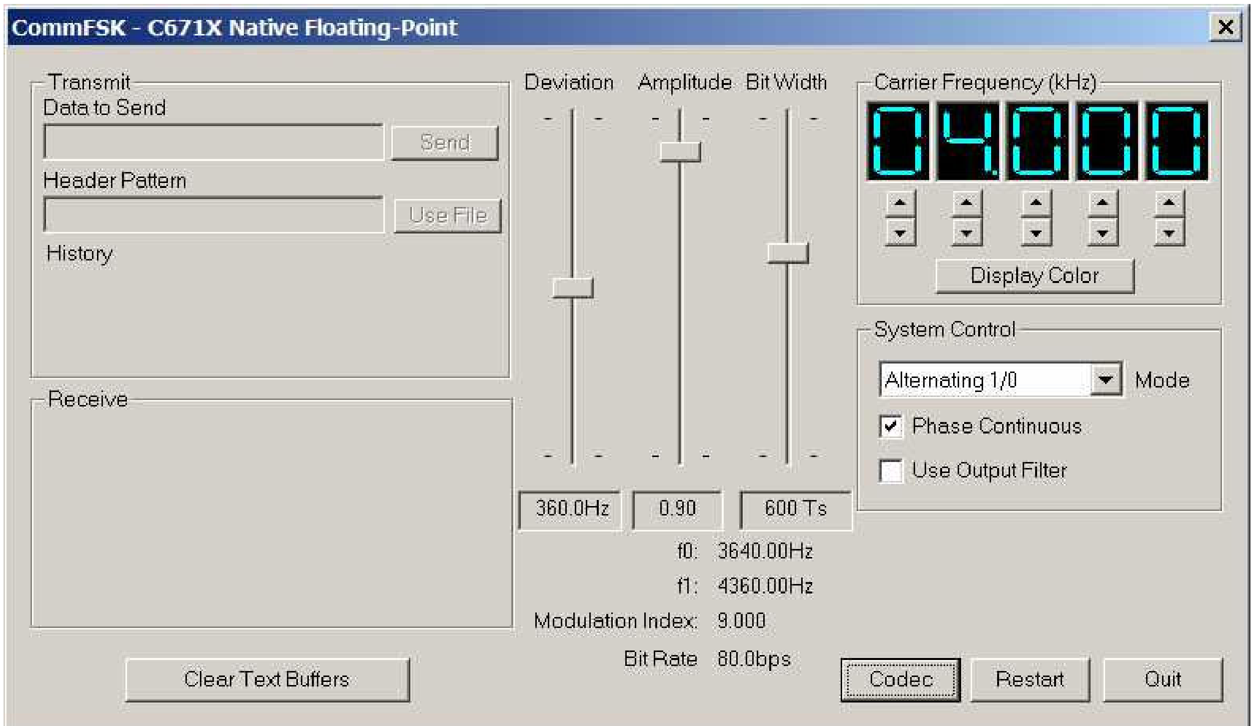


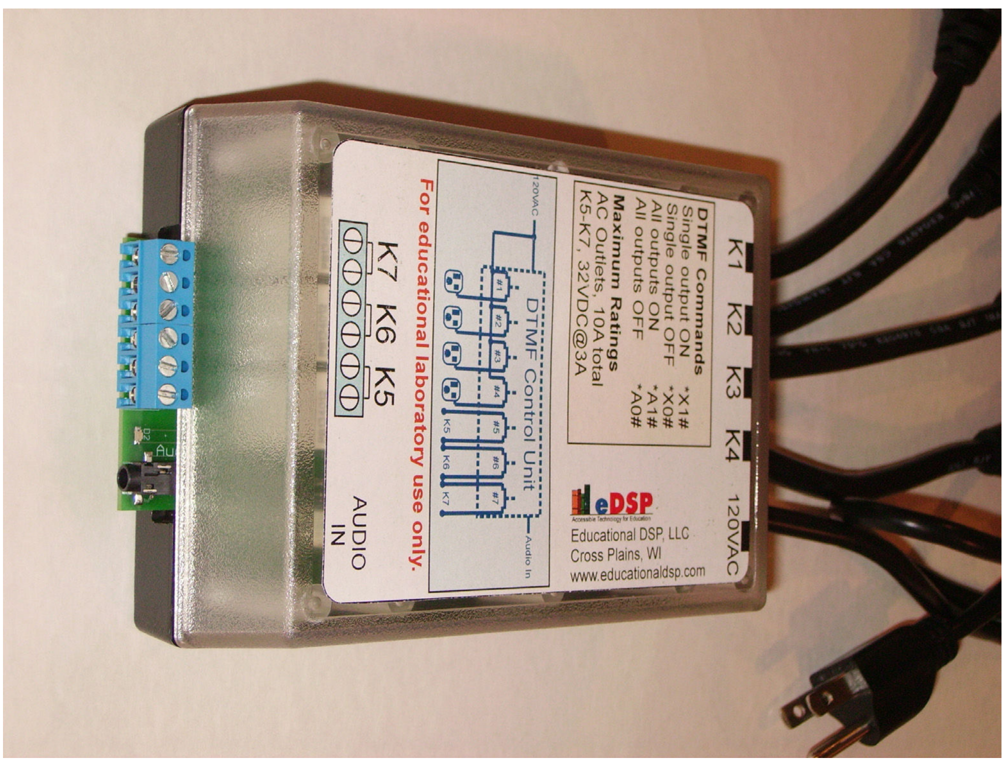
Figure 4: The commFSK user interface.

the basic configuration of low cost DSKs or EVMs (evaluation modules), the available real-time outputs are typically limited to:

- Audio signals
- Light emitting diodes (LEDs) that can be turned on, off, or caused to flash
- Digital input/output pin (0 V and $+5$ V logic control)
- Screen output to the host computer's monitor
- Or with a good deal of effort, stand-alone host computer applications with textual or graphical display windows

While these outputs are informative, we have found that adding the ability to turn on or off an electric motor, a light, or some other appliance adds considerably more interest for many people. For example, suppose a voice/speaker recognition algorithm had as its primary function the ability to recognize the designated user's voice uttering the phrase "fan…on" or "fan…off." While a simulated response such as turning on or off an LED might be used, we have found it to be a much more motivating demonstration if a fan actually turned on or off when the correct phrase is recognized. We have seen many cases in which such a demonstration significantly motivates the observers far more than when an LED or a beep or a screen message is used as the indicator.

(a)



(b)

Figure 5: The new DTMF decoder and power switch box that allows various appliances to be controlled via DSP. (a) The AC power line for supply to the unit and the four AC connectors for controlling external appliances are shown. (b) The three low-voltage relay connections and the audio signal (DTMF) input connector socket can be seen.

The current device is a newly redesigned and improved version of a relay control unit that was described in.[14] During the design of this newest DTMF decoder and power switch box, the system requirements changed several times as we gained a better idea of how we would use the device. The final system requirements follow.

1. Capable of being controlled by any DSP or microprocessor that is capable of controlled generation of DTMF signals
2. Sturdy yet compact enclosure with only 2 cabled connections. These connections are:
   (a) Standard audio cable for the control signal from the DTMF signal generating device (e.g., DSP board, general purpose microprocessor, or microcontroller)
   (b) AC power to supply the relay-switched outlets that subsequently connect to the switched appliances. All of the required control circuitry is powered from a self-contained DC power supply inside the enclosure.
3. Capable of independently controlling up to 4 appliances
4. Provide 3 additional low-voltage relay connections (for a total of 7 switches)
5. Power on/system status indication

4 Outreach and Engineering Education

The real-time DSP-based tools described above have been invaluable in making our engineering-related community outreach efforts more effective, and have improved several of our more traditional courses. In general, we find both prospective students and current students become very interested when they see and use these DSP tools. Better understanding of DSP topics and a higher student retention rate have been qualitatively observed; we are trying to develop a more quantitative method for measuring this, but it has proven challenging.

A brief description of some examples of our use of these tools in community outreach efforts and in our more traditional courses follows. Regarding outreach efforts in particular, the University of Wisconsin-Madison is has the most mature efforts using our real-time DSP tools, followed by the University of Wyoming; Boise State University is just starting to implement these tools under the direction of their new ECE Department Head. Thus the discussion below provides a snapshot of three different progress points for incorporating real-time DSP into these activities.

4.1 At the University of Wisconsin-Madison

The Society of Women Engineers holds a one week summer program entitled "Engineering Tomorrow's Careers" for young women between their junior and senior years in high school. The intent is to expose them to engineering and allow them to interact with people who work in a variety of engineering disciplines. As part of this experience, we have hosted a 90-minute combination classroom/lab session entitled "What is digital? (and why do I care?)." In the classroom, we start off by asking them to form small groups and to create a list of all of the things that "digital" means to them. The answers would surprise most engineers: while they identify the more utilitarian aspects of digital technology (faster, better picture, smaller), they also use words like "sleek," "precise," and "sophisticated." We then introduce them to the basic concepts of digital signals, especially the idea that a digital signal is sampled, and because of that we need to worry about quantization and aliasing. Both effects are demonstrated using winSK6 in the classroom. For quantization, the students are asked to guess how many bits of resolution we need in a music signal before they won't be able to recognize it; no one yet has offered up the correct answer of one bit! This provides a great opportunity to hear what a noise floor sounds like, and to discuss how sophisticated human hearing is. We also discuss and demonstrate basic filtering (for example, how a moving average filter affects a music signal), we talk about some basic audio effects (i.e., flanging, vocoding, etc. . .). In the lab, we then turn them loose in groups of three, with a DSK, microphone, music, and winDSK6, and encourage them to experiment. The lab becomes an incredibly active place, with a very engaged group. We have received very positive comments about the experience; most of the students greatly enjoy the hands-on lab, and many comment on recognizing the various sound effects as things they have heard before in popular music. In addition to outreach activities, we also use these real-time DSP tools in several of our regular ECE courses.

In the capstone design course ECE 468, "Computers in Control and Instrumentation," winDSK6 is used as an example of an appropriate student project outcome. The student projects must utilize the DSK6713 which includes the HPI daughtercard. The winDSK6 program is also used to demonstrate some of the DSP software that the students need to write for their projects. The audio effects, FIR and IIR filter routines, and the scope/spectrum analyzer are used as a reference for the functionality of the project code. The audible effects of aliasing and quantization noise are also demonstrated in class using winDSK6.

In ECE 330, the first signals and systems course for ECE students, winDSK6 is used as a demonstration tool. This course introduces students to the Fourier transform, the sampling theorem, and some (analog) signal processing among other things. The winDSK6 program and a real-time audio spectrum analyzer are used to demonstrate (using sight and sound) how effects like amplitude modulation, high pass, low pass, band pass and notch filtering can be used to productively modify a signal. The effects of violating the sampling theorem are demonstrated using the Talk-Thru application of winDSK6. The demonstrations spark a great deal of interest and discussion among the students, and elicit many favorable comments in their course evaluations.

In ECE 353, "Introduction to Microprocessor Systems," one week of the course is dedicated to analog signal conversion. At the end of this material, winDSK6 is used to demonstrate quantization and aliasing effects. We also use it to impress upon students the power of computer processing of digital signals, by demonstrating FIR filtering, numerous audio effects, and signal generation. In each case, we then pose the question, "okay, what does this look like in software?" In this particular course, winDSK6 has been used for the past 6 years. Remarkably, when we meet these students years after graduation, they still talk about the impression that these demonstrations had on them.

4.2 At the University of Wyoming

For our college freshmen and sophomores, all of our electrical engineering, computer engineering, and electrical engineering (with bioengineering option) majors take ECE 1010, "Introduction to Electrical and Computer Engineering." This course provides extensive hands-on lab exercises that span most facets of the field, but at a purely introductory level. This course has been effective at improving the retention rate for the three ECE majors. Many topics, such as sampling and quantization, basic signal processing, audio special effects, and digital communications are demonstrated using the C6713 DSK and winDSK6. We also have students in this course write a small piece of C code and use Code Composer Studio to personally experience the programming and development tools.

We also use the real-time DSP tools mentioned in this article for several other courses. For example, we use them to provide demos for undergraduate courses such as a signals and systems course (which concentrates on discrete time), a communications theory course, and an elective DSP theory course. We also use these tools extensively in certain graduate-level courses, such as the "DSP Hardware" course and the "Communications Measurement Laboratory" course, both of which make extensive use of the authors' real-time DSP text.[16]

We are in the early phases of incorporating these DSP tools into our outreach efforts. For example, we conduct the summer High School Institute (HSI) program for high school sophomores, which provides exposure to engineering topics to interested and motivated high school sophomores from around the state. Only about 100 applicants are accepted each year for this program, now in its 22nd year. The students live on the University campus for three weeks and learn about humanities, sciences, and engineering. A sequence of classes/demos is given by the ECE department, which covers a broad range of topics in digital systems. We plan to augment several of those lessons by using the C6713 DSKs with winDSK6 software. In particular, audio special effects and a very basic introduction to sampling are appropriate for this audience.

We also conduct the Engineering Summer Program (ESP) for high school juniors. This program is much newer than HSI, is focused on the various branches of engineering, and accepts 30 applicants from around the state each year. This program is also an excellent candidate for using the C6713 DSKs.

In a future article, we will describe the results of adding these real-time DSP demonstrations for these two high school level audiences.

4.3 At Boise State University

A relatively new program involving the utilization of real-time DSP demonstrations has recently commenced at this university. Outreach involves support of local magnet schools' science and math curricula as well as providing career guidance during presentations that focus on such topics as, "what do engineers do?" We also expect to incorporate some of the DSP tools described in this article into some of our existing ECE courses in the near future.

5 CONCLUSIONS

We have discussed the utilization of winDSK6 along with the new DTMF decoder and power switch box to not only educate our own students but also to reach out into the local community to encourage future college students to consider studying engineering. We have found these real-time DSP tools to be highly effective motivators for this diverse audience.

The basic capabilities of the new DTMF decoder and power switch box were described. This system has added a significant power handling capability (as in AC power) to any DSP or microprocessor capable of controlled generation of DTMF signals. These control boxes have been exceedingly well received during our real-time demonstrations. See[23] for more details on this unit.

Finally, none of these demonstrations would be nearly as seamless without the winDSK6 software package used to generate any desired sequence of DTMF signals on the C6713 DSK, and thus control the DTMF decoder and power switch box. This software is freely available for educational, non-profit use, and we invite user suggestions for improvement. See[19,23] for details. Interested parties are also invited to contact the authors via e-mail with suggestions for improvements to the software and hardware tools for real-time DSP.

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