Introduction of DSP Based Experiments In Electrical Engineering Technology Courses

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Abstract

Digital signal processing (DSP) technology has become an important technology with applications ranging from mobile phones, fax machines, multimedia computers, CD players, and will soon replace analog circuitry in TV sets and telephones. It is important that the electrical engineering technology students at the undergraduate level should be exposed to broad hands-on knowledge of the current DSP technologies. The purpose of this paper is to present our efforts in introducing DSP based experiments in a number of undergraduate courses in electrical engineering technology program at the State University of New York Institute of Technology, Utica/Rome. The paper will also review the material and resources available in digital signal processing education. It is expected that such an endeavor in our curriculum will update the program and make the students better prepared for the changing job market.

I. Introduction

The department of electrical engineering technology at the State University of New York Institute of Technology (SUNY), Utica, New York, offers B.S. programs in electrical engineering technology, computer engineering technology and photonics. It also offers an integrated Master of Science Program in Advanced Technology jointly with mechanical and industrial engineering technologies departments. The curriculum in these programs emphasizes hands- on education and has a number of laboratories in the areas of communications, control, digital systems, computer vision, microprocessors, multimedia and networking technology. SUNY Institute of Technology is an upper division transfer college for students who have completed their first two years at a community college.

According to Forward Concepts, a Tempe, Ariz, market research firm, the sale of programmable digital signal processor (DSP) hit more than $3 billion in 1997, and is expected to reach to an estimated $14 billion by the end of year 2002. Much of this growth is driven by the use of digital signal processors (DSPs) in modems for cellular telephony and data communications over the public switched telephone network. Its use is increasing as the demand for internet access has exploded due to its applications in business, work and entertainment. As standards and protocols in these applications continue to change and new features are continually added with higher data rates, the use of programmable DSPs ensures the equipment is upgraded simply by loading new software.[1] Manufacturers of programmable DSP chips are employing new architectures to improve performance and adding support for high-level languages in order to shorten development times.

To respond to the importance of DSP technology, and a need of trained people in this field, the electrical engineering technology department has been working toward introducing DSP- based experiments in a number of courses at the undergraduate level, starting from the Fall of 1999. A two credit-hour course based on the Texas Instrument digital signal processing starter kit (DSK) is also offered for the Fall of 2000.

II. Development Efforts

All the major manufactures of digital signal processors in USA such as Analog devices, Lucent Technologies, Motorola and Texas Instruments have educational kits and University support programs for DSP education and collaborative research.

The authors received a donation in the Summer of 1999 from Texas Instruments for DSP starter kits (DSKs) TMS320C3x and TMS320C3x DTKs under the University Program to introduce DSP based experiments in electrical engineering technology curriculum. The principal author worked in the Summer of 1999 at the Air Force Research Lab at Rome, New York, to investigate the use of C31 DSK kit in the implementation of low data rate modem.[2] A DSP reshapes the signal for transfer over the network in a wired modem and digital wireless applications. Its functions include modulation, demodulation, channel coding and decoding, speech compression, and echco-cancellation. It was therefore decided to introduce experiments and expose the students to programmable DSPs in the following courses.

1. ETC 316 Communication Transmission Techniques (4 credit –hour). A Junior level course and a core course for students concentrating in the area of communications.
2. ETC/CET 416 Data Communication and Computer Network Technology (4 credit- hour). A junior level course for students concentrating in the area of communications and a core course for students majoring in computer engineering technology.
3. ETC 419 Satellite Communications (2 credit-hour course). A senior level course for students concentrating in communications.
4. ETC 421 Wireless Communications Systems (4 credit-hour). A senior level course for students concentrating in communications.
5. ETC 475 Data Compression & Multimedia Technology (4 credit-hour). A senior level course for students interested in communications and multimedia technology.

The Texas Instruments TMS320C3x DSP starter kit (DSK) is based on C31 floating point digital signal processor, which is currently used for a wide range of applications from communications and control to speech processing. It also finds use in cellular phones, fax/modems and disk drives. The C31 DSP is a 32 bit processor with 2K words of internal memory and has a 24-bit address bus to address 16 million words for program, data, and I/O. The DSK board includes a TLC32040 Analog Interface Circuit (AIC) chip with A/D and D/A converters, input (anti-aliasing) and output (reconstruction) filters. The C3x DSK has a host interface port that connects to a parallel port in the host PC. DSK includes all the basic elements to learn the programming of the TM320C31 digital signal processor. The software provided in the C3x DSK includes an assembler, a debugger, and examples of applications.[3]

MATLAB [4] of the Math Works Inc. was updated to include DSP toolbox to introduce students to signal processing and used in lab assignments. The program, SPTOOL, is available on student version of MATLAB 5 and is integrated in the DSK kit via a program developed by Cameron H.G. Wright and others. [5]

III. Experiments

Many Universities and Colleges in US have introduced DSK based courses, mainly in electrical engineering curriculums at the undergraduate level. The students in these courses are well prepared in mathematics to handle the theory required by digital signal processing courses. Our objective, however, was to introduce these experiments for electrical engineering technology students who may not have a strong mathematical background.

The reason for introducing the DSP based experiments was two fold. The first reason was to make students interested in digital signal processing, which is normally considered to be a difficult subject because of the math required to understand it. The second reason was to make the students handle and program the systems based on programmable DSPs. The experiments were designed to insure that students with little or no knowledge of Assembly or C language were able to implement the programs without being intimidated by tedious programming. The following equipment is required to run the experiments:

1. Texas Instrument TMS320C3x DSP starter kit (DSK)
2. Power supply for the DSK
3. Parallel printer port cable
4. Personal computer (IBM compatible)
5. Oscilloscope
6. Signal generator
7. Microphone
8. MATLAB with SPTOOL sof

The DSK starter kit includes a circuit board with a DSP, two manuals and a disk, an external power supply for the DSK board, and a printer port cable. IBM or compatible PC with 386 or higher running at a minimum of 10 MHz is required. Windows 95 or above can be used. Windows NT requires special drivers, which are not supplied by the Texas Instruments. One unused parallel port and a hard disk with at least 10MB of free space is required. An oscilloscope to view the output waveforms and a probe for signal input and output is also required. A signal generator , which can provide a bipolar sine, square, and triangular waveform of 10Hz to 20KHz with a peak to peak voltage of 6V is required. A connecting lead terminated in an RCA jack plug is also needed with the oscillator. A high impedance microphone, terminated in an RCA jack, or used with an adapter is required.

Prior to starting the experiments, it is important for the students to learn to interface the DSK board to the PC, as explained in the TMS320C3x DSP Starter Kit User's Guide [3] (1996), supplied by the Texas Instruments. The next step is to install the software, which consist of two parts: the assembled code for the DSK board and the MS-DOS executable for the PC. The DSK software involves the installation of the DSK, modifying CONFIG.SYS File, modifying the PATH statements and verifying the installation. The executable MS-DOS for PC is used to access the applications used in some experiments. It is important that both the installations must be completed before any experiments are run. DSK software should be installed first.

The first lab assignment introduced at the junior level courses dealt with the use of DSK kit to generate a sinusoidal signal at different frequencies in the time domain and view it on the oscilloscope. The tone of the audio signal was monitored by making use of the sound card and the speaker of the PC. Different frequencies of the sinusoidal signal gave different notes and the higher frequency signal produced higher pitch of the note. Two groups of students can take part in this experiment by using a second DSK and second PC, which can be programmed to act as an oscilloscope. The application for generating the sinusoidal waveform was provided by the Texas Instruments with the DSK kit.

The second lab assignment was to demonstrate analog signals in the frequency domain by the execution of FFT algorithm. This experiment made use of PC-based spectrum analyzer obtained by FFT executable file supplied by TI on the software disk. The DSP performs a 256-point radix-2 FFT on the buffered data to convert it to the frequency domain. The PC reads the 128 values representing the magnitude of the signal into a local buffer and shows 128 data values as a frequency range between DC and the current Nyquist frequency rate. In order to improve the signal-to-noise ratio, the PC can also average the input buffer up to eight previous values. The signal to be analyzed was taken from the signal generator at different frequencies. It is also possible to use an internal ramp signal and view its spectrum on the same PC. Two groups of students can perform spectrum analysis experiment by employing two stations consisting of PCs and DSK kits. One of the station can act as a spectrum analyzer and the other station as an oscilloscope. The signal to be analyzed can be obtained from a signal generator.

The third lab assignment was based on the use of MATLAB to introduce the concept of real-time signal processing techniques by way of DSK kit. The student edition of MATLAB [4] (version 5) and Signal Processing Toolbox (version 4.x, written for MATLAB 5.x) is provided with SPTOOL software, which has an excellent interactive graphical user interface (GUI) for designing digital filters and allows interactive viewing and analysis of signals and their spectra. It is compatible with the program called "qfilt" for filter coefficient quantization developed by Wright C.H.G., Welch, T.B., Morrow M.G. and Gomes III W.J.[5] When the students have designed the filter using SPTOOL, and "qfilt", their design can be downloaded to the C31 DSK kit by clicking the "Load/Run DSK" button on the GUI, which will give them the real-time realization of the filter algorithm. It is achieved by activating a 32-bit dynamic link library (DLL) written with Microsoft Visual C++ 5.0 and the MATLAB MEX file process to run under window 9x or windows NT. The program is freely available on the web site http://wseweb.ew.unsa.edu/ee/LINK/EE.Links.htm, and communicates with the DSK kit and eliminates the need for tedious programming of the DSK. This experiment was introduced at the senior level courses.

The following additional experiments are planned for future implementation.

1. Filters
2. Modulators
3. Modem
4. Equalizers
5. Echo Cancellation
6. Image Enhancement

IV. Results and Resources Used

The introductions of DSP-based experiments were implemented as a part of three communication courses listed above. The experiments were part of the hands-on component of the courses. It was exciting for the students to see the functions and applications of a real –time programmable digital signal processor and how it can be programmed.

The two books [6,7] dealing with digital signal processing using TMS320 C3x were found to be useful sources for developing experiments and lab assignments. The book[6] by Rulph Chassaing lists additional support tools, which are freely available or can be downloaded from the Internet. All the manufactures of DSPs have a lot of helpful information available on their web site and often arrange free workshops on their products. Some manufactures have virtual labs available on their web site and can be used for certain experimentation. Texas Instruments published an Instructor's Guide[8] for TMS320C3x Digital Signal Processing Teaching kit and an introductory book [9] entitled "A Simple Approach to Digital Signal Processing" by Craig Marven and Gillian Ewers. Texas Instruments also holds an annual DSP festival to provide DSP educators a forum to present their research, learn about TI products, discuss new and innovative methods for teaching DSP technology, and learn about the opportunities available through the Texas Instruments University Program. It is also attended by third party and end equipment representatives to demonstrate their products and build relations with educators. A number of on-line tutorials, demonstrations and discussion groups to exchange and share information on DSPs are also available on the Internet.

V. Conclusion

The introduction of DSP-based experiments initially incorporated in the course work of the three courses helped the students understand the concept of digital signal processing and become interested in the use of programmable DSPs and their applications. In the future, we plan to introduce additional experiments (listed in III above) based on Assembly or C language, and MATLAB and by making use of the easily available resources. As the use of DSPs are finding a wide range of real-time applications , the manufactures of DSPs are introducing new products and educational tools. It is expected that with the availability of new hardware and software, many electronic systems will become programmable, where instead of changing an electronic chip for adding new features , it will be simply programmed with new software. DSP technology is certainly an important skill for electrical engineering technology students to acquire, and it is expected that such a skill will make them better prepared for the changing job market and make our program more challenging.

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Bibliography

1. Stevens J, " DSPs in Communications", IEEE Spectrum, September 1998.
2. Qazi S, "Implementation of low Data Rate Modem Using Digital Signal Processing Starter Kit", Final Report for Summer Faculty Research Program sponsored by Air Force Research Laboratory, Rome Site, New York, September 1999.
3. Texas Instrument, Inc., TMS320C3x DSP Starter Kit User's Guide, 1996.
4. MATHLAB: The language of Technical Computing, The Math Works, Inc., Natick, MA, 1996.
5. Wright C.H.G. , Welch, T. B, Morrow, M.G., Gomes III, W.J. "Teaching Real-World DSP Using MATLAB and the TMS320 DSK", Proceeding of the 1999 ASEE Annual Conference, Charlotte, N.C. June 1999.
6. Rulph Chassaing , " Digital Signal Processing", Laboratory Experiments Using C and the TMS320C31 DSK, John Wiley & Sons, INC. 1999.
7. Tretter S.A. " Communication System Design Using DSP Algorithm " with Laboratory Experiments for the TMS320C30, Plenum press, New York. 1995.
8. TMS320C3x Digital Signal Processing Teaching Kit, Instructor's Guide, Texas Instruments, 1998.
9. Marven C, Ewers G, "A simple Approach to Digital Signal Processing", John Wiley,1966.

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