ICASSP 2002 Special Session Paper (Signal Processing Education II)

Benefits of DSP Extra-curricular Activities: A Look at the Texas Instruments DSP and Analog Challenge

Torrence H. Robinson (Texas Instruments), Nimrod Peleg (Technion, Israel Institute of Technology), Patrick Frantz (Rice University), Jacob Rhodes (Rice University)

Description of DSP the TI DSP and Analog Challenge

This paper describes the benefits associated with student and faculty participation in digital signal processing design activities that fall outside of the usual university course requirements. It will also describe industry's role in sponsoring these extra-curricular activities. The paper details the lessons learned, skill sets honed, of both students and faculty who participated in the 2000 Texas Instruments Digital Signal Processor (DSP) and Analog Challenge™.

The TI Challenge was a skills-based competition for university students in countries around the world. The requirements were to create and submit to TI, an original design, which employed a TI DSP, associated analog components, and included any applicable original software program. The design was to operate as a functional application. From program announcement, student teams consisting of undergraduate, graduate and/or doctoral candidates, had approximately three semesters to complete and submit their projects. Teams were not constrained by limiting the types of applications they could pursue. They enjoyed full use of their ingenuity to create entirely new applications or to enhance existing applications. The awards for winning the competitions ranged from US$1,000 for regional semi-finalists to US$100,000 for the grand prize winning team.

The opportunity to win a monetary award, however, was not the only benefit that students and faculty gained from participating in the TI Challenge. Students gained invaluable "hands-on" experiences that are transferable to careers within the high-tech industry. Most student teams were exposed to the mercilessness of uncompromising time schedules, and to the challenges of effectively assigning project responsibilities so as to best match team member capabilities. Extra-curricular design activities provide students with the chance to apply leadership, organizational, programming and design skills to a project where there is more than a grade at stake.

The ability to effectively communicate is a common attribute of "successful" engineers. Student teams were required to use their communications skills when meeting the competition criteria of quality, clarity and preciseness. These qualities were first assessed in the written report, and if the project scored high enough to have a chance of winning an award, the team had to present the same quality, clarity and preciseness via the oral presentation. Examples of the importance of communication include that of an engineering team leader who must convince her manager that the solution created by her team is the best for the department or company. Her ability to communicate how her team's solution addresses company requirements such as cost, performance, and ease of use are critical for her team's, the company's and her career success. Another example, is the technologist that is called into a business meeting to explain the details of an application to a prospective customer. The ability of the technologist to answer customer questions succinctly and convincingly will again drive company and individual success.
The role of DSP extra-curricular activities in the educational process of the engineer

In addition to honing what many would term "soft" skills, or those skills which may be deemed complementary to the fundamental technical abilities required to be an engineer, DSP extra-curricular activities help develop and refine many of the "core" engineering competencies. The team from the Technion, Israel Institute of Technology (Israel), whose project, "Real-Time Digital Watermarking System for Audio Signals Using Perceptual Masking", was awarded the TI Challenge grand-prize, is an example of this learning opportunity. By participating in the TI Challenge Technion team members, under the guidance of the faculty team advisor, had the opportunity to solve a real-time digital signal processing problem while adhering to industry constraints such as, time, competitive forces, and limited resources. They began to tackle the design process by first defining a conceptual solution, and then letting the students (with the supervision of the academic and technical staff) create their own solution for the problem.

To initiate the DSP-based project, the following three steps were first carried out:

1. Selection of an algorithm that gave a suitable answer to the problem
2. Selection of a simulation and software environments in order to examine the solution.
3. Selection of a suitable DSP architecture that would achieve an optimal real-time cost-performance.

The activities involved in each of these steps are depicted in the block diagram below:

One of the most challenging learning opportunities when developing a design solution, is selecting a suitable platform (i.e. a DSP family and a specific component). Suitability is measured in the context of performance, cost, power dissipation, availability of development equipment, quality of software development tools and more.

The students needed to learn and apply many design aspects and development tools, such as:

- **DSP Concepts**: Harvard architecture, multiple busses, parallel programming, fixed-point programming, etc.
Software analysis: Profiling, analyzing and writing DSP software to fit the specific architecture selected.

Fixed-point: Determine how to achieve the best results while still using a cost efficient fixed point architecture (e.g. filter design)

Code translation for real-time implementation: Dealing with the problems of converting from a general Matlab™ / 'C' code into an assembly application, e.g., sampling data from an analog-to-digital converter (ADC) instead of using disk storage or a standard sampling card.

TI's eXpressDSP™: Using this strong tool as a guide for the whole design process, code building, debugging, analysis, and fine-tuning.

DSP/BIOS™ kernel: Used as a real-time kernel for professional and standard implementation of multithreading, analysis tools and peripheral configuration libraries.

Other important aspects of the Technion project related to concepts in audio signal processing, such as:

- Sampling and reconstruction of audio signals (input and output filters, sampling rates etc.)
- Understanding the human speech production system, the human auditory system, and the MPEG psycho-acoustic masking model that was used in the system.
- Quantization of signals and its effect on signal quality
- FIR/IIR filter design aspects
- Encryption techniques

In addition to using the engineering design process in creation of their application, the Technion had the added factor of integrating the team members' strengths and weaknesses in developing their application. Technion team members, Yuval Cassuto and Michael Lustig described the experience as follows, "Differences in our working methods and preferred solutions worried us initially, but these differences turned (out) to be a great advantage. Whenever we faced a problem, we managed to come up with different approaches and one usually worked. Whenever one person's method was found to be slow or inefficient, the other's approach brought progress." ¹

Rice University's (Houston, TX, USA) project, "Paladin: Personal Mobile Wireless Video", earned the team one of two finalist awards. TI Challenge participation provided its faculty team leader the opportunity to teach students two main concepts. The first was practical applications of DSP theory. The application involved the wireless transmission of video data. It is one thing to do an implementation of theory (in this case, video coding) in a high-level program such as Matlab™. It is an entirely different matter to move that application to a DSP. Rice team members had to wrestle with things like fetching code and data from off-chip memory, which can introduce unexpected delays. In other cases, intimate knowledge of the DSP architecture was required and assembly code needed to be written to extract the fullest possible performance. Wrestling with these problems reinforced the idea for the students that theory and practice go hand in hand. New theory can produce applications that never existed before, while practical restraints and obstacles that arise during implementation can encourage theoreticians to develop more optimal and implementation-friendly algorithms. The two are not incompatible.

¹ “A Mark of Distinction”, New Electronics on Campus, Spring 2002, pp. 18-19
The second concept this experience introduced to the students was a total immersion into the world of hardware and product design. Rice chose to design its own DSP-based hardware for the competition, and the students learned that this is not always as easy as it sounds. During the design process, the students were forced to reckon with things such as unexpected delays, circuit boards that were not manufactured properly, and parts used in the design that were unavailable (due to forces beyond their control). These are "real-world" issues that every practicing engineer will face at some point in his/her career. Above all, students learned that engineering is all about design tradeoffs, and that product engineering is not quite as easy as it appears. The formidable task is comprehension and successful completion of the details.

Again, a lesson learned from a student team member perspective, was exposure to nearly all aspects of the design process. From initial top-down design, to schematics and board layout, and finally to board fabrication and assembly. Traditional courses based on research do not have "turn times" to get your work back; you simply finish proving something and proceed to proving something else. Similarities would include such courses as VLSI design where students must also meet industrial deadlines, though not nearly in such a time-crunched scale.

The most significant lesson learned about the design process is that the schedule really does matter. Since the Rice project involved hardware and software development, the team faced a number of complexities. The most significant of these was the challenge of software and hardware co-development. The initial work was done with a TMS320C6211™ DSP Starter Kit (DSK), but in the end the team wanted to target a different member of the TMS320C6000™ family, which had a different feature set (e.g. memory map, peripherals, etc.). Rice designed its own image capture hardware that had to be integrated with the development system and with its own DSP hardware. When it became clear that its custom DSP hardware could not be built, the team had to quickly shift focus and devise an alternative plan that involved major software code changes. The experience was described as very stressful, but at the same time very exciting because these were the same problems that are often faced by design engineers. Students really understood this after completion of the project.

Additional benefits and challenges of implementing a DSP extra-curricular activity

Faculty and staff benefit from the DSP extra-curricular activities because they are able to provide their students with an experience that allows them apply the theory they have learned to a meaningful application, as defined by the students. The TI Challenge provided a framework for exposing students to a real world design experience, similar to that found in a capstone design course, with the additional opportunity for award, recognition, and publication.

All of the members of the team were exposed to a real-life case study of the team environment. They were forced to deal with each other's schedules and time resources. There were often times when work had to be distributed based on individual skills and pick up work from other members when they needed more direly to work on something else.

The time investment, although difficult, is almost certainly a positive experience. The hours in the lab were less than desirable at the time, given that participation in the competition was in addition to a full course schedule. One students remarks, however, that "I cannot help but think that our learning was as acute during this period than it's ever been in any of our courses."
Even though only one team can win the grand prize, and the effort expended to compete can be exhausting, the Rice team members admitted that they would all do it again. The students learned a great deal about DSP in particular and engineering in general. And I learned a tremendous amount about effective team management. I also learned a lot about what I can expect from undergraduate and graduate students, in terms of their abilities as engineers. This experience has definitely helped us in a number of other research and prototyping efforts at Rice University.

**Industry Benefits**

Industrial sponsors also benefit from offering such competitions. Benefits include an experienced pool of applicants familiar with relevant technology, applicants which have experienced the challenges of working in teams, the spark of new application ideas, and an opportunity to foster new and strengthen old university relationships.

Activities that lessen the time period between "raw, new college hire" to "fully productive, experienced contributor" help improve company competitiveness. Other industry benefits due to a better qualified applicant pool, are employees who understand the positive impact of effective teaming, and employees who truly appreciate the importance of meeting schedules, timelines, and group expectations.

In addition to the individual student impact resulting from industry sponsorship of extra-curricular design activities, there is also the opportunity to form new and stronger relationships with the university partners. Industry invests hundreds of millions of dollars annually in university research because of how important university research is to the continued advancement of technology. There is also no doubt that university engineering education is equally, if not more, important. Engineering education is not as "glamorous" today as cutting edge engineering research, but without improvement in that area universities will continue to graduate less engineers. Well run, focused, industry sponsored extra-curricular design activities help promote relevant educational activities for the next generation of engineers.

**What you should do now**

In today's highly competitive marketplace it is critical that students graduate with the skills necessary to successfully compete. Engineering programs who provide its students with the opportunities to tie together DSP theory with practical, relevant implementation examples are the programs which are providing superior value to its students and industry partners, thereby enhancing the overall value of the program.

Actively promote participation in future TI Challenge or similar programs that are designed to promote the learning described in this paper. Challenge your colleagues, department chairs, and deans to work through the challenges that semester or multi-semester lab intensive projects can present. The end-result will help continue the drive for continued innovation by engineers who are prepared for the task.