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

by
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Abstract

This paper describes the benefits associated with student and faculty participation in DSP design-related 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 and skill sets honed of both the students and faculty who participated in the 2000 Texas Instruments Digital Signal Processor (DSP) and Analog Challenge™.

The TI Challenge was a worldwide skills-based competition for university students, where they were challenged to create and submit an original design that employed a TI digital signal processor and included any applicable original software program. Student teams were free to apply their ingenuity to create entirely new applications or improve upon already existing applications, as they competed for prize awards up to US$100,000.

In addition to the opportunity for a monetary award, students gained invaluable hands-on experiences by working with state-of-the-art equipment. They were exposed to the reality of uncompromising time schedules and to the challenges of effectively matching project responsibilities to team member capabilities. Faculty and staff benefited because they were then able to offer students the advantage of a comprehensive experience that allowed them to put into practice the theory learned in the classroom, and industry benefited by expanding the pool of applicants experienced with the entire design process. In short, the TI Challenge provided a framework for exposing students to a real world design experience with the additional opportunity for award, recognition, and publication.

Description of DSP the TI DSP and Analog Challenge

The Texas Instruments Digital Signal Processor (DSP) and Analog 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 were 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 and maximize 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, company, and personal 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.

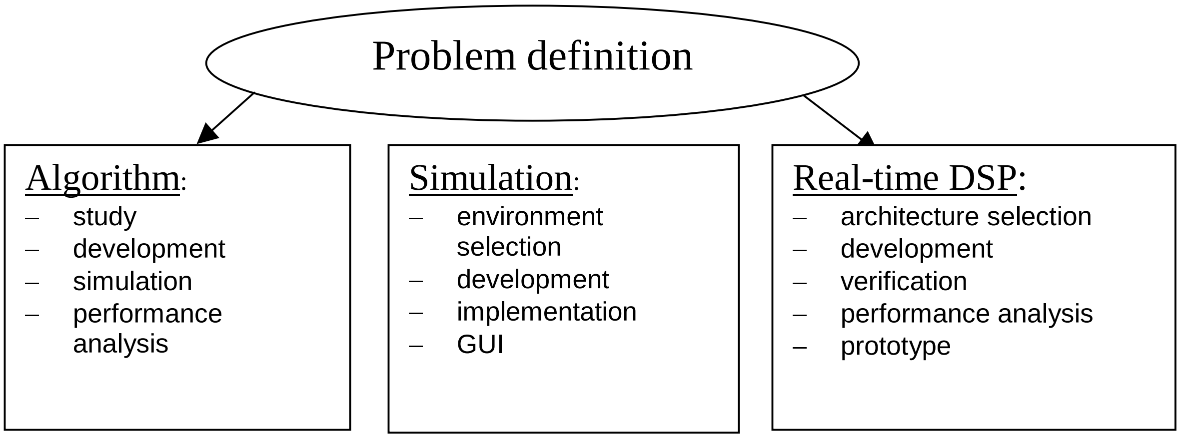
The Role of DSP Extra-curricular Activities in the Educational Process of the Engineer

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 team faculty 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 realistic *conceptual* solution, and then letting the students (with the supervision of the academic and technical staff) create their own *practical* 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 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*™: Use of 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 tasks 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.

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 cope with obstacles 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 a VLSI design course or a "capstone" design course, where students must also meet deadlines similar to those in industry, 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,

[1] "A Mark of Distinction", New Electronics on Campus, Spring 2002, pp. 18-19

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

Students are not the only group that benefits from DSP extra-curricular activities. Faculty and staff benefit as well because they are able to provide their students with an experience that allows them apply the theory they have learned to a *meaningful*, student-defined application. The TI Challenge provided a framework for exposing students to a real world design experience, similar to that found in a capstone design course.

Project participants were exposed to real-life case studies of the team environment. They were forced to deal with each other’s schedules and time resources. Team members had the experience of redistributing work assignments based on individual skill levels and progress and urgency of different areas of the project.

The time investment, although difficult, is almost certainly a positive experience. The extra hours in the lab were most likely perceived as less than desirable at the time, given that participation in the competition can equate to a full course schedule. One student remarked, 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 could win the grand prize, and the effort expended to compete was 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. Patrick Frantz, the Rice team’s faculty advisor, indicated that he learned a tremendous amount about effective team management. He also learned a lot about what faculty can expect from undergraduate and graduate students, in terms of their abilities as engineers. Frantz claimed that the experience definitely helped Rice in a number of other ongoing research and prototyping efforts at the school. Another faculty benefit cited by the Technion, was a 50% increase in their lab course registration, attributed to the publicity garnered by Technion student success in the competition.

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 as a result of 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.

Industry invests billions of dollars annually [2] in university research because of the significant contributions universities make to the continued advancement of technology. There is also no doubt that university-level engineering education is equally, if not more, important. Engineering education may not be as "glamorous" today as cutting edge research, but without improvement in education universities will continue to graduate fewer 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 that 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 address the type of learning experiences 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 fully prepared for the task.

[2] U.S. R&D expenditures, by performing sector and source of funds: 1953-2000, Science and Engineering Indicators 2002, Table 4-5, http://www.nsf.gov/sbe/srs/seind02/append/c4/at04-05.xls