Effective Research Experience of Electrical Engineering Technology Students

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Abstract - This paper describes a project in which undergraduate engineering technology students, engineering graduate students, and a technical high school minority student experienced the research environment and worked together towards the success of a project in power electronics. Various aspects of the student research experience including teamwork, responsibility distribution, discussions, co-ordination, and strategies for the development of the project are outlined. Specific initiatives undertaken at Wayne State University to increase undergraduate research are mentioned. Impact of the project and its influence on research and education and future challenges are highlighted.

I. BACKGROUND

Several initiatives have been taken by many universities nationwide in the last decade to improve participation of undergraduate students in research. Also evident are the increasing efforts of universities to increase minority student involvement in research. As outcome of such efforts, faculty members have made available their experiences in papers, few of which are referenced here [1-4]. These efforts are taken attributing to the needs from prospective employers who have begun demanding strong basic engineering knowledge and problem solving skills in the engineers they hire. At Wayne State University (WSU), with a predominant undergraduate emphasis, the NSF funded Alliance for Minority Participation (AMP), and Undergraduate Research Experiences (REU) are two major programs, which involve already enrolled engineering student population in research. The university publishes an undergraduate research catalog annually in which selected faculty members are listed along with their research areas and opportunities for student research.

In efforts to attracting the best and talented students to the university, the university has a ‘Research Apprentice program’ (RAP), specifically targeted towards the technical high school minority students in the metro Detroit area. High technical aptitude students recruited under the program are attached to chosen faculty mentors to work on a one-on-one basis during summer. Also this year, WSU college of Engineering under a grant from the Michigan Space Grant Consortium, has begun a ‘Women in Engineering Training’ program for seventh grade girls. The program provides these students with examples of engineering careers through interactions with female engineering students and faculty at WSU. The WSU chapter of the society of women engineers is to play an important role in this project. This faculty member is one of the member’s associates with program.

Last year for the very first time, the undergraduate student council at WSU, along with the office of the vice-president for academic affairs introduced a university wide new undergraduate research program, which revolved around students rather than around a faculty member, in terms of the research project, and the process. The student council advertised for three-page research proposals from students in a format describing the research project, its goals, outcomes, and a description of each student role. Also requested was the faculty mentor role. A small budget of $1000 was also associated with the proposal for student efforts with up to three students in a team. The faculty mentor would receive $500 for project costs.

In this paper, the research project funded to the students under the above program, and its essential elements including the outcomes are described. The effective involvement of the technical high-school minority student is detailed. The paper is concluded with the scope of future challenges listed and details of the on-going work.

II. THE PROJECT

The student research revolved around a power electronic application. This section describes briefly the actual research project, which the students worked on. The objective was to derive variable frequency currents from a fixed frequency voltage source simultaneously minimizing switching losses in a power converter. The converter was novel and utilized resonant principles for its operation. It consisted of three power stages, an input rectifier, a resonant link and an output bridge, the inverter. The function of the link was to achieve minimized losses through resonance. The digital controller had to appropriately determine and provide the switching signals for the devices of the three stages. The output of the converter was to drive a motor at variable speeds. Additional goal was to utilize a Texas Instruments TMS320C30 digital signal processor (DSP) in the controller and tailor it to this application. DSP’s, traditionally meant for communication applications, have been found in several other applications due to their capability to handle complex tasks numerically. The students were to use their C programming capabilities such
that freedom from tackling assembly language instructions was achieved.

This DSP based project required knowledge of both hardware and software from the students in order to accomplish the goals of the project on time. The technical background required was in dc/ac circuits, power electronics basics, analog/digital logic, a/d and d/a conversion, assembly and / or C language programming skills. There have been reports of digital signal processing courses already introduced at some universities [5-7]. This knowledge if available, would eliminate the initial preparation of the students in learning about DSP’s and yield much quicker progress.

The project had previous funding from WSU and the Michigan Space Grant Consortium for research in 1995-97. Currently the faculty member and an engineering graduate student are also funded internally through a minority faculty/staff summer research grant.

### III. METHODOLOGY

Two senior undergraduate electrical engineering technology students were identified. Upon recognizing the expressed interests, the faculty member made the scope of the research project known to the students. The students wrote the proposal with guidance from the professor. These students won the inaugural WSU undergraduate research grant for this project in the beginning of summer 1997 in a university wide competition with a mention that it was the best-written proposal. A metro Detroit technical high school student recruited under the previously mentioned research apprentice program was added to the team.

The project consisted of the design and development of the power converter controller. The hardware and software features were to be designed. The software features consisted of (i) developing the switching strategies of the three-phase power converter, (ii) programming the digital signal processor using C++ and (iii) generating the code for the switching signals. The hardware features involved developing the processing stages for the signals before actual connection to the power devices. The actual building of the power circuits of the converter was also essential.

The expertise and experience of the undergraduate ET students and the graduate students determined the tasks of the project. One of the two undergraduate students acted as the project team leader. The project activities were distributed per the educational level, background, and experience of the individual. The progress of the project was determined by the modes of self-learning, team effort, and peer observation and evaluation. The students themselves coordinated the various activities of the project.

The project tasks were divided into the following:

(a) Power circuit development and
(b) Controller design and development
(c) Testing

A working prototype of the single-phase power converter was provided as an example for the students to build the three-phase version. The same power components other than the power devices were utilized for the three-phase circuit. The various steps in the power circuit development were:

(i) Layout of input, output and link power circuits (ii) Placement of dc link and resonant link power components and (iii) Input and load connections and power circuit wiring

The essential steps involved in the design and development of the controller were:

(i) Derivation of strategies and development of algorithm to achieve power converter device switching patterns (ii) Development of interface circuitry (iv) Testing of controller

The controller consisted of a 486 IBM PC which housed a System Board consisting of: a) DSP b) a/d and d/a converters, c) Intel 8255 parallel peripheral interface board, along with the software tools.

### IV. STUDENT ROLE AND EXPERIENCE

The task of the high school student was to build circuits from schematics and to document the board layouts and connections. Being a technically sharp and very keen to assume highly technical oriented tasks, it took only about a few weeks for the professor to make the high-school student aware of the Kirchoff’s laws, Pspice simulation, components, their identification, nomenclature, placement, wiring, and usage of integrated circuits. With this initial investment of only few hours per week, one-on-one with the high-school student, the rewards were very huge. The undergraduate students taught her how to solder components together. At this stage, the high school student could work independently with guidance from the undergraduate students and the professor when needed. She did the preliminary layout of the power circuit boards with only the schematic as a guide and with only occasional help from the undergraduate students. She was also independent in wire wrapping the connections or in connecting them on breadboards, or in developing a Pspice simulation model of the circuits involved.

The task of one of the undergraduate students was to plan and mount the different power and control circuit components. With his background in telecommunications, the student made provisions for minimized electromagnetic interference. Using one of his circuit boards as a template, the high school student was able to mount and connect the components of the power circuit efficiently. The other student’s quality control experience insured professionalism in the project work. His supervisory skills were utilized in guiding the team and establishing satisfactory progress. He was also responsible for developing the switching strategies of the devices of the three-phase power converter, and to modify the C++ programs to generate the three-phase signals.

As prior work, four electrical and computer engineering graduate students and three EET undergraduate students had developed and tested the single-phase prototype of the controller using the DSP in 1995-97. Development of variable frequency generation algorithms, C++ programs and data transfer methodologies between the 16 bit PC and 32
bit DSP bus were made possible by two graduate students. Another minority undergraduate student, funded under the AMP program during winter 1997 semester had interfaced the DSP to an Intel 8255 parallel peripheral device for the real-time signals. Details of this student’s work will be available in the 1998 ASEE Annual Conference Proceedings [10].

The hardware experience of the undergraduate students allowed them to design, plan, build and test the printed circuit boards of the interface circuitry while adopting proper troubleshooting procedures. Programming languages and digital hardware design learned in the students’ undergraduate education were utilized. Pspice simulation technique learnt in the network analysis and digital design courses enabled them carryout simulation of the several stages of the control circuits. This supported their analysis while testing the circuit.

The high-school student also prepared the computer layouts and termination descriptions of the different power and signal processing boards based on those prepared by the senior student. She converted the hand written documents and board layouts, given by the team leader to typed documents using Microsoft Word and its drawing palate. The circuit diagrams were drawn in Pspice and pasted to the documents. She became very proficient in using both of these programs.

When all the aspects of the controller were ascertained, the testing of the prototype power circuit was attempted. Currently the development is functional in a three-phase motor drive controller configuration.

V. OUTCOMES

Early results of this project were presented at a local conference through a poster presentation [8]. Here again, the students prepared the poster boards with guidance from the professor only towards the consistency and relevancy of the material. By the end of summer, the high-school student summarized her contribution to the project and presented it to the authorities of the program at WSU and Detroit public school personnel. On a mutual interest basis, the research apprentice was reassigned for this research experience from Fall 1997 till Winter 1998 and continued to be a significant part of the research experience. For all the efforts of the high-school student, the professor has not been monetarily responsible, other than providing mentoring and research opportunity. The RAP program and the Detroit public school system paid for this student’s efforts. This student, at the time of writing this paper has graduated from her high school and has accepted admission at the University of Michigan, Ann Arbor in its Electrical and Computer Engineering Program.

The team leader of the project took initiative to compete in the 1997 Texas Instruments DSP Challenge along with another Electrical and Computer Engineering graduate student who also worked under the professor. The competition required the application for the competition to be built around the capabilities of a TI DSP and this suited the time frame of this research experience perfectly. The entry was accepted for the challenge. A final report was submitted to TI by the end of last October in the format specified. Though the outcome of this competition hasn’t been heard till date, the experience gained through participation was very valuable. Enormous usage of the TI Internet site was made in order to compete well in the challenge. One of the students carried his contribution towards this research project to fulfil his senior project requirements and defended his work through a presentation and graduated in December 1997.

As part of the initiative of the university, a first annual undergraduate research conference was held on February 10th, 1998 in which all the recipients of the undergraduate grants presented their results in oral and poster presentations in the newly built undergraduate library. The appropriate site chosen disseminated the scope of this research program to large extents. Along with, the faculty mentors were recognized for their contribution during the conference.

As a final stage of the project, a three-page report was submitted by the team leader to the undergraduate research council at the end of February 1998 [9]. The team leader, also a minority senior undergraduate student, wrapped up his contribution for inclusion into his senior project requirements at the division. This student was also one of the co-authors of a paper presented at the 1998 IEEE International circuits and systems symposium held at Monterey, California in June 1998.

VI. IMPACT AND FUTURE CHALLENGES

The impact of this research experience are in several dimensions and directions. Examples of the advantages are available in literature [1]. The one-to-one discussions, understanding, work, and communication between the professor and the students and amongst themselves, has increased confidence levels of the students and in presenting themselves. Their working at the research setting and several times with the professor has yielded the success expected of the project. For the students, commercially the contribution to this research project has strengthened their resume to market themselves better and fulfils the requirements of present day employers who demand overall sound engineering skills. The experience has provided them exposure and experience at least in computer hardware and software, communications, power electronics, mixed signal analysis and simulation, and microprocessor based real-time peripheral interfacing, etc. Though the project funding is extremely small, the results are many times in magnitude and in reality not comparable. Thus the funding has served as just a token. The project results will be submitted for a university wide research award competition later this year under the same program. Additionally the team leader of this research project is due to receive a $300 travel grant from the university vice president’s office towards attending the conference in which his paper is accepted for presentation.
The project has remained as a successful example at the university for the college of engineering and to the division of engineering technology students in particular. It also reflects very well on the hands-on experience of engineering technology students.

Proposals from a student team of two senior electrical engineering Technology and an electrical engineering sophomore, and another of one minority senior undergraduate EET student were submitted to this year’s undergraduate research council grants. The first one of these, concerning the development of intelligent automotive applications based on Motorola 68HC12 microcontroller has been funded and currently the project is under progress. The same team has also submitted their entry [11] into the 1998 Motorola Design Contest. The results of the contest are anticipated in July 1998. Just last month, the same team has also submitted a proposal to the National Collegiate Inventors and Innovator’s Alliance (NCIIA) for securing further external funding for their project. In addition, under this year’s WSU Research Apprentice Program, another Detroit Area Technical high school minority student has been recruited and the student is expected to join the research team under this faculty member in mid June. Added perspective for the research apprentice is participation in the Detroit and Michigan Science fair’s in 1999 and an opportunity to experience the research environment at Wayne State University and make his/her future career choices.

To the professor, this research example provided constant interaction with students. The development of thought process, resulted in advancement of research in power electronics, and in significant scholarly publications. Being a student prominent research project, it provided the professor an opportunity to step aside and be an observer several times and only provide guidance when needed. This example also serves to well justify research progress at divisions where funding for research is minimal.

The AMP program continues to be university wide active program. Securing NSF and other funding for the REU site establishment are under progress. Attributed to the success component of this research program, its key elements will be offered for incorporation in the AMP program and in the other existing REU sites at WSU.

VII. REFERENCES