INTRODUCING MICROCONTROLLERS AND PLCS

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Abstract — *At the University of Western Sydney's School of Engineering, students are introduced to a revised unit of study that covered microcontrollers and programmable logic controllers in an integrated manner. The students who took up the unit came from various bachelor programs such as mechatronic/robotics and electrical engineering. Around 50% of the class were students in the second year of a mechatronic/robotics program with the remainder coming from electrical and computer engineering programs. The aim of the course was to expose students to the theoretical and practical experiences in applying the two different types of platforms to control type problems. In lectures the microcontrollers and PLCs were compared and contrasted. The course included a significant hands-on practical component; the students would work with the microcontroller in one week and the PLC in the next week, alternating in this manner throughout the semester. The students were introduced to assembly and ladder logic programming and as extensions, given small, problem based tasks to solve with the two controllers. The student assessment of the unit at the end of the first offering of the integrated unit had mixed results. In all 31% of the class found the overall experience not to their liking, some 13% % were neutral and 56% had a satisfactory experience. Developments of the next iteration for future delivery have continued.*

Index Terms — Programmable logic controllers, microcontrollers, Omron, integrated delivery

INTRODUCTION

As part of the coursework for the undergraduate bachelors degree in engineering, engineering students in their second year of study undertake a unit of study that introduces at the same time microcontrollers and programmable logic controllers. At the University of Western Sydney, students undertake the study of 4 units of 10 credit points each for 14 weeks per session. One academic period is termed a "session" and consists of 13 teaching weeks, one week of study vacation followed by 2 weeks of formal examinations. Prior to the 2007 Autumn session. the unit had been delivered with the contents as two separate parts [1] and the need was recognized for the two parts to be integrated into a more holistic version following a review by the School of Engineering. The theme used to take a new approach and to integrate the two devices making use of the theme of "embedded controllers", with the microcontroller and the PLC being looked upon as the main controller of a control oriented task. In essence, the controllers make use of CPU type intelligence and so at this level they have many similarities. The user interface is where the key difference lies. The two types of controllers typically become transparent to the user in the final control configuration.

The students that made up the class consisted of students in various strands of different bachelor degrees. For example, for students in the mechantronics / robotics strand, the unit was part of their core studies that had to be completed. For others the unit was an optional elective. For example, during the 2007 delivery, the cohort consisted approximately of 44% (18/41) students in the mechatronics/robotics program, 46% (19/41) students in the electrical / computer strands. There were also two students enrolled in the industrial design engineering strand and 2 postgraduates.

The bachelor degrees offered by the School of Engineering are fully accredited by the Institution of Engineers, Australia (IEAust), and allow for graduate entry into the Institution. As part of the accreditation requirements, certain graduate attributes must be observable at graduation. In fact both the University as well as the Institution of Engineers have sets of graduate attributes. For example one of the the IEAust attributes is "the ability to undertake problem identification, formulation and solution". Also the "ability to apply knowledge of basic science and engineering fundamentals" along with " in depth technical competence in at least one engineering discipline". It was thought that this unit would be relevant to the development of these attributes.

To gauge the context in which the Microcontrollers and PLCs unit would be received, in week 1 students were asked to fill out a starting survey and 16 surveys were returned. The questions of interest to the presenters were the number of hours spent in casual employment and the time devoted to independent study. Of the 16 surveys returned, 11 stated that casual work up to 12 hours and more was as a norm undertaken. A full time student would be expected to devote up to 40 hours per week in study; an additional 12 hours or more in casual work meant that the students would be completing 50+ hour weeks. Would this be sustainable over the teaching session?

With regard to the number of hours spent in independent study, the design of the course was based on units of 10 credit points. The 4 units per session would amount to 40 credit points, with an expectation that a 40 hour working week would apply. Thus for each 10 credit point units, some 5-5.5 hours would be spent in face to face contact, and the remainder in independent follow up study. Of the 16 survey respondent, 10 stated that 6 hours per week would be expended in independent study. The remaining 6 or 38% would not devote 6 hours to independent study.

DELIVERY

The material in the unit was delivered through lectures and combined tutorial/practical sessions. The students were required to purchase a Reader which contained the revised unit outline, an outline of the contents of each lecture, a practical schedule and the manufacturer's manual for the microcontroller kit [2], among other items. The microcontroller employed was of the Intel 8051 family and was a high end microcontroller, the SAB 80C517A, manufactured by Siemens. As circumstances prevailed at the time, there had been insufficient time to incorporate the needed PLC material into the Reader, consequently, the material for the PLC was disseminated via Blackboard during the course of the session.

In contrast to the microcontroller, the PLC was a low end of the market device manufactured by Omron [3]. The advantage of the Omron PLC was in the fact that the software used by the students was the same as that used for the whole range of Omron PLCs in this type of device; the only difference was that some drivers for the high end PLC were not included. So the students could experience essentially the same software they would encounter on the job during their introductory sessions to the PLC.

The topics covered in the unit included an introduction to microcontrollers and PLCs, discussion of the hardware features of the two controllers, controller instruction sets, ladder and assembly programming, timers, interrupts and serial communications.

PRACTICAL TASKS AND ASSESSMENTS

The practical tasks commenced in week 1 with an introduction to the 8 bit microcontroller and to the microcontroller development board (MDB). In the second week, the students were introduced to the programmable logic controller. The practical tasks would thus alternate each week until the end of the session, with microcontroller tasks one week and PLC tasks every other week. The emphasis was on the novel idea of integrating the application of the two units, comparing and contrasting, trying to emphasize how the two devices were similar and how they differed.

The microcontroller tasks consisted of the introduction to the MDB by Darmicon, simple input/output operations including the use of a look up table, pulse width modulation control of a DC motor, timers used to generate square waves, the use of interrupts to generate square waves and serial RS232 communications. The PLC tasks involved an introduction to the Omron apparatus and software; introductory ladder programming with a start/stop station; investigations that involved ladder instructions such as inversion, parameter watching, the detection of rising and falling edges and timers, more timer applications including counters along with the use of interrupts and subroutines on the PLC.

The assessments of the unit comprised 35% for practical tasks, 25% for two multiple choice quizzes (10% and 15%) and 40% for the final exam. The break-up was intended to put emphasis on the practical hands on aspects of the material. A certain amount of problem based learning was included. The taskls to be completed were on a continuum basis. The next task could not be attempted until the present task was completed. This approach was adopted to compensate for the students who were slower to complete and meant that the quicker completing students would not be held back. There were also challenge tasks for those who completed tasks quickly and who wanted to take up extra tasks; naturally bonus points would apply.

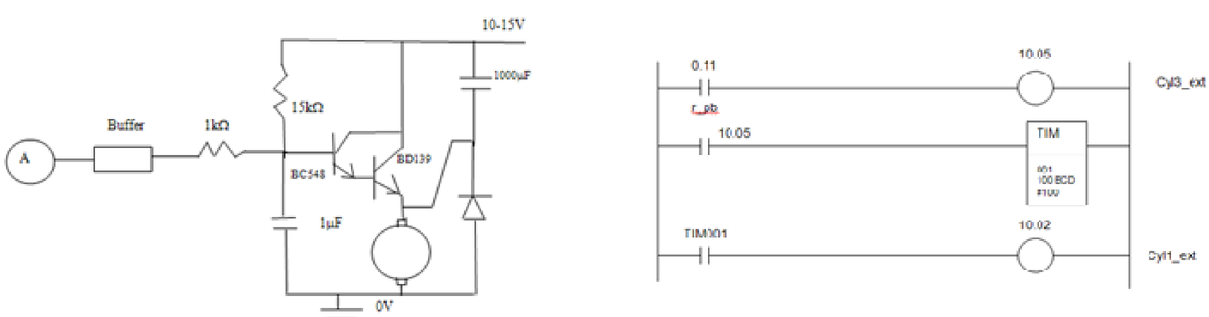

FIGURE 1
TYPICAL MICROCONTROLLER AND PLC APPLICATIONS.

Students had to meet the challenge presented to them, especially when it came to understanding the requirements of the microcontroller. To succeed in the microcontroller tasks, students had to develop an good understanding of the internal structure of the microcontroller, the registers involved and the addresses needed [6], [7, [8]. This was not the case with the more straightforward PLC. Figure 1 shows typical applications as carried out in the laboratories.

With regard to record keeping, students are expected to record their practical work in a practical workbook. The workbook should be written in such a manner that anyone not fully conversant with the subject matter at hand could follow the entries made. Students are supplied with a marking sheet at the start of the session indicating how marks would be allocated. This allows them to plan ahead when writing up their practical tasks. In all, some 12 tasks were completed, 6 that involved the microcontroller and 6 that involved the PLC. The marking of the practical workbook would involve the random selection of only one completed and written up task, selected by drawing lots. The students are made aware of this at the start of the session. Since the actual task that will be graded is unknown, the students must keep meticulous records of all completed tasks to the same high standard.

PLC APPARATUS

The PLC apparatus had been previously designed with only mechanical actuators in mind and consisted of solenoid valve operated pneumatic cylinders. One of the first tasks of the students was to map out the apparatus and to identify which inputs were connected to the respective PLC terminals and likewise with the outputs. The arrangements and connections of the cylinders varied with some cylinders having a spring return mechanism and some requiring the actuation of a solenoid valve in order to retract. In some respects the PLC apparatus was somewhat limiting ; there were no connections for motors for example in the given apparatus.

The PLC was programmed through a personal computer on which was installed the required Omron "Junior" software. As mentioned before, this was the same Omron software that the student would encounter as an engineer on the job. Learning to use the software was not difficult, and students soon became proficient in its operation. In fact some of the comments that was often repeated was that the software allowed the user to see what was occurring during the programming of the PLC. Lines of ladder code, for example, would change colour depending on the state of the PLC and its I/O. The PLC had several states such as program mode and run mode. Certain changes could be made in program mode that could not be made in program mode. Once in run mode, the PLC program stored in memory would be executed. Program code had to be transferred or downloaded, to the PLC via the Omron software [3], [4], [5].

MICROCONTROLLER APPARATUS

The microcontroller part of the overall apparatus consisted of two printed circuit boards mounted on top of each other [2]. The 8 bit, 12 MHz microcontroller located on the underside and memory, serial port connections and screwed port terminals on the upper PC board. The whole assembly was mounted atop of disused computer cases along with other peripherals such as toggle switches and led indicators along with their respective buffers, a small DC motor, a loudspeaker, and an LCD display. This arrangement meant that inadvertent short circuit connections would be avoided as all the modules were fixed into position and only the access terminals could be connected. Past experience with modules not so fixed into position showed that unintended errors occurred due to accidental connections to parts of the modules.

COMMON APPROACH

The common aspects of the material were stressed during the delivery of the unit. Students were asked to think about how the microcontroller and the PLC were similar and how they were different. The basic block diagrams were introduced with common elements such as processor, memory, power supply, input / output connections, memory size and location. The user programs were stored in memory in both devices; how the user program was written differed, but both had to be downloaded into the memory of the respective controller before being run. For the microcontroller, the user was taught to program in assembly language. In practice, this meant that more had to be understood of the structure of the microcontroller. For the PLC, the user learnt to program using ladder diagrams. The general consensus was that programming via ladder diagrams was easier than trying to program in assembly language.

User code had to be downloaded into the memory of the respective controller. For the PLC, this was done via the option available with the Omron software. For the microcontroller, Hyper-terminal was used to connect serially and to download. Initially Darmicon had supplied a simple downloader program but with successive upgrades of laboratory PCs, proved to be too slow in data transfers and consequently unreliable. Hyper-terminal could be delayed in the times needed for data transfer and proved to be useful and reliable in downloading.

Tasks set for the students were based on sample code that the student ran and examined. The students were then asked to complete a task that extended the concepts already examined and that would challenge their lateral thinking. Students found the programming of the microcontrollers associated with interrupts particularly challenging.

Only one written up and signed off practical is graded at the end of the session. This is made clear to the students at the start of the session. The actual practical graded is chosen by drawing lots, hence the students must keep accurate and

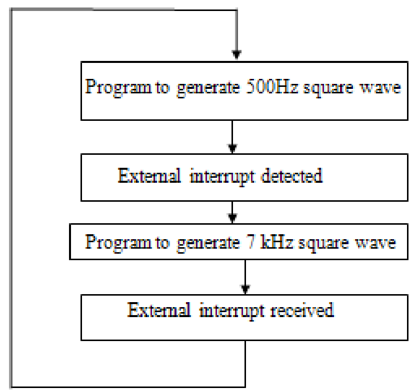

FIGURE 2
INTERRUPTS WITH THE MICROCONTROLLER

PROGRESS QUIZZES

As a means of accumulating marks towards their total assessment, two multiple choice quizzes were included. The quizzes were completed during the lecture time in weeks 5 and 11 and comprised of 10 questions which had to be answered in 45 minutes. The quizzes were intended to encourage the students to keep up with the concepts being presented and to be rewarded for doing so by scoring well in the quizzes.

In Quiz 1, the average mark was 7, the maximum mark was 10 and the minimum mark was 5. At this stage all students passed their first quiz. Difficulties arose as shown by the results if the second test. For Quiz 2, the average mark was 4, the highest mark was 7 and the lowest mark was 1.

CONCLUSIONS

The presentation of the material received a mixed response. In general, as shown in Figure 3, the results of the Student Feedback on Units (SFU) was below that of the university wide results. The SFU tries to gauge the acceptance of the material presented in the unit through 13 general questions. In this instance, the SFU was completed by only 42% of the overall cohort, which amounted to the 16 out of 39 who attended class and completed the survey. Students would grade their answers according to a scale of 1-5, with 5 representing “Strongly Agree” and 1 representing “Strongly Disagree”. For example, Question 1 of the survey asked if whether or “the unit covered what the unit outline said it would’. For this question, 10 of the 16 students agreed or strongly agreed.

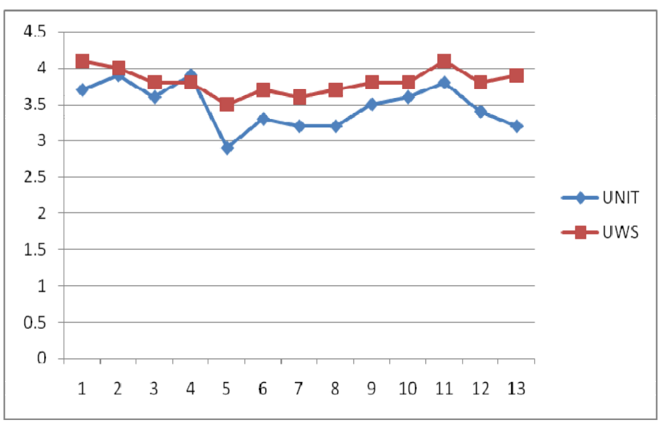

FIGURE 3
SFU RESULTS

Question 13 asked the question “Overall I’ve had a satisfactory learning experience in this unit”. In this case, 9 of the 16 students gave positive responses, 2 were neutral and 5 disagreed or strongly disagreed. Individual open ended comments indicated that the PLC portion was liked but the microcontrollers portion was not, indicating a major weakness in the presentation of this part. With regards to the question “I was able to see the relevance of this unit to my course”, 13 students out of the total of 16 responded with “agree or strongly agree”, while 5 were neutral and 1 disagreed. To the question “This unit helped me develop my skills in critical thinking, analyzing, problem solving and communicating”, curiously, 9 agreed or strongly agreed, 5 were neutral and 2 strongly disagreed. Seems the delivery was not as successful as might have been expected in this regard.

At the conclusion of one delivery of the integrated version. the decision was made by the School of Engineering to revert to the previous modus operandi. The current (2010) delivery of the unit involves delivery by two separate staff members, as neither could deliver material that encompassed both devices. Each staff member deals with only one part of the unit. The PLC portion being delivered by robotics / mechatronics staff and the microcontrollers by electrical engineering staff.

Encouraging the students to think about the similarities and the differences between the microcontroller and the PLC was one step in trying to make the students as well prepared as possible for their future roles as professional engineers.

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