Session 1620

# A Robotics-Based Microprocessor Course for Engineering Technology

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**Abstract:**

An innovative robotics-based microprocessor course has been designed for the electrical engineering technology associate degree program at the-Penn State Abington-Ogontz campus. The course focus is the team design, testing, and troubleshooting of a microcontroller-based autonomous mobile robot. Topics include robot design and control, microcontroller architecture, 6811 assembly and high-level (C) programming. Mini-lectures and workshops are scheduled on an "as-needed" basis. A robot competition is held at the conclusion of the course. The project-based course has proven to be highly motivating for the student participants. This project was supported, in part, by the National Science Foundation Advanced Technological Education under Grant No. DUE-9454547.

## 1.0 Introduction

A robotics-based microprocessor course has been designed for the associate degree electrical engineering technology program at the Penn State Abington-Ogontz campus. The focus of this sophomore-level course is the team design, testing, and troubleshooting of a microcontroller-based autonomous mobile robot. This project-based course is a single module in a Penn State multi-campus NSF Advanced Technological Education grant with the objective of developing project-based educational modules for the Associate Degree Engineering Technology programs that also provide bridge programs to high schools and integration with math, physics, communications, and the humanities. This engineering technology activity also ran concurrently with a baccalaureate freshman engineering design program and high school outreach program which utilized similar robot design tools and resources.

Several important developments have occurred in the past few years that allow for microcontroller-based robotics projects to be more accessible and manageable to educators. One such development is the availability of low-cost, high-level programming language environments for microcontrollers (e.g. Interactive-C from MIT.) Second, low cost robot kits are available that are comprised of fully assembled microcontroller boards, hardware for rapid prototyping (e.g. LEGO), sensors, motors, gears, etc. This availability reduces. the overhead for instructors and institutions with limited resources. Third, support for students and faculty engaged in robotics projects can readily receive technical support through various newsgroups over the Internet.

The paper will discuss the course philosophy and objectives, the robot kit, the hardware and software environment, the success of the collaborative approach, and the effectiveness of the project-based approach.

## 2.0 Course Description and Objectives

The course philosophy represents a departure from the sequential, top-down approaches that characterize traditional introductory microprocessor courses. The course emphasis here is on the design and realization of an autonomous, mobile robot using high-level C programming (as opposed to assembly language programming,) and microcontroller interfacing with motors, sensors, and actuators. The robot design activity and preparation for the competition begins on the first day of class and provides the focus for the entire course. The robot project provides the context from which the students can explore issues and concepts in microcontroller/microprocessor technology. It is hypothesized that the hands-on and context-based approach provides a foundation that facilitates and enhances the learning process.

Course topics include mobile robot design and control, microcontroller architecture, 6811 assembly and high-level (C) programming. An introduction to motor and sensor interfacing is also covered. The lab component largely consists of hands-on design, testing, and troubleshooting the robot. The lecture component consists of short lectures, discussion groups, and collaborative problem-solving. Mini-lectures and workshops will be scheduled on an "as-needed" basis. Rapid-prototyping and incremental design methodologies were introduced. Several mini-competitions were held throughout the semester to pace the robot progress. A robot competition is held at the conclusion of the course.

The design and development student teams were comprised of 3 to 4 electrical engineering technology students at the sophomore level. The only prerequisite was an introductory course in digital electronics. Each student team was provided a robot kit and the competition rules and regulations that guided their designs.

Lecture topics on assembly language, microcontroller architecture, etc. were strategically delayed until student teams have progressed sufficiently on the robot design, and possessed the context, foundation, and motivation on which to build their knowledge. The primary textbook and reference for the lecture special topics was Jones[1] and Driscoll[2]. A manual with hands-on exercises was developed by this author to supplement the documentation supplied with the robot kits. Students were required to submit project status reports every 2 weeks. Frequent meetings with the instructor to discuss progress were encouraged.

In addition to the team-built mobile robot, each student was individually responsible for a small-scale project that related to the microcontroller operation or sensor technology. Individual project topics included: investigation of PWM motor control; analysis of servo control; sonar sensor interfacing; IR motion detector; assembly language; house/car alarm system; sound digitization; audio output; and motor stall detection.

## 3.0 The Robot Kit

The robot kit used in this design course was developed at the MIT for their annual 6.270 intercession course and consists of a 6811-based microcontroller board (Rev. 2.21), Interactive-C (IC) software, LEGO building blocks, gears, wheels, DC motors, infrared sensors and emitters, photoresistors, bump switches, wires, connectors, servomotor, lead-acid batteries and charger [3,4]

The 6270 controller board features:

- (4) Motor Outputs (PWM)
- (4) General Purpose Motor Outputs (Unidirectional)
- (8) Digital Inputs
- (16) Analog Inputs (8 bits each)
- (2) LED outputs
- Shaft encoder support
- 40KHz IR transmitter/receiver support
- Servomotor controller
- LCD panel

The Interactive C (IC) programming environment is a multi-tasking, interpreted C language which supports error checking and promotes incremental testing and development. A rich set of library functions provides full support of all the above hardware features. The interactive nature of the software allows students to invoke functions (e.g. turn on motors, read a sensor, etc.) without the edit, compile, link, download cycle. While the library functions insulate the user from the underlying hardware details, the accompanying source code allows for in-depth investigations. The IC software is available from a FTP site [5].

Below is an example of a simple program to control a robot in such a way that it proceeds forward until a front bump sensor (mechanical switch) detects a wall, then the robot will stop. It is assumed in the example that the robot is driven by two drive motors.

```
void main()
{
  motor(0, 1 00);          /* turn on motor plugged into port #O to 100'?4o power*/
  motor(1,100);            /* turn on motor plugged into port #1 to 100'?4o power*/
  while (digital(1) = O)          /* do nothing (allow motors to run) until bump "/
       {    }                     /* switch (plugged into dig port #1 ) is closed */
   off(0);                 /* turn off motor plugged into port #O */
   off(1);                 /* turn off motor plugged into port #1 */
}
```

In addition to the 6270 controller board, several other boards appropriate for a robot design course are available and which also utilize the IC software. One board is the "Rug Warrior," described by Jones and Flynn [1] and available directly from the publisher. The Rug Warrior has somewhat less functionality than the 6270 board in terms of input and output ports, but is capable of expansion. Fred Martin (MIT Media Lab) has recently designed the "Handy Board" [6] that is close in functionality to the 6270 board and claims to possess some advantages. It is recommended that the reader monitor the Internet newsgroup “comp.robotics.mist” for information regarding alternate hardware and availability issues.

The relative ease of use, and the power of the IC software has been instrumental in the success of the robot program. The IC software has been successfully used by students with little or no prior programming experience.

## 4.0 “Robo-Hoops” Competition

The objective of the contest, called “Robo-Hoops,” is to design an autonomous robot that can score points by picking up Nerf balls and shooting or dunking the balls into a basketball net in a head-to-head competition with another robot. The playing field is a flat surface 48 inches by 80 inches. The net is located 12 inches above the playing surface on a vertical backboard, 48 inches long and 30 inches high. One point will be earned for dunking or dropping the ball into the net. Two points will be earned for shooting the ball into the net. Each match in the competition will be limited to 60 seconds total. The robot with the most points after a 60 second time limit will be declared the winner of the match. In the event of a tie, the robot that scored the first point will be declared the winner. The maximum size of the robot at the start of the competition is 12 inches by 12 inches by 12 inches. Once the contest has begun, the robot can assume any size. Each robot must be fully autonomous and no radio-controlled equipment of any type is allowed. No tethered robots are allowed, and no audible, ultrasonic, infrared link of any kind can be established with the robot. There can be no intervention by any team member once the match starts.

Five foam balls, each 3.5 inches in diameter, are placed in prescribed positions on the playing surface prior to each match. The two robots start at opposite ends of the playing field in each match, and indicator lights (beacons) are used to trigger the start of the match. An additional indicator lamp (beacon) is positioned under the net to enable robots to search for the net location. Friendly interaction between the two robots is allowed.

Sophistication, functionality, and strategy of the robots varied considerably. Many robot platforms consisted of two independently driven rear wheels with gear reduction systems and a front pivot wheel. The mechanisms for picking up the foam ball and either dropping or shooting the ball, the use of sensors, and the software algorithms were quite diverse. The winning robot in the competition was capable of lifting a ball from the playing field using a belt-driven feed mechanism, sensing the net indicator beacon, and catapulting the ball into the net.

## 5.0 Summary and Conclusion

The project-oriented microprocessor course based on the mobile robot design and competition was judged a major success by the student participants and instructor. All student teams were able to design and implement a robot that was suitable for competition. The students displayed a great deal of enthusiasm and tenacity throughout the course. From the students’ perspective, the strengths of the course included the hands-on orientation, the team approach, the competition and the development of troubleshooting skills. The weaknesses identified were largely focused on the hardware and included shortage of LEGO pieces, a few faulty motor IC chips, some battery problems, and miscellaneous equipment shortages. Several of the 16 participants felt that there was not sufficient time. Overall, students spent approximately 4-8 hours per week on their robot projects, and this time approached 10-20 hours per week in the last 2 weeks of the course in preparation for the contest. The investment of time on the part of the students can be controlled somewhat by varying the level of difficulty of the robot competition.

Although most student participants acknowledged the benefit of working in a team fashion, some participants felt that the early stages of teamwork were frustrating. To this end, team-building exercises at the outset may prove beneficial to the students. A peer-review process is also under investigation for future use.

From a technical content perspective, the students exceeded many of the instructor's expectations. A few of the secondary goals, such as incorporating assembly language into the robot designs, were never filly achieved and will be attempted in future offerings. The Robo-Hoops competition was successful, and alternate competitions can be designed to meet a wide array of course objectives.

The second phase of this project is to integrate mobile robotics technology into other areas of the associate degree program, and to develop a bridge program for high school students. As an example of possible integration, a physics laboratory to experimentally investigate DC motor speed/torque relationships and gear reduction systems for robotics is currently under construction. Also, computer-aided drafting and design (CAD) coursework appear to have natural links with the robotics design activity and will be explored. Preliminary results from high school participation in the Philadelphia, PA, and York, PA areas show great promise. Four Philadelphia area high school teams successfully participated in the Robo-Hoops competition held at the Penn State Abington-Ogontz campus in December of 1995.

## 6.0 Acknowledgment

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## 7.0 References

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