Senior Design Projects Using Basic-Stamp Microcontrollers

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The Electronic Engineering Technology (EET) program at Florida Agricultural and Mechanical University (FAMU), has instituted tools to ensure that the curriculum is in line with the demands of the ever evolving industry trends of today. That includes annual meetings with the Industry Advisory Council (IAC), Employer Surveys, Alumni Surveys, Senior Exit Surveys, annual conferences and faculty continuous development. Creating a new courses and upgrading of existing course content in hardware and software may be required to ensure that our students are knowledgeable and well prepared to enter the technological workforce. For several years two microprocessor courses have been offered as core requirement and technical elective. The core course *CET 2123 Microprocessor Fundamentals*, covers basic concepts in the microprocessor, including the assembly language and the hardware architecture. The technical elective course *CET 4149 Microprocessor Interfacing* covers more advanced topics and concepts, such as ADC (Analog to Digital Converter), serial port communication and timers. In both courses the PIC18 microcontroller is used as the main teaching platform. However, when presented with options, students never use this platform for class projects or capstone projects. Surveys showed that this was due to the fact that the laboratory experiments were topic specific and did not present a system design approach which made it difficult for students who attempted to use this microcontroller [1]. A new platform, the C-Stamp microcontroller, was introduced as an alternative for their design. This development boards provide a pre-assembled hardware platform, which include common peripheries in addition to programming libraries. These benefits encouraged some students to implement the C-Stamp microcontroller in their senior design projects with fairly successful outcomes [1]. The introduction of a new course in robotics has allowed students to be exposed to additional microcontrollers such as Arduino and Basic Stamp. Unlike the PIC18 microcontroller, these development boards provide a pre-assembled hardware platform, which include the necessary peripheries and programming libraries.

This paper presents the trends in the EET program regarding the selection of a microcontroller for capstone projects by our senior students. The paper begins with an overview of past microcontroller platforms used in the capstone course projects including some examples of successful projects in C-Stamp. Then, the basic stamp module, microcontroller is introduced and its implementation in the robotics course is presented, including some class projects. This is followed by discussion of some successful capstone project based on the basic stamp module. Finally, the correlation between the extensive use of the basic stamp and student recent line of employment is presented.

PIC Microcontroller

The Peripheral Interface Controller (PIC) from Microchip Technology Corporation is an 8-bit microcontroller with small amounts of data RAM, a few hundred bytes of on-chip ROM for the program, one timer, and a few pins for I/O ports, all on a single chip with only 8 pins [1] [3]. PIC has some of the following advantages in terms of architecture. PICs gained popularity due to their low cost, wide availability, large user base, extensive collection of application notes, low cost of free development tools, and serial programming (and re-programming with flash memory) capability[1].

When used in the two microcontroller courses, we made use of the PIC 2 Starter Kit [3] and PIC18/PIC16 Trainer board [4] for laboratory experiments along with the MPLAB assembler form Microchip [3]. Laboratory topics included examine the flag, arithmetic operations, ASCII and BCD conversion, microchip C18 programming, data transfer, testing PIC I/O ports, interfacing an LCD to PIC, PIC serial port programming, ADC programming in the PIC, interfacing a sensor to PIC, and event counter programming[1] [3].

C Stamp microcontroller platform

Unlike the PIC microcontroller, the C Stamp microcontroller platform comes in a module depicted in Figure 1. This module is integrated with the CS310X00 (μC 101) Microcontroller Fundamentals Board of Learning (BOL) [6], depicted in Figure2. The BOL provides for an easy access to functions and signals within. The module comes with the microcontroller IC PIC18F6520, which contains the C Stamp Operating System, internal memory (RAM, EEPROM, and Flash), a 5-volt regulator, a number of general-purpose I/O pins (TTL-level and Schmitt Trigger inputs, and 0-5 Volts outputs), communication and other peripherals[2].

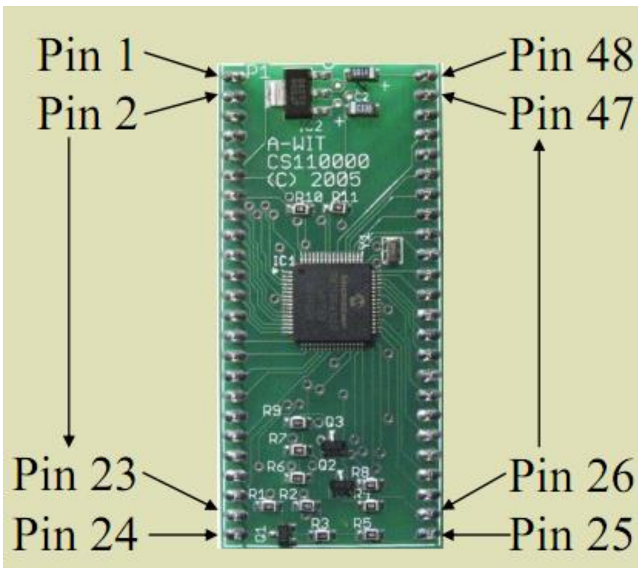

Figure 1 CS 110000 C Stamp module

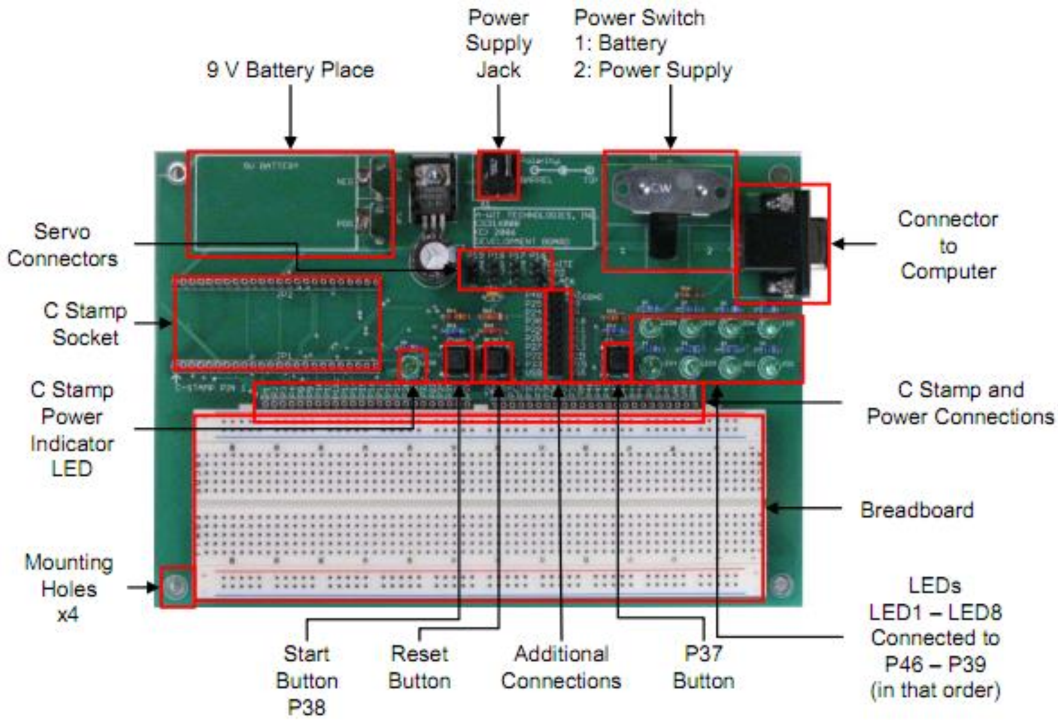

Figure 2 CS310X00 BOL with all features highlighted

Examples Capstone Project Using the C Stamp Microcontroller

Automated Parking System

One of the successful capstone projects that made use of the C Stamp microcontroller was a self controlled parking system. The system main goal is to determine the best available parking location, display the information at the entrance gate for the driver and guide the vehicle an empty parking location. This is accomplished through the implementation of a priority algorithm which makes use of infrared sensors signals from each parking location. Sensors are also used to keep count of the vehicles entering and leaving the lot. Once the lot is full, the display will notify the drivers, and the gate/arm will remain down until a parking location is available. Figure 3 shows a layout of the design [2].

Arcade Basket Ball Game

A second project which made use of the C Stamp microcontroller was the design of an electronic scoreboard. The scoreboard connects to two basketball rims. One player can shoot baskets and play alone or two players can compete. After a set time has elapsed the score and the winning players are displayed. Figure 4 shows the design block diagram. In the center there's C-STAMP microcontroller. It will interface with outside world using key pad and LCD& LED display [2].

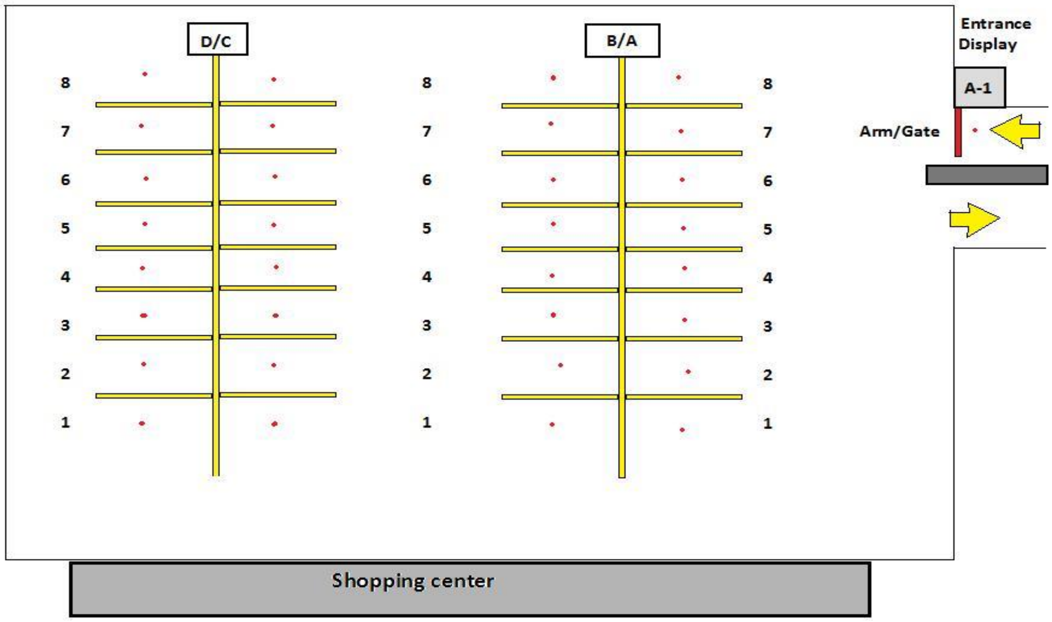

Figure 3 Parking lot Layout

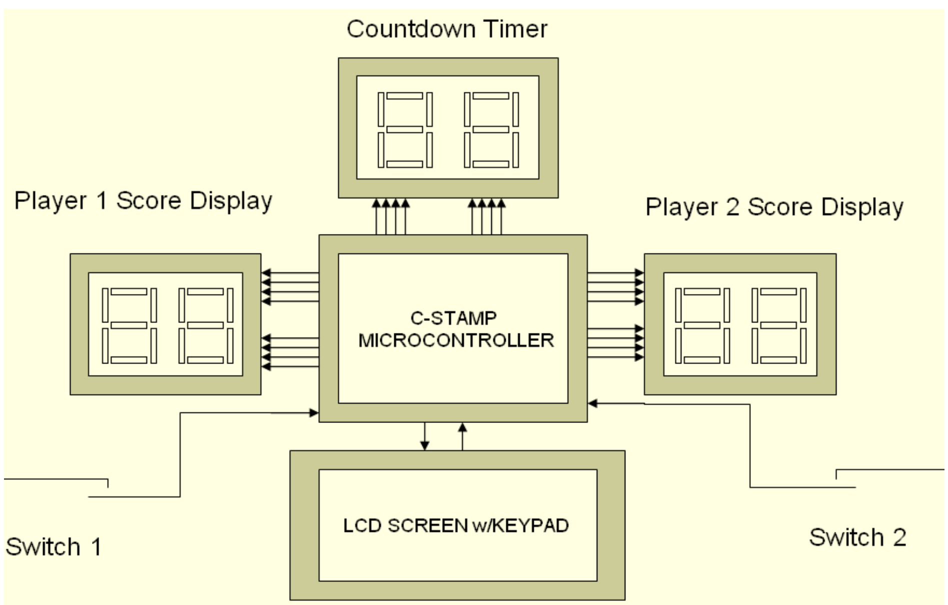

Figure 4 Arcade Basketball Game Design Block Diagram

Although students reported good experiences while designing these systems using C Stamp microcontrollers, they still had little difficulty in software development and programming.

The BASIC Stamp Microcontroller

The BASIC Stamp microcontroller was introduced by Parallax Inc. in 1992. Since then, the microcontroller has been used by engineers and hobbyist alike. Similar to the C Stamp microcontroller, the BASIC Stamp is a module with a microcontroller built into it. BASIC Stamp modules microcontrollers can be seen as small computers designed for use in a wide array of applications. Any embedded system project with some level of intelligence can use a BASIC Stamp module as the controller. There are two models of the BASIC Stamp, BASIC Stamp 1 (BS1) and BASIC Stamp 2 (BS2). The Basic Stamp 2 has seven sub-variants. Figure 5 shows the different modules of the BASIC Stamp microcontroller. Each BASIC Stamp has different features. Table 1 shows the BASIC stamp modules features comparison [6].

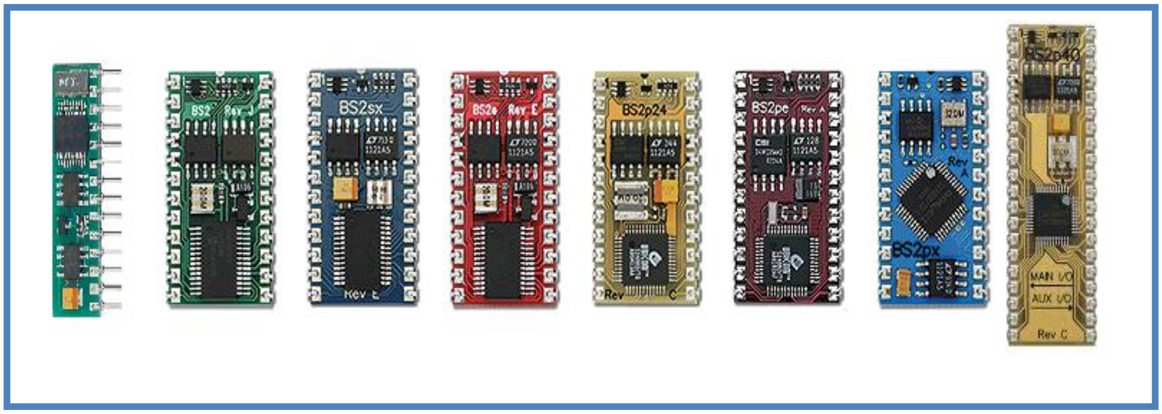

Figure 5 BASIC Stamp Modules, left to right: BS1, BS2, BS2sx, BS2e, BS2p24, BS2pe, BS2px and BS2p40

Each BASIC Stamp comes with a BASIC interpreter chip, internal memory (RAM and EEPROM), a 5-volt regulator, a number of general-purpose I/O pins (TTL-level, 0-5 volts), and a set of built-in commands for math and I/O pin operations and are capable of running a few thousand instructions per second[6]. The BASIC Stamp is programmed in a simple language called PBASIC. PBASIC incorporates common microcontroller functions, including PWM, serial communications I^2C and Wire communication, communications with common LCD driver circuits, hobby servo pulse trains, pseudo-sine wave frequencies, and the ability to time an RC circuit [7].

The integrated development environment (IDE) used to write programs for the BASIC Stamp is the BASIC Stamp Editor. The BASIC Stamp Editor Software is the programming environment for all BASIC Stamp modules, and custom devices built with Parallax’s PBASIC Interpreter chips. A built-in Debug Terminal supports bidirectional (unidirectional on BS1) communication between the BASIC Stamp and the PC during run-time. Once a program has been written in the 'Stamp Editor', the syntax can be checked, tokenized and sent to the chip through a serial/USB cable, where it will run. The BASIC Stamp is programmed in **PBASIC**, a version of the popular BASIC programming language [6] [7].

Table 1 BASIC Stamp Model Comparison Table

Released Products	BS1-IC	BS2-IC	BS2e-IC	BS2sx-IC	BS2p24-IC	BS2p40-IC	BS2pe-IC	BS2px-IC
Package	PCB w/Proto / 14-pin SIP	24-pin DIP	24-pin DIP	24-pin DIP	24-pin DIP	40-pin DIP	24-pin DIP	24-pin DIP
Package Size (L x W x H)	2.5"x1.5"x.5 / 1.4"x.6"x.1"	1.2"x0.6"x0.4"	1.2"x0.6"x0.4"	1.2"x0.6"x0.4"	1.2"x0.6"x0.4"	2.1"x0.6"x0.4"	1.2"x0.6"x0.4"	1.2"x0.60"x0.4"
Environment	-40 to +185 °F (-40 to +85 °C) **	-40 to +185 °F (-40 to +85 °C) **	-40 to +185 °F (-40 to +85 °C) **	-40 to +185 °F (-40 to +85 °C) **	-40 to +185 °F (-40 to +85 °C) **	+32 to +158 °F (0 to +70 °C) **	+32 to +158 °F (0 to +70 °C) **	+32 to +158 °F (0 to +70 °C) **
Processor Speed	4 MHz	20 MHz	20 MHz	50 MHz	20 MHz Turbo	20 MHz Turbo	8 MHz Turbo	32 MHz Turbo
Program Execution Speed	~2,000 instructions/sec.	~4,000 instructions/sec.	~4,000 instructions/sec.	~10,000 instuctions/sec.	~12,000 instructions/sec.	~12,000 instructions/sec.	~6,000 instructions/sec.	~19,000 instuctions/sec.
RAM Size	16 Bytes (2 I/O, 14 Variable)	32 Bytes (6 I/O, 26 Variable)	32 Bytes (6 I/O, 26 Variable)	32 Bytes (6 I/O, 26 Variable)	38 Bytes (12 I/O, 26 Variable)	38 Bytes (12 I/O, 26 Variable)	38 Bytes (12 I/O, 26 Variable)	38 Bytes (12 I/O, 26 Variable)
Scratch Pad RAM	N/A	N/A	64 Bytes	64 Bytes	128 Bytes	128 Bytes	128 Bytes	128 Bytes
EEPROM (Program) **Size**	256 Bytes, ~80 instructions	2K Bytes, ~500 instructions	8x2K Bytes, ~4,000 instructions	8x2K Bytes, ~4,000 instructions	8x2K Bytes, ~4,000 instructions	8x2K Bytes, ~4,000 instructions	16x2K Bytes (16K for source)	8 x 2k Bytes, ~4000 inst.
Number of I/O pins	8	16 +2 Dedicated Serial	16 +2 Dedicated Serial	16 +2 Dedicated Serial	16 +2 Dedicated Serial	32 +2 Dedicated Serial	16 +2 Dedicated Serial	16+2 Dedicated Serial
Voltage Requirements	5 - 15 vdc	5 - 15 vdc	5 - 12 vdc	5 - 12 vdc	5 - 12 vdc	5 - 12 vdc	5 - 12 vdc	5 - 12 vdc

The BASIC Stamp 2 (BS2)

By far, the most popular BASIC Stamp microcontroller is the BS2 module shown in Figure 6. Widely used in education, hobby, and industry, this module has enough program space, execution speed, and I/O pins for many applications. The BS2 is an embedded system comprising:

- A PIC16C57 microchip which is the brains of the system. It provides BASIC interpreter, serial communication, and I/O.
- A Memory (EEPROM) for program storage and long term data storage.
- A Voltage Regulator which generates 5Vdc from supply power of 5.5Vdc to 15Vdc.
- A Resonator to generate a 20MHz Clock.
- Miscellaneous Support Components

The BS2 uses surface mount components to fit in a small 24-pin DIP package. Its Dimensions are 1.20 x 0.63 x 0.15 in (30.0 x 16.0 x 3.81 mm) and operating temperature range between -40 °F to +185 °F equivalent to -40 °C to +85 °C). The Processor Speed is 20 MHz and can process approximately 4,000 PBASIC instructions every second while handling 42 PBASIC Commands. It has 16 general-purpose I/O pins and two dedicated serial I/O pins. The I/O pins have a 25 mA sink current limit and a 20 mA source current limit. It has a 32 Byte RAM (26 bytes + 6 bytes for storing I/O). The EEPROM is 2K bytes and can handle 500 PBASIC instructions. The module input source is unregulated between 5.5 V to15 V DC, which is internally regulated to 5 volts. Alternatively, a 5 Volts source can be applied to VDD, in which case the input unregulated should not be connected [7].

The BASIC Stamp 2 module is currently being used in the robotics course. Figure 6 shows the BS2 module components

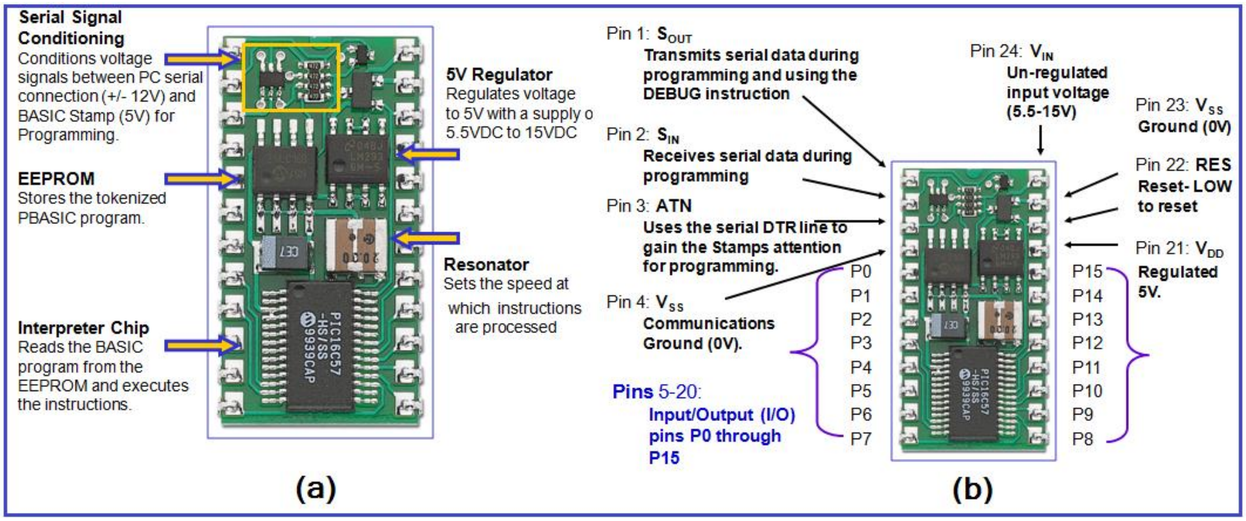

Figure 6 BASIC Stamp 2 Module Components (a) and I/O Pins (b)

In order to use the BS2 module a connection must be established with the software through a computer. Communication is via serial port (9600 baud for programming). When using the module independently, communication connections must be made carefully and should follow the schematic in Figure 7. Pin 1 (SOUT) is the serial output from the module and connects to PC serial port RX pin (DB9 pin 2 / DB25 pin 3) for programming. Pin 2 (SIN) is the serial input and connects to PC serial port TX pin (DB9 pin 3 / DB25 pin2) for programming. Pin 3 (ATN) connects to PC serial port DTR pin (DB9 pin 4 / DB25pin 20) for programming. Pin 4 (VSS) is system ground (same as pin 23) and connects to PC serial port GND pin (DB9 pin 5 / DB25 pin 7) for programming [8].

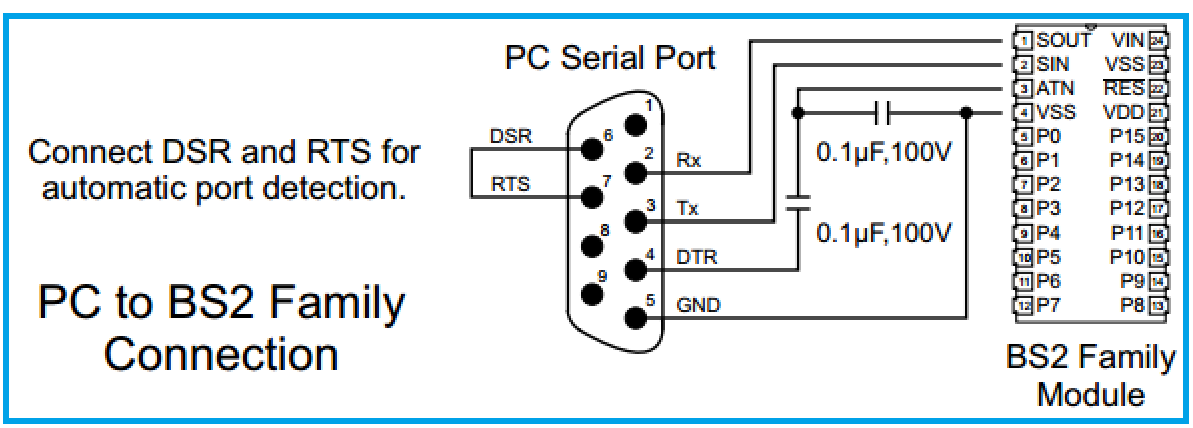

Figure 6 Programming and Run-time Communication Connections for all BS2 models.

The BASIC Stamp can be used on a variety of carrier boards, used for programming and testing. The board makes it easy to connect a power supply and programming cables to the BASIC Stamp module and makes it easy to build circuits to be connected to the BASIC Stamp module to perform a variety of functions. The most popular carrier boards used to support the BASIC Stamp are the Board of Education (BoE) and the HomeWork Board (HWB) which are depicted in Figure 8. The HWB has the module integrated into it while on the BoE the module is in an IC mount and can be removed and replaced.

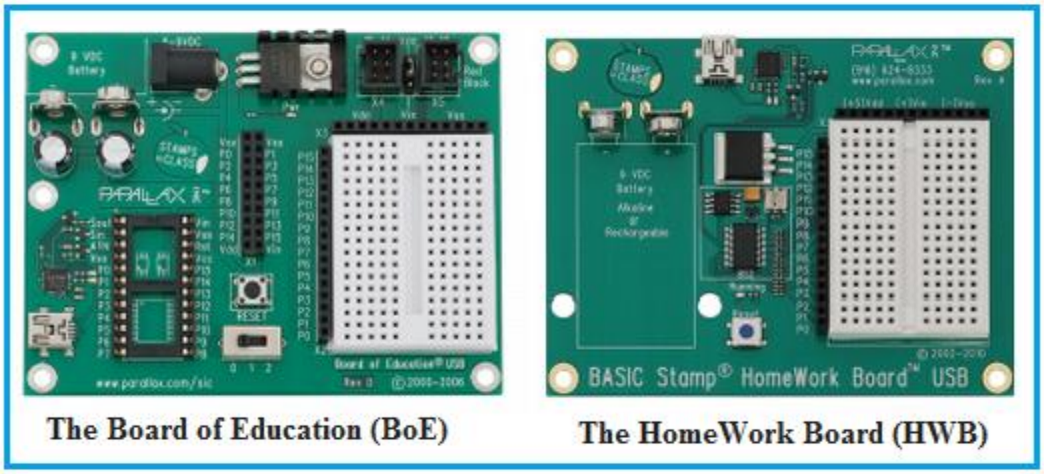

Figure 8 Parallax Board of Education (left) and the HomeWork Board (right)

Using the BASIC Stamp 2 to Teach Introduction Robotics

The last two years EET program introduced a course in robotics, EET 3930 (Introduction to Robotics) to provide seniors an alternative to their technical elective. However, designing the course and compiling course textbook and other teaching sources proved to be a challenge because all robotics textbooks present an in-depth mathematical and theoretical analysis which is unsuitable for EET curricula. This required a new approach for the course.

Ultimately, the course was designed from grounds up using a Mechatronics approach to introduce robotics concepts. Initially students are introduced to general robotics concepts including history of robotics, laws of robotics and current trends in the robotics field. This is followed by a discussion on engineering, Mechatronics and systems design concepts. The main components of a robotic system are then presented including mechanical concepts, electrical circuits, and software design. To implement these concepts in the laboratory, the Parallax Boe-Bot platform was selected. This platform uses the BS2 module on a board of education. For the first quarter of the semester students perform experiments on the microcontroller alone learning how to control hardware, generate signals and perform operations. As the mechanical concepts are introduced in the lecture, students are asked then to build their robot platforms. From there, a series of experiments on controlling motion, navigation, sensors, displays etc. are performed. Students are then assigned three to four projects for the remainder of the semester. One of these projects will be a group project. In the next section some of these projects are presented.

Last term, there were three projects assigned to the students. Two were individual projects and one was a group project. Students are given a problem which they must solve using their robots.

Project 1: Follow Wall or Path

The first project was individual and involved navigation and object avoidance using infrared sensors, whiskers or a combination of the two. Students were to design a robot to follow wall, turn around at when the wall finish and follow it on the other side on the way back to the starting point as shown in Figure 9. When the robot reaches the end it must play a melody and flash an LED.

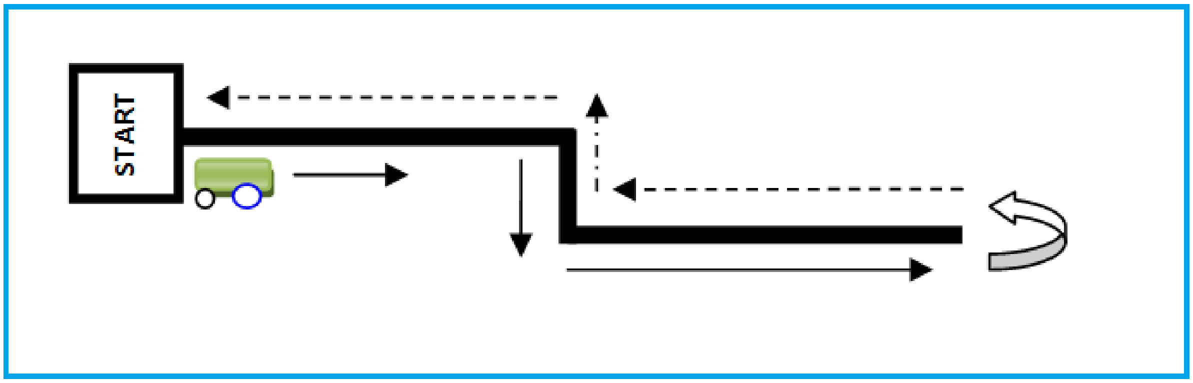

Figure 9 Project 1 course layout

Project 2: Group Project

The second project was a group project of two to three students. Table 3 shows a list of these projects.

Table 3: Project 2 Description

Project Title	Project Description	Group
Table Top Navigation	Design a Robot that will run continuously and autonomously on the top of a table and never fall down.	Group1
Follow the Leader	Design a Robot that will follow the instructor’s robot (leading robot) regardless of the maneuver performed by the leading robot.	Group2
Distance Calculation and Object Avoidance	Design a Robot that will navigate a tide space avoiding collision by calculating its distance to the objects and reacting accordingly.	Group3
Line Following	Design a robot that will follow a black line	Group4

Project 3: Use Additional Hardware

The third project was individual. For this project students must use additional hardware to accomplish specific goals. Table 4 shows a list of these projects.

Table 4: Project 3 Description

Project Title	Project Description	Student
Crawler Kit	Use the crawler kit to design a robot to navigate a rugged terrain	Student 1
Ping Sensor	Use the pink sensor kit to design a robot that is constantly scanning the surroundings and avoid collisions	Student 2
Tank	Use the tank kit and a set of sensors to design a robot tank	Student 3
RFID	Use RFID Tags to control the motion of a robot	Student 4
Color Sensor	Use a Color pall sensor to control a robot. Use red yellow and green for stop slow down and move forward respectively	Student 5
Bluetooth	Use a Bluetooth module to control a robot using your laptop or any handheld device	Student 6
Remote Control	Use a Sony remote control to control the navigation of your robot	Student 7
Sound Module	Use a sound module to give direct command to your robot.	Student 8

Similar projects have been part of the course since its inception. Students are very engaged, show a higher level of enthusiasm and performed better than in other courses. This is supported by research regarding project-based learning (PBL). With its emphasis on “learning by doing”, it becomes a very suitable tool for engineering technology disciplines, which strongly focuses hands-on learning. The success of PBL in engineering technology education is based on instant gratification which has been proven to be good for students to get immediate feedback on their learning.

Capstone Projects Using BS2 Data

As students moved on to their senior year and enrolled in the capstone project, when given a choice of microcontroller to implement their design, they opted to use the BASIC Stamp 2. Table 5 shows the relationship between students who successfully completed the robotics course and their selection of microcontroller in the implementation of their design project. As it can be seen an overwhelming 69.56% of all students who completed the course selected the BS2. Students who did not use the BS2 opted to use the Arduino platform or their design did not require a microcontroller.

Table 5 Students Choice of Microcontroller for Capstone Projects

Semester	Number of Students Enrolled	Number of Students who Successfully Completed the Course	Number of Students who Used BS2 in Capstone Project
Fall 2012	8	7*	4
Fall 2013	8	8	8
Fall 2014	8	8	4

*One student has not enrolled in the senior design course

BASIC Stamp Usage Correlation with Job Placement

A survey was conducted on the students who used basic stamp 2 in their capstone projects to investigate the effect, if any, that this experience may have had on students' careers. We wanted to know if students who had graduated and secured a job were working in a robotics related field. For students who graduated but have not secured a job and for those who are still in school we asked in which field they would like to be employed. Table 6 shows the job placement or job preference for students who used the BASIC Stamp 2 in their capstone project. All students who graduated in the fall 2012 work in a robotic and/or automation related field. Five of the students who graduated in fall 2013 work in a robotic and/or automation related field and one have plans to work in a robotic and/or automation related field. This represents 75% of all students who used BASIC Stamp 2 in their capstone that semester. Two of the four students (50%) who used BASIC Stamp 2 in their capstone project in the fall 2014 plan to work in the robotics field.

Table 6 Students Choice of Microcontroller for Capstone Projects

	Employed	Graduated	In School
Fall 2012	4		
Fall 2013	5	1	
Fall 2014			2

Conclusions

The implementation of a robotics course in the Electronic Engineering Technology program has been a great success as it relates to the students' experiences and knowledge gain. The course uses the Parallax BASIC Stamp 2 module to implement project based learning which motivates students and improves their performance. It was observed that after the introduction of the robotics course, approximately 69% of the students selected the BASIC Stamp 2 as the microcontroller for their capstone projects. Those who used the basic stamp in their capstone projects, about 75% are employed or plan to be employed in an area related to robotics and automation. The success of this course has prompted the EET program to start working on a future track in Mechatronics.

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