Senior Design Project

RFID Reader/ Sensor
for
LEGO Mindstorms NXT

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Executive Summary

The team has selected to build and demonstrate an RFID sensor that is interfaced to the LEGO Mindstorms NXT. The LEGO Mindstorms NXT is an example of a robotics prototyping system that, in addition to providing a pastime for hobbyists, is a model for solving real world problems. Research into the product revealed that a missing element from array of readily available sensors was a sensor for an RFID reader. With the widespread adoption of RFID systems, such an interface is likely to prove of value and hence the team's interest in developing the sensor. The team's objectives in this project are to: 1) research an available low cost RFID reader, 2) develop the hardware and software necessary to implement and interface the sensor, and 3) demonstrate a working model of a LEGO Mindstorms NXT robot using the developed RFID sensor.

In researching design alternatives for the RFID reader, the primary criterion was finding a low cost reader with secondary criterion in simplicity of interface and small in size. The Parallax RFID Reader Module met the criterion with a cost of $50.13, four output pins, and 62.2 x 82.5 x 3.6mm in dimension. The RFID tags, purchased with the reader, are passive tags, and thus have limited read range of 10cm. Since the project is a prototype for future applications, the read range was not a factor.

The hardware design portion consists of building an interface for the RFID reader which will produce the RFID sensor. The initial design will consist of a series connection between a Parallax RFID reader, a PIC18F2420 microprocessor, and an RJ12 connector on standard breadboard. The RFID reader will be powered by an external battery supplying 4.8V DC. As soon as the team is satisfied with testing the interface, the parts will be placed on a printed circuit board to minimize the space and weight. Currently, the team has obtained all the necessary components and is scheduled to commence building the sensor on June 4th.

The software system, NXT-G, is based on National Instruments LabVIEW. Development of this software is done using the LabVIEW Toolkit for the LEGO Mindstorms NXT on LabVIEW by creating programs, known as blocks, that will be uploaded onto the NXT-G software (the default programming language for the LEGO Mindstorms NXT). Both NXT-G and LabVIEW utilize graphical user interfaces (GUI) for simple construction of programs as oppose to text based languages. Currently, the team has created two program blocks, "Get Tag Data" and "File Tag Data," that have been uploaded onto NXT-G. The blocks are awaiting the construction of the sensor for testing. A third block, Bluetooth Dongle, is under development and will send the stored tag information to a computer. A secondary software design task is to program the PIC18F2420 microcontroller to convert the data from the RFID sensor to the NXT.

The integration task consists of interfacing the hardware and software onto a prototype robot (*see **Figure 1***). The RFID sensor will be connected to port 4 of the NXT, and the robot will be uploaded with a line follower program that includes the three designed blocks to utilize the RFID sensor.   The integration portion must wait on both the hardware and software portions before it may commence.

The body of this report will address the specific objectives, the details of the design, a definition of the demonstration, the progress to date and the issues that encountered so far. At the present time, the tasks and their duration are being reassessed based on the experience to date.
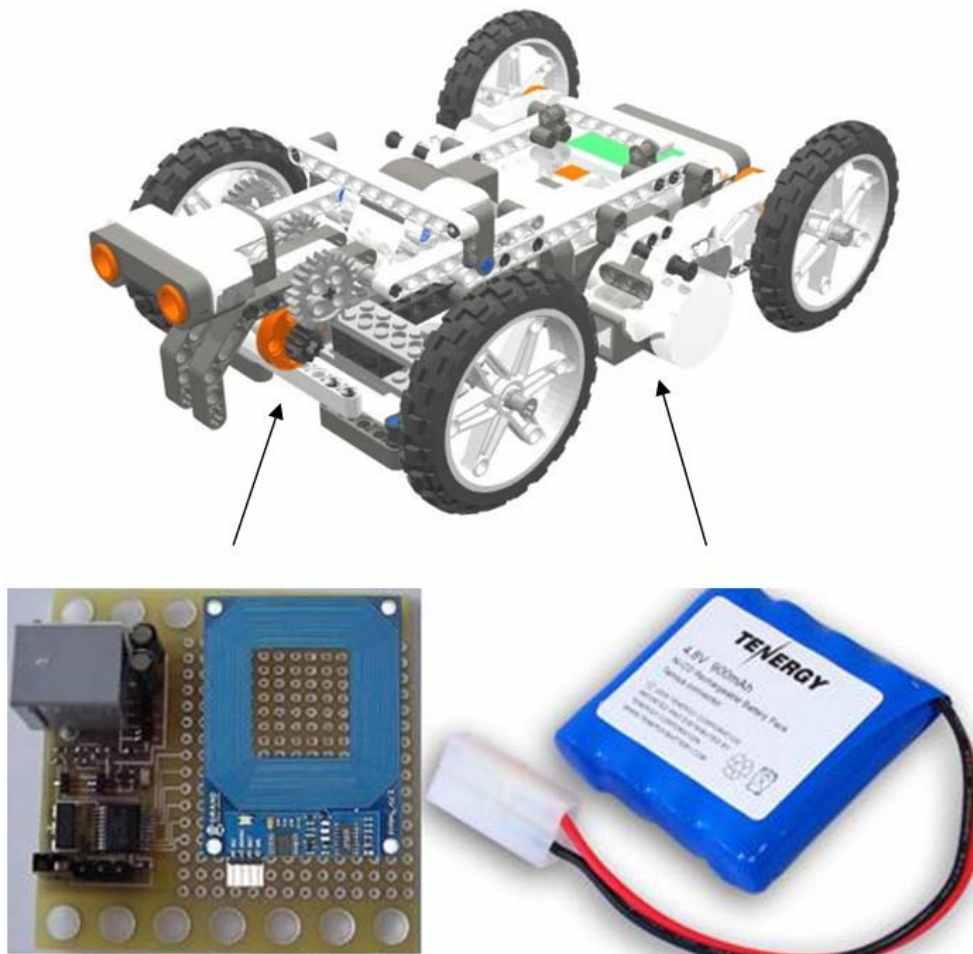

Figure 1. Robot Model, RFID sensor will be located on the bottom of the robot.

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1 Introduction

The team has selected to build and demonstrate a Radio Frequency Identification (RFID) sensor that is interfaced to the LEGO Mindstorms NXT. The LEGO Mindstorms NXT is an example of a robotics prototyping system that, in addition to providing a pastime for hobbyists, is a model for solving real world problems. With the widespread adoption of RFID systems, such an interface is likely to prove of value and hence the team's interest in developing the sensor.

1.1 LEGO Mindstorms NXT

The LEGO Mindstorms NXT is the newest product in the LEGO Mindstorms series. LEGO Mindstorms is a series of intelligent robots with a central processing unit (CPU) and sensors that enable them to interact with the environment (*see **Figure 2***). The NXT kit includes several sophisticated sensors, such as an ultrasonic sensor, a light sensor, a sound sensor, a touch sensor, and an enhanced "Intelligent Brick" (CPU). Since LEGO promotes creativity in the use of its product, users can program the NXT for a wide array of applications using the sensors and servo motors available.

The LEGO Mindstorms NXT was released in July of 2006. Since then, enthusiasts have constructed numerous other sensors and interfaces to add to the basic kit. Such innovations include a magnetic compass, a PlayStation 2 controller interface, a motor multiplexer, and an acceleration sensor. A Radio Frequency Identification (RFID) sensor, however, is not part of the LEGO Mindstorms NXT kit and is not available for purchase.

Figure 2. LEGO Mindstorms NXT, 3 Servo Motors, 4 Sensors, and Intelligent Brick

1.2 Radio Frequency Identification (RFID)

RFID technology consists of using an integrated circuit microchip in a tag or label to transmit stored data to a reader when the tag or label is excited by radio waves of the correct frequency from the reader. The reader is interfaced to a smart device that interprets the information from the tags for proper use. Tags and labels generally consist of an antenna connected to an IC chip on a substrate (*see Figure 3*). Active tags have an internal power source while passive tags are powered by the radio wave sent from the reader. The IC chip on tags and labels can be programmed with information about the product they are on. Unlike barcodes, RFID readers can read the information sent to it from the tag as long as it is within signal strength range and not necessarily in line of sight of the tag, like barcodes. The read range of the system varies from inches to 100 feet depending on the antenna's signal strength on both the reader and tag and the radio frequency used.

The field of RFID is a booming field that has recently been developing rapidly. The technology dates back over 20 years when it was first used in the Defense Industry for missile tracking and telemetry. In the 1980s, when RFID tags decreased in size and cost, the technology expanded to animal tracking and industrial uses. In the early 2000s, RFID technology extended further to include applications for parking and toll roads. Currently, a broad range of companies, such as Wal-Mart, are implementing RFID tags and readers in their warehouses to track the inventory and movement of their products. In another current project, McCarran International Airport, in Las Vegas, has replaced bar-coding with RFID technology to sort and track luggage.

Figure 3. American Express Credit Card with Embedded RFID tag

The use of RFID technology is increasing with the cost of the technology decreasing. As the cost decreases, the usage can expand into numerous areas. Also, with improvements in technology, the size of the readers and tags are decreasing and the read range of the systems is increasing.

2 Technical Background

The following information about the Inter-Integrated Circuit (I2C) computer bus will give the reader insight on technical aspects of the design of the project.

2.1 I2C

The Inter-Integrated Circuit (I2C) is a computer bus developed by Philips. It is the digital communication protocol used in the NXT Brick to communicate with external devices. I2C consists of two types of devices, Masters and Slaves. The Brick is going to act as a Master who initiates the communication where an external device is going to be the slave which will respond to the Master by sending information. The I2C bus has two lines connected from the Master to the Slave (*Serial Data, Serial Clock*). The I2C Master will pull its Serial Data Line (*SDA*) low while the clock is high and this initiates the communication between the Master and Slave (*start bit*). Then, the Master will send the slave's address (*one slave in this case*) followed by a write bit. After that, the Master will write the register number that it wants to read from followed by a stop bit which is a change in the SDA state from low-to-high during the down cycle of the clock. Next, the Master will send another start bit with the same Slave address followed by a read bit to start reading. Finally, the Slave will send the information to the Master and the Master will send a stop bit to stop the process. *Figure 4* shows the I2C bit sequence. It is important to notice that SDA and SCL are bi-directional lines.
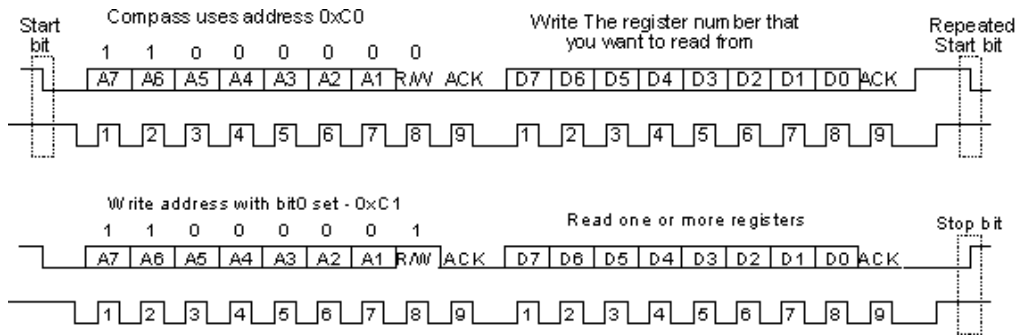
Figure 4. I2C Bit Sequence [1]

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[1] [1] "Robot Electronics Website," [http://www.robot-electronics.co.uk/htm/using_the_i2c_bus.htm] Accessed April 27, 2007

3   System Description

3.1   Problem Statement

The client, ViaSat, wants the team to design, build, and interface a sensor to the LEGO Mindstorms NXT robot. The sensor and its applications should serve practical use in the real world. ViaSat views the LEGO Mindstorms NXT robot as a miniature replica of the real world that can be manipulated for practical uses at lower cost.

> The project objective is to design and interface a sensor having an RFID reader for the LEGO Mindstorms NXT robot.   The sensor will read information from RFID tags and process the information to the NXT Brick. The objective of the robot in this project is to read tags placed alongside a set path as the robot follows a line defining the path. At the end of the path or interval, the robot will relay the inventoried tags' information to an external computer via Bluetooth.   In addition the system should meet these requirements:
>
> ✓ RFID reader should have a minimum range of 10 centimeters.
>
> ✓ Size of system should be on the same scale as the NXT Robot.
>
> ✓ Price to consumer should not exceed $70.
>
> ✓ User-interface should allow amateur LEGO users to utilize the RFID sensor.

The expanding interest and implementation of a whole variety of applications in the field of RFID make the technical aspects important and appropriate for an electrical engineering senior project. The project provides the team with an opportunity to serve the need for ViaSat and contribute to the advancement of RFID technology. The advancement will benefit not only the Mindstorms NXT hobbyists but also potentially those industries that can make good use of RFID.

3.2   Project Functions

The LEGO RFID sensor is an RFID reader designed specifically to operate with LEGO Mindstorms NXT. The sensor will be able to read RFID tags within 10 cm. After the reader recognizes an RFID tag, the reader will send a signal back to the NXT Brick via an RJ12 6-wire industry-standard connector. The Brick will receive the transmitted signal and store the information for later use. The reader will be able to recognize different RFID tags, and the Brick will store the information from each tag in different registers.

Upon the completion of the project, the programmed robot will maneuver its way in a predetermined path set by the user. The robot will move in the path towards the RFID tags laid down for it to follow. At each RFID tag, the RFID reader on the robot will read the RFID tag and save the tag's information. Once the robot finishes the path, it will send

all the tags' information to a personal computer via Bluetooth. This application might be practical to inventory purposes where the robot can scan the warehouse and send the product information to a computer. The LEGO Mindstorms NXT is not limited to the application stated; creative users will find more applications for the RFID sensor.

3.3   System Block Diagram Description

The System Block Diagram is shown in *Figure 5*. It consists of five major blocks and shows the signal/data flow of the system. The five major blocks are the RFID Reader, Power Supply, Printed Circuit Board (*PCB*), LEGO Mindstorms NXT Brick, and Bluetooth Dongle. The RFID Reader is powered by the external Power Supply. The RFID Reader will read the RFID tag data and send it to the PCB. The PCB will receive the data, save it, and transmit via I2C bus to the LEGO Mindstorms NXT Brick. The Brick will receive the I2C bus data and send it via Bluetooth communication signal to the Bluetooth Dongle. The Bluetooth Dongle will receive the tag's data where it can be processed in the external computer.
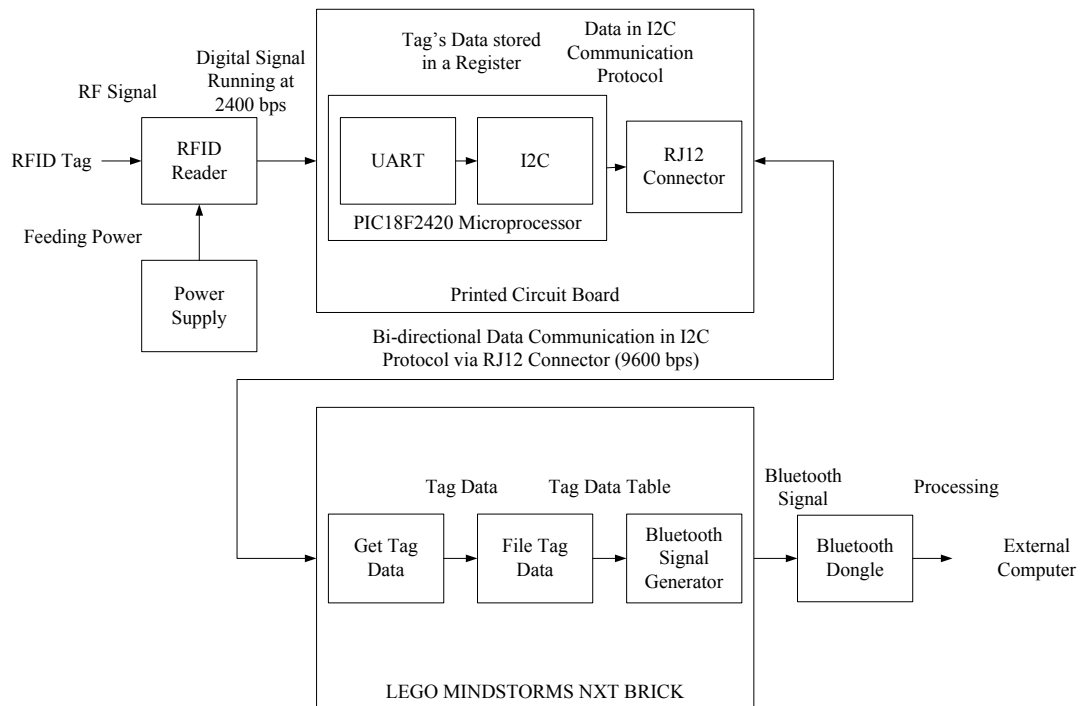
Figure 5. System Block Diagram

3.3.1   RFID Reader
The RFID tag will reflect a radio frequency signal at 125 kHz back to the RFID Reader. The RFID Reader will read the RFID tag information and send it to the PCB using serial data communications. The serial data communication is a 96 bit (5V high and 0V low) signal that can be read as an ID number if converted into a 12-byte ASCII string.

3.3.2   Power Supply

The external power supply will feed the RFID Reader with the necessary voltage and current to operate efficiently. See *Section 4.3* for more information.

3.3.3   Printed Circuit Board (PCB)

The input of the PCB is a digital signal with a 2400 baud rate. The PCB will save the signal's data and output the data in I2C communication protocol at 9600 baud. The PCB contains a Microprocessor (PIC18F2420) and an RJ12 connector for interfacing. The Microprocessor has a built-in Universal Asynchronous Receiver/Transceiver (UART) and I2C communication bus. These components will be discussed in further details later in the report (*see Section 4.2*).

3.3.4   LEGO Mindstorms NXT Brick

The Brick contains a processor and memory that will run NXT-G software. The input will be an I2C input containing the information from the RFID Reader. It will then output the tag numbers via Bluetooth in a text file. The NXT-G software will have three components that will be designed specifically for the RFID Reader. The three blocks are named "Get Tag Data", "File Tag Data" and "Bluetooth to Computer." The three blocks will be discussed in detail further in the report (*see Section 6*).

3.3.5   Bluetooth Dongle

The Bluetooth Dongle will interface via USB with a computer to allow the computer to get information via Bluetooth. The Bluetooth Dongle allows the computer to receive/transmit Bluetooth data. Once the Bluetooth Dongle receives the data from the Brick, the data will be processed by the computer.

3.4   Specifications

3.4.1   Overall

The RFID Sensor has to be LEGO Mindstorms NXT compatible. The use and programming of the sensor within the LEGO Mindstorms NXT environment have to be similar to other standard kit sensors. In addition, the price range of the sensor has to be reasonable for the NXT users. Typical NXT sensors have a cost range of $16.99-$46.99. However, RFID technology is expensive currently. Therefore, the team believes it is reasonable to push the price range further. The price should not exceed $70 a piece. Moreover, the sensor should be physically small analogous to the standard NXT sensors.

3.4.2   Technical

The technical specifications of the RFID sensor are shown in *Table 1*. The operating frequency of the RFID Reader is 125 kHz with a 10 cm read range. The sensor will contain an RJ12 female connector for NXT compatibility. In addition, I2C communication interface at 9600 baud is used.

Table 1. RFID Sensor Technical Specifications

Specifications	
Operating Frequency	125 kHz
RFID Tag	Passive
Interface	I2C (9600 baud)
Connector	RJ12
Programming Language	NXT-G
Read Range	≈10 cm

3.5   User Interface

The user will be able to connect the RJ12 connector from the NXT Brick directly to the RFID Sensor. This connecter is standard for all LEGO Mindstorms NXT robots. Therefore, the user will simply connect the RFID sensor analogous to any other sensor developed by LEGO. However, the user has to connect the external power supply to provide the necessary power for the RFID reader. The power supply has a female Tamiya connector (*see Figure 1*). Therefore, a male Tamiya connector will be soldered to the RFID Reader header to allow the user to simply connect the RFID reader to the power supply for use (*see Figure 6*).
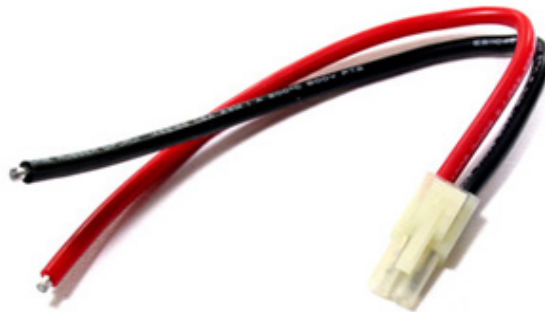
Figure 6. Tamiya Male Connector.

The user interface for the software will consist of three NXT-G blocks. The first Block will read the data from the RFID reader. This Block requires no input plugs but would output three different data outputs. The first plug that outputs data starting from the top would be if an error has occurred, this is a Boolean result. Next it would tell the user what kind of error has occurred. The last plug would be the raw value of the data that has been read. The next Block would be the file tag data block. This block has one input and one output plug. One would input tag data into the input plug and the tag data would be filed and stored. The output plug would also be a duplicate of the input to be used as the user wishes. Finally there will be an open tag data/ Bluetooth block. This Block opens the file that has tag data filed and then will Bluetooth it into the computer. The Block has no input or output plug because it is simply a command that requires no extra

information. The user will be able to use these three blocks separately to help design an application of their choice (*see **Figure 5***).

4 Hardware System

The project's hardware can be seen in ***Figure 7***. The hardware consists of four major components. The major components are the RFID Reader, the PCB, the NXT Brick, and the Power Supply. It is important to keep in mind that the PCB contains a microprocessor, two pull-up resistors, and an RJ12 connector. Each component, excluding the NXT Brick, design will be discussed thoroughly in the following subsections with an overview of the whole design later on.
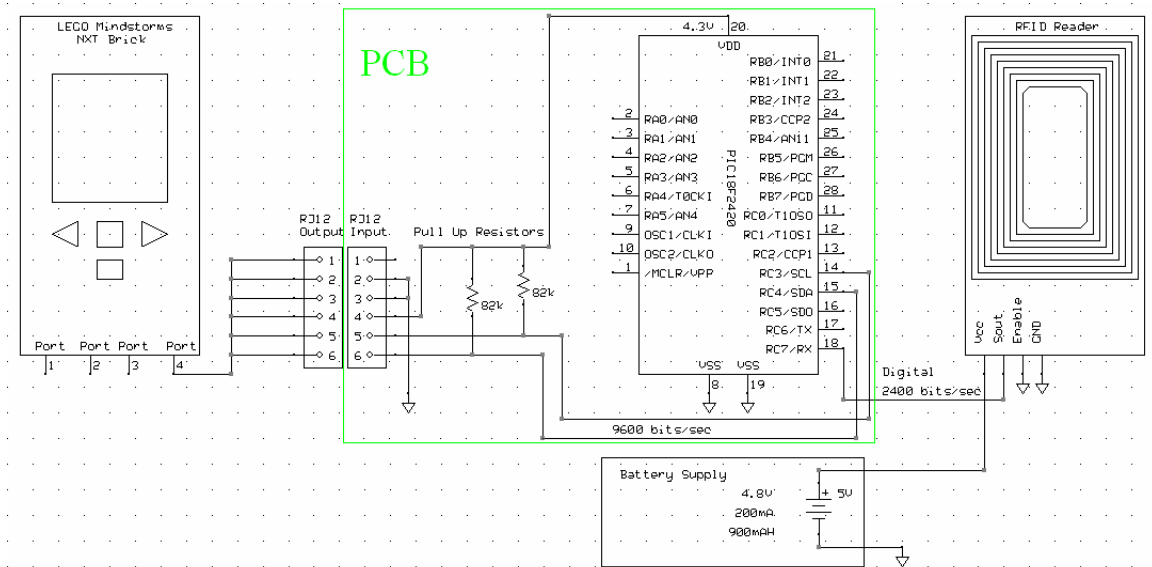
Figure 7. RFID Sensor Hardware Schematic

4.1 RFID Reader

The RFID Sensor needs to sense RFID tags. Therefore, an RFID Reader and tags are required. The RFID Reader will read the RFID tag data sent through a radio frequency signal at 125 kHz. The 96 bits (5V high and 0V low) tag ID will be sent to the PCB through serial data communications at a 2400 baud signal that can be read as an ID number if converted into a 12-byte ASCII string.

The RFID Reader works after being supplied with power, enabled, and being exposed to a tag. The RFID Reader has four pins (GND, VCC, Enable, and Sout). The VCC and GND pins are the power supply. The Enable pin is the controller of the Reader. It has to be low to activate the reader where Sout is the Serial Output pin. The connections of the pins can be seen in ***Figure 7***. The following subsections show the methodology of purchasing and testing the RFID Reader.

4.1.1 Evaluations of Design Alternatives

The team decided to choose the smallest RFID reader possible with a reasonable price to fulfill the Problem Statement requirements (*see Section 3.1*). The team selected the Parallax RFID reader which satisfied all the requirements and output a very common communication protocol (*see Appendix F for RFID specifications*). Other candidates included the Phidget RFID Reader Only (USB) and Apsx RW-210 RFID Reader/Writer. The Phidget RFID Reader Only (USB) has the same specifications compared to the Parallax RFID reader except for the USB interface. However, it costs more compared to the Parallax RFID reader (*see Table. 2*) and the USB interface is not needed in this case. The Apsx RW-210 RFID Reader/Writer has a higher range (*up to 15.24 cm*) and uses the same communication protocol as the Parallax. However, it costs more than Parallax and is bigger in size.

RFID systems can use different frequencies and RFID tags. There are two major types of tags available in the market, passive and active. The team purchased a passive tag for the Parallax reader which has a low range *(≈ 10 cm)*, no power source, and operates at a Low Frequency *(125 kHz)*.

Table 2 shows a comparison between all the RFID readers considered. The team decided to choose the Parallax RFID reader due to its common communication protocol, low price, medium reading range, and small size.

Table 2. RFID Readers comparison

Name	Range (cm)	Price ($)	Reader/Writer	Comm. Protocol	Dimensions (cm)	Power (V)
Parallax	10	39.99	Yes/No	TTL	8.25 x 6.22	5
Phidget	10	59.95	Yes/No	USB	8.1 x 6.9	5
Apsx Rw-210	15.24	54.65	Yes/Yes	TTL	11.43 x 6.86	6

4.1.2 Test Plan

The RFID reader serial output will be tested using an oscilloscope to verify its voltage threshold. The output supposes to be a 96 bit digital signal running continuously with a 5V high and 0V low.

4.1.3 Test Results

The RFID reader oscilloscope test results were identical to the manufacturer's specifications. The digital signal output is shown in *Figure 8*. It has an amplitude of 4.97V which is close to the 5V amplitude specified by Parallax. In addition, the whole 12 byte (*96 bits*) digital signal is shown in *Figure 9*. The signal repeats periodically when the tag is close to the RFID reader.
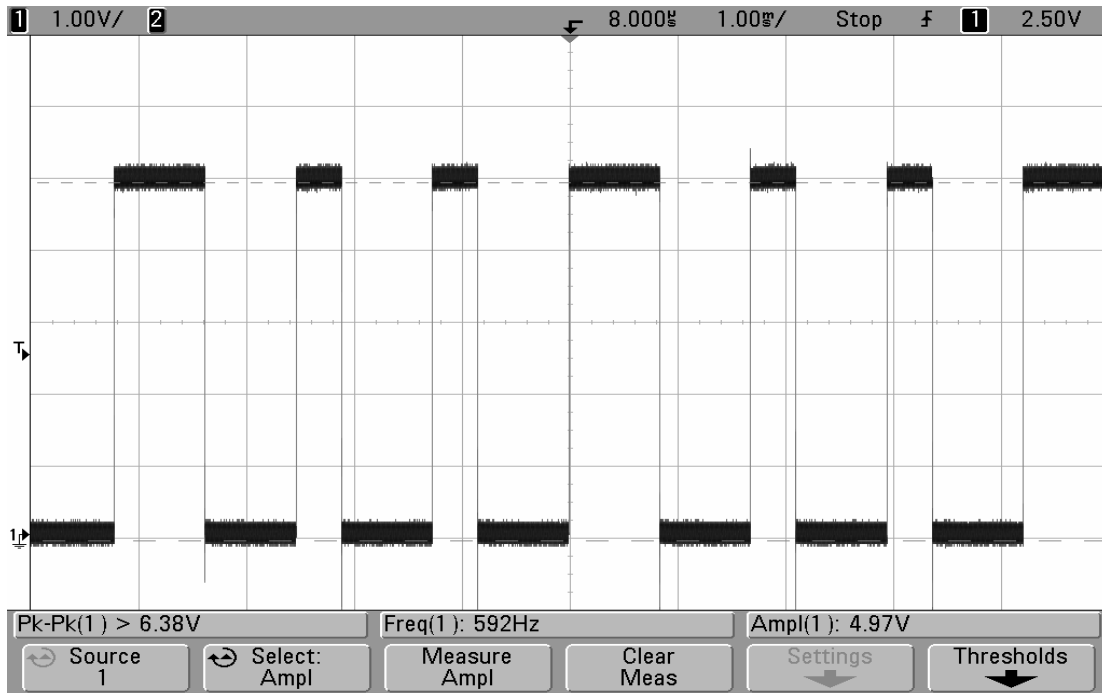
Figure 8. A Close Capture of the RFID Reader Sout Output
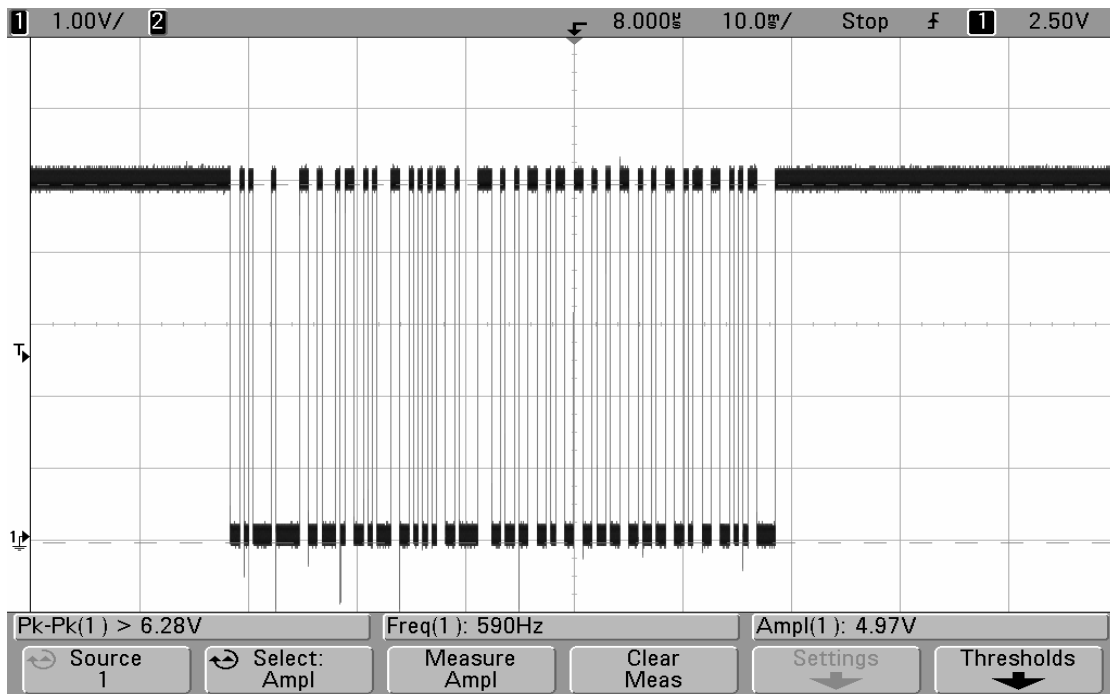
Figure 9. A 96 bits Capture of RFID Reader Sout Output

The tag ID numbers were not supplied by Parallax. Therefore, the team had to develop a method to read the tag ID numbers. First, the team mentor Mr. Bill Clench developed a driver to interface the Agilent Technologies MSO 6012A oscilloscope to LabVIEW. He

developed a program to read the RFID tag data and display the data in a 12 x 9 LED array. The 12 columns were used to display the 12 bytes of the RFID tag and the 9 columns were used to display the bits of each byte with one stop bit at the end of each byte. However, the team has used a different method to display the tag information. A dsPICDEM 2 board was used with a dsPIC30F3012 microprocessor to display the tag's information using the built-in UART of the chip and an RS-232 interface with a PC. A HyperTerminal was developed and a program has been written in C and downloaded to the board via MPLAB to accomplish the task. The results of the RFID tags data experiment are shown on *Appendix D* and the tags information is shown in *Table 3*.

Table 3. RFID Tags ID Numbers

RFID TAGS NUMBER	RFID TAGS DATA
TAG 1	04158228DA
TAG 2	0415822FF5
TAG 3	0415821F4C
TAG 4	041582144C
TAG 5	0415821242
TAG 6	0415822B09
TAG 7	0415823223

4.2 Printed Circuit Board

The system needs to translate the output of the RFID Reader from bits to bytes and store the data. Furthermore, the saved data must be converted and outputted in I2C to interface with the Brick. Therefore, a microprocessor is needed to perform these functions. The microprocessor will be embedded with other components into the PCB. The PCB of the system will contain a microprocessor, 2 pull-up resistors, and an RJ12 connector. These are the major components of the PCB. However, some by-passed capacitors might be added to the power supply pins in order to by-pass unnecessary AC signals.

The microprocessor should have a Universal Asynchronous Receiver/Transceiver (*UART*) which is a hardware piece that translates data between parallel and serial interfaces. A UART converts bytes of data from and to bits. The conversion process is done using a shift register. The speed of the UART is typically measured in "bits per second" with a typical speed range of 110 to 230,400 bps. The speed is also referred to as the baud rate.

The UART will receive the 2400 bps signal from the RFID Reader and converts it to bytes. In addition, it will save the data bytes into specific registers. The microprocessor should also have I2C Communication Bus due to its compatibility to the NXT Brick. The I2C Bus will send the saved data in the microprocessor register to the NXT Brick. Lastly, the RJ12 will physically connect the PCB, via a cable, to the NXT Brick. The RJ12 connector is used due to its compatibility to LEGO Mindstorms NXT.

The microprocessor is the most critical part of the PCB. The RJ12 and the resistors are used for interfacing purposes. The following subsections show the criteria of choosing and testing the microprocessor.

4.2.1   Microprocessor Evaluations of Design Alternatives

A microprocessor is needed to interface the RFID reader to the Brick. The digital signal coming out of the RFID reader must be converted to I2C communication protocol to be able to communicate with the Brick. The 2400 baud rate of the reader's digital output must be converted to 9600 baud, to be compatible with the LEGO Mindstorms NXT Hardware [2]. The microprocessor should contain I2C and UART, but these requirements can be met by almost any popular microprocessor/microcontroller family. The team decided to use a Programmable Integrated Circuit (*PIC*) microprocessor since the team has had previous experience with a PIC in the ELEC 310 Microcontrollers course.

The microprocessor desired features are clear. The microprocessor must contain a UART, I2C, and minimal number of pins to make a LEGO Mindstorms NXT compatible sensor. The team arrived to the following five candidates [3].

- dsPIC30F2011
- dsPIC30F3012
- PIC18F2320
- PIC18F2321
- PIC18F2420

All of these chips satisfy the requirements. Some have additional features such as digital signal processing (*dsPICs*) which is superfluous. Others have more memory which might be beneficial. The team decided to narrow down the choices by choosing a PIC that can be programmed using a PIC C Compiler (*a compiler used to program PIC chips using C code*). All the PIC microprocessors are supported by the PIC C Compiler [4]. However, the dsPICs are not supported. Microchip is currently working for a PIC C Compiler that supports dsPICs. This limited our selection to 3 choices. Finally, the PIC18F2420 was chosen because it was used in ELEC 310 course and it has the biggest memory among all the other processors. See ***Appendix F*** for PIC18F2420 specifications.

As mentioned earlier, the microprocessor is going to be built on a PCB that contains an RJ12 connector, pull-up resistors, and capacitors as needed (s*ee **Figure.7***). The microprocessor will be powered by the NXT Brick using the 4.3V terminal (*see **Figure 7***).

4.2.2   Microprocessor Test Plan

The PIC18F2420 microprocessor will be tested by the PICDEM 2 PLUS DEMO BOARD. The PICDEM 2 PLUS DEMO BOARD is purchased and will be used to download the programs into the PIC microprocessor and demonstrate the program's functionality. Once the demonstration works as expected, the prototype hardware will be

built into a bread board using a DIP microprocessor to build the schematic shown in *Figure 7* and the board will be interfaced and tested with the Brick.

4.2.3   Microprocessor Test Results

The microprocessor test is broken down into simpler tasks that have to be accomplished. The team members have developed simple programs and downloaded them into the dsPIC microprocessor to increase their familiarity with the dsPIC environment. The programming was done using C in MPLAB which works for the PIC/dsPIC identically except for changing one header file. However, simple programs have been developed. One program displays "Hello USD" in the dsPICDEM 2 LCD. The other program was developed to read the tags information as mentioned before. The results can be seen in *Appendix D*.

4.3   Power Supply

The RFID Reader needs to be powered externally due to the limited power supplied by the Brick. Therefore, an external power supply is needed. The external power supply will provide the RFID Reader with the necessary power to be in its active state. The power supply will be directly connected to the RFID reader as shown in *Figure 7*.

4.3.1   Evaluations of Design Alternatives

An external power supply is necessary to power the RFID reader since the RFID reader draws 200 mA in its active state. The Brick can only supply a maximum of 180mA and this current is shared by all ports. The team chose a power supply based on its size, recharge ability, voltage, and mAh ability. The Tenergy NiCd 4.8V 900mAh Battery Pack satisfied all the requirements and was inexpensive (*see Appendix E*). Therefore, the team decided to use the Tenergy NiCd as an external power supply. See *Appendix F* for the Tenergy NiCd specifications.

4.3.2   Test Plan

The power supply will be tested by charging it and measure its output voltage and current. The voltage should be within the 4.5V-5.5V range required to power the RFID reader. The current supply must be 200 mA, which is the amount drawn by the RFID reader in its active state. According to the manufacturer, the power supply should provide 4.8V and 900 mAh. The testing will be done just to verify the manufacturer's specifications.

4.3.3   Test Results

The power supply test has also succeeded and provided the expected results. It provided 5.22V and 230 mA according to our measurements.

4.4   Hardware Design

The hardware configuration for the project is shown in ***Figure 7***. The PCB will convert the 96 bits (*12-byte*) signal coming out of the reader into I2C communication protocol to enable the communication with the NXT Brick.

The RFID Reader is directly connected to the PIC microprocessor, within the PCB. The RFID Reader has four connections. Both GND and Enable are connected to ground, VCC is connected to the 4.8V power supply, and the Sout is connected to the UART receive pin. The UART receive pin will receive the 96 bit (*12-byte*) signal and save it in a register. It is important to note that the RFID Reader Enable pin activates the RFID Reader when it is pulled low. The Reader only reads tags data in its active state. Therefore, the Reader was set to active during the run phase of the robot.

The PIC microprocessor will be powered by the Brick and will be connected to Pin 4 of the RJ12 connector which provides a 4.3V supply. The I2C Serial Data will be sent along with the Clock for synchronization purposes from the PCB to the Brick. The Serial Clock and Serial Data pins are the I2C interface pins. They will be connected to pins 5 and 6 in the RJ12 connector. The LEGO Mindstorms Hardware Development Kit [17] recommended using two 82 kΩ pull-up resistors for these connections. The pull-up resistors are necessary for the I2C protocol to work. SCL and SDA lines are "open drain" drivers, meaning that the chip can drive them low, but it cannot drive them high. Therefore, the two resistors will help pull the SCL and SDA pins high. If the resistors are missing, the pins will always be low and thus the I2C protocol will fail. Pin 2 and 3 of the RJ12 connector are connected to ground, and Pin 1 is an analog input terminal which is superfluous to our needs.

It is important to note that the clock will be provided by the NXT Brick which will act as a Master. Masters typically produce the clock and send it to their Slaves. Moreover, the PIC microprocessor, pull-up resistors, and RJ12 connector are the PCB components.

4.5   System Test

After testing and verifying the outputs of all the hardware components, the hardware (PCB+RFID Reader) will be connected to the NXT Brick and the integration process will start. The team will use a Logic Analyzer to analyze the I2C serial clock and data lines. Some important parameters have to be analyzed such as the start bit, slave address, write/read bit, register number, and tag data. The Logic Analyzer enables us to see the whole sequence of the I2C communication protocol. Thus, it is a valuable piece of equipment to the project.

Thus far, the Hardware segment of the project is proceeding at a good pace. Yet, the team has to program the PIC microprocessor to enable the I2C interface in order to communicate with the Brick. Moreover, the UART interface must be used with the RFID reader to convert the tags information into bytes and store them in a register in order to

send the data via I2C to the NXT Brick. The PCB will be built upon completion of the microprocessor program and testing the microprocessor on a bread board.

5 NXT Robot Design Issues

The original TriBot (*3 wheeled driving robot*) was built without heavy consideration of the weight and size of the interface. The TriBot was used for mock tests using NXT-G programs, see *Figure 10*. However, the robot will be modified to a four-wheeled vehicle, seen in *Figure 1*. The design for the robot was downloaded from a public source off of www.nxtasy.org. The design will give the robot more stability even with a potentially large and heavy interface. The robot in *Figure 1* will also be modified according to our needs.

As mentioned earlier, the robot will maneuver its way in a predetermined path using light sensors. The Parallax RFID reader will operate at 125 kHz and be mounted on the bottom of the robot. As the robot follows its path, the Reader will sense RFID tags within 10 centimeters. Subsequently, the Reader will send a signal to the PIC18F2420 microprocessor. The processor will convert the data into I2C and send it along with a clock via an RJ12 6-wire industry-standard connector to the NXT Brick informing it of the tag presence and data. The NXT Brick will store the RFID tag/tags data until the robot finishes the path. Then, the NXT Brick will send the stored tags' information to an external computer (*i.e. iPAQ or PC*) via Bluetooth where the data can be used for inventory purposes.

Figure 10. LEGO Mindstorms NXT Tribot

6 Software System

NXT-G is programming software that comes with the LEGO Mindstorms system that is used to program the robot. It was created by LabVIEW, making it compatible with LabVIEW, and like LabVIEW, works as a graphical based language rather then text based language like most programming software, see ***Appendix C,*** a line following program for LabVIEW. In order to upload a program, a newly created sensor, onto the NXT-G software, the designer must create the program on LabVIEW, save the program as a block, and upload the block onto NXT-G. This would allow users to use the created blocks to create programs of their choice. An example of blocks and their respective programs are seen in ***Figures 11-13***. The block is then easily uploaded onto NXT-G, as seen in ***Figure 14***.

Since LabVIEW and NXT-G are both graphical based platforms. Graphical user interfaces (GUI) make it easy to visually see the processes of the program and make modifications. LabVIEW seems to be the standard tool for creating projects amongst users, giving access to more resources than alternative software.

The RFID sensor Block will consist of small blocks, such as the ones in ***Figure 13***. Creating small blocks allows for simulation and testing of each piece individually before they are placed into the whole. Once all the small blocks are created, they will be filed as subprograms under a larger block that will be able to read and store tag data.
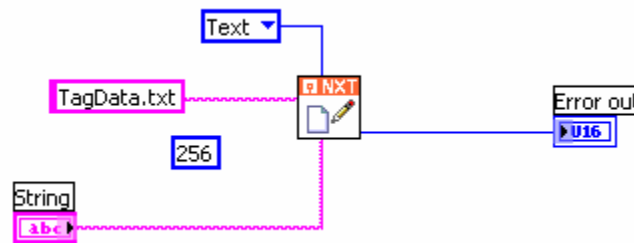
Figure 11. "File Tag Data" LabVIEW Diagram
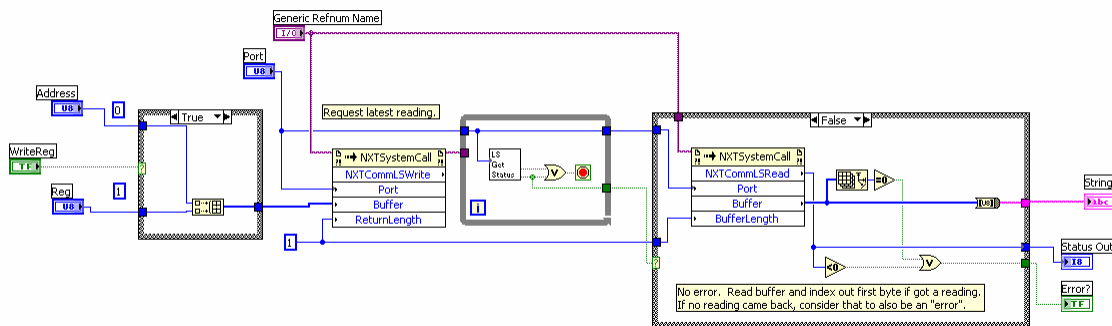
Figure 12. "Get Tag Data" LabVIEW Diagram
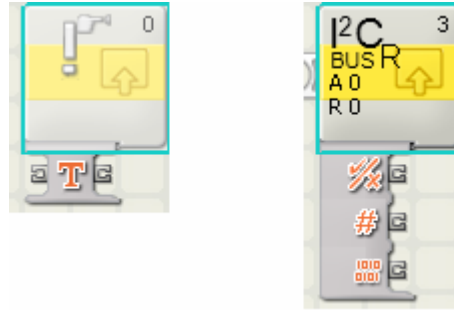
Figure 13. "File Tag Data" and "Get Tag Data" NXT-G Blocks Respectively
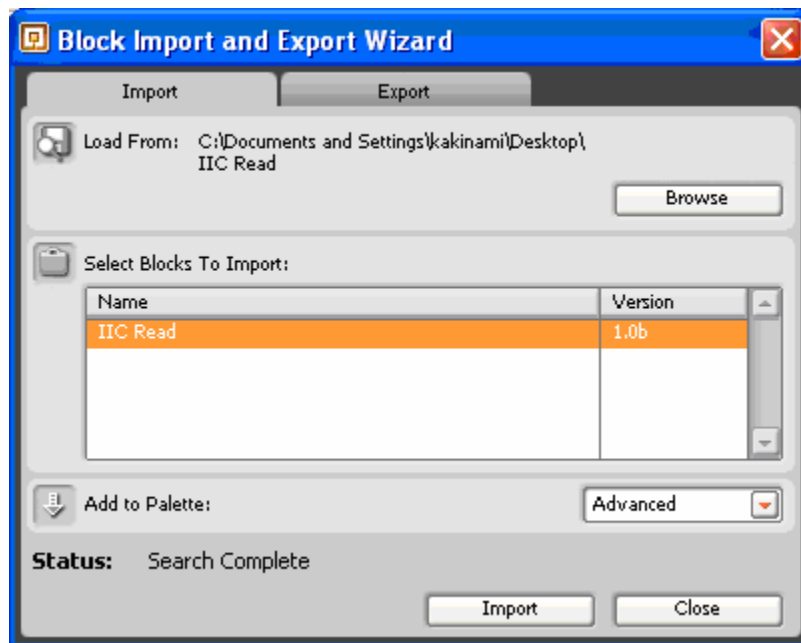
Figure 14. Importing a block into NXT-G from LabVIEW

6.1   Evaluations of Design Alternatives

The LEGO Mindstorms NXT Brick contains a versatile processor that can be programmed using various firmware such as NXT-G, RobotC, Java, and NBC since LEGO has released the firmware for the NXT Brick as open source.

Initially, RobotC was chosen as a platform based upon the fact that it was text based and similar to the C programming language. In addition, some similar programs in RobotC require less programming than in NXT-G, see *Appendix B and C,* example of a line following program in both RobotC and LabVIEW. Upon further review, this choice was found to be incompatible with the desire to create an NXT-G block for beginner users to utilize. The only compatible software that will allow us to create a block on NXT-G is LabVIEW using the LabVIEW Toolkit for the Mindstorms NXT. Therefore, LabVIEW is selected as the programming environment for the project.

6.2 "Get Tag Data" Block

6.2.1 Design

"Get Tag Data" is an NXT-G block that will be created in LabVIEW. The block will send a request for data to the PCB board. The request is required by the I2C protocol that the Brick and the PCB use to communicate. Initially, the request consists of sending the start sequence. The start sequence consists of the I2C address of the slave, the read/write (R/W) bit low, and the internal register number being written to. Then, the start sequence and the I2C address will be sent again - this time with the read bit set to one to enable reading. The Block then reads as many data bytes as requested and terminates the transaction with a stop sequence. Once the data is received, the data is stored into a local register on the NXT Brick to be used by another portion of the program.

6.2.2 Test Plan

The "Get Tag Data" Block will get data from the RFID Reader by using the I2C protocol. It will then store this data on a local register on the NXT Brick to be used by the user. To test this NXT-G Block the team will first test to make sure that the request sequence is correct. To do so a request will be sent and then the response data will be probed with a spectrum analyzer. A set of numbers that have been pre-defined will be used. The team hopes that the spectrum analyzer will then show that the request went through and a response has been sent with the data that has been requested. Knowing that the requested data is correct the other aspects of the block will be able to be tested. The goal is to see if this Block will take these numbers and set them into a string. The string will be added to an array with the port number that the data has come from. This information will then be outputted by the Block to be used by other blocks. The test is to see that the outputted data is an array of the random set of numbers and the port information.

6.3 "File Tag Data" Block

6.3.1 Design

"File Tag Data" is another NXT-G Block that will be connected to the "Get Tag Data" Block. Once the "Get Tag Data" Block receives the data it will send it to the "File Tag Data" Block which will then take the tag number and save it into a file. Every time a new tag's data is received by this Block, it will add that tag's data onto the file until all the tags are read.

6.3.2 Test Plan

The "File Tag Data" Block will be tested by inputting a set of known information into the Block. Different information will be input over a short period of time. By inputting data over a short period of time it will be simulating what will actually happen as the robot moves around and gets different tag data over a period of time. The file will then be opened and checked to see that the file contains a table of the data that has been input.

6.4   Bluetooth Block

6.4.1   Design

Once all tag data has been received and filed, this NXT-G block will be called upon to take the saved file, with all the tag data, and send the data via Bluetooth to a computer.

6.4.2   Test Plan

When testing the Bluetooth one wants to make sure that files get sent and received. To do so the range capabilities of the Bluetooth dongle as well as the Bluetooth on the NXT Brick need to be verified. One will also have to make sure that the files being sent do not get corrupted in anyway and that it is accurate.

6.5   Software Test Results

6.5.1   NXT-G Blocks

Most of the NXT-G blocks have not been tested yet. However, they will be tested when the hardware interface is complete and ready for testing. The team has been able to save data onto the NXT Brick and have also been able to successfully access the data. This has been demonstrated by saving a set of values on the NXT Brick and then running an entirely new program and being able to display these values on the Brick's display. The Bluetooth functions have been demonstrated as well by sending a file to the NXT Brick and accessing that file then displaying the information on the NXT Brick display. Thus far, no data has been able to be transferred from the NXT Brick to a computer via Bluetooth.

6.5.2   NXT-G Program

A line follower program, which uses the light sensor to allow the robot to follow a predefined line on the ground, was downloaded from a public source off of www.nxtasy.org. The program was tested using the TriBot demo robot, and the robot successfully followed a black line. This program will be used within the final program in which the robot will follow a path and simultaneously read and store data from RFID tags that it encounters.

7   Schedule

The project has reached significant milestones such as completing the design of the prototype RFID sensor and creating two NXT-G Blocks used for interfacing the RFID sensor. Although not listed on the original Gantt chart, the microprocessor remains to be programmed in order to send the RFID Reader signal to the NXT Brick, and it would mark the completion of the prototype RFID sensor. The sensor would then be tested, improved, and placed onto a PCB board. Also, the two NXT-G Blocks will be tested using the completed prototype RFID sensor. A final Bluetooth block must also be created in order to transfer the stored data to Bluetooth capable computer. The project was originally assumed to be completed by May 9th, but the date will be moved to August 3rd.

7.1 Hardware

The hardware portion of the project is almost complete (*see **Figure 15***). Mr. Ali AlMatrouk researched the necessary components that will be used in interfacing the RFID reader to the LEGO Mindstorms NXT Brick. All the necessary parts are on hand, and the hardware circuit will be constructed on a breadboard for testing purposes by June 4th. Once the circuit has been improved and deemed acceptable, it will be constructed on a printed circuit board (*PCB*). **Figure 15** is a proposed Gantt chart, and thus, contains the amplifier design, which was not necessary, and does not contain the microprocessor. During the design phase, Mr. AlMatrouk realized that a microprocessor was necessary. This modification set the hardware development back slightly. In accordance with the Gantt chart, the hardware was not constructed on time.

ID		Task Name	Duration	Start	Finish	Predecessors
1		**Hardware - Ali AlMatrouk**	52 days?	Thu 2/8/07	Fri 4/20/07	
2	✓	Purchasing LEGO Mindstorms NXT kit	0 days	Thu 2/8/07	Thu 2/8/07	
3	✓	Research RFID Reader and Tag	10 days?	Mon 2/19/07	Sun 3/4/07	
4	✓	Order Approperiate RFID Reader and Tag	0 days	Mon 3/5/07	Mon 3/5/07	3
5	✓	RFID interface research	24 days?	Mon 3/12/07	Thu 4/12/07	
6	✓	Research RJ12 Female Connector	3 days?	Mon 3/12/07	Wed 3/14/07	
7	✓	Order RJ12 Female Connector	0 days	Wed 3/14/07	Wed 3/14/07	6
8	✓	Research Power Supply	12 days?	Mon 3/12/07	Tue 3/27/07	
9	✓	Oder Power Supply	0 days	Tue 3/27/07	Tue 3/27/07	8
10	✓	Amplifier Design (If applicable)	23 days?	Tue 3/20/07	Thu 4/19/07	
11		RFID Hardware ready to install	0 days	Fri 4/20/07	Fri 4/20/07	5,10

Figure 15. Hardware Design Gantt Chart

7.2 Software

The software portion is not progressing as quickly as originally intended (*see **Figure 16***). The group ran into a large obstacle when learning the LabVIEW software. The learning curve for this particular software was steeper than expected. LabVIEW is a programming tool that uses GUI rather than third generation programming language. However, the team has recently received the assistance of Mr. Bill Clench, ViaSat Software Engineer. Mr. Clench has over 12 years of experience working on LabVIEW, since 1991. Mr. Clench is currently instructing the team on how to construct program blocks for the RFID sensor. Two of three blocks have been created for testing.

ID		Task Name	Duration	Start	Finish	Predecessors
13		**Software - Jeff Kakinami**	37 days?	Tue 2/27/07	Fri 4/20/07	
14	✓	Labview conference	0 days	Tue 2/27/07	Tue 2/27/07	
15		Learn Labview Software	32 days?	Wed 2/28/07	Thu 4/12/07	14
16		Create a Block for the RFID Reader	20 days?	Fri 3/9/07	Thu 4/5/07	
17		RFID Block Due Date	0 days	Fri 4/6/07	Fri 4/6/07	16
18		Labview Program Due Date	0 days	Fri 4/13/07	Fri 4/13/07	15
19		Programs Ready to Install	0 days	Fri 4/20/07	Fri 4/20/07	17,18

Figure 16. Software Design Gantt Chart

7.3   Integration and Testing

The integration and testing portion is waiting for the hardware and software portions to complete their initial designs for testing, as (*see **Figure 17***). In the mean time, not shown on ***Figure 17***, a line-follower program was constructed on NXT-G (*see **Appendix C***). Also, a basic TriBot robot was built from the inherent instructions, but the robot will be modified in the shape of a four-wheeled vehicle (*see **Figure 1***).

ID		Task Name	Duration	Start	Finish	Predecessors	February			March			April			May		
							2/1	2/11	2/21	3/1	3/11	3/21	4/1	4/11	4/21	5/1	5/11	5/21
21		**Integration and Testing - Alfredo Bermu**	**13 days**	**Mon 4/23/07**	**Wed 5/9/07**													
22		Testing the Labview Program	4 days	Mon 4/23/07	Thu 4/26/07													
23		Testing the I2C interface	2 days	Mon 4/23/07	Tue 4/24/07													
24		Testing RFID reader with RJ12	4 days	Mon 4/23/07	Thu 4/26/07													
25		Testing Amplifiers (If applicable)	3 days	Wed 4/25/07	Fri 4/27/07													
26		Interfacing the RFID and the robot	6 days	Mon 4/30/07	Mon 5/7/07	22,24,25,23												
27		Testing the Final Project	2 days	Tue 5/8/07	Wed 5/9/07	26												
28		Final Project Due Date	0 days	Wed 5/9/07	Wed 5/9/07												5/9	

Figure 17. Project Manager/Integrator Gantt Chart

Note: For more information about the Gantt chart, please refer to ***Appendix A***.

7.4   Team's Qualifications

The team members are first year electrical engineering seniors at the University of San Diego. The members have taken electrical engineering courses and completed design projects that will qualify them for the senior project. The most relevant courses for this project are Microprocessors, Digital Design, Radio Frequency Engineering, Programming, Power, and Electronics, refer to project personnel and resumes in ***Appendix H*** for more information.

8   Budget

The total cost is estimated at $2,181.22 (see ***Table 4***). Currently, $1,085.40 has been spent. Some costs have accrued that were not predicted in the original budget, such as a Data Acquisition Device and a RobotC compiler, but the budget has remained well below its threshold. All purchases are approved by the project manager, Mr. Alfredo Bermudez, and a project advisor, Dr. Kathleen Kramer.

Table 4. Estimated Cost of Project

Part	Quantity	Price Per Unit ($US)	Price total ($US)
LEGO Mindstorms NXT Kit	1	249.99	249.99
NXT Brick	2	134.99	269.98
Compass Sensor	1	46.99	46.99
Color Sensor	1	46.99	46.99
Bluetooth Dungle	1	37.99	37.99
Remote Control	1	19.99	19.99
Connector Cables	1	9.99	9.99
RFID Reader Module	3	39.99	119.97
RJ12 Female Connector	4	5	20.00
Microprocessor	15	5.8	87.00
Portable Power Supply	1	40	40.00
HP iPAQ hx2495 Pocket PC	1	399.99	399.99
Reasearch Materials	5	40	200.00
Miscellaneous		300	300.00
Overhead Costs		10% of above	184.89
TAX (7.25%)			147.45
TOTAL COSTS			2,181.22

9 Conclusion

There were three primary objectives for this semester. The first objective was to construct the hardware for the RFID sensor which consisted of the RFID Reader and its interface to the NXT Brick. The second objective was to create the programs that would enable the RFID sensor to be used by a programmed NXT. The final objective was to integrate the RFID sensor with the NXT Brick and implement the RFID sensor into an NXT program.

The first objective is 90% complete. The design of the prototype RFID sensor is complete, and the parts are ready to be installed onto a breadboard. The parts were individually tested minus the microprocessor which is currently being programmed. The completion of the first objective was delayed by the implementation of a microprocessor. The prototype RFID sensor will be complete by June 4th.

The second objective is 70% complete. Two of the three NXT-G Blocks have been created on LabVIEW but are waiting to be tested on the prototype RFID sensor. The third block is currently under development. The second objective faced difficulty initially in learning how to use the LabVIEW software. The program blocks will be complete by July 1st.

The final objective is waiting for the first two objectives to be met. Miscellaneous tasks such as constructing the correct robot model and creating an NXT-G line follower program were completed. The final objective will be met by August 1st.

The project has reached major milestones, including the completion of the hardware design and the completion of two NXT-G Blocks. The design phase of the project is complete, and thus the project is on track for its scheduled completion by August 3rd.

10 Acknowledgements

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                http://ww1.microchip.com/downloads/en/DeviceDoc/70139E.pdf
                ▪ dsPIC30F3012
                http://ww1.microchip.com/downloads/en/DeviceDoc/70139E.pdf
                ▪ PIC18F2320
                http://ww1.microchip.com/downloads/en/DeviceDoc/39599F.pdf
                ▪ PIC18F2321
                http://ww1.microchip.com/downloads/en/DeviceDoc/39689E.pdf
                ▪ PIC18F2420
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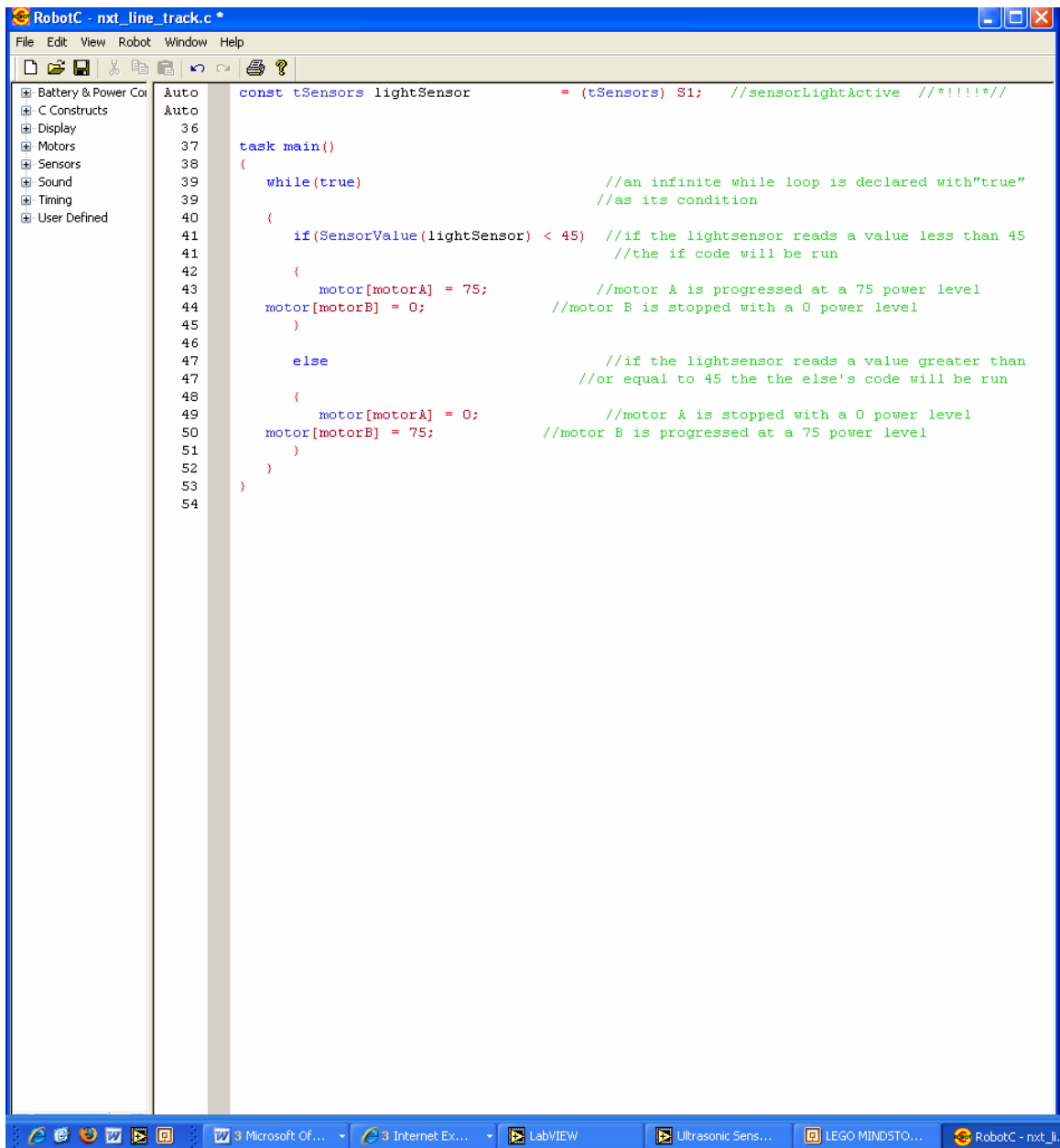
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        Division of Engineering and Applied Sciences
        Phone: 617-496-6434
        E-mail: rad@eecs.harvard.edu

13   Appendix A Gantt Chart (Time Schedule)

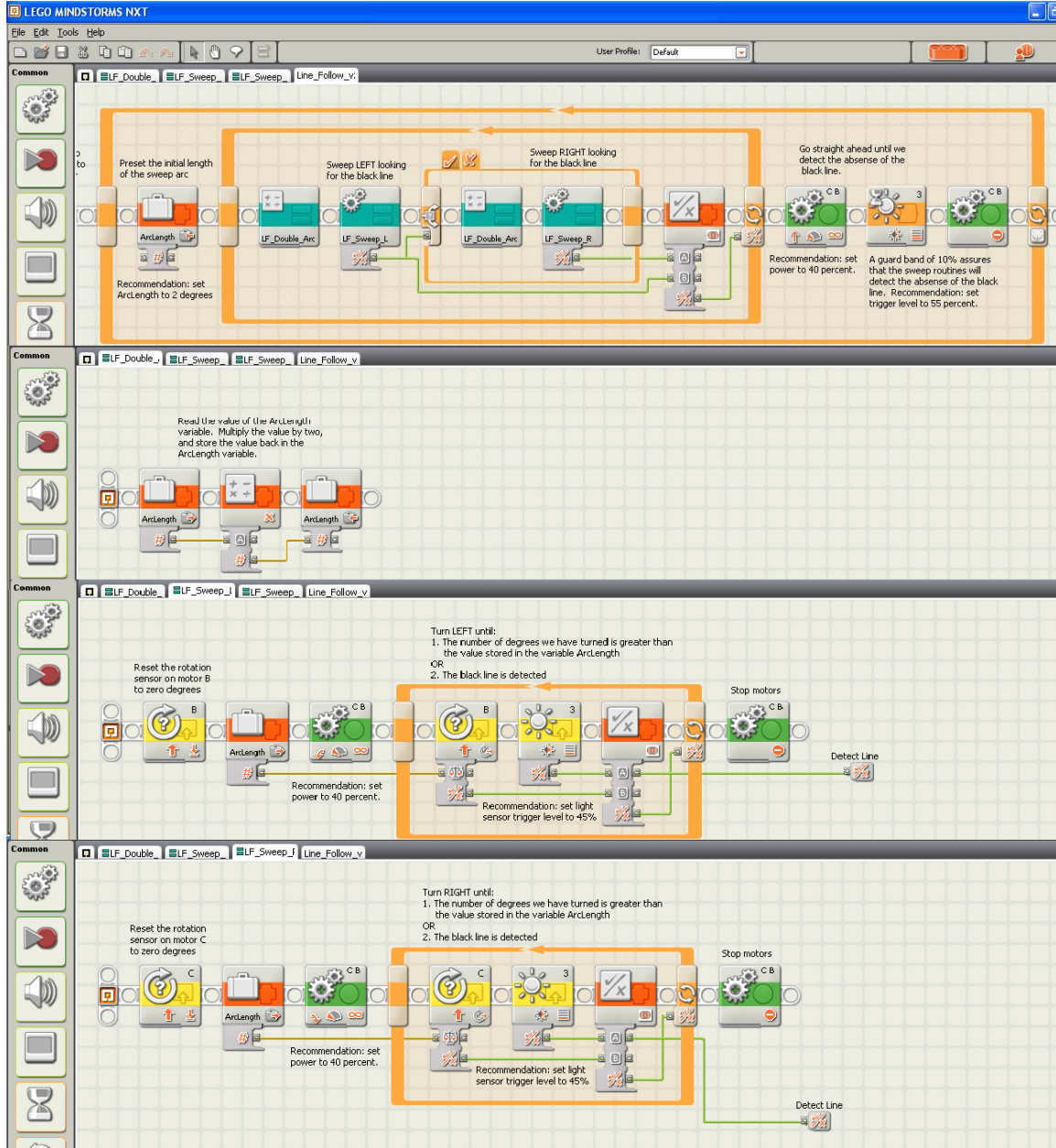| ID		Task Name	Duration	Start	Finish	Predecessors
1		**Hardware - Ali AlMatrouk**	**52 days?**	**Thu 2/8/07**	**Fri 4/20/07**	
2		Purchasing LEGO Mindstorms NXT kit	0 days	Thu 2/8/07	Thu 2/8/07	
3		Research RFID Reader and Tag	10 days?	Mon 2/19/07	Sun 3/4/07	
4		Order Approperiate RFID Reader and Tag	0 days	Mon 3/5/07	Mon 3/5/07	3
5		RFID interface research	24 days?	Mon 3/12/07	Thu 4/12/07	
6		Research RJ12 Female Connector	3 days?	Mon 3/12/07	Wed 3/14/07	
7		Order RJ12 Female Connector	0 days	Wed 3/14/07	Wed 3/14/07	6
8		Research Power Supply	12 days?	Mon 3/12/07	Tue 3/27/07	
9		Oder Power Supply	0 days	Tue 3/27/07	Tue 3/27/07	8
10		Amplifier Design (If applicable)	23 days?	Tue 3/20/07	Thu 4/19/07	
11		RFID Hardware ready to install	0 days	Fri 4/20/07	Fri 4/20/07	5,10
12						
13		**Software - Jeff Kakinami**	**37 days?**	**Tue 2/27/07**	**Fri 4/20/07**	
14		Labview conference	0 days	Tue 2/27/07	Tue 2/27/07	
15		Learn Labview Software	32 days?	Wed 2/28/07	Thu 4/12/07	14
16		Create a Block for the RFID Reader	20 days?	Fri 3/9/07	Thu 4/5/07	
17		RFID Block Due Date	0 days	Fri 4/6/07	Fri 4/6/07	16
18		Labview Program Due Date	0 days	Fri 4/13/07	Fri 4/13/07	15
19		Programs Ready to Install	0 days	Fri 4/20/07	Fri 4/20/07	17,18
20						
21		**Integration and Testing - Alfredo Bermu**	**13 days**	**Mon 4/23/07**	**Wed 5/9/07**	
22		Testing the Labview Program	4 days	Mon 4/23/07	Thu 4/26/07	
23		Testing the I2C interface	2 days	Mon 4/23/07	Tue 4/24/07	
24		Testing RFID reader with RJ12	4 days	Mon 4/23/07	Thu 4/26/07	
25		Testing Amplifiers (If applicable)	3 days	Wed 4/25/07	Fri 4/27/07	
26		Interfacing the RFID and the robot	6 days	Mon 4/30/07	Mon 5/7/07	22,24,25,23
27		Testing the Final Project	2 days	Tue 5/8/07	Wed 5/9/07	26
28		Final Project Due Date	0 days	Wed 5/9/07	Wed 5/9/07	
29						
30		**Paper and Oral Work**	**62 days?**	**Fri 2/16/07**	**Tue 5/15/07**	
31		Project proposal Outline	6 days?	Fri 2/16/07	Fri 2/23/07	
32		Submit Project Proposal Outline	0 days	Fri 2/23/07	Fri 2/23/07	31
33		Project Proposal Draft	3 days?	Fri 2/23/07	Tue 2/27/07	
34		Submit Project Proposal Draft	0 days	Tue 2/27/07	Tue 2/27/07	33
35		Prepare Proposal Presentation	3 days?	Fri 3/2/07	Tue 3/6/07	
36		Practice Proposal Presentation	2 days	Wed 3/7/07	Thu 3/8/07	35
37		Submit Project Proposal	0 days	Fri 3/9/07	Fri 3/9/07	
38		Give Project Presentation	0 days	Fri 3/9/07	Fri 3/9/07	
39		Prepare Portfolio	7 days?	Tue 4/10/07	Wed 4/18/07	
40		Submit Portfolio	0 days	Wed 4/18/07	Wed 4/18/07	39
41		Preliminary Design Review (PDR)	14 days?	Mon 4/23/07	Thu 5/10/07	
42		Submit PDR	0 days	Fri 5/11/07	Fri 5/11/07	41
43		Prepare Final Portfolio	15 days	Tue 4/24/07	Mon 5/14/07	
44		Submit Final Portfolio	0 days	Tue 5/15/07	Tue 5/15/07	43
45		Prepare Final Presentation	6 days?	Mon 4/30/07	Mon 5/7/07	
46		Practice Final Presentation	3 days?	Tue 5/8/07	Thu 5/10/07	45
47		Give Final Presentation	0 days	Fri 5/11/07	Fri 5/11/07	46

14 Appendix B RobotC Line Follower Program

15 Appendix C NXT-G Line Follower Program

16 Appendix D RFID Tags Data Using a HyperTerminal

```
ali2 - HyperTerminal
File  Edit  View  Call  Transfer  Help

0415823223

dsPIC
0415823223
04158232232C Pot=1.9
0415823223

d
04158232
0415823223l.93v
0415823223

dsPICDEM
0415823223
0415823223Pot=1.93v
0415823223

dsPI
0415823223d
041582322323C Pot=1.
0415823223
```

```
0415823223
0415823223
0415823223
0415823223
0415823223
0415823223
0415823223
0415823223
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0415823223
0415823223
0415822B09
0415821242
04158228DA
041582144C
0415821F4C
041582144C
0415821242
0415822B09
0415823223
0415823223
04158228DA
0415822FF5
0415821F4C
```

```
Connected 6:32:27    Auto detect    2400 8-N-1    SCROLL    CAPS    NUM    Capture    Print echo
```

17   Appendix E Current Expenses

Date	Purchase Cost	Description	Purchaser	Date Receipt Submitted	Date Reimbursed
2/15/2007	$268.11	LEGO Mindstorms NXT Kit	Alfredo Bermudez	2/15/2007	3/1/2007
3/3/2007	$100.26	2 RFID Readers	Ali AlMatrouk	3/5/2007	3/12/2007
3/11/2007	$33.17	7 RFID Tags + 3 day shipment	Ali AlMatrouk	3/12/2007	3/16/2007
3/16/2007	$318.51	LEGO Mindstorms NXT Accessories	Ali AlMatrouk	3/16/2007	4/2/2007
3/16/2007	$18.40	10 RJ12 Connectors	Ali AlMatrouk	3/19/2007	3/21/2007
3/18/2007	$41.00	2 Binders and 3 Dividers	Alfredo Bermudez		
3/21/2007	$46.48	External Power Supply and Charger	Ali AlMatrouk	3/21/2007	3/30/2007
4/10/2007	$111.62	Data Acquisition Device	Ali AlMatrouk	4/13/2007	
4/14/2007	$37.70	Extreme NXT Book	Ali AlMatrouk	4/20/2007	4/25/2007
4/17/2007	$30.00	RobotC Compiler	Jeff Kakinami	4/17/2007	
4/20/2007	$80.15	Microprocessors	Ali AlMatrouk	4/20/2007	4/25/2007
Total	$1,085.40				

18   Appendix F System Components Specifications

Parallax RFID reader and tag specifications:

- o RFID reader
  - Parallax RFID Reader Module
  - Operating Frequency is 125 kHz
  - Dimensions are 62.2mm x 82.5mm
  - 4 pin (Vcc, /Enable, Sout, Gnd)
  - +5V DC input
  - Operating Temperature -40∘C to +85∘C
  - 2400 bps baud rate
  - unique ID will be transmitted as a 12-byte ASCII string
- o RFID tag
  - 54 mm X 85 mm Rectangle Tag and/or 50 mm Round Tag
  - Operating Frequency is 125 kHz

LEGO Mindstorms NXT kit specifications:

- o LEGO Mindstorms NXT Brick
  - Main Processor: Atmel 32-bit ARM processor (256 kB Flash, 64 kB RAM, 48 MHz)
  - Co-processor: Atmel 8-bit AVR processor (4 kB Flash, 512 byte RAM, 8 MHz)
  - 4 input ports: 6-wire interface supporting both digital and analog interface
  - 3 output ports: 6-wire interface supporting input from encoders
  - Power Source: 6 AA batteries
  - Connector: 6-wire industry-standard connector, RJ12 Right side adjustment
  - USB 2.0 Communication Full speed port (12 Mbits/s)
  - Bluetooth wireless communication CSR BlueCore 4 v2.0 +EDR System
    - Supporting the Serial Port Profile (SPP)
    - Internal 47 Kbyte RAM
    - External 8 Mbit FLASH
    - 26 MHz

PIC18F2420 specifications:

- Architecture: 8-bit
- Program Memory Type: Flash
- Kbytes: 16
- KWords: 8
- Self Write: Yes

- DATA EEPROM: 256
- RAM: 768
- I/O: 25
- ADC Channels: 10
- ADC Bit: 10-bit
- ADC Sample Rate (ksps): 100
- Comparators: 2
- Timers/WDT: 1-8bit/3-16bit/Yes
- HW RTCC: No
- Interface: EUSART / MI²C / Compatible/SPI
- Max. Speed MHz: 40
- Int Oscillator (MHz): 8
- ICSP™: Yes
- BOR: PBOR
- LVD: PLVD
- ICD - # of Breakpoints: 3
- CCP / ECCP: 2/0
- PWM Channels: 2
- PWM bits: 10
- Parallel Port: No
- Nanowatt: Yes
- Vdd Min.- Vdd Max: 2V-5.5V
- Pin Count: 28
- Packages: 28/QFN 28/SOIC 300mil 28/SPDIP

Tenergy NiCd 4.8V 900mAh Battery Pack specifications:

- Voltage: 4.8V
- Current: 900mAh
- Battery: NiCd
- Connector Type: Standard Tania.
- Dimensions: Height 0.6"; Width 2"; Length 2.2"
- Weight: 4 Oz.

An optional hardware piece might be Hewlett Packard iPAQ.
The specifications of the iPAQ are shown below.

- o Hewlett Packard iPAQ hx2495 Pocket PC
  - Wi-Fi (802.11b) and Bluetooth wireless technology
  - Intel PXA270 processor 520MHz
  - Genuine Windows Mobile 5.0 Software for Pocket PC, Premium Edition
  - 3.5" viewable size, 16-bit color transflective
  - 256 MB total memory (192 MB ROM 64 MB RAM); up to 192 MB user available persistent storage memory
  - Removable/rechargeable Lithium-Ion (1440 mAh)

- 3.01 W x 0.65 D x 4.71" H

An optional Bluetooth Dongle is needed if the PC or Mac does not support Bluetooth Communication. The Bluetooth Dongle will enable the PC or Mac to communicate with the NXT Brick via Bluetooth Wireless Communication Protocol.
The Bluetooth Dongle specifications are shown below.

- Supported Bluetooth® software includes Widcomm Bluetooth for Windows (newer than v. 1.4.2.10 SP5), and the Bluetooth stacks included in Microsoft Windows XP (with Service Pack 2) and Apple MacOS X (10.3.9 and 10.4).
- Requires USB Connection.

19   Appendix G ABET Design Constraints

The project includes but not limited to the following constraints.
- Economic
    - The project's cost should not exceed the available budget. However, based on our projected financial costs and current spending (*see **Section 6***), the team believes that they have sufficient funding for the project.
    - The RFID sensor cost should not exceed $70 a piece. Typical NXT sensors have a cost range of $16.99-$46.99. However, RFID technology is expensive currently. Therefore, they believe it is reasonable to push the price range further.

        The main barrier is finding an RFID reader with the desired read range that meets our cost limit of $70. The size of the RFID reader should be small enough to fit as a LEGO sensor and small enough for the robot to carry. Also, it should be priced reasonably. Otherwise customers will not be interested in purchasing such a sensor.
- Power
    - Most of the equipment used has limited current/voltage output and requires a certain current/voltage to drive them. Due to limited power supply, an additional power supply might be added. This will increase the size of the system which is unfavorable in our situation. Thus, a proper use of power is vital to minimize the size of the system.

- Legal
    - The system must operate in the allocated frequency range set by the FCC. The FCC regulations state that intentional, unintentional, and incidental radiators can be operated without an individual license. This includes electromagnetic energy in the radio spectrum between 9 kHz and 3 GHz. Moreover, the FCC states that the RFID system must be constructed with good engineering design practice. The system must not cause harmful interference with other radio systems. Furthermore, the system must comply with the limitations listed in part 15 of the FCC regulations.
- Health
    - The system must not cause any type of harm to its users. The voltages (*5-10 VDC*) of the robot components, including the RFID reader, will not harm the human body in case of a physical contact because of their low voltages. Also, the LEGO Mindstorms NXT robot is approved by the FCC. The device complies with part 15 of the FCC rules (*FCC ID: NP153788*). Therefore, the system meets reasonable safety standards.

20   Appendix H Project Personnel

Alfredo Bermudez is a staff sergeant in the United States Marine Corps. He has been responsible for the supervision of a power plants work center consisting of six Marines and four test cell facilities. He has received leadership training at the Staff Academy for sergeants. As a test cell operator, he worked both as an electrical and as a mechanical technician, and is therefore well suited to view the project from the whole perspective. Mr. Bermudez is interested in becoming a project manager after several years in the engineering industry. The team has decided to appoint Mr. Bermudez as the project manager and integrator due to his various leadership and technical experiences.

Jeffery Kakinami has programming experience in PHP, HTML, C++, VHDL, Verilog, Basic, and JAVA. Mr. Kakinami has held a job for the past 7 years as a computer technician that has gotten him well acclimated with numerous software programs, many of which have to do with programming and simulation. He has programmed numerous hardware components including but not limited to, PICs, FPGAs and CISCO routers. Therefore, he is well qualified to be the software engineer of the project.

Ali Al Matrouk has experience in teaching linear Electric Circuits lab. He was the project leader in design projects that involved microprocessors and amplifiers during his academic career. Mr. Al Matrouk is interested in becoming a Communication Engineer and working with broadband communication networks such as G3 and HSDPA. In addition, his interest's area cover RF circuits design. Mr. Al Matrouk is well qualified to be the hardware engineer of the project

ALI ALMATROUK

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EDUCATION

University of San Diego, San Diego, CA   **GPA:**   **3.97**
BS/BA in Electrical Engineering/Liberal Arts   **Major GPA:**   **4.00**
Minor in Mathematics   Expected Graduation: August '07

Relevant Coursework
- RF Design (Network Analyzer)
- Communication Systems
- Signals & Systems
- Control Systems
- Microcomputers PIC18F4420
- Digital Signal Processing
- Electronics
- Digital Design
- Electromagnetics
- Electrical Power

DESIGN EXPERIENCE

Multi-staged BJT Amplifier with By-passed Resistors   *January '06 - May '06*
- Planned, Designed, Analyzed, and Implemented a design of a multi-staged amplifier.
- Amplifier had certain bandwidth, gain, input and output resistance values that had to be met.
- Series-Shunt feedback was used to meet the design goals.

NATCAR Project   *September '05-December '05*
- A smart car that follows a pre-determined path through light sensors.
- Used PIC18F4420 to control the car.
- The project involved C-programming and MPLab to download the program into the microprocessor.

Fischertechnik Carnival Ride Project   *January '05- May '05*
- Designed a model Carnival Ride for general USD introduction to engineering project.
- Project consisted of a computer controlled electromechanical system using fischertechnik components.
- Submitted formal documents.

WORK EXPERIENCE

University of San Diego   San Diego, CA
Teacher Assistant   *January '06 - May '06*
- Assisted in Electrical Circuits Lab.
- Taught students how to use oscilloscopes, function generators, and soldering.
- Helped students with their homework assignments.

Mezzan Holding Company   Kuwait
Logistics Manager Assistant/Financial Analyst   *June '02 - August '02 /*
   December '04 - January '05

- Managed distribution and merchandising of goods.
- Financial analysis and budget setting.

SKILLS

Computer Skills
- C++
- Electronics Workbench (Multisim 9)
- Advanced Design System (ADS)
- Maple, MathCAD , Mathematica
- PIC C Compiler
- Cadence, PSpice
- MPLab
- Microsoft Office Professional
- MATLAB
- Smith V2.01
- Logic Aid , Logic Works
- Ansoft Designer SV2

Languages
- English
- Arabic

AWARDS & AFFILIATIONS

Institute of Electrical and Electronics Engineers
- Academic Excellence [2005]
- Academic Excellence [2006]

University of San Diego
- Dean's List – First Honors

Institute of Electrical and Electronics Engineers, USD Student Branch
- Secretary [2005-2006]
- Chairman [2006-Present]

Eta Kappa Nu *Electrical and Computer Engineering Honor Society*, Kappa Etta Chapter
- Secretary & Treasurer [2005-2006]
- Chairman & Treasurer [2006-Present]

ALFREDO J. BERMUDEZ

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EDUCATION

University of San Diego, San Diego, CA   **GPA:**   3.17
BS/BA in Electrical Engineering/ Liberal Arts   **Major GPA:**   3.21
Minor in Mathematics   Expected Graduation: May-08

Relevant Coursework
- RF Design (Network Analyzer)
- Microcomputers (PIC18F4420)
- Communication Systems
- Electromagnetics
- Digital Design (Spartan 3)
- Digital Signal Processing
- Signals & Systems
- Electrical Power
- Electronics
- Control Systems

WORK EXPERIENCE

Marine Aviation Logistic Squadron (Power Plants Division)   MCAS Beaufort, SC
Jet Engine Mechanic   *November '00 - November '01*
Test Cell Operator/ Collateral Duty Inspector/ Work Center Supervisor   *November '01 - May '04*
- Removed and Replaced modules and components from the F404-GE-400/402 jet engine in accordance with the A1-F404A-MMI-200,201,210,211,220 manuals.
- Inspected modules and components of the F404-GE-400/402 jet engine in accordance with the A1-F404-MRC-200 engine maintenance requirement cards
- Tested, Troubleshot, and Certified the proper operation of the F404-GE-400/402 jet engine for Navy and Marine Corps squadrons in accordance with manuals.
- Maintained the T-10, T-6, T-23, and T-26 test cell facilities in proper operation in accordance with manuals.
- Trained and Certified subordinate Marines and Sailors to become test cell operators and collateral duty inspectors.
- Supervised the performance and production of the Test Cell Power Plants work center to include the manpower, equipment, and logistics.

DESIGN EXPERIENCE

Multi-staged BJT Amplifier with By-passed Resistors   *January '06 - May '06*
- Planned, Designed, Analyzed, and Implemented a design of a multi-staged amplifier.
- Amplifier met bandwidth, gain, input and output resistance specifications.
- Series-Shunt feedback was used to meet the design goals.

NATCAR Project   *September '05-December '05*
- A smart car that follows a pre-determined path through light sensors.
- Used PIC18F4420 to control the car.
- The project involved C-programming and MPLab to download the program into the microprocessor.

SKILLS

Computer Skills
- C++
- Electronics Workbench (Multisim 9)
- Agilent Advanced Design System
- Xilinx ISE 7.1e
- PIC C Compiler
- ModelSim XE III
- MPLab
- Cadence PSpice
- MATLAB
- Smith V2.01
- Ansoft Designer SV2
- ExpressSCH

Languages
- English
- Spanish

AWARDS & AFFILIATIONS

United States Marine Corps, United States Military
- Letter of Commendation [2003]
- Sergeant of Marines [2003-present]
- Navy and Marine Corps Achievement Medal [2003]
- Sergeant's Leadership Course, Staff Academy [2003]

Naval Reserve Officer Training Corps, San Diego Consortium
- Pro Lab Coordinator [2005-2006]
- Squad Leader [2005]

Institute of Electrical and Electronics Engineers, USD Student Branch
- Vice Chair [2006-2007]
- Member [2005]

University of Maryland, Extended Campus MCAS Iwakuni, Japan
- Dean's List [2001]

JEFFREY M. KAKINAMI

jkakinami@gmail.com
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714 ISTHMUS COURT SAN DIEGO, CALIFORNIA 92109

EDUCATION

University of San Diego, San Diego, CA   **GPA:**   3.35
BS/BA in Electrical Engineering/Liberal Arts   **Major GPA:**   3.46
Minor in Mathematics   Expected Graduation: Aug-07

Relevant Coursework

- Digital Design
  VHDL, Xilinx XSA-100
- Signals & Systems
- Microcomputers
  PIC16F84A

- Digital Signal Processing
- Communication Systems
- Electronics

- Applied Electromagnetic
- Radio Frequency Design
- Electrical Power

Special Skills

- C++
- Verilog and VHDL
- PIC C Compiler
- Advanced Design System (ADS)
- Maple, MathCAD , Matlab

- Ansoft Designer SV2
- Cadence, PSpice
- MPLab
- Electronics Workbench
- Smith V2.01

- MATLAB
- Microsoft Office Professional
- PHP
- Apple OS X technician
- Web Design

EXPERIENCE

Education Resource Design
Technical Analyst   *Sept. '00 – Present*
- Computer troubleshooting, programming, webpage design, program training

ENGINEERING DESIGN PROJECTS

Multi-staged BJT Amplifier with By-passed Resistors   *Jan. '06 - May '06*
- Planned, Designed, Analyzed, and Implemented a design of a multi-staged amplifier.
- Amplifier had certain bandwidth, gain, input and output resistance values that had to be met.
- Series-Shunt feedback was used to meet the design goals.

Digital System and Computer Design   *Sept. '04-Dec. '04*
- Implement a computer using Verilog HDL
- Implement multi-cyle MIPS processor using Verilog

Fischertechnik Carnival Ride Project   *Jan. '05- May '05*
- Designed a model Pin Ball Game for general USD introduction to engineering project.
- Project consisted of a computer controlled electromechanical system using fischertechnik components.
- Submitted formal documents.

AFFILIATIONS

Institute of Electrical and Electronics Engineers, USD Student Branch Member   *Sept. '06-Present*

National Honors Society, College Branch Member   *Sept. '02-Present*