March 9^{th} 2006

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 – Design Specification for Oxygen Caddie

Dear Dr. Rawicz,

The subsequent document, Design Specification for an Oxygen Caddie, details how we plan to implement our ENSC 440 project. Our proposed product is an assistive device that will caddie around an oxygen tank and follow the user. This product is meant to make life easier for those, mainly seniors, who need an oxygen therapy system.

The project is currently in the development phase and we are in the process of collecting data. The overall circuit layout has been competed and will be outline in this document. The software architecture has been decided on and we have an idea on data that the sensors have to be able collect. We already made plans on how to divide the work load. Richard Chan will be working on the sensor system and parts of the PIC programming. Robin Chuang will be working on motor control. Nathaniel Culham will be working on the motors and the physical design. Jason Czerniej will be working on the battery, the battery charger, and the emitter that will be connected to the person. Rex Lin will be doing the PIC programming.

Orange Health Group consists of five enthusiastic 4th-year SFU Engineering Science Students; Richard Chan, Robin Chuang, Nathaniel Culham, Jason Czerniej, and Rex Lin. For questions or concerns you may contact Rex Lin at 604-783-3167, or contact us via email at OHGroup@gmail.com.

Sincerely,
Rex Lin

CEO
Orange Health Group

Enclosure: Design Specifications for the Oxygen Caddie

Design Specification for Oxygen Caddie

By Orange Health Group

Project Team:
Rex Lin
Nathaniel Culham
Richard Chan
Robin Chuang
Jason Czerniej

Submitted to:
Dr. Andrew Rawicz
Steve Whitmore
School of Engineering Science
Simon Fraser University

Contact Person:
Rex Lin
OHgroup@gmail.com

Executive Summary

As the baby boomer ages, support for the elderly will become increasingly important. The workforce will decease and there will be less people to take care of our seniors. To ensure that these baby boomers live a comfortable and healthy retirement we will have to provide them with the technology to remain independent as they age.

Today's current solution is to provide our seniors with a portable oxygen supply that consists of an oxygen tank attached to a cart. This solution forces seniors to drag the oxygen tank around under their own strength which makes walking awkward, as well as may cause them to tire out faster. Our proposed solution, the Oxygen Caddie, is a device that follows the user carrying an oxygen supply and whatever else the subject may want to be carried.

We have already outlined the functional specifications of our proposed product. The design specifications outlined in this product is being implemented and will be tested to conform under our high standards. This document is written with the assumption that the read has technical knowledge in engineering and is not intended to be read by our customers. The first prototype is expected to be completed by March 15 and a refined version will be released on April, 1, 2006.

Orange Health Group
Following the future...

Table of Contents

Orange Health Group
Following the future...

List of Figures

List of Tables

1. Introduction

The Oxygen Caddie is an automated mechanical device that is able to follow a user while carrying an oxygen tank. This is achieved by mounting infrared sensors on the Oxygen Caddie and attaching an emitter on the user. The sensors will be able to recognize the emitter and will follow it from a certain range of distance. The intention of this device is to make the lives of those in need of constant pure oxygen, but have trouble physically carrying their oxygen tank, much easier. The Oxygen Caddie is designed to be used almost everywhere, and special consideration is made to hospitals. The first prototype of the Oxygen Caddie is due for April 2006, which will then be followed by improvements to the design and functionality to be fully marketable to the general public.

1.1 Scope

In this document, we will discuss in detail the system specification and design details that the first prototype will meet by April 2006. The specifications stated in the document are the technical and physical specifications of each component that has been decided to be used in building the system.

1.2 Intended Audience

The document is prepared by Orange Health Group to provide the designers to have a final guideline as they implement the design. The purpose of this document is for the designer to reference the specification of each component as they do integration and further designs. The document also allows the customer and investor to understand more thoroughly of what the system is capable of doing.

1.3 Acronyms

The table below shows the Acronyms that we will use in this document.

Term	Definition
AC	Alternating current
A/D	Analog to Digital Conversion
DC	Direct Current
EEPROM	Electrically Erasable Programmable Read Only Memory
IR	Infrared
I/O	Input-Output
PIC	Programmable Interrupt Controller
PWM	Pulse Width Modulation
SRAM	Static random access memory

Table 1.1: List of Acronyms

2. System Overview

The Oxygen Caddie is a device that will move an oxygen tank around for users by tracking and following the user's movement. The device can be divided into three modules: the sensing system, the mechanical system, and the program for the PIC. We will be attaching an emitter to the user to generate a signal that will be tracked. The sensing system will detect the signal emitted and determine the direction and the distance the user is away from the device. The Oxygen Caddie will then turn to face towards the user and then move toward the user. The sensing and moving cycle will repeat until the device is turned off. The overall system is depicted in figure 2.1 below.

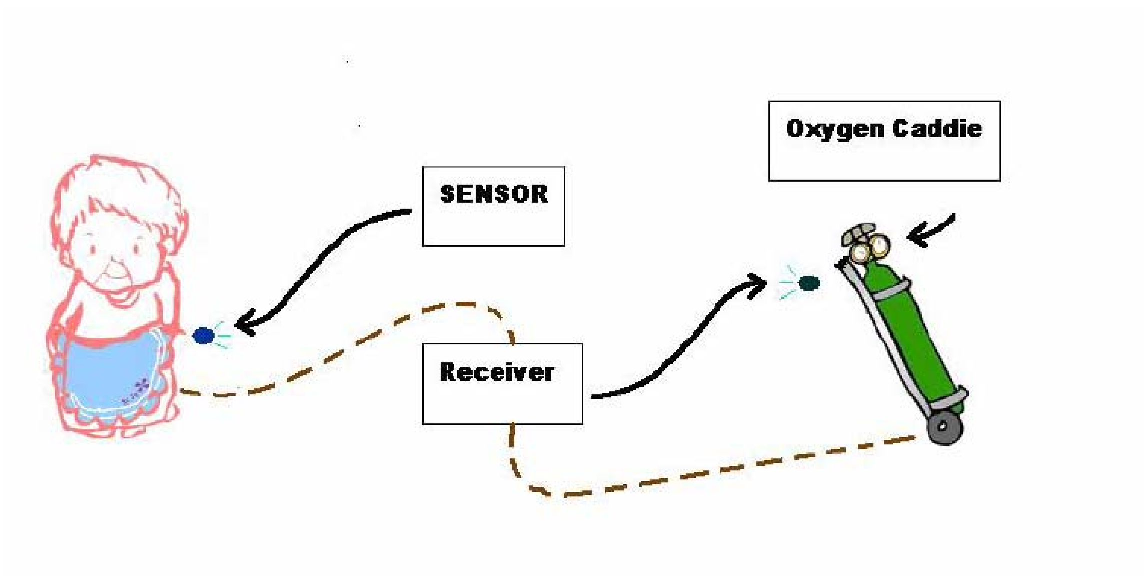

Figure 2.1: System Overview

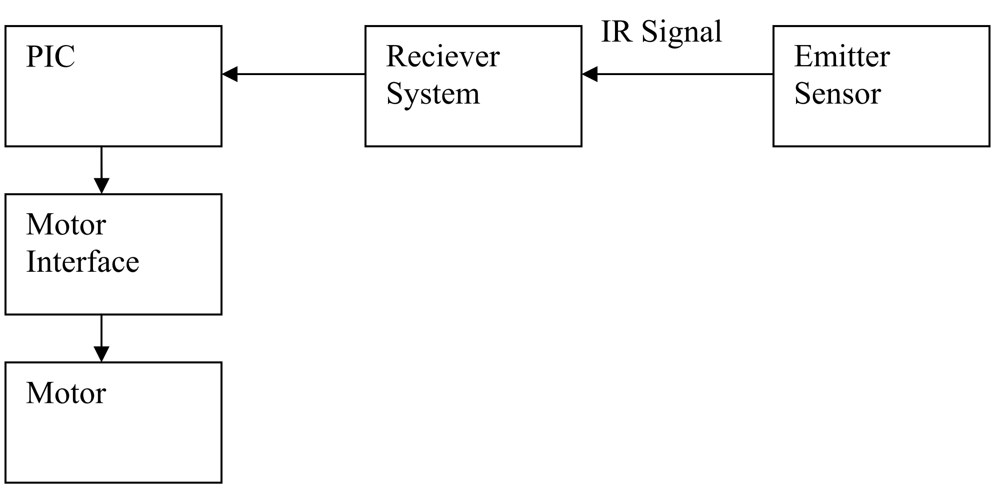

Figure 2.2: System Overview of modules

3. Mechanical Design

An overview of our oxygen caddy system can be seen in figure 3.1 below.

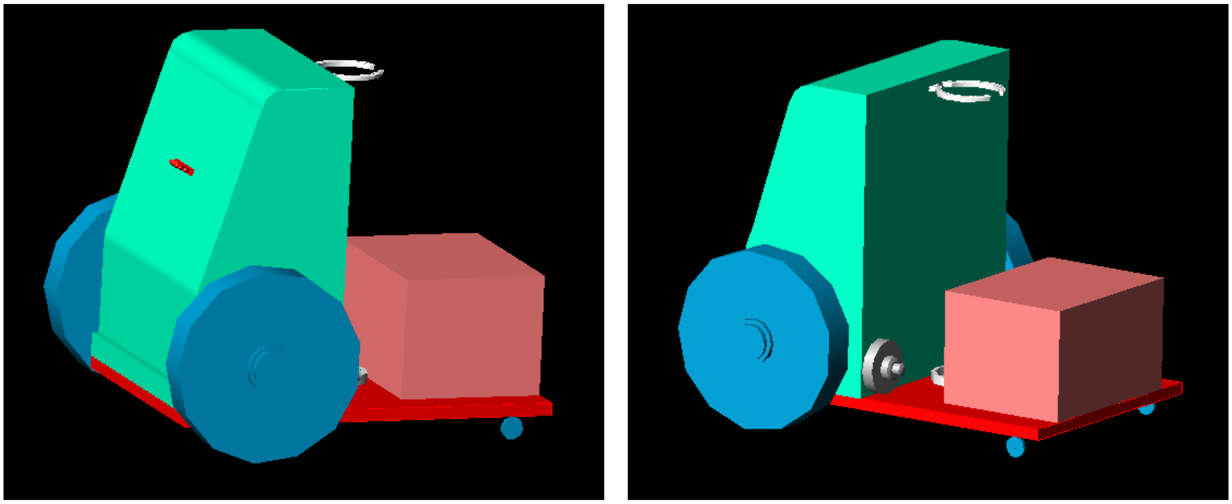

Figure 3.1: System Design Overview

3.1 Physical Design

In designing the physical aspects of our oxygen caddy we wanted to minimize size and weight while containing all essential components. Another important characteristic of the physical design is to keep the center of gravity as low as possible to make the caddy as stable as possible.

While designing our oxygen caddy we considered the factors that pose limiting problems in our physical design. The main factors to be considered are the motors, oxygen tank placement, and the battery because they are the largest components.

Figure 3.2 shows a top view of the dissection of our oxygen caddy. We have designed our caddy such that it is front wheel drive so that it has a better capability of climbing over small obstacles if necessary. With the caddy being front wheel drive, the motors are mounted at the front corners of the caddy. Because our caddy will be regularly accelerating and decelerating we would like the front to back weight distribution to be as even as possible to minimize the chance of the caddy tipping over. Thus, as in figure 3.2, the battery is placed at the rear of the caddy, and the oxygen tank is placed offset centre towards the front of the caddy. Also, we decided on 4 wheels for our caddy to ensure stability.

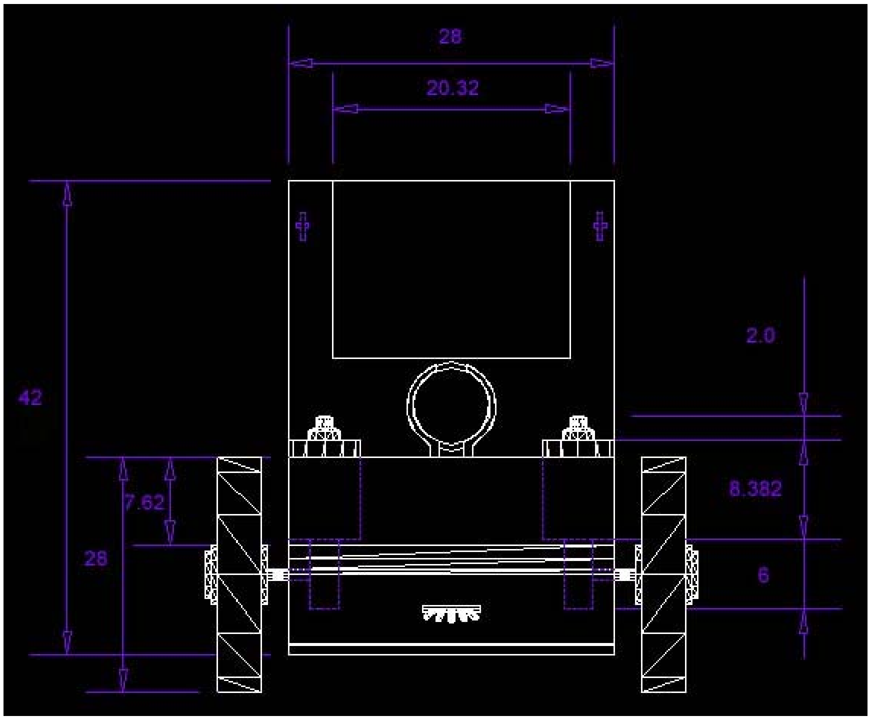

Figure 3.2: System Design Top View

In figure 3.3 we have a side view of our oxygen caddy. The main feature apparent here is that the face of our caddy is at a 60° angle. The face is where our IR sensors will be mounted, ensuring that the sensors are aimed at the subjects midsection.

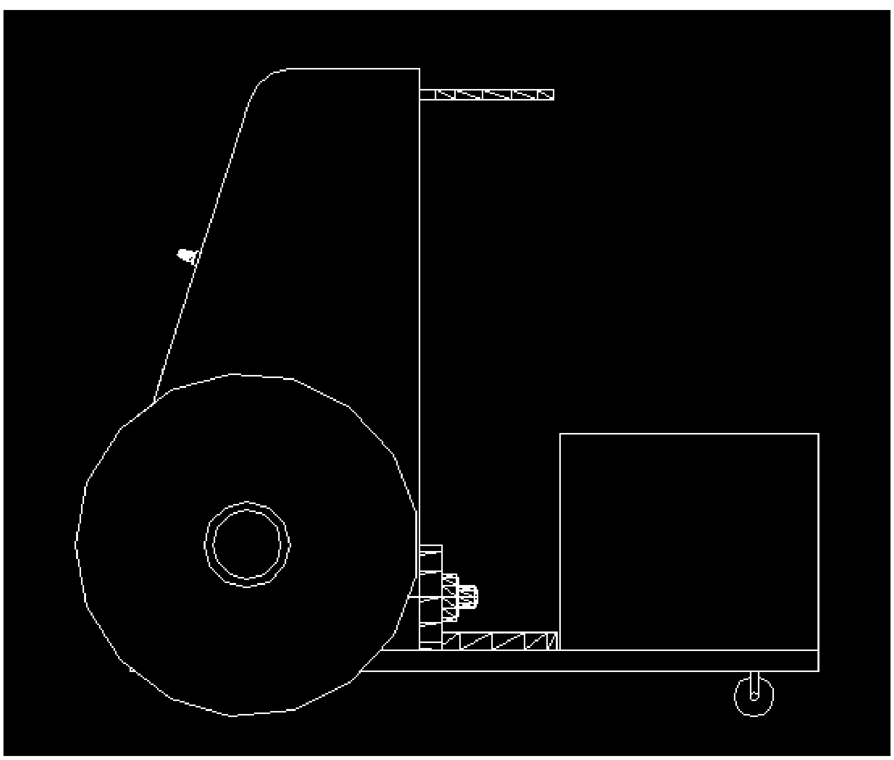
Figure 3.3: System Design Side View

The physical specifications are found in table 3.1a, and 3.1b below.

Caddy Components	Weight
Motors (2)	2.3 kg
Oxygen tank	4.0 kg
Battery	3.0 kg
Misc. Components	3.0 kg
Total Caddy Weight	12.5 kg

Table 3.1a: System Estimated Weights

Dimensions	
Height	60 cm
Width	28 cm
Length	42 cm

Table 3.1b: System Dimensions

This physical design will fulfill the requirements [R0]-[R2], [R5]-[R7], [R20]-[R22] and [R24] stated in our functional specifications.

3.2 Motor Design

The motors selected for our oxygen caddie must be able to overcome the forces needed to move a 12.5 kg object at approximately 1 m/s. When choosing a motor there were many options available to us with different RPM, torque, and voltage rating. Many of the motors had RPM ratings in the 1000s; these would have required a gear system to reduce the RPM and increase the torque for our application. Instead, we obtained a motor already geared for out application, the AME 12V 212 in-lb gear motor, part number 218-1001. An illustration of this motor can be seen in figure 3.4 below.

Figure 3.4: 3D Motor View

A summary of the specifications of the AME motor are found in table 3.2 below.

Parameter	*Value*
Nominal Voltage	12 VDC
RPMs	116rpm (no load)
Amps at No Load	1.4
Amps at Stall	21.3
Torque Nominal	11.1 Nm
Weight	1.15 kg

Table 3.2: Motor Specifications

Performance Specifications of the motor are found in figure 3.5 below.

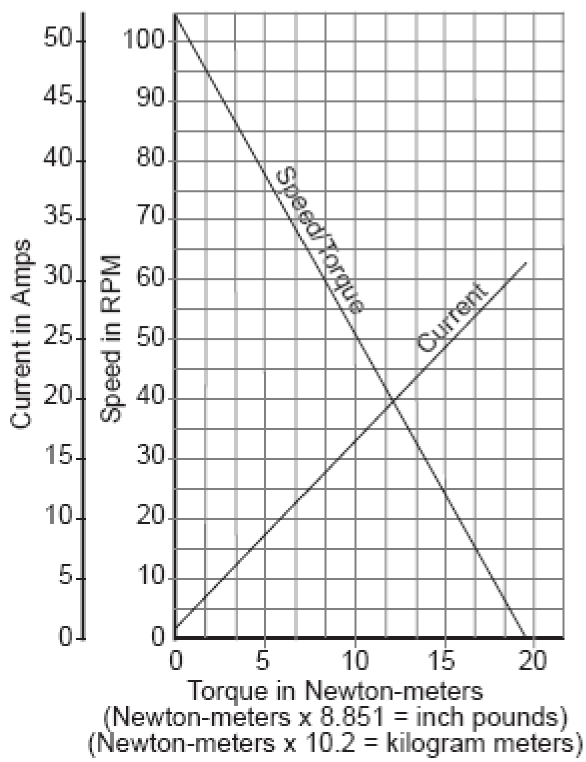

Figure 3.5: Motor Performance Specifications

At no load with wheels of 20cm outer diameter, these motors are capable of a no load speed of 1.21 m/s fulfilling the majority of our motor requirements stated in our functional specifications.

3.3 Emitter Housing

The product is designed to follow the emitter wherever it goes, and it is designed to follow the user of the oxygen caddy. It is impractical for the user to be responsible for housing the emitter on themselves. This leaves a large chance for the emitter to be lost, damaged or improperly placed on the user. Therefore, it is beneficial to design housing for the emitter to be contained in.

The emitter housing will be designed to attach easily to a belt, and resemble a cell phone waist clasp. It will also be generally as big as a cell phone clasp casing. For our initial design, the dimensions of the case will be 8 cm wide by 8 cm long and 3 cm tall. These size constraints should be adequate to fit the emitter circuit within, and will be made smaller or larger as necessary. The power supply will occupy most of the volume, so trying to keep this as small as possible is important.

The emitter housing will be made out of a type of strong, rigid plastic. This will protect the emitter circuit from impacts and possible falls from mishandling. The clasp on the housing will be able to attach on to the belt or pants of the user. The emitter is desired at this level because it allows the signal between the sensors and emitter to be clear of low obstacles. Furthermore, the waist of the user is relatively steady; the signal will not change greatly when the user is walking.

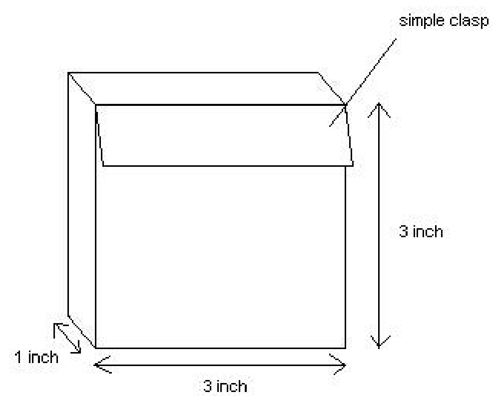

Figure 3.6: Emitter Housing Dimensions

3.4 Battery

The motor for our project requires a power source to run. The only viable option is to use a large battery because they provide sufficient current to run our motors. More specifically, we will use a 12 V battery which will be attached on the product.

The requirements for our battery are simple; it must be as small as possible, be safe in a hospital, and be able to provide power to the motor. Other concerns are the weight of the motor, battery life, and exact dimensions of the battery.

Overall size is important because we only want the oxygen caddy to be big enough to hold a standard oxygen canister. This relates to the mass of the battery. The product must be as light as possible, to maximize the speed of the caddy. The battery is also chosen because of its high lifetime without recharging. The product must be able to practically function long enough in an active typical day for an oxygen user. Exact dimensions of the battery are a minor issue, because most batteries usually have the same shape. We do not wish for the battery to be of irregular shape, as this will introduce some complexities in the physical design of the caddy.

The safety of the battery in a hospital environment is of paramount concern if we are to market our product to the health care system. Lead acid batteries carry a health concern because the acid may spill on the ground and endanger the patients. Gel batteries are much safer but cost a bit more. Also, while lead acid batteries are able to survive high current spikes, the gel batteries might be more limited in this concern. Never the less, we will go with gel batteries because of the safety concerns. Our proposed battery will satisfy the requirements stated in our functional specifications.

Figure 3.7: Sample Battery for Proposed Design

3.4.1 Battery Charger

The battery that we use to power out motor will need to be recharged periodically. We assume that the battery will be recharged when it is empty or near empty.

Figure 3.8: Battery Charger

To recharge the battery, we use the Motomaster 10 amp Battery Charger. The specifications for the Battery Charger are outlined in the tables below.

Length	20 cm
Width	15 cm
Height	13 cm
Input Voltage	12 V

Input Current	2 A
Output Voltage	12 V
Output Current	10 A

Table 3.3: Specifications of the Battery Charger

These specifications are more then adequate for our needs. When the battery is known to be low on power, the user will be required to first turn off the product, open the housing around the battery, and correctly attach the un-powered charger cables on the positive and negative nodes of the battery. Then, the charger can be powered by plugging the power cord to an electrical socket. The charger should be in 10 amp mode.

The analog indicator on the charger will monitor how much power is in the battery. A full battery will have the indicator pointing at 12 V.

4. Circuitry Design

4.1 Circuitry Design Overview

The overall electronic layout is shown in figure 4.1. As we can see, the PIC is the heart of our device and connects all our main components together. The PIC takes input from the receivers and user input from three switches. Using that data, the PIC will operate the motors through the H-Bridge. The Opto-couplers are used to shield the PIC and other components from the motor.

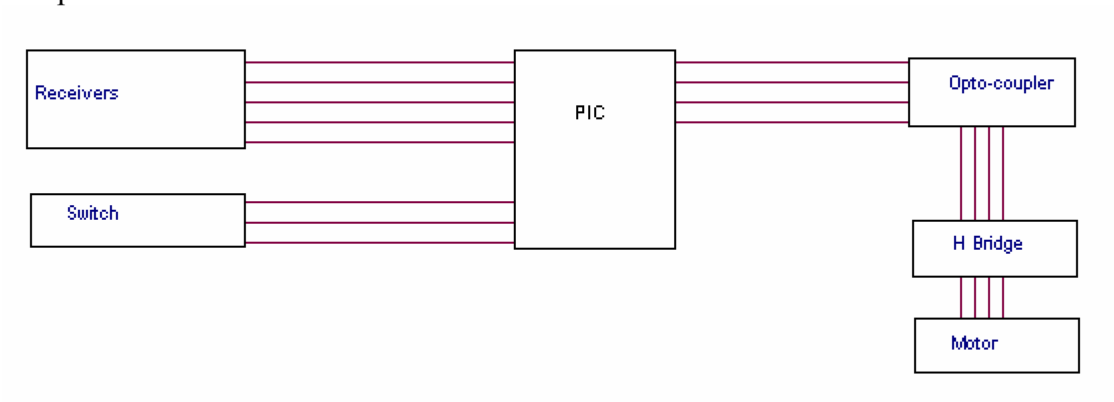

Figure 4.1: General System Overview

4.2 Sensor and Emitter

The sensor we use for this system is an infrared emitter & detector from NexxTech. Infrared ray sensors are cheap, widely available, and easy to control. We require 5 detectors for the system. The emitters are placed on the user and constantly emit a signal generated by an LM555 timer circuit (found in appendix).

With each detector sensitive in a ±20° range, 5 sensors all together will provide us with an approximate 180° view in front of the system. The detectors detect the signals emitted from the user's emitter box. Depending on which detectors receive the strongest signal we can determine the location of the user relative to the caddie. The distance can be determined by comparing the A/D signal to experimentally determined signal values; for example, if we read in a value of 2.5 V at the A/D converter input, the PIC will be able to compare this to experimentally found values for the IR sensors reading 2.5V. Since we have 10 bit A/D values, the digital resolution is 5 Volts/2^{10}. Hence, with different signal strength levels we can measure the distance accordingly and save them in a look up table.

The following is the specifications of the sensors and detectors.

Detector	
VCEO Collector to emitter	70V
VECO Emitter to collector	5V
Ic Collector current	50mA
Total power dissipation	150mW
Peak sensitivity wavelength	850 nm
Spectral bandwidth range	620-980nm
Angle of half sensitivity	±20°

Emitter	
Reverse Voltage	5v
Continuous forward current	150mA
Forward voltage	1.3V typical 1.7V max
Radiant power output	13-15mW
Wavelength at peak emission	950nm

Table 4.1: Specifications of Detector and Emitter

The five infrared receivers act as BJTs but the signal to the base of the BJT is an infrared signal. The five infrared receivers are each connected to a separate A/D converter as show in the figure 4.2. When the signal is strong, the receiver will allow current to pass through them and will pull the voltage at the A/D pin low. When there are no signals, the voltage seen by the A/D converter will be high (5 volts).

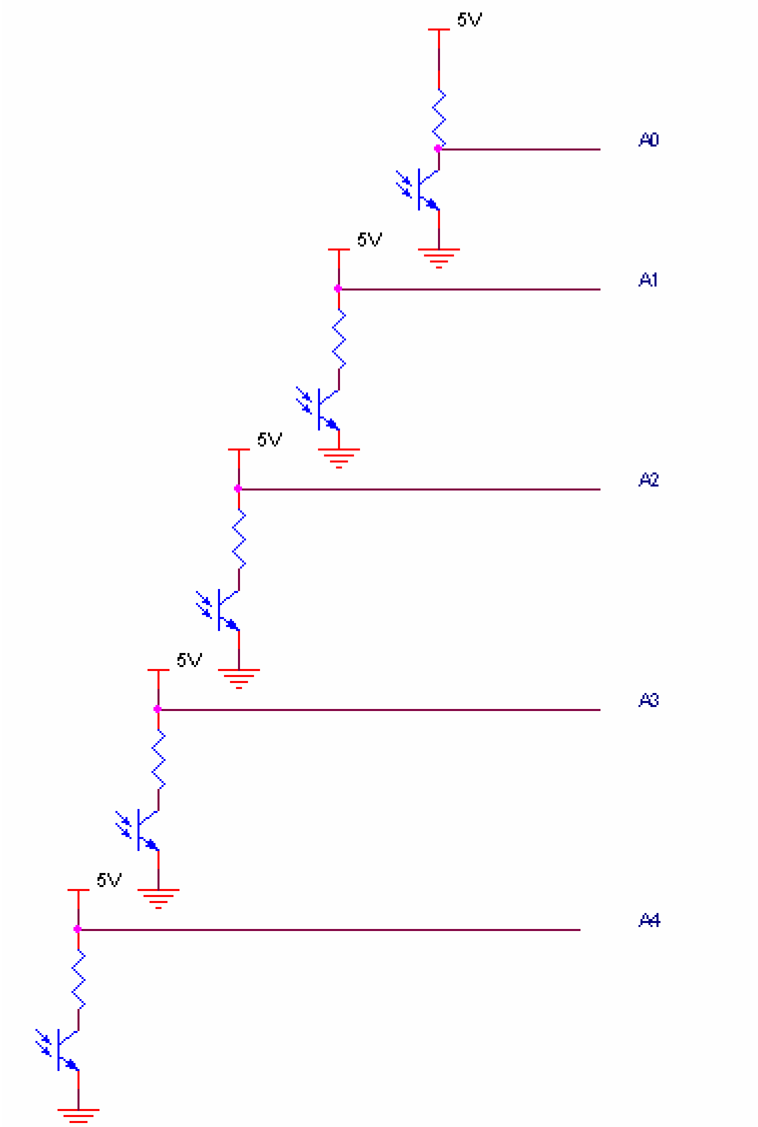

Figure 4.2: The Five Circuits for the Sensors Connected to the A/D Channels

4.3 Microprocessor

4.3.1. Microcontroller

To control the operation of our sensors and motor, a PIC16F876A microcontroller was chosen as the brain of our product. We decided to use a PIC from Microchip because they are cheap and a programmer with the required software is readily available to use at SFU. This chip was chosen because it met the following requirements:

- Has enough memory to store our program
- Has enough I/O pins for our application
- Has a 10bit A/D converter
- Has support for PWM
- Have timer modules to activate interrupts
- Electronically erasable to decrease time spent debugging
- Operates at 5 volts

The PIC16F876A meets these requirements with the following features:

- 368 bytes of SRAM
- 256 bytes of EEPROM
- 22 I/O Pins
- Two 8 bit timers and one 16 bit timer
- Two Capture, Compare, PWM modules
- 5 channels of 10 bit A/D
- An operating speed of 20 MHz
- Operates at 5 volts

The physic layout of the I/O pins are shown in figure 4.3 below

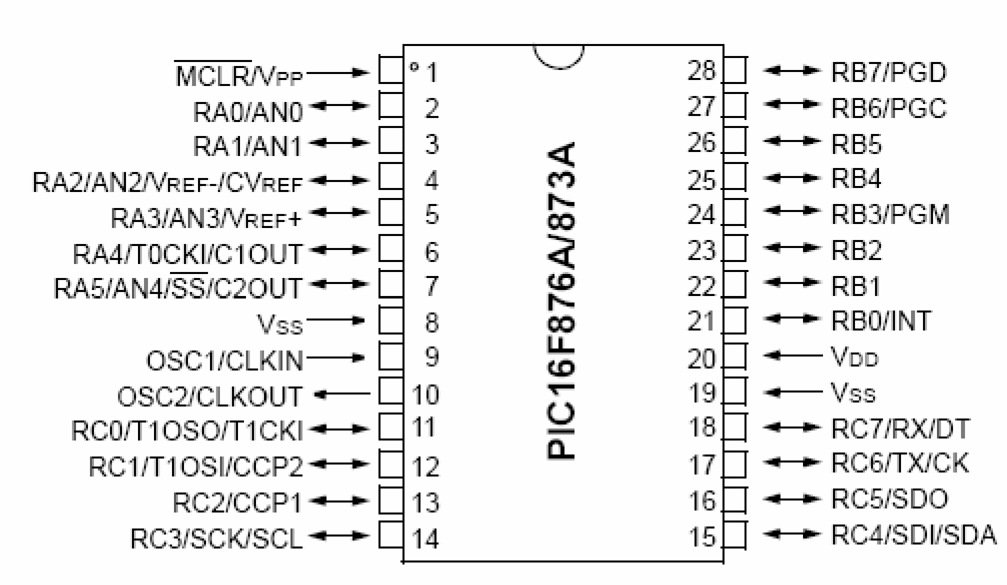

Figure 4.3: PIC16876A Layout

4.3.2 I/O Allocation

The PIC comes with the three I/O ports PORTA, PORTB, and PORTC. PORTA is a 6 bit port and will mainly be used as the inputs for the 5 channel A/D converter. Four of the five A/D channels will be set aside to read the values of the sensors. The last remaining one will be set aside to be used as an input for speed control. PORTB is used as an input port for our speed control. PORTC will be used as the outputs to control the motors. The overall I/O allocation is shown below

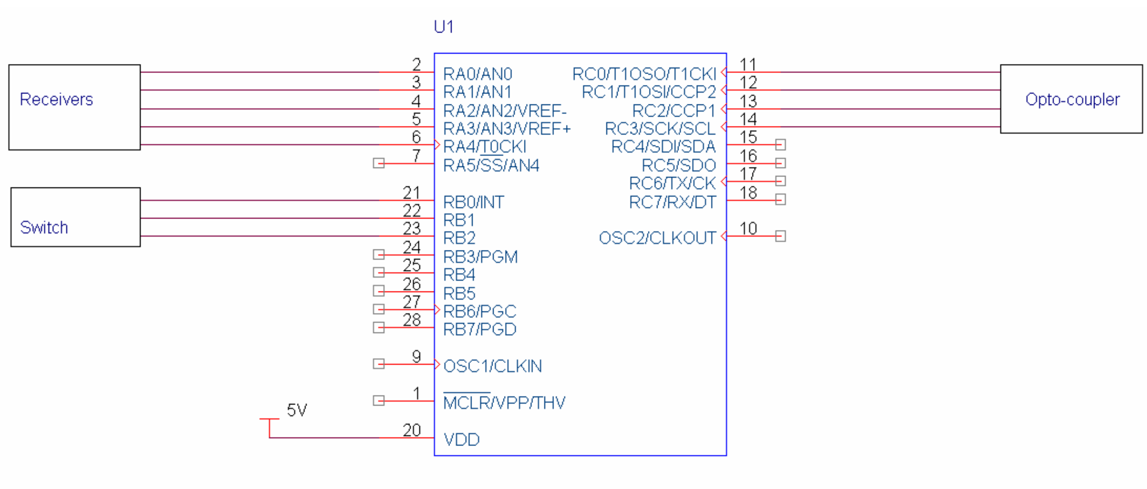

Figure 4.4: I/O Allocation from the PIC Point of View

4.4 Opto-coupler

We use opto-couplers between the PIC microcontroller and the H-bridge driver to provide 2 purposes. Motors generate a lot of interference which may affect signals in the signal transmission wire. Opto-couplers are placed to prevent these interferences from affecting the function of the control system. Moreover, motors tend to draw a lot of current that the microcontroller cannot provide. Opto-couplers are used to isolate the controller power supply from the motor power supply.

An opto-coupler is a combination of a light source and a photosensitive detector. In the opto-coupler, or photoncoupled pair, the coupling is achieved by light being generated on one side of a transparent insulating gap and being detected on the other side of the gap without an electrical connection between the two sides.

The opto-coupler we selected to use is Fairchild 4N25. This particular chip has good availability and good switching speeds for below 10 μs. Each chip contains 1 opto-coupler that is relatively small in size to provide an efficient design. Each chip has 6 pins and the layout is shown in the following figure.

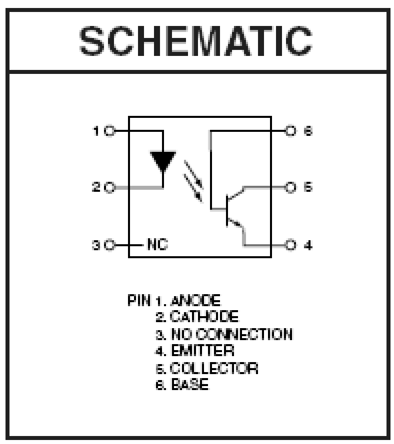

Figure 4.5: Opto-coupler Schematic

4.5 H-bridge driver

In our design, we chose to use the TPIC0108B from Texas Instruments as our H-Bridge driver. The TPIC0108B is a Pulse Width Modulation (PWM) control intelligent H-bridge designed specifically for DC motor applications. The reason why we chose this chip over the others is because the device provides the basic forward, reverse, and brake modes of operation that we need, it also provides protection against over-voltage, over-current, over-temperature, and cross conduction faults; moreover, a logic supply of 5V is internally derived from V_{CC} which is consistent with the PIC chip we are using in our system. Finally, another benefit of this chip is that it is quite affordable. Figure 4.6 shows the schematic of the chip.

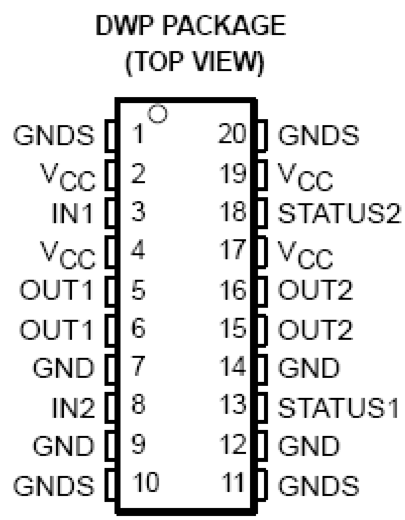

Figure 4.6: Schematic of TPIC0108B

The next figure, figure 4.7, shows the block diagram of the internal circuit of the chip. Notice here, the circuit elements encircled by the dotted lines are the H-bridge driver which will be explained under the general H-bridge section.

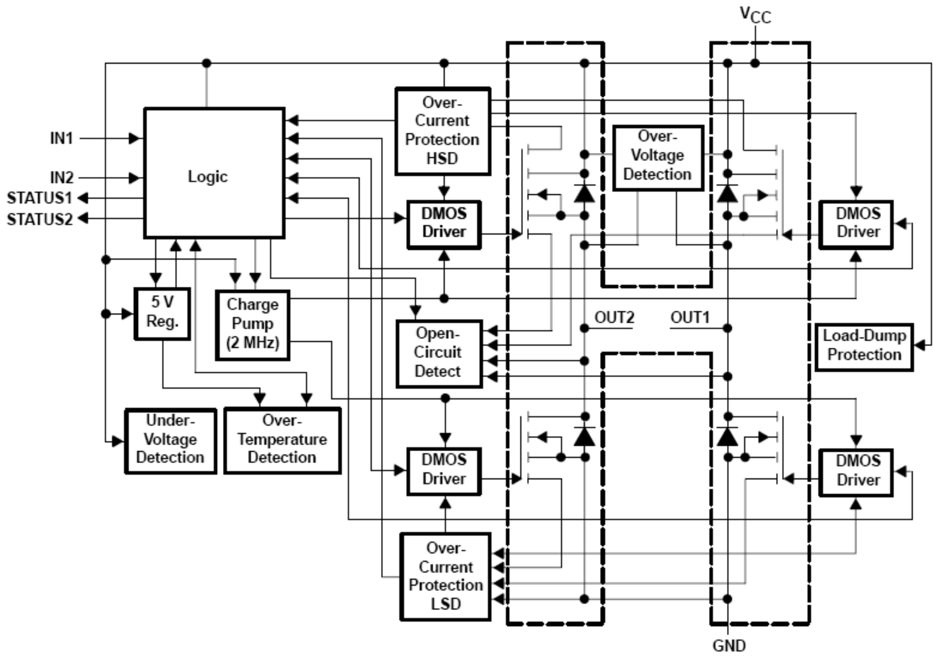

Figure 4.7: Block Diagram of the Internal Circuit of the Chip

The following is the function table for the chip which shows the outputs and modes corresponding to different inputs. Under the OUT1 and OUT2 column, a HS (High state) means a voltage level of greater then 0V. A LS (Low State) means a voltage level less then 0V.

FUNCTION TABLE

IN1	IN2	OUT1	OUT2	MODE
0	0	Z	Z	Quiescent supply current mode
0	1	LS	HS	Motor turns clockwise
1	0	HS	LS	Motor turns counter clockwise
1	1	HS	HS	Brake, both HSDs turned on hard

Table 4.2: Truth Table of the Chip

Our system contains two H-bridge drivers. Each one of them is responsible for the operation of one of the Oxygen Caddie's two motors. More specifically, we could control the speed and direction of the machine through the commands sent to motors by H-bridge drivers. Figure 4.8 illustrates a general H-Bridge driver.

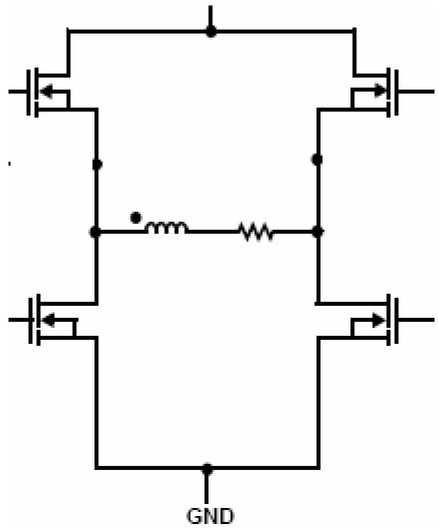

Figure 4.8: General H-Bridge Driver Circuit

As shown in the diagram, an H-bridge driver consists of four transistors and four diodes. The motor in the center, depicted by the inductor, could be driven in either direction through the control of the four transistors. With our knowledge of transistors, we know the transistors are turned on when they have high base voltage. By saying “turned on”, we mean the current flows through the collector-emitter of the transistor. The transistors are turned on in pairs, either high left and lower right or lower left and high right. As a consequence, different combinations of the transistors being turned on would drive the motor in either the forward or reverse direction.

In our case, figure 4.8 is actually the circuit encircled by the dotted line in figure 4.7. The four transistors are replaced by the DMOS which would not affect the function of the chip since the DOMS operates the same as a transistor- high base voltage turns it on and low base voltage turns it off.

The following is a table showing the recommended operating electrical characteristics, and operating temperature range at V_{CC} = 5V.

Symbol	PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$r_{DS(on)}$	Static drain-source on-resistance (per transistor) $I_{(BR)} = 1$ A	LSD	$T_J = 25°C$			550	mΩ
			$T_J = 150°C$			850	
		HSD	$T_J = 25°C$			600	mΩ
			$T_J = 150°C$			870	
$I_{(QCD)}$	Open circuit detection current			10	40	100	mA
$V_{(UVCC(OFF))}$	Under voltage detection on V_{CC}, switch off voltage		See Note 1			5	V
$V_{(UVCC(ON))}$	Under voltage detection on V_{CC}, switch on voltage		See Note 1			5.2	V
$V_{(STL)}$	STATUS low output voltage		$I_O = 100$ µA, See Note 1			0.8	V
$V_{(ST2H)}$	STATUS2 high output voltage		$I_O = 20$ µA, See Note 1	3		5.4	V
$I_{(ST(OFF))}$	STATUS output leakage current		$V_{(ST)} = 5$ V, See Note 1			5	µA
V_{IL}	Low level logic input voltage			–0.3		0.5	V
V_{IH}	High level logic input voltage			3.6		7	V
ΔV_I	Hysteresis of input voltage			0.3			V
I_{IH}	High level logic input current		$V_{IH} = 3.5$ V	2	10	50	µA

NOTE 1: The device functions according to the function table for V_{CC} between $V_{(UVCC)}$ and 5 V (no parameters specified). STATUS outputs are not defined for V_{CC} less than $V_{(UVCC)}$.

Table 4.3: Table of Recommended Characteristic

Having talked about the control of the direction, we now focus on how H-Bridge controls the speed of the motors. In order to control the speed of the motor, we apply PWM. According to the information we have collected, the width of the pulse is directly proportional to the H-bridge drive output voltage levels. In other words, the longer the width of the pulse, the faster the speed the motor will be operating at. This is because motors only respond to the average voltage or current. As a result, by controlling the width of the pulses sent into the PWM pins of the H-bridges drivers, we can control the average voltage across the motors and therefore the motor speed. In our system, we will send pulses of 5 V with different pulse widths, the voltage shown at the output of the H-bridge drive and therefore the speed of the motor will be different.

4.6 Distance Control Input

To provide input to our microcontroller, we will use the circuit below. The circuit provides three binary inputs to our PIC. Theses three binary input will form a three bit number which will represent how closely we will follow the user.

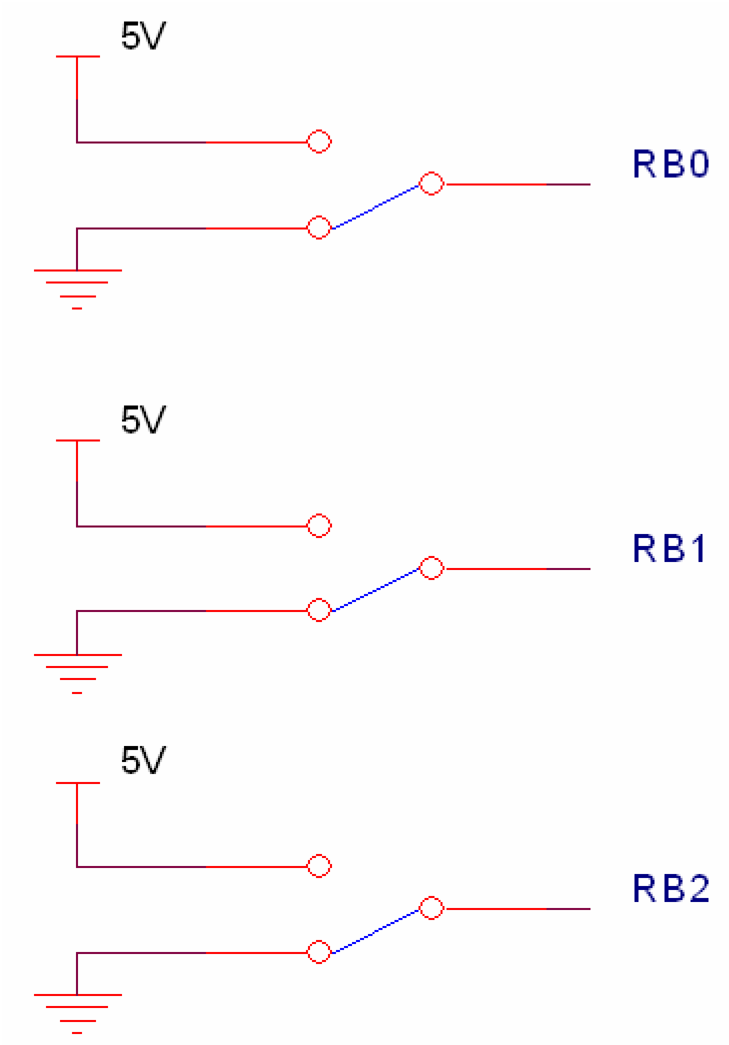

Figure 4.9: Distance Control Input Circuit

5. Software Design

5.1 Overall layout

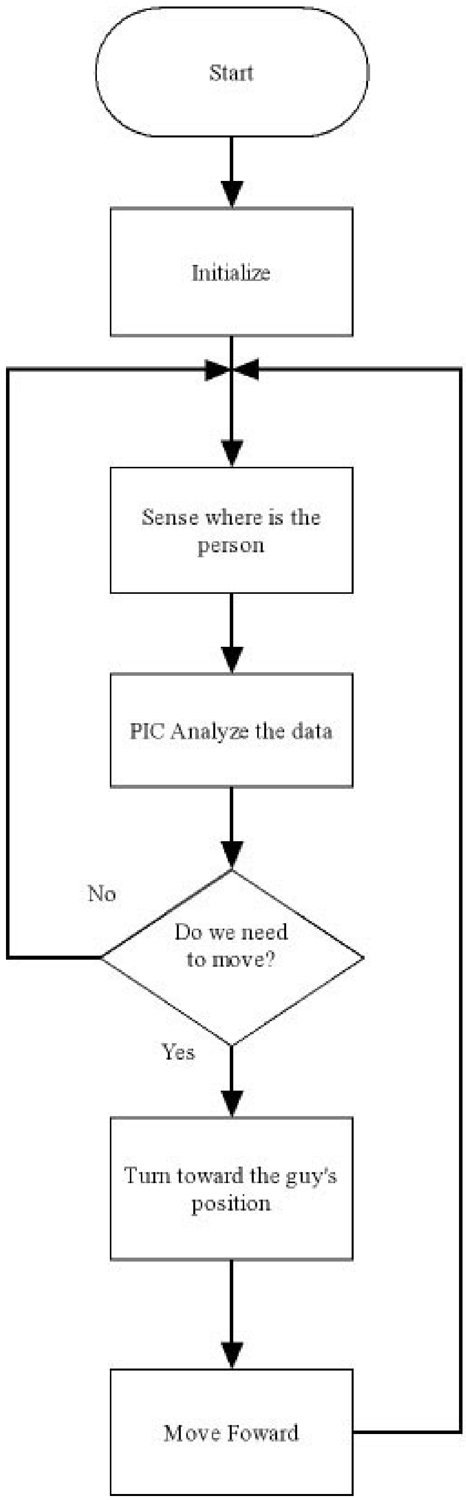

Figure 5.1: Software System Overview Flowchart

When the system initializes at power up, the modules and the I/O will be set up. The PIC will then begin sensing to locate the user. If the user is not detected, the device will not move until we see a signal. Once a signal is detected, we analyze the data collected from the IR receivers to determine where to turn and how far forward the caddy has to move.

5.2 Sensing Algorithm

To gather information about the location of the senior, we will collect data from each of the sensors one at a time. This is because we can only collect data from one of the A/D channels at a time. We also try to take several samples because the signal we are measuring resemble a square wave, which means that we might measure the voltage at a time when the voltage is high and the value is not useful. To find the voltage of the lower part of the square wave, we hope that we will run the A/D when the voltage is at is lowest for one of the samples. An illustration of why we need to take multiple samples is shown below.

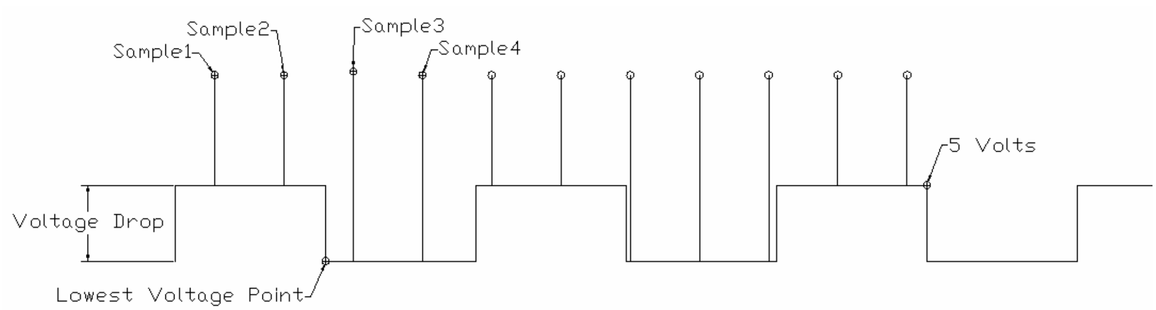

Figure 5.2: A/D Samples

As we can see, when there is no signal, the A/D module should see a constant 5 Volt signal. When there is a signal, the voltage will drop, and we must detect how much the voltage has dropped to determine signal strength.

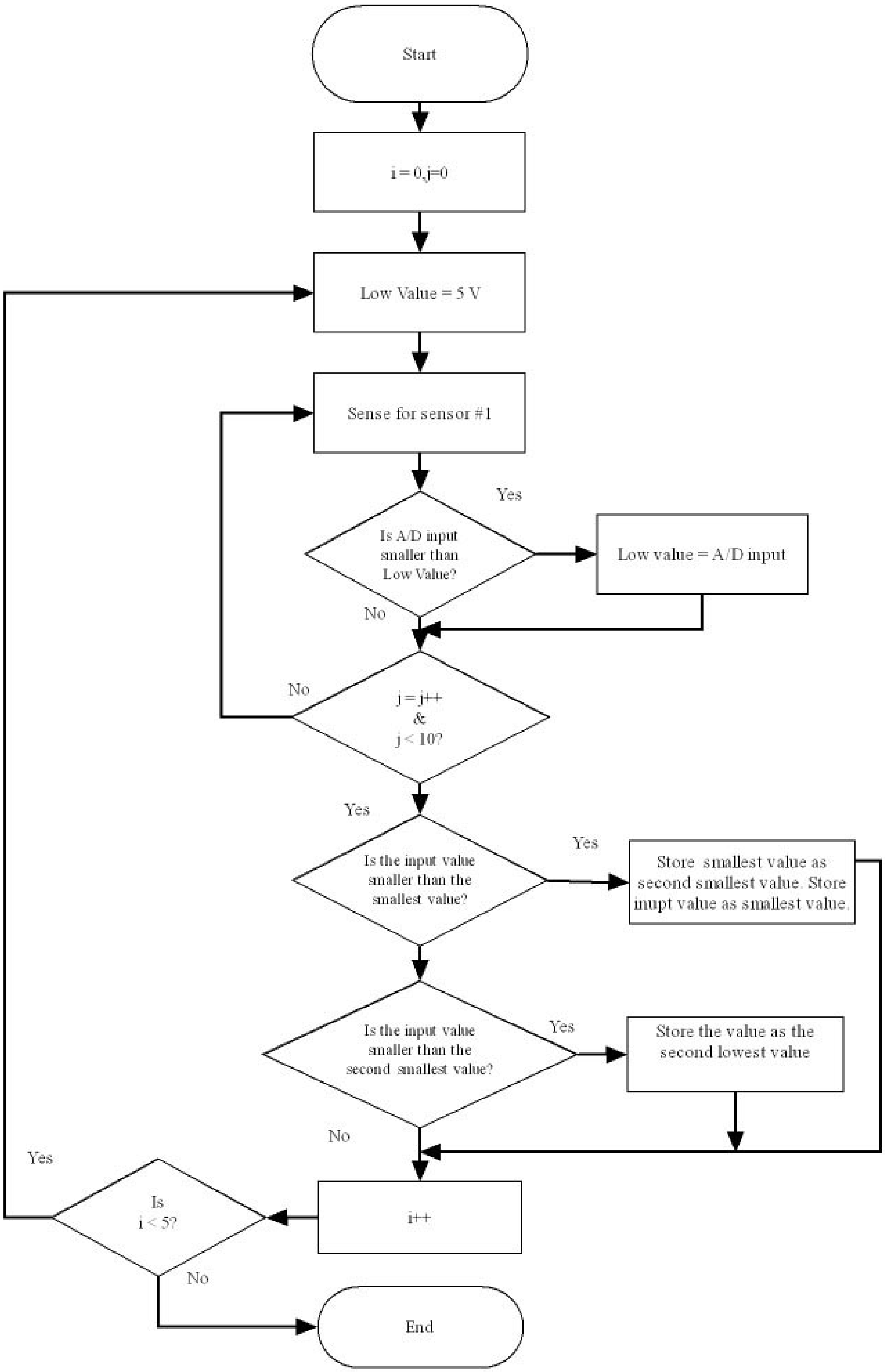

Figure 5.3: Sensing Algorithm Flowchart

5.3 Movement Determination Implementation

The PIC will determine how the caddy will move according to the input data produced from the sensors.

The sensing module produces a pair of data values from the sensors reading the largest values. The movement determination process class takes the two pieces of data and analyzes them. Then, it loads the corresponding set of movement actions stored in permanent memory and outputs the appropriate function to the H-bridge driver which then controls the motor.

There are five sensors in total, and we translate the signals obtained into 9 possible directions that the caddy may be facing. Five of these positions are identified when one of the two signals is 0.1V greater than the other; this means that the sensor with the largest signal is facing the emitter. The final 4 positions are identified when the two pieces of data are within 0.1V, which means that the emitter will be found somewhere in between these two sensors.

Once we determine which direction the caddy is facing relative to the emitter, we load the preset data from the memory and output the control signals to the H-Bridge Drivers. The process then waits for the movement to be completed. The wait interval is calculated and stored in the memory as well. Once the movement is completed and wait is over, the process then calculates the strength of the signal determining the distance from the caddie to the user. With the distance calculated, the control signals determine how long the motors should be turned on for. The following flowchart describes the stream of how the program decides the movement of the system.

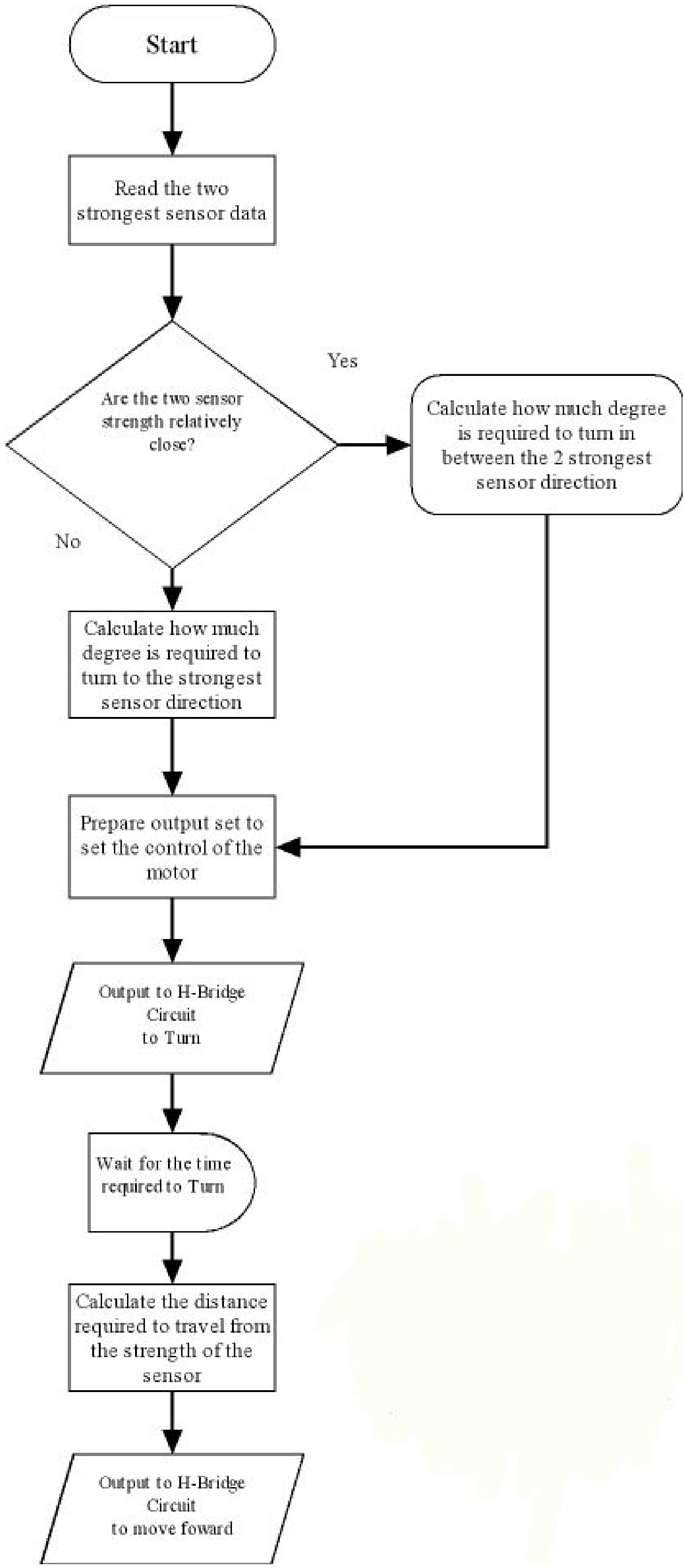

Figure 5.4: Movement Determination Algorithm

6 Reference

1] Wayne Yi-wei Chen. 2003. *Development and Implementation of Inexpensive Mini Hockey Robots*. Simon Fraser University, Burnaby, BC

[2] David F. Voralik, Home Medical Equipment, Feb. 15, 2005, http://www.home-med-equip.com/oxygen-concentrator/hp4021.html,

[3] Robot Motors, *The Robot Market Place* Feb. 18, 2006. http://www.robotmarketplace.com/marketplace_motors.html

[4] The Pololu IR Beacon. *Pololu corporation.* Feb. 18, 2006. http://www.pololu.com/products/pololu/0001/

[5] Road Management. *Tran Safety Inc.,* Feb. 10, 2006, http://www.usroads.com/journals/rej/9704/re970404.htm

[6] Invacare Portable Oxygen Tank System. *American Discount Home Medical Equipment,* March 7, 2006. http://www.home-med-equip.com/oxygen-concentrator/hp4021.html

[7] http://hypertextbook.com/facts/2002/RaymondTran.shtml

[8] http://www.sdscooters.com/Scooter-Batteries.html

[9] Opto-coupler. *Mikroelektronika,* March 6, 2007. http://www.mikroelektronika.co.yu/english/product/books/PICbook/7_04chapter.htm

Appendix

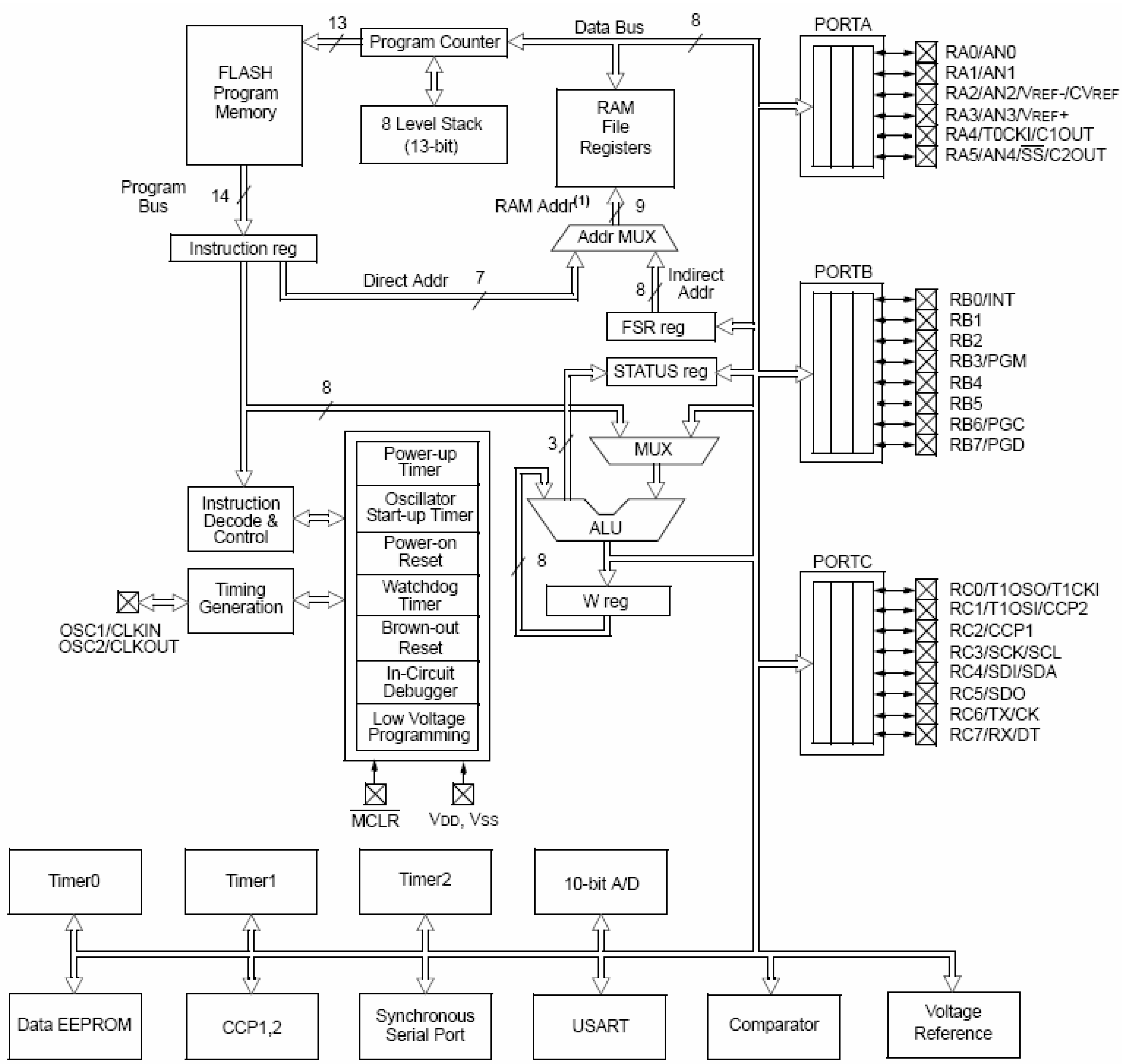

Figure A-1: PIC block diagram

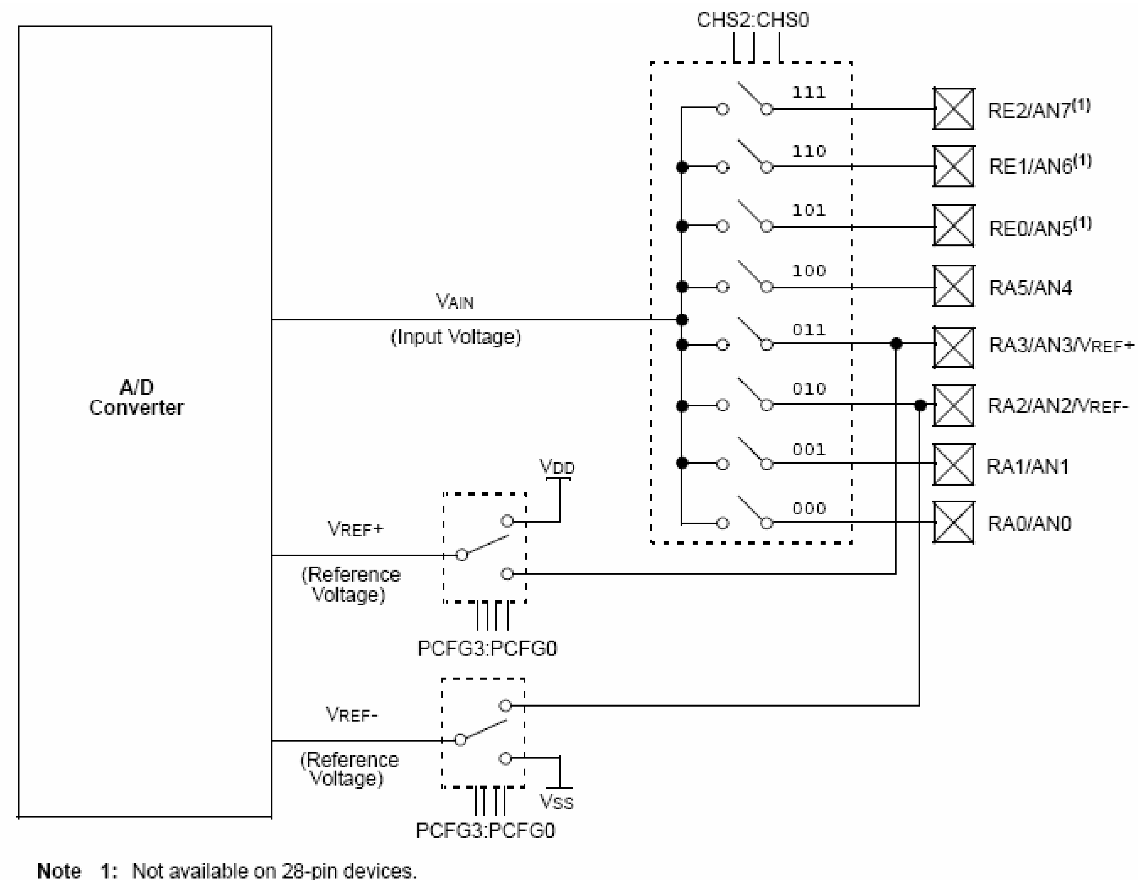

Figure A-2: The PIC A/D Converter Usage

AD Clock Source (TAD)		Maximum Device Frequency
Operation	ADCS2:ADCS1:ADCS0	Max.
2TOSC	000	1.25 MHz
4TOSC	100	2.5 MHz
8TOSC	001	5 MHz
16TOSC	101	10 MHz
32TOSC	010	20 MHz
64TOSC	110	20 MHz
RC(1, 2, 3)	x11	**(Note 1)**

Table A-1: PIC Max operating speed for different AD T_{AD}

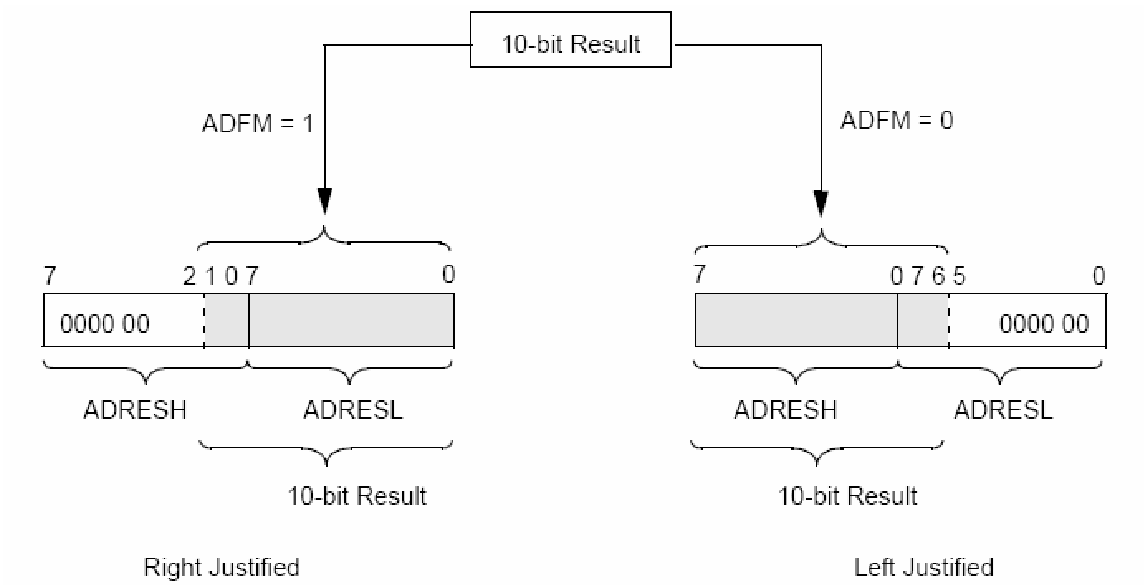

Figure A-3: A/D Storage of Bits

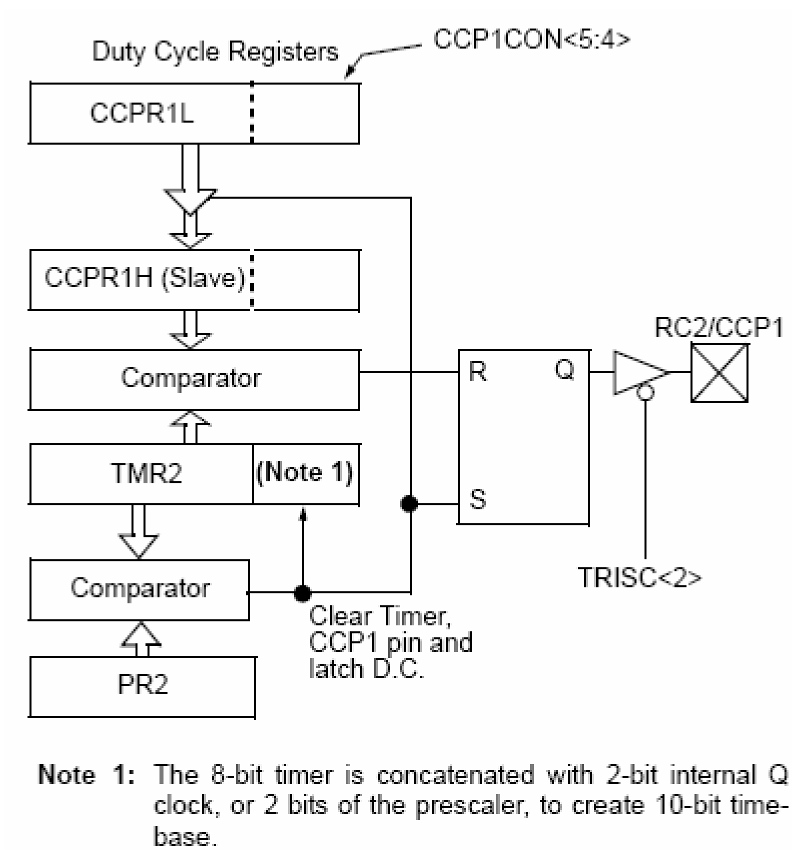

Figure A-4: Diagram of the PWM modulate

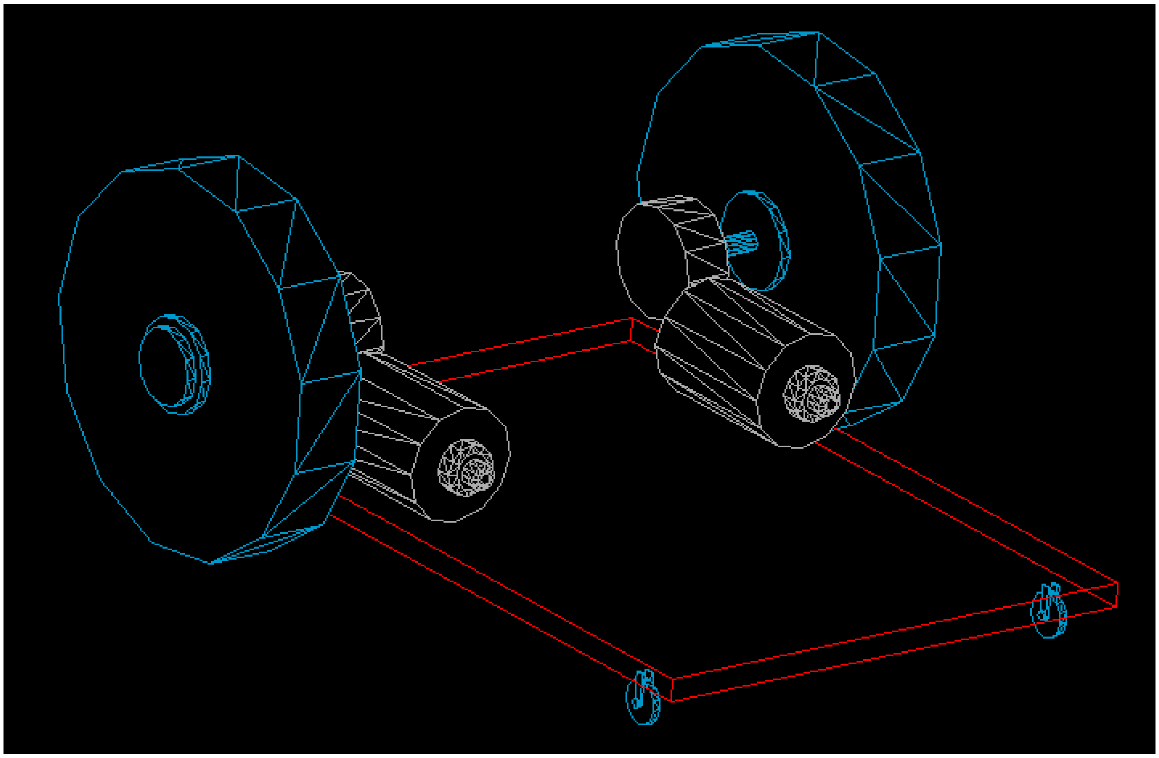

Figure A-5: Diagram of Drive System

Regulated Power supply

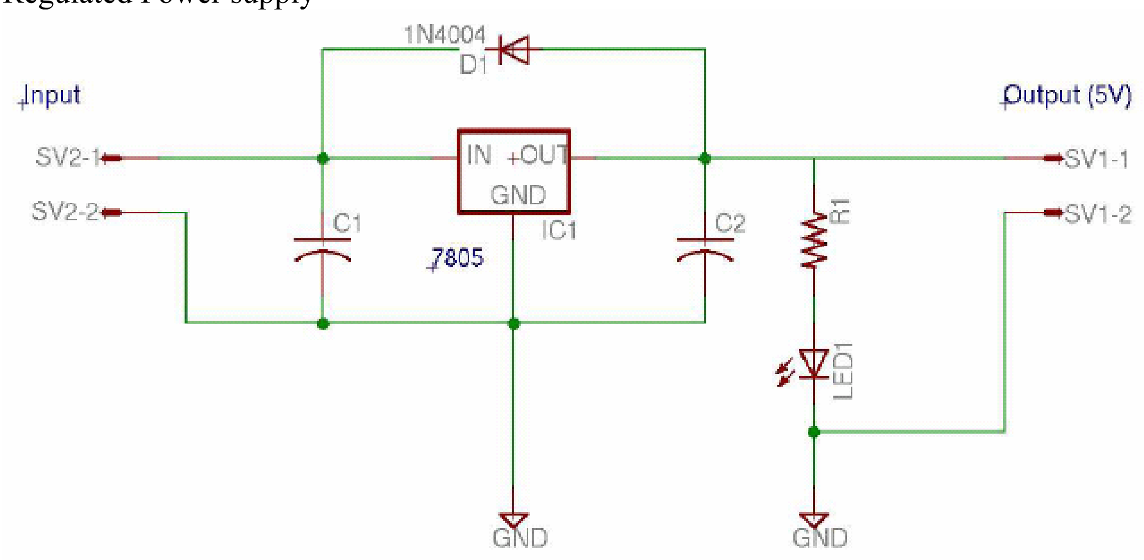

Figure A-6: Power Supply

For 5V, 1A current supply
C1 ranging from 1-220µF, C2 ranging from 10-22 depending on input voltage

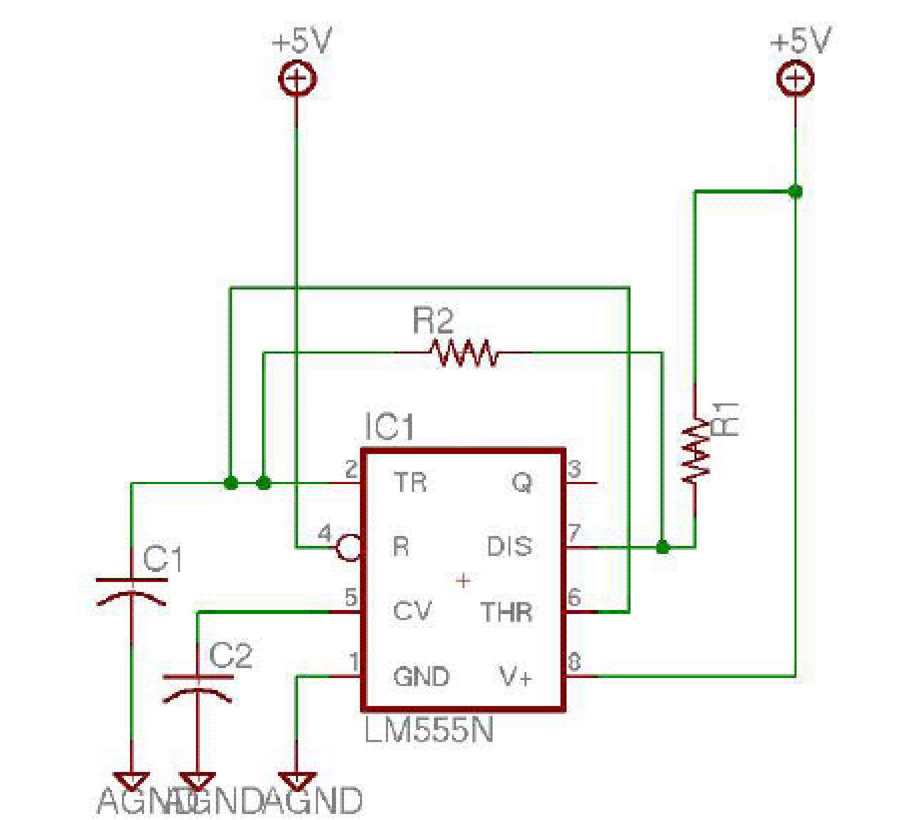

Figure A-7: Timer Circuit

With the frequency given by the following formula,

$$\frac{1.44}{((R1+2R2)\times C1)}$$

And the duty cycle given by,

$$\frac{(R1+R2)}{(R1+2R2)}100$$

With the pulse width varying by a diode between nodes 2 and 7.