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December 15, 2004

Dr. Andrew Rawicz
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Re: ENSC 340 Project Post Mortem for a Tactile Vision Glove for The Blind

Dear Dr. Rawicz:

The attached document, *Post Mortem for a Tactile Vision Glove for The Blind*, outlines the process S3 Technologies went through to design and implement our project for ENSC 340 (Special Project Course). We designed and build a glove that would inform a visually impaired person, via tactile feedback, of the existence and shape of the nearby obstacles. With the help of our product, the blind person can find his desire path and identify unknown objects.

This document details the current state of the device, problems encountered during development, deviations from our original plans, and our future campaign for the device. In addition, we compared our estimated and actual budget and schedules, as well as the marketability of our product. Each group member also discussed the technical experience gained through this project.

S3 Technologies consists of three motivated, enthusiastic, had working and talented fourh-year engineering students: Shaun Marlatt (CEO), Sina Afrooze (COO) and Mahmoud-Sam Zahed (CFO). Should you have any questions or concerns, please do not hesitate to contact us at s3tech-ensc@sfu.ca.

Sincerely,

Shaun Marlatt

Shaun Marlatt
President and CEO
S3 Technologies

Enclosure: *Post Mortem for a Tactile Vision Glove for The Blind*

Post Mortem for

Tactile Vision Glove for the Blind

S3 Technologies: Shaun Marlatt
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Post Mortem
for a Tactile Vision Glove for The Blind

December 15, 2004
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1 Introduction

For the past four months, S3 Technologies has been devoted to developing the idea of a tactile glove for the visually impaired. Three outstanding individuals (Shaun Marlatt, Sina Afrooze and Mahmoud-Sam Zahed) have worked untiringly and passed over numerous challenges towards the realization of Tactile Vision Glove.

This report outlines the process of developing our idea from concept to reality and documents the invaluable experiences of each of the four members. Also described are the current functionality of the Tactile Vision Glove, problems encountered, and future plans for this device. Budgets, timelines and marketability are discussed as well to evaluate team and product performance.

2 Current State of the Device

The Tactile Vision Glove is an assistive device for the blind that enables them to ‘see’ remote objects from a distance through touch. The glove helps the blind person to determine the make-up of their relative surroundings, by measuring the distance to nearby objects, then conveying their approximate shape to the blind person through tactile feedback. Using the Tactile Vision Glove, a blind person will be able not only to locate the objects and obstacles and their distance from him/her, but also to sense the rough shape of the object, as if they were actually touching it. Figure 2.1 illustrates the system overview.

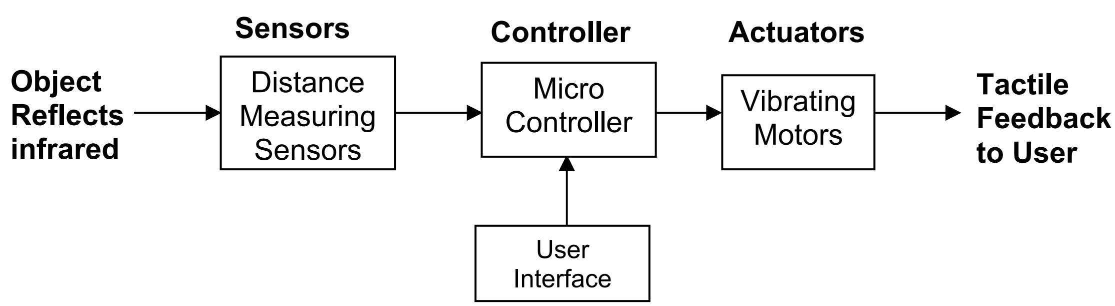

Figure 2.1 : System Overview

As Shown in **Error! Reference source not found.**, the Tactile Vision Glove is composed of several sub-components. The current state of the device will be explained by reviewing each of these components.

2.1.1 Sensors

The chosen sensors are infrared distance measuring sensors from Sharp Microelectronics. These sensors have a narrow focus Infra Red LED and a distance measuring range of 15-200 cm. The distance voltage characteristic is nonlinear because the sensors measure distance based on return path angle, rather than returned intensity. Figure 2.2 shows, the graph of output voltage vs. distance of the sensor.

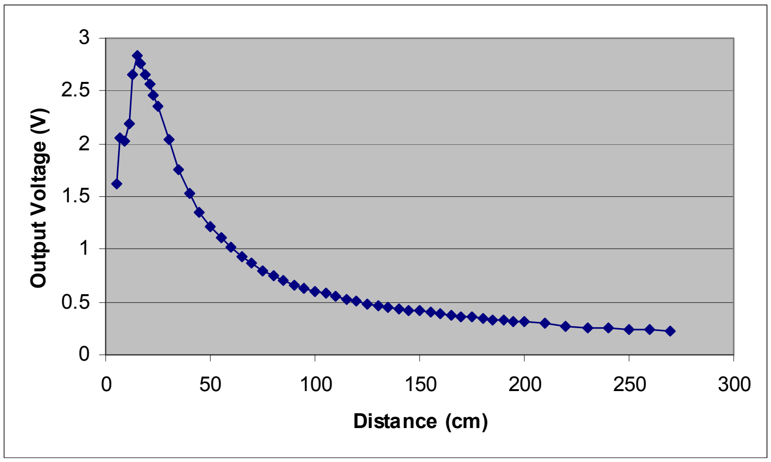

Figure 2.2: Voltage vs. Distance for the Infrared Distance Sensor

2.1.2 Vibrating Motors

Three Panasonic KHN4NB pager motor were chosen to fulfill our requirements. By using pulse width modulation (PWM) the control circuitry for the power intensity control R[34] of the pager motors is greatly simplified. The use of pulse width modulation controls the power to the motor by varying the width of digital pulses on a square wave carrier with a fixed period. The power supplied to the pager motors is then proportional to the currently selected duty cycle, which is given by the following equation:

$$duty\_cycle = \frac{Pulse\_width}{PWM\_Period} \times 100\%$$

Figure 2.3 illustrates the proportional voltage control circuit for PWM. The power amplifier stage provides a low impedance output for the motor, while the feedback loop facilitates proportional voltage control.

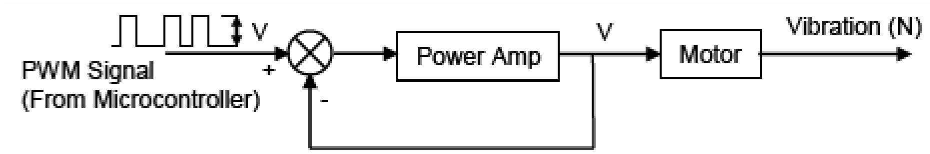

Figure 2.3: Amplification of PWM signal from microcontroller

The amplifier used is the TLV4112 general purpose high power op-amp. The TLV4112 is capable of supplying in excess of 300 mA per channel, which more than satisfies the power requirements of the motors. It also operates at low supply voltages of 3-6 V on single side rail (VDD) so it is also compatible with the voltage supplied by the battery powering the glove.

2.1.3 System Software

One of the major design issues in the development of Tactile Vision Glove was to come up with an efficient algorithm that has fast response time. The complete flow chart of the system algorithm can be found in the Appendix B of the design specification. The flowchart can be summarized in following sequence:

1. Turn one of the sensors on.
2. Turn the timer on for 50 ms (This is the start up time for the sensor) R[35].
3. Check for user inputs and perform proper action for each input R[37 to 50].
4. If the timer over flow flag is not set, go to step 3, else go to next step.
5. Read the output of the sensor through A/D.
6. Turn the sensor off and turn next sensor on.
7. Turn the timer on for 50 ms.
8. Adjust the vibration of vibrators according to the new value read from the sensor.
9. Go to step 3.

Since the power supply of the product is a battery, we should try to minimize power consumption as much as possible and avoid frequent charging or replacing of the battery. As a result, we use the microcontroller and additional circuit to switch the power between the three sensors in a round-robin fashion and keep only one of them on at a time, which can be noticed in the above listed algorithm sequence. Therefore, after the first sensor is read, it is turned off and the second sensor is turned on to collect data and so on. After turning on a sensor, a timer is turned on to count for 50 ms time space. This amount of time allows the sensor to stabilize and output a reliable value R[35].

3 Deviation of the Device

3.1 Overall System

We successfully achieved the desired functionality of the device. Due to time constraints, we were unable to finish packaging the device and to integrate all the components into a single glove as described in the functional specifications.

Currently, our prototype consists of one vector board. The sensors and actuator are mounted on a card board so that they can be easily put on by the user. Leaving the board exposed allows us easy access to debug the circuits. Figure 3.1 shows the conceptualized physical design of the device.

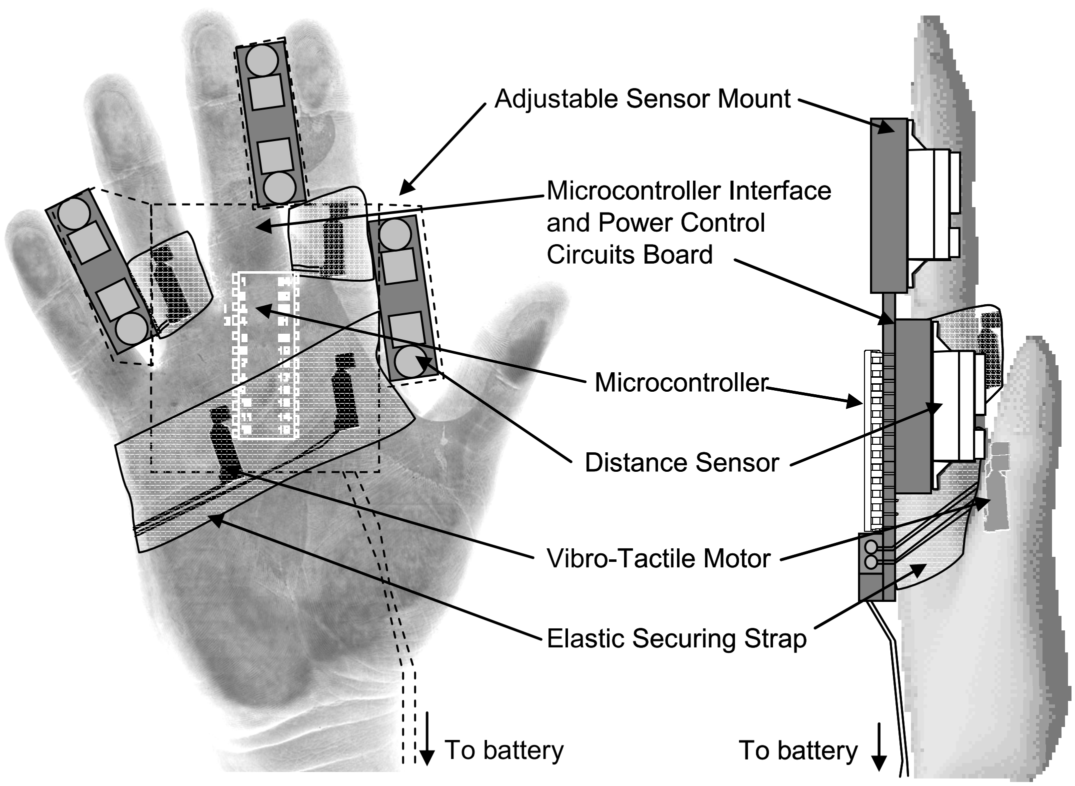

Figure 3.1. Physical placement of components on the hand

The realized design of the device is very similar and show in Figure 3.2.

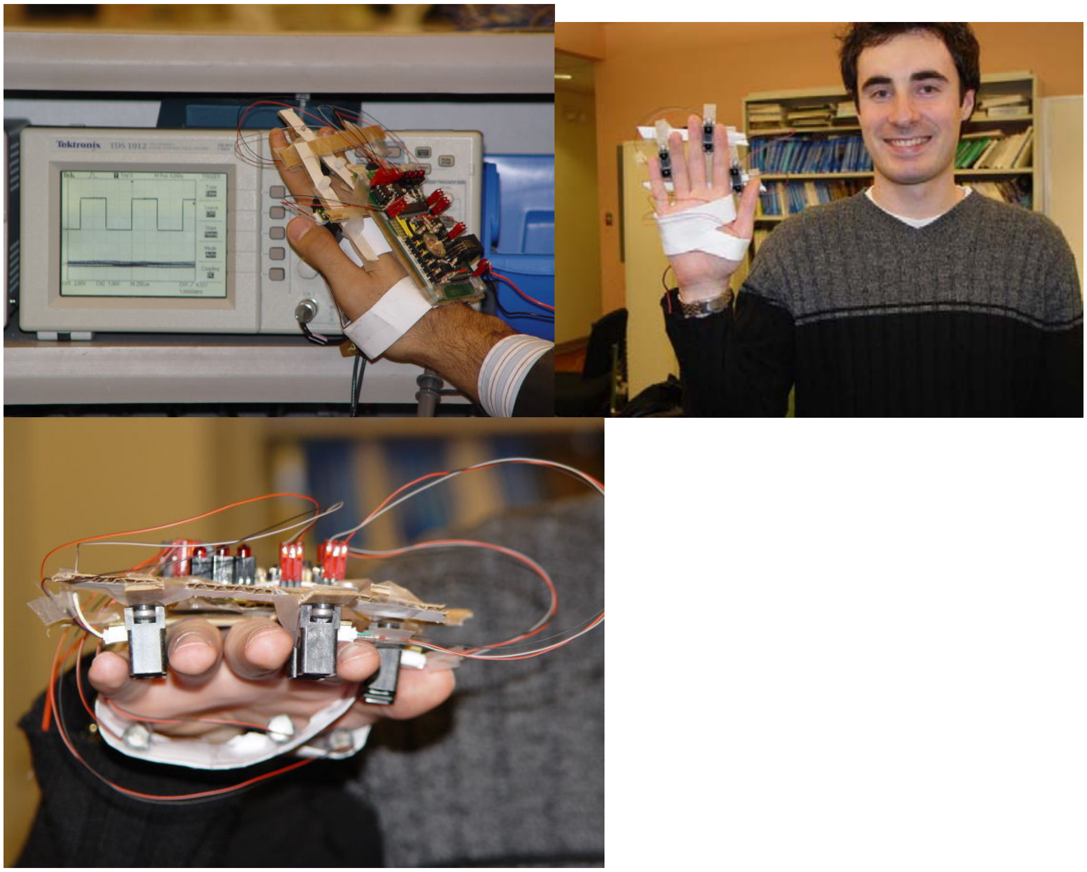

Figure 3.2. The Tactile Vision Glove in operation.

3.2 Sensors

Because the response of the sensor to change in distance is not linear we proposed to separate the response curve into several pieces that each one is approximately linear and use this linear approximation to find the distance. However, after a inspecting the problem in more detail, we decided to use a look up table and map each sensor reading to a calculated vibration intensity. Therefore, instead of liberalizing the curve we used MATLAB to increase the number of points in the curve to 256 and stored the result in a table. The table essentially implements a function that takes the AD voltage reading as an index and returns the distance value for that index as a PWM duty cycle. It also allows us to implement arbitrary transformations (in the class of one-to-one mappings) from sensor voltage to PWM duty cycles to increase both the sensitivity and resolution of the PWM duty cycle to the actual distance.

3.3 Vibrating Motors

As opposed to four vibrating motors mentioned in previous documents, we were forced to use three of them. The reason is that PIC microcontroller has six PWM channels and we thought we can use four of them for our design. However, after going through details of PWM operation, we found out that the PWM channels are actually complimentary. Internally, the PIC only has three PWM duty cycle generators, meaning that we can only generate three distinct PWM signals at any instant. As a result, we reduced the number of motors to three. This also simplified some of the design because we could directly associate each of the sensors with one pager motor.

3.4 Power Requirements

Instead of voltage regulators previously considered to convert the power from battery to the proper value needed for each component, we decided to use the microchip output voltage and convert it by a simple gain circuit and then use a high output opamp to draw the required current for each device.

The sensors need 6Volts at their pins and therefore the circuit in Figure 3.3 was designed and used:

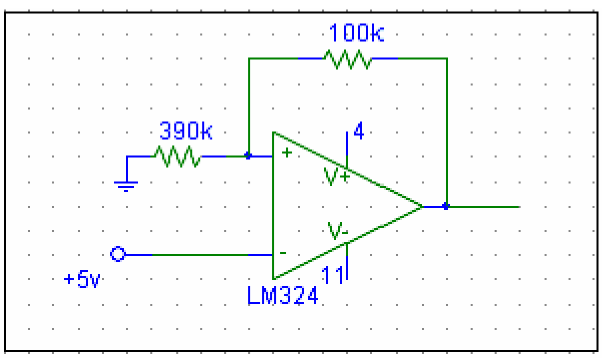

Figure 3.3: Sensor Power Circuit

The resistor values are chosen to get a total gain of 1.25.

$$\frac{V_0}{V_i} = 1 + 100K / 390K = 1.256$$

Figure 3.4 shows the divider used to step down the 5V to 2V and the opamp current driving circuit.

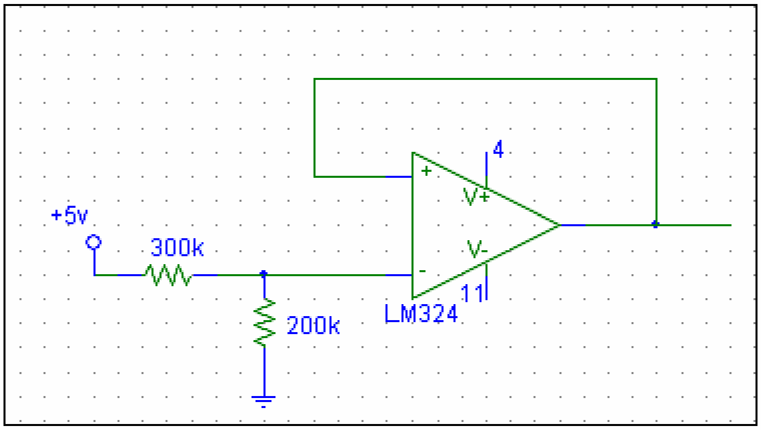

Figure 3.4: Motors Power Circuit

3.5 Algorithm

The proposed algorithm has not changed much. However, some small modifications were made to accommodate extra features like the LED display and sound feedback through the speaker.

4 Future Plans

Since we did not have an actual glove in our prototype, we could not satisfy the physical requirements corresponding to that as mentioned in the functional specification document. A suitable glove should be design in future and meet the requirements.

5 Budgetary and Time Constraints

Overall, we managed to control our costs, by keeping our design simple and doing thorough preliminary research and design. Probably the best decision made was to carefully define our requirements in the functional spec before deciding on parts. In this way, we where able to choose sensors and actuators that met our requirements. We did not attempt to over-engineer the problem by finding the best sensor available. Instead we found the best sensors and actuators that met the functional requirements at a reasonable price. This philosophy kept the cost of the project under control. Another decision that helped towards the end of the project was to order the sensors and actuators first so we could fully characterize them in the lab, before attempting to design a controller for them. As a result, the integration phase of our project went very smoothly, with the only difficulties being soft software bugs on the microcontroller.

5.1 Budget

We managed to predict our budget very well. By considering the price of components, the cost of ordering parts 3 times and adding a $25 for extra parts we originally proposed a budget of $190. At the end of the semester our total cost came to $205. The difference arose because we forgot to factor in the cost of non-circuit components such as the vector board.
We also managed to secure ESSEF funding and received $300, although we only requested $200. As a result, we have $95 left. This money could be used to continue work on the glove and make future improvements, particularly to the user interface and the physical design of the glove itself.

Table 5.1 summarizes our budget.

Table 5.1 Project Budget Sumary

Proposed Budget	$190
Actual Cost	$205
Funding (ESSEF)	$300
Profit	$95

5.2 Time

The following table compares the proposed time that we expected major milestones of the project to complete and the actual time that they took. Overall, we were behind schedule by about 2 weeks for most of the semester. As always, the testing and debugging stage took much longer than expected. Building the prototype was also much more time consuming (especially populating a vector board). The difficulties of debugging errors of a circuit on a vector board resulted in our initial prototype taking about a month longer than expected to build.

Table 5.2 Comparison of Proposed and actual times during project developement.

Task	Proposed	Actual
Research Complete	Oct-10	Oct-17
Preliminary Design Complete	Oct-20	Oct-31
Initial Prototype Built	Oct-30	Nov-30
Testing and Debugging	Nov-20	Dec-08
Demo	Dec-01	Dec-17

6 Inter-Personal and Technical Experiences

6.1 Mahmoud-Sam Zahed

When S3 Technologies was formed four months ago, I was excited to work with two of my best friends to take one of the most fun courses in engineering. I knew this course would give us some opportunities that we were not given before. During the past four months and despite all challenges and sleepless nights, I gained priceless experience and enjoyed a fun team project.

First of all, I realized how a successful product is developed and how the idea behind it is formed at the first place. I was exposed to the challenging experience of "starting from scratch and going on by yourself and without any instructions". Working as a member of a team, I learned to take responsibilities, contribute toward a common goal, express my ideas while compromising in some cases and deal with problems. I also learned how to get the answer to the problems you do not know and where to find them. While research may be the first choice to lead you to your desired answer, there are some knowledgeable people that are willing to help and you just have to find them. After all, it all comes to solving the problem quickly and efficiently. Additionally, mistakes should not be something that I am afraid of. Although mistakes could be depressing and inevitable you can always learn from them and try to avoid them afterwards.

Furthermore, I became familiar with new products and technologies and on top of them PIC microcontroller. I enjoyed low level programming when I tried to communicate with PIC microcontroller in its own assembly language. I learned to look for the efficient way, and not the obvious one, when solving a problem. Moreover, I was introduced with various limitations to be considered in design process, such as the budgetary and time constraints.

In terms of interpersonal skills, we tried to work with each other closely and let every one involved in all the aspect of the project. Although the tasks were divided in some cases, every one tried to fill in other members in meetings and ask for suggestion and help.

Over all, I really had a great time doing this project and I believe it made me ready to take the next step and get involved in real life projects. I will remember all the good times we had and respect the friendship we shaped.

6.2 Sina Afrooze

ENSC 340 was one of the most memorable and useful course that I have ever taken. I learned more than any other conventional lecture based classes. Researching about new technologies gave me a good insight about sensors, vibratos, microcontrollers and assembly programming. During the course of this project I was able to apply what I learned in school to both the design and implementation of an industrial equivalent project. In addition, I also improved my assembly programming skills and got familiar with PIC processors. Now I have more confidence that I can finish a complex engineering project and be able to walk through difficulties and problems. I was always very good at handling group work, and it was not until this project that I had to deal with new group dynamic problems. This course taught me how to be involved in a team and split the task in a way that everyone contributes to major problem.

Perhaps the most valuable single thing I learned is that when working on a project of this magnitude, not everything can be perfect. There were many times near the beginning when I would spend many hours perfecting a small aspect of the project. Towards the end, I learned that sometimes 'good enough is good enough', which is a huge step for me as I am known as a bit of a perfectionist.

This project has shown me that many hours of research and development must go into a product in order to ensure a high quality end result. The project required us to work on all aspects of a product design, including research, hardware/software design, assembly and testing, purchasing and finances, and documentation.

Finally, I enjoyed doing this project very much and will always remember the hard work good memories attach to it.

6.3 Shaun Marlatt

Having prior experience with projects of this scale before, I entered 340 with the goal of choosing a project that would not be overly ambitious to complete in a single term. Initially we thought the project might be too simple, because in the design phases it didn't seem like there was too much to do. Simply get some distance sensors, compute an appropriate PWM duty cycle in the PIC and send it to the motors. From prior experience though, I new there would be details that would actually make the implementation more difficult. Little things like the fact that PICs use a RISC instruction set and are 8-bit, making it very difficult to do multiplies or divides in software. Implementation of a FIR filter on the PIC was a challenge to do using 8-bit operations. However, in the process I learned quite a few useful tricks in assembly language. (Who would think you could divide by multiplying).

As for group dynamics, I think that our team worked very well together. We managed to escape the semester as friends. I think that everyone had the chance to contribute their part as we divided the workload evenly between members. Although we had no formal meetings, we often worked together and always made sure we kept each other informed on the current state of the project and any small design changes that might effect the others implementation. By making sure everyone was informed, the integration phase went very smoothly. Overall, I found the experience very enjoyable, and would work with Sina and Sam on a similar project in the future.

I also found that the process of documenting the project was very helpful in keeping the project on track. By sticking with our functional specifications, and carefully thinking through the design before actually building something, we were able to minimize the number of complications that normally arise during the development cycle of a project. It also kept us focused on our goal and gave us well defined milestones. I think that the project documentation played as big a part in the success of the project as the ability of our team members to work together and communicate.

Overall, I learned a great deal this semester and had a fun time doing it. The experience I gained here will no doubt provide me with the knowledge to approach complex projects in the future with confidence.

Appendix A: Microncontroller Signal Flow Diagram

The following figure shows the path sensor data takes through the microcontroller code. Since the code is written in assembly, it is more convenient to represent the data manipulation as if it where a digital circuit.

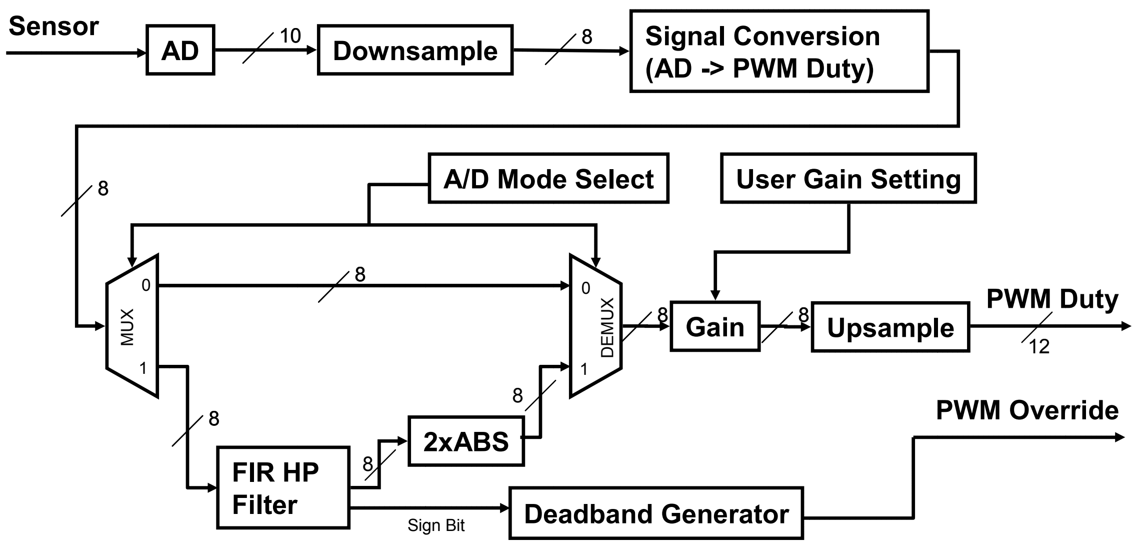

Figure 3 Signal flow diagram

The signal flow can be described as follows: First, voltage from the sensor is converted by the AD (Analog to Digital) block into a 10 bit binary number. Since the PIC is an 8 bit processor, we convert the 10 bit number to 8 bits in the downsample block by truncating the 2 least significant bits. Then, the signal conversion stage, which changes the 8 bit AD value into a 8 bit PWM duty cycle representation, is accomplished through the use of a 8 bit lookup table. The PWM duty cycle from the lookup table is then sent through two paths depending on the operation mode of the device.

Path 1: Absolute mode (0) – The PWM duty cycle is sent directly to the gain stage.

Path 2: Differential mode (1) – The PWM duty cycle is sent through an 8 bit – 8 tap High Pass FIR (Finite impulse response) Filter. The filter removes the DC component of the PWM duty cycle. Essentially, this means if there are no changes in the PWM duty cycle, the output is zero.
The frequency response of the filter is shown in the following figure:

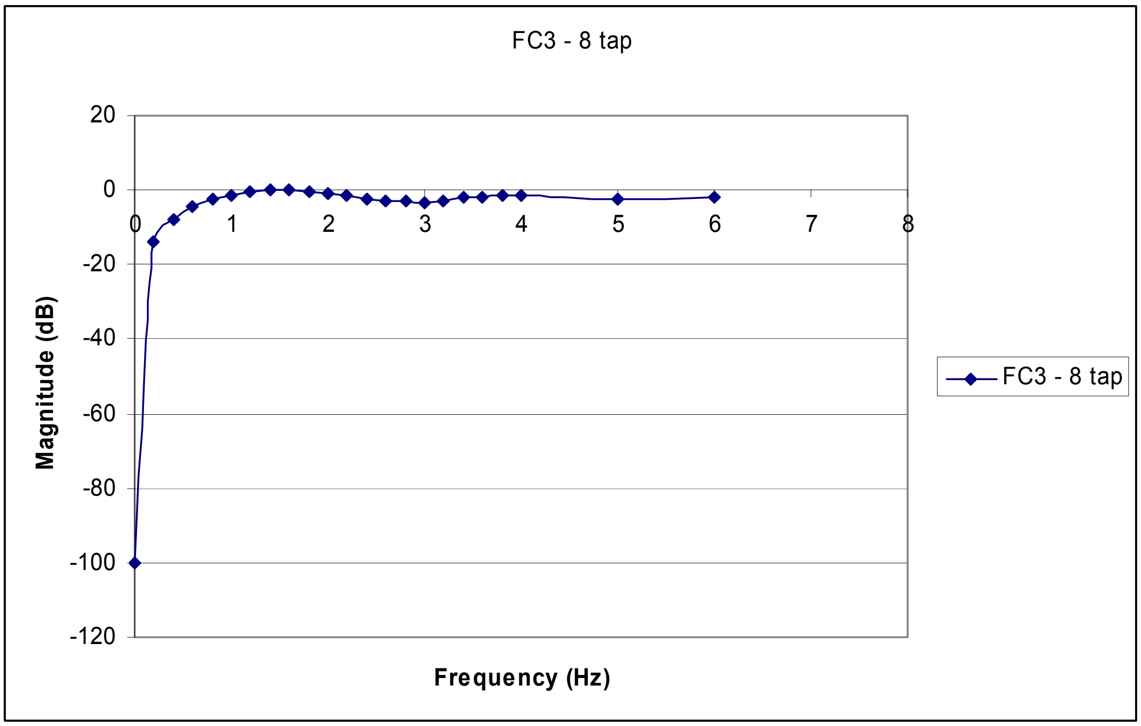

Figure 4 Filter frequency response.

The filter also outputs a sign bit that is sent to a deadband generator. The deadband generator uses the PWM override to toggle the PWM generator output off for 50 ms at a rate of 4 Hz, whenever the sign bit is negative. This allows the user to distinguish between positive and negative changes in amplitude.

Before being sent to the PWM generator both signal pathways go through a gain stage the amplifies the current PWM signal. The gain can be set by the user from 0 to 200%.