288 Seymour River Place • North Vancouver, BC • V7H 1W6
animationtoys@gmail.com

April 26, 2005

Mr. Lucky One
School of Engineering Science
Simon Fraser University
8888 University Dr.
Burnaby, BC V5A 1S6

Re: ENSC 440 Post Mortem for a Gyro Cat Toy

Dear Mr. One,

On behalf of Animotion Toys Ltd., please find attached a document entitled *Post Mortem for a Gyro Cat Toy*. This interactive toy ball plays with a cat by simulating a live mouse. By rolling back and forth and responding to the cat's input, the ball is capable of acting life-like.

Within the document, we have discussed the current state of our design, the major problems that were encountered, a comparison of our actual design versus our functional specifications, and the future possibilities of the toy. We also compare the differences between our actual timeline and budget to the ones set forth in the original proposal. This report also includes a personal description of the experiences for each founder.

Animotion Toys Ltd. consists of three ambitious and hard-working fourth year engineering students: Robert Grant, Ahmad Danesh and Di Xu. Feel free to contact me directly by phone at 604-329-4198 or by email at animotiontoys@gmail.com if you have any concerns.

Sincerely,

Robert Grant
President and CEO
Animotion Toys, Ltd.

Enclosure: *Post Mortem for a Gyro Cat Toy*

Post Mortem for a Gyro Cat Toy

Project Team: Robert Grant
Ahmad Danesh
Di Xu

Team Contact E-mail: animotiontoys@gmail.com

Submitted to: Mr. L One – ENSC 440
Mr. M Sjoerdsma – ENSC 305
School of Engineering Science
Simon Fraser University

Date Issued: April 26, 2005

Executive Summary

Over the past years humans have had less and less free time to spend with their pets, and according to Michigan State University, over 34% of families have pets in the United States. As the family's free time is filled with work, school, soccer practice, and other time consuming activities, the pets are left at home by themselves. The Ontario Veterinary Medial Association warns that pet owners should "play with [their] cat daily to ensure it is getting enough exercise" and suggests that "cat toys [are] an excellent way for cats to stay in shape." Unfortunately, with their busy lives, many pet owners are unable to play with their cat on a daily basis.

This document proposes the design of an automated cat toy developed by Animotion Toys Ltd. The toy will be a small ball which will have the capability to roll when the cat is nearby. When the cat is within ten feet of the ball, it will begin to roll and will turn itself off when the cat loses interest. By rolling back and forth, acting like a small mouse, the ball will captivate the cat without the need of human presence.

Animotion Toys Ltd. consists of three fourth year engineering science students from Simon Fraser University. Two of the company founders are studying the systems option, providing detailed knowledge of control systems and software programming. The other founder is studying the electronics option, providing knowledge of microcontroller implementation as well as data communication.

Table of Contents

List of Figures and Tables

1. Introduction

According to Mike Richards, a Doctor of Veterinary Medicine, free-choice feeding and the use of litter pans seems to be driving the trend towards cat ownership. As well, he suggests that cats are a better choice for homes with a single working adult or where both adults work. The fact that a cat can be left alone during the day or over the weekend has also driven this trend. However, the Ontario Veterinary Medical Association (OVMA) suggests you should play with your cat daily to ensure that it is getting enough exercise and that chasing cat toys is an excellent way to keep them in shape. Unfortunately, the career-based lifestyle of most North American families does not allow for sufficient time to care to these needs.

Cats have always played an important role in people's everyday lives. In recent years, the physical and emotional health of cats has become an important issue and concern for cat owners everywhere. Animation Toys Inc. is devoted to engineer a solution that is not only intelligent and practical for the daily entertainment and exercise of cats, but is also user friendly and a time saver.

Over the past semester, our team has worked hard to make our vision of an automated cat toy a reality. We faced many difficulties and long hours to develop this product to the standards that we set forth earlier in the semester.

2. Current State of the Product

The current prototype of the Gyro Cat Toy is capable of demonstrating key features of the initial proposal and fulfills most requirements stated in the function specifications. The results are very encouraging. Figure 2.1 shows the over all system layout of the Gyro Cat Toy.

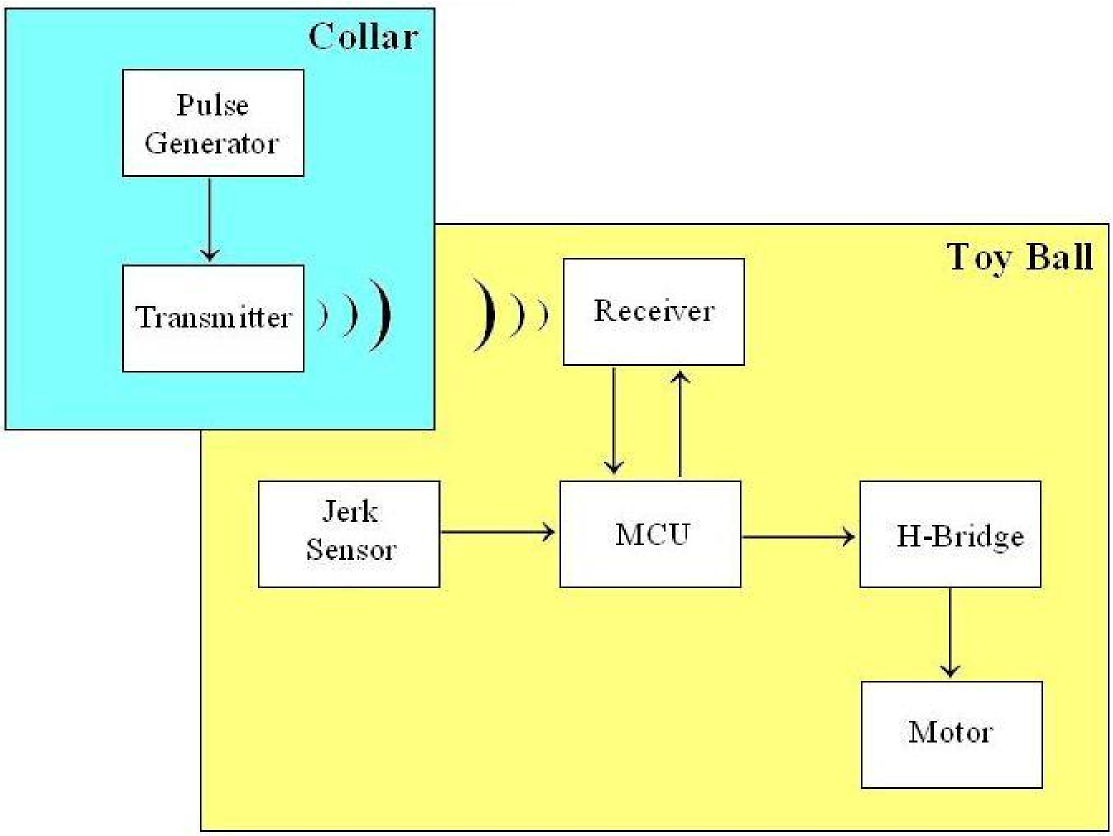

Figure 2.1: System Layout

2.1. Collar

Figure 2.2 shows the current prototype collar components. The pulse generator is below the transmitter as shown in Figure 2.2. This low power signal generation device developed using digital logic reliably outputs a periodic signal with period of 100ms and a duty cycle of 1%. As seen in the Figure 2.2 the antenna used in our current prototype is the square design. This antenna design was the least directional depended on the ones we designed with good reliability. A potentiometer is positioned between the ground and level adjust (ladj) of the transmitter, TXM-418-LC such that the range of the signal transmission is easily adjustable. The prototype collar transmitter is powered by a 3V lithium coin cell right below the transmitter antenna shown in the picture. The entire collar component draws an average of 30µA and with a calculated lifetime of approximately two years. Although the prototype already fits in a compact package we hope to reduce this size of this component even more for a more economically feasible product.

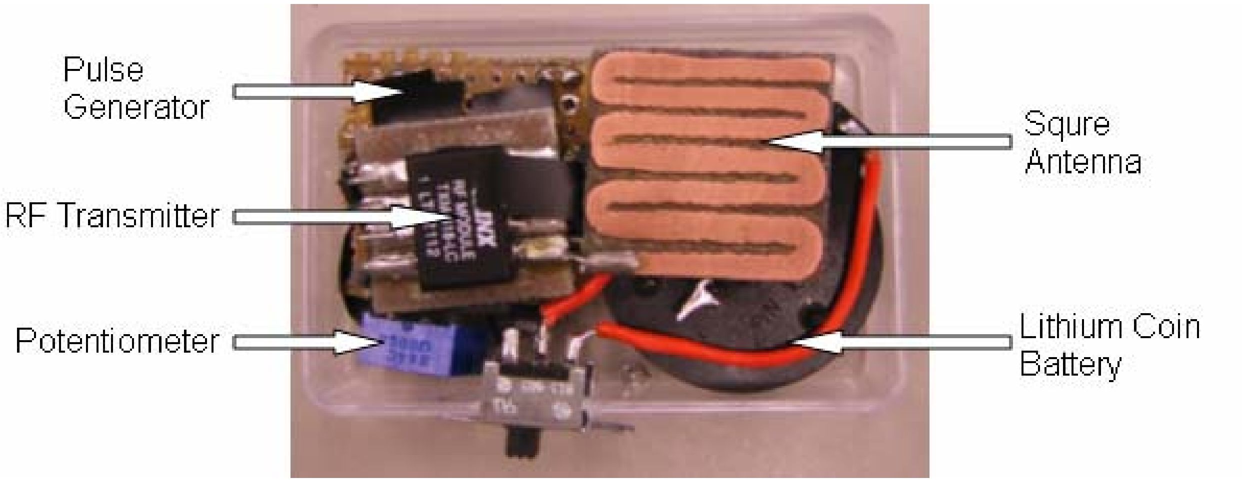

Figure 2.2: Collar Component Prototype

2.2. Toy Ball

The final Toy Ball prototype for the Gyro Cat Toy is shown in Figure 2.3 below. The motor used in this prototype is a geared motor operating at 3V. At 3V operation the geared motor draws 108mA and runs at 80 RPM. The microcontroller unit (MCU) used for this prototype is the MC68HC908QT4 from Freescale. The MCU uses input capture to obtain signals from the RXM-418-LC-S AM receiver and interrupt pulses form the jerk sensor.

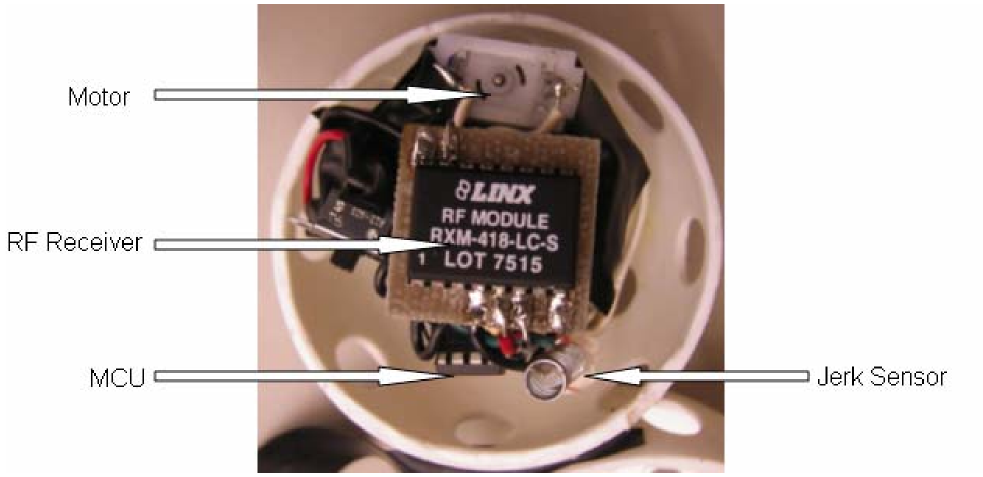

Figure 2.3: Toy Ball Prototype

The jerk sensor is the spring and pin design described in functional specifications and operates with fairly good reliability. Note in Figure 2.3 the H-bridge and the batteries are behind the receiver and cannot be seen. The H-Bridge used in our current prototype is the FAN8200D from Fairchild. The Toy Ball prototype runs on two AAA batteries. The ball draws 110mA total on average and can stay in full motor operation for 6.36 hours. The external shall is elliptical in shape with both major and minor axis meeting our design specifications.

3. Problems Encountered

3.1 Transmitter and Receiver

The transmitter unit, which was to be used on the collar, was powered by a single 3V lithium coin cell. The intention was to create a unit that would last at least 6 months without having to replace the battery. The problem with this was that the TXM-418-LC module drew too much current while transmitting to make this feasible. The solution was to create a pulse generator circuit so that we could minimize the amount of transmitting time. Using calculations of the maximum speed of a typical household cat and the data rate of our transmitter, we decided that a frequency of approximately 10Hz with a duty cycle of roughly 1% would be ideal. We first used a 555 timer circuit to create the pulses, yet we found that the timer circuit itself drew too much current. Next, we chose a low-power digital logic circuit, as shown in figure below.

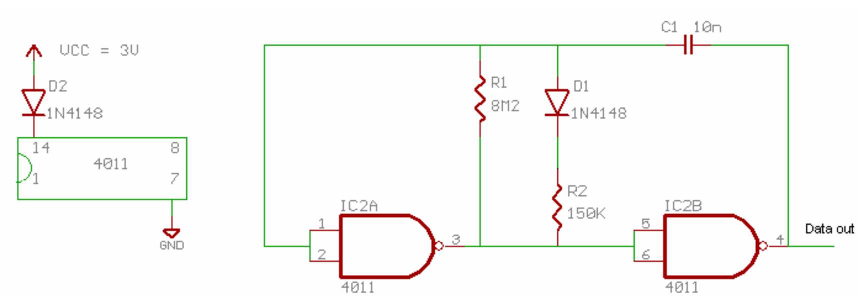

Figure 3.1: Pulse-Generator Circuit

With this circuit implemented with the transmitter unit, we were able to have a total current consumption of only 30uA.

The other main problem with the transmitter that we encountered was the design of a reliable antenna. At first, we tried to use a loop of wire as the antenna, yet we soon found out that the fluctuations and vibrations of the wire caused unreliable signals. We decided to create a trace antenna by etching into a copper clad board. After testing three different antennas, we found that the middle antenna in the figure below created the most omni-directional of the three.

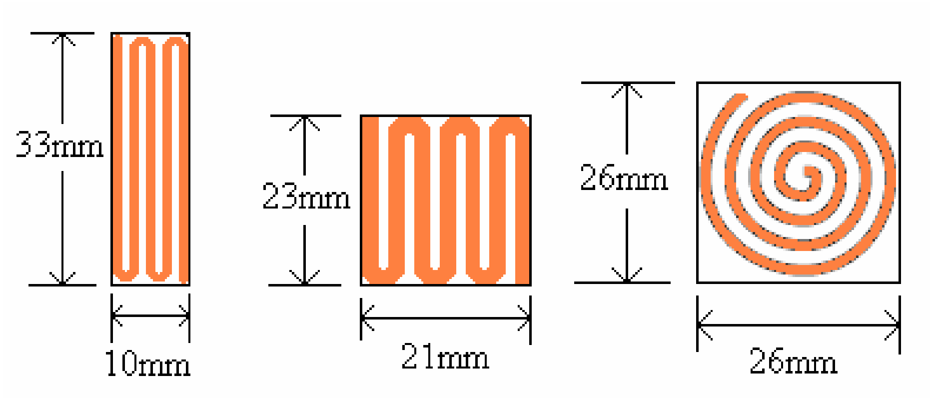

Figure 3.2: Antenna Configurations

The major problem with the receiver was that it picked up noise that was created from the motor. To fix this problem, we created software configured filters that ensured that the intended pulse width was received for two consecutive pulses. However, we found that even the filter design did not get rid of this problem. Other possibilities to fix this problem are to enclose the motor with aluminum foil, thus eliminating any noise that is created from the motor.

3.2 Microcontroller

We did not encounter many problems with the microcontroller or emulator board. The only problems we had were with the initial learning curve that was required to get a good grasp of how the software and hardware was configured so that we could use the circuitry to our advantage.

3.3 Jerk Sensor

The jerk sensor was designed to give a pulse when it had been triggered. Since we implemented this sensor using a spring, it would vibrate back and forth very quickly, which caused multiple interrupt triggers on the microcontroller. Our first solution to this problem was to create a pulse widener circuit that would hold the output high for 2 seconds when it had been triggered. The output of the circuit was then used to trigger the microcontroller interrupt. This solution worked very well, yet we realized that we could also solve the problem using software, thus eliminating the need for additional external hardware. We used the input capture feature, which holds the pin at a low voltage, and chose it to be triggered by a rising edge. Once it had been triggered the first time, we masked the interrupt pin for 2 seconds, thus achieving the same result as we had with the pulse widener circuit.

3.4 Motor

The motor was by far the biggest problem that we encountered because the toy relied greatly on its operation. At first, we used a DC motor that met our low-current requirements, yet it did not turn the ball very well. We then decided to get a higher current motor which was able to turn the ball, yet the current was so high that it made it infeasible to meet our battery life-time specifications. The final solution was to use a geared DC motor that had a high torque rating as well as a low current rating. With this motor, we were able to meet our battery life-time specifications while also being able to turn the ball.

Another problem that was encountered with the motor was that when we changed the direction of the motor, the back EMF was so high that it caused the microcontroller to reset. We first tried to use a diode and capacitor to hold the voltage constant on the microcontroller, yet this was not a feasible solution because the 0.7V diode-drop did not allow the microcontroller to turn on. Alternatively, we created a software solution to the problem. Instead of switching the direction of the motor instantaneously, we turned it off for 0.5 seconds, and then turned it in the opposite direction.

4. Our Design vs. Functional Specifications

This section describes how the final prototype conformed to the functional specifications, which was outlined in the document entitled *Functional Specification for a Gyro Cat Toy*.

4.1. Ball Requirements

Our basic requirements made it necessary for the final prototype to detect signals from the collar, and filter noise from the signals. The prototype detected signals, and implemented a noise reduction algorithm in the software. Unfortunately, the final design did not filter all noise from the receiver's output. Once a signal is detected, the functional specifications states that the ball should roll in both directions, with a radius no less than one metre. Our final design meets both of these requirements and rolled in almost a direct line.

Our functional specifications indicated that the ball must be powered by no more than 6VDC and should operate for more than 2 days of regular play without changing the battery. Regular play was defined as being two hours of play a day. Our design utilized a 3V battery, with a lifespan of 100mA/hrs. From our measurements, the ball draws 1μA while in its idle state and 110mA while the motor is running. Our calculations indicate 6.36 hours of run time, or slightly more than 3 days of regular play.

The specifications implied that the ball would be in the shape of a spheroid, with a minor axis no greater than 7cm and a major axis no greater than 12cm. Our design has a minor axis of 7cm and a major axis of 9.5cm. Next, the performance requirements of the ball stated that it should roll with a translational velocity of more than 15cm/s and should respond to a jerk sensor within 1 second. Our design rolled at a velocity of 35cm/s and the microcontroller was programmed to respond to a jerk sensor after a maximum time of 500ms.

4.2. Collar Requirements

Our basic requirements of the collar was that it transmits a signal to communicate with the ball, that it is powered by less than 4.5 volts, and that its is functional for a minimum of 60 days. Our design transmitted the required signal, and was powered by a 3 volt battery with a lifespan of 500mA/hrs. From our measurements, the collar draws an average current of 30µA. From our calculations, the collar would last for approximately 695 days without having to replace the battery.

The performance requirements stated that the collar's signal should be detected within a range of 60cm and that its signal should be omni-directional. The prototype had the capability of having a detectable range between one foot and the size of a whole room. This capability was due to a potentiometer on the power-level adjustor that as the resistor value changed the output power of the transmitter changed. The transmitter was tested for various resistance values, and it was found that the transmitter was omni-directional. However, the signal had some dead spots as can be seen in Figure 4.2.1.

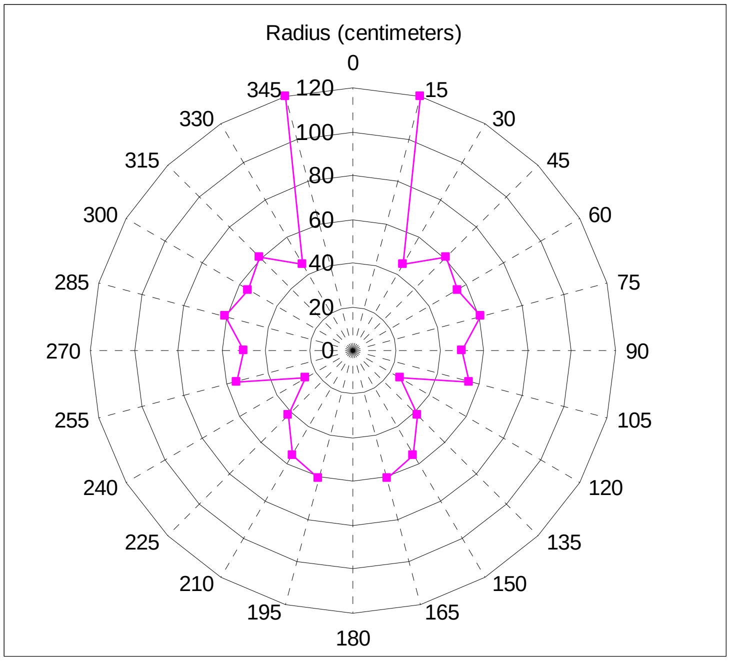

Figure 4.1. Omni-Directional Output of Transmitter

5. Budget and Timeline

5.1. Budget

Table 5.1 compares the budgeting of our estimated cost for prototyping and the actual cost of the prototype.

Table 5.1. Prototyping Cost Comparison

Prototype	Estimate($CDN)	Actual($CDN)
Microcontroller	15	15
Batteries	5	10
Actuators	5	70
Sensors	15	210
Enclosure	10	10
Microcontroller programming kit	400	-
RFID tag kit	400	-
Misc.	-	60
Total	$850	$375

Looking at our estimated prototyping cost and actual cost there are several major discrepancies. First there's the sensor cost which we budgeted to be $15 but spend over $200. This is because initially we budgeted for RFID tag sensors only. During the research and development cycle of our product, our group investigated other possible alternatives including magnetic, ultrasound, and RF sensors and order multiples of each which greatly increased the cost of this category. In the initial estimate we also under estimated the cost of actuators and h-bridges which reflects in our actual cost. However our final prototyping cost is much lower than our projected costs due to two major reasons. First is that in our original design we wanted to use RFIDs which required a kit of $400 that we saved. Secondly we would like to thank Mr. Lucky One and the engineering faculty for providing us with microcontroller programming and emulation hardware and software so we can develop our microcontroller without any incurred cost to our group.

Table 5.2 compares the production cost of our current prototype to our estimated value for quantities of 1000. As shown in the table, the major cost is due to the RF transmitter and receiver. In our second stage of prototyping we hope to develop our own RF transmitters and receivers at a low cost to greatly reduce the production cost of our product. This will make our product affordable and profitable in a promising market.

Table 5.2. Production Cost (in 1000s) Comparison

	Estimate($CDN)	Current($CDN)
Microcontroller	2	0.99
Batteries	1	1.00
Motor	2	4.00
RF Transmitters	2	17.00
Enclosure	2	4.00
H-Bridge	-	0.21
Total	$9	$27.20

5.2. Timeline

Figures 5.1 and 5.2 shows the proposed timeline and actual timeline for our project respectively. Comparing the two we realized two major patterns. First is that our group spend less time for documentation in our actual timeline. But on the other hands the design of each individual component required much more time than we have anticipated. Documentation was done throughout our project as shown in the actual timeline and part ordering was also continuous throughout the development of the project.

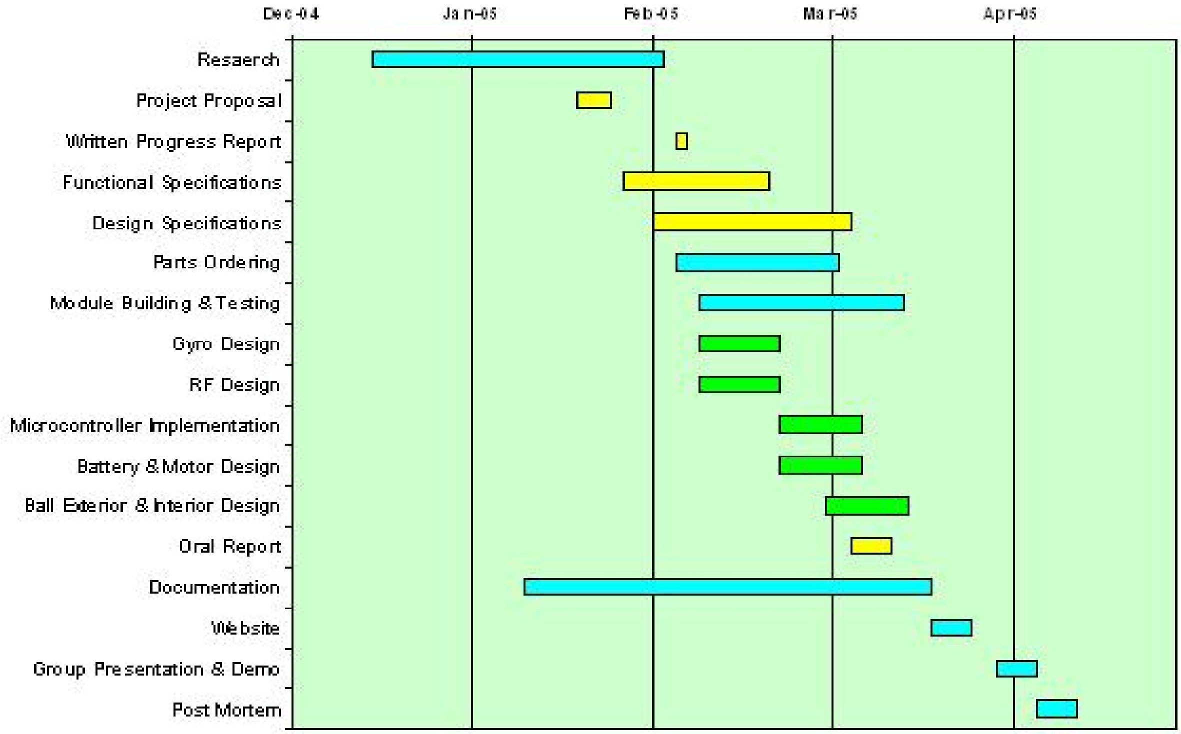

Figure 5.1: Proposed Timeline

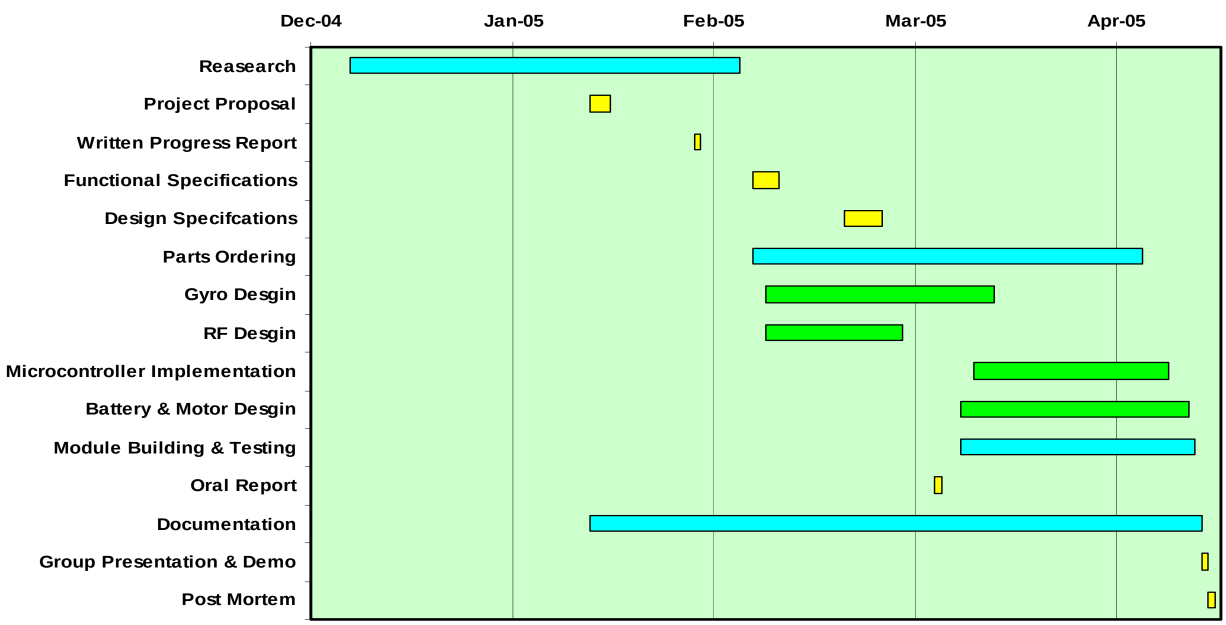

Figure 5.2: Actual Timeline

6. Future Improvements

One of the major issues that we always kept in mind during the past four months was how we could improve our system in the future. Since we are intending to take this product to the market, one of the major considerations is the cost. As outlined in the cost analysis section, the RF transmitter/receiver pair alone cost $17. This equates to more than half of the parts cost for the entire project and must obviously be decreased if we are to adhere to our intentions of capturing a significant market share. The actual costs of the parts inside these RF modules are quite insignificant. The modules are expensive solely because of the R&D work that Linx Technologies had to go through to develop the units. That being said, we feel that with sufficient time, we can design a reliable transmitter/receiver pair for a small fraction of the incurred cost of the prototype.

The final production unit should also be much smaller than the prototype unit that we have designed. This will likely require some research to determine the optimum size and esthetical features of the toy. For our prototype, we mostly used PDIP packages because they are easy to solder and test, yet for the final production unit, most of the chips and circuitry can be made using small surface mount parts. By making the unit smaller, we are also able to decrease the weight of the unit and, therefore, also increase the translational velocity of the toy. This will enable the toy to 'run' away from the cat. It is also important to note that cats typically abuse their toys significantly. Thus, the production unit should be much stronger than our prototype and should also be water resistant to ensure that the cat's saliva does not affect the toy's operation.

Apart from the physical requirements of the toy, many features can be added to add to the functionality. For example, ultrasonic, magnetic, and infrared sensors can be added at very low costs. The software can then use these inputs to create a much more intelligent toy and can greatly increase the life-like features of the toy. For example, we can add more states to our state diagram that allow for "play-dead" or "run-away" modes.

7. Personal Reflections

Robert Grant

From this project I gained a large amount of experience with the research and development stages of electronic design. Reflecting on our proposal, I realized that we made some gross errors in our estimated timeline. We should have provided more time for research, and also should have broken our design up into larger subgroups. For example, instead of a section for Motors and a section for the H-Bridge, we should have scheduled for the design of the actuator circuitry. Another key mistake was in our budgeting for the project. We should have budgeted for the research and testing of various types of sensors and actuators, rather than assuming we would only be purchasing one type.

One of the most beneficial skills that I learnt from doing this project was implementing the control algorithms using assembly language. Although we have had past experience using assembly language, this project went into much further detail and brought the big picture of embedded software into mind. When writing the code we found that using good comments and appropriate variable names was vital. This meant that when we looked at each other's code it was much easier to determine what the individual had programmed.

In terms of teamwork, it was a great experience working with both Ahmad and Di. Since we all have the characteristic traits as leaders, it was beneficial to step back from a leadership role and listen to what each other had to say. The dynamics of our team has allowed me to develop my team working skills throughout the course of this project.

Ahmad Danesh

During these four months, I have learned a great deal about the design process. Most importantly, I have learned how to tackle a problem rather than finding a quick fix to mask the problem. This proved to be a valuable tool because it allowed me to have a big-picture perspective of the tasks and the system overview. For instance, if one component of the system was not working, I thought of what caused the problem first and tried to come up with possible solutions that would entirely get rid of the problem. If such a solution was not available or was infeasible, I then thought of how to fix the problem.

Besides the design experience that I have gained during this semester, I have also learned about group dynamics and how to resolve issues without getting any tempers flared. I am sure that this will prove to be extremely valuable throughout my career because conflicts are bound to happen when working in groups. The one thing I try to keep in mind is that it is usually not worth the energy to get aggravated over the small details. Mentally, it is much healthier to take constructive criticism seriously and to truly attempt to resolve the problems that are encountered.

I also realized the importance of testing and how it plays a crucial role in the entire design process. It is not sufficient to assume that a particular design will work under all conditions. To create a reliable product, many different solutions should be tested and the best one should be chosen based on the particular advantages and disadvantages.

Di Xu

ENSC 440 is a course that provides a great opportunity for engineering students to realize a vision using skills and knowledge from their past years of studies and co-op experiences. I found the innovative idea that is our project exiting and challenging. Starting the course full of energy and motivation I found myself nearly drained of both as I write this review.

Looking back however this course has been a valuable experience. With a small group composed of three members we had to work hard and effectively. Through this journey I picked up many new skills and remember long forgotten old ones. This project not only helped me develop my technical skills but also my interpersonal skills. Although at times our group members had different views we learned to work together to reach an optimum solution. This project has really strength the bonds between me and my group members.

Having finally completed the project I am excited about the rest ahead. However I am looking forward to take this promising product to a new stage of prototyping and potentially market this in the future.

8. Conclusion

This document outlines the final progress towards the development of the gyro cat toy prototype. It covers how the prototype adheres to the specification outlined in the *Functional Specification of a Gyro Cat Toy* as well as the areas where we encountered any problems with the design. This document concludes with an analysis of the project written by each team member.

By adhering to the requirements specified in the various documents written by Animotion Toys, we have been able to develop our prototype to the highest of quality. Beyond the prototyping and proof-of-concept stages, Animotion Toys will continue to pursue their design of a gyro cat toy towards marketable production stages.

9. Sources and References

1) Ontario Veterinary Medical Association
http://www.ovma.org/pets/human_animalbond.shtml
http://www.ovma.org/pets/cat_handbook.shtml

2) American Animal Hospital Association
http://www.aahanet.org/index_adds/POS04.html

3) Michigan State University
http://www.aec.msu.edu/product/documents/Working/1-12031.pdf

4) VetInfo.com
http://www.vetinfo.com/chzpet.html

5) CBC
http://www.cbc.ca/consumers/market/files/health/rawdogfood/canpetfood.html