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

March 17, 2005

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

Re: ENSC 440 Design Specifications for a Gyro Cat Toy

Dear Mr. One,

On behalf of Animotion Toys, Ltd., please find attached a document entitled *Design Specifications for a Gyro Cat Toy*. Our project is a toy ball for cats that will simulate a live mouse by rolling back and forth while responding to the cat's input.

This report describes the different subsystems of the project in detail and outlines the performance specifications of each component. Wherever possible, we have included diagrams to further explain the functionality and tables to summarize the design specifications. The document also includes a detailed test plan that we will use to ensure that our subsystems are functioning as expected, prior to integration.

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: *Design Specification for a Gyro Cat Toy*

Design Specifications 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:	March 17, 2005

Executive Summary

Over the past years people have had less and less free time to spend with their pets, which play important roles in their lives. According to Michigan State University, over 34% of families have pets in the United States [9]. As the family's free time is filled with work, school, soccer practice, and various other activities, their pets are not getting the amount of attention they need. The Ontario Veterinary Medial Association warns that pet owners should "play with [their] cat daily to ensure it is getting enough exercise" [4] and suggests that "cat toys [are] an excellent way for cats to stay in shape" [4]. Unfortunately, with their busy lives, many pet owners are unable to find time for this simple yet essential task.

Animotion Toys Ltd. is determined to engineer a fully automated toy that fulfills the need of cats and their owners. The toy will be a spheroid that is capable of freely rolling around the house. When the cat is within close proximity of the toy, the toy will begin to move. By rolling back and forth, simulating a live object, the ball will captivate the cat without the need of human presence. As the cat loses interests and leaves the proximity, the intelligent toy will enter a sleep mode and wait for the cat to return.

This document lists the design specifications that have been created for the Gyro Cat Toy. These design specifications were created following the guidelines set forth in our previous document, *Functional Specifications of the Gyro Cat Toy*. All functional specifications have been strictly adhered to in order to ensure a quality product.

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1. Introduction

Our objective is to create a toy ball for cats that will not require any human input. The main idea is that the ball will be able to detect the presence of the cat and will roll forwards and backwards depending on the actions of the cat. By simulating a live mouse, the ball will be able to attract and maintain the cat's attention. By doing so, we will provide a fun and interactive solution that will allow cat owners to ensure that their cat maintains a healthy level of daily exercise.

1.1 Scope

This report describes the different subsystems of the project in detail and outlines the performance specifications of each component. Wherever possible, we have included diagrams to further explain the functionality and tables to summarize the design specifications. The document also includes a detailed test plan that we will use to ensure that our subsystems are functioning as expected, prior to integration.

1.2 Goals

The purpose of the design specifications is to provide detailed information about the progress and performance of the project to engineers, upper management as well as lawyers. By describing the subsystems in detail while providing specific data about the performance of each component, we can easily justify our design decisions. Further, the design specifications act as a detailed summary of the work that has been completed to date, which can play a large role in defending intellectual property.

2. System Overview

Animotion's gyro cat toy is an interactive ball that rolls around on the floor and responds to your cat's actions. Attached to the cat's collar is a small device which interacts with the ball, relaying the proximity of the cat to the ball. Depending on the distance between the cat and the ball, the ball will roll in different patterns.

The cat's collar will utilize an RF transmitter to send pulses to the ball. When the pulses are received by the ball, the RF receiver will send data to the microcontroller. When the cat is within range, the microcontroller will turn on the motor, which includes an H-Bridge to allow the motor to turn in both directions. The ball will roll back and forth, under control by the microcontroller's program, appearing to be life-like. When the ball is hit by the cat, or it runs into a wall, the jerk sensor will detect the jerk and send a pulse to the microcontroller. This pulse will cause the microcontroller to reverse the direction of the motor, thus making it run away from either the cat or the wall. The system configuration is shown in Figure 2.1.

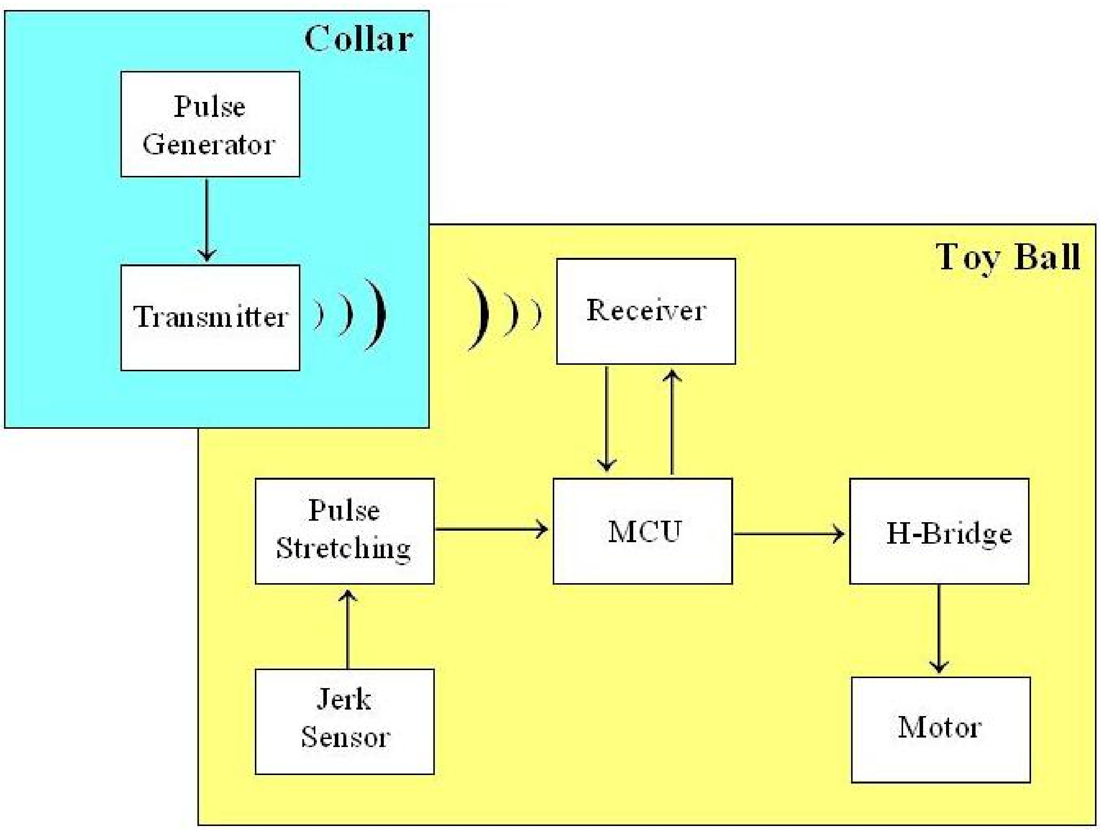


Figure 2.1. System Configuration

3. RF Module

The RF module is an important part of the Gyro Cat Toy. Its purpose is to determine the proximity of the cat. Using the Linx TXM-418-LC AM transmitter and Linx RXM-418-LC-S AM receiver, reliable proximity sensing can be done with low power consumption. The transmitter chip is embedded in the cat collar and it transmits a periodic pulse at a preset power level. When the collar is in range, the receiver inside the toy ball will be able to pick up the transmitted pulse and will relay the cat's proximity to the microcontroller. Figure 3.1 displays the functionality of the RF module.

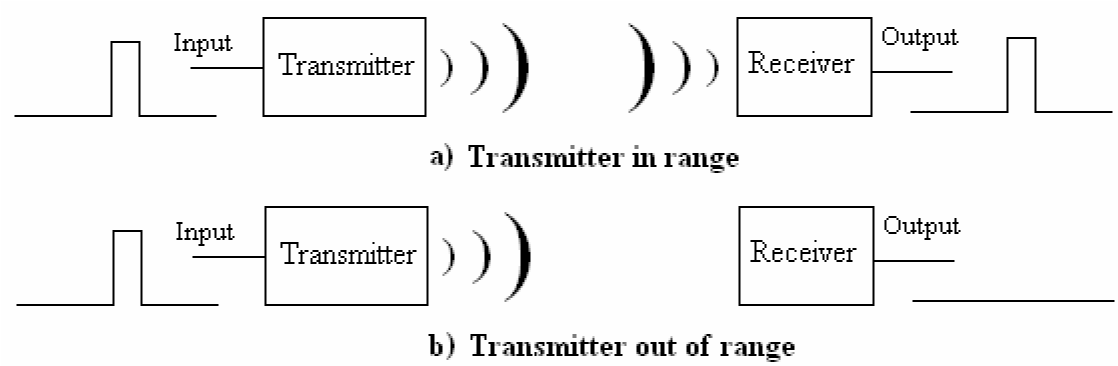


Figure 3.1: RF Module operations

3.1. Transmitter Chip

The transmitter chip we chose is the Linx TXM-418-LC. This 8-pin chip is an AM transmitter with a carrier frequency of 418 MHz. The major benefit of using this transmitter is that the chip has low power consumption. It is capable of operating at 3 V with a current rating of 1.5 mA during transmission and only 1.5 μA while in sleep mode [7]. With no need for additional external circuitry except for a signal source, the TXM-418-LC is cost effective and easy to use. The TXM-418-LC takes a square pulse as its input and transmits the signal using a simple transmission and no transmission scheme. When the input is a high, the TXM-418-LC transmits by modulating the signal at the carrier frequency. While the input is low, the transmitter does not transmit and stays in sleep mode therefore conserving power. Since our application requirement for the transmitter is to send a simple pulse signal, this modulation method used by the TXM-418-LC accomplishes the task effectively without extra cost of complexity.

One of the most attractive features of the TXM-418-LC is its power level adjustability. By altering a single resistor connected to the level adjust (ladj) pin of the transmitter, the chip's output power can be adjusted. By using this feature, we are able to limit the range of successful signal detection to the desired amount while maximizing power saving.

Figure 3.2 shows the basic circuit schematic for the TXM-418-LC which is used in our design. Note that R1 is the resistor used for power level adjustment.

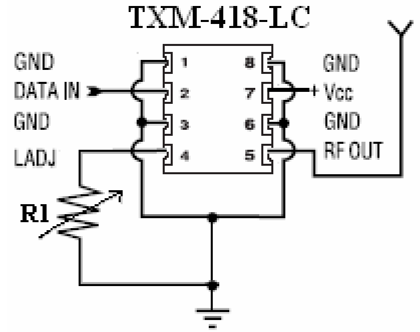


Figure 3.1.1: Transmitter Circuit Schematic

Figure 3.1.2 shows the output power of the transmitter as a function of the resistor value attached to the ladj pin. Using this graph as a guide, we were able to determine the optimum ladj resistance value for our desired range to be 230Ω. Table 3.1.1 shows the tested current characteristics of our transmitter design.

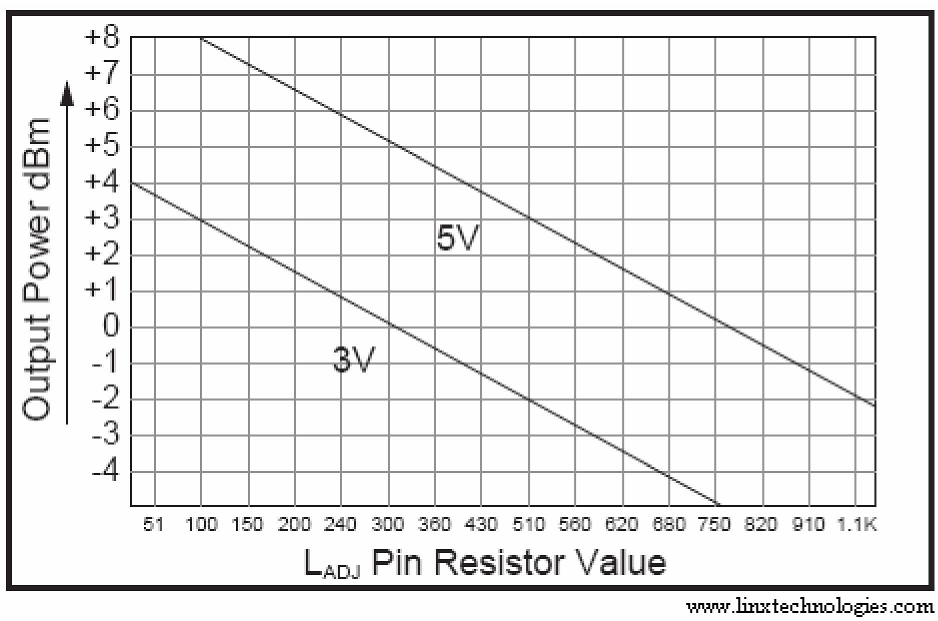


Figure 3.1.2: Power Output vs. *LADJ* Pad Resistor Value

Table 3.1.1. Transmitter Chip Current Parameters at 3.0V

Parameters	Typical	Max	Units
Current Transmitting Continuous	3.5	3.7	mA
Current Transmitting Pulse	55	58	µA
Current Sleeping	1	1	µA

3.2. Transmitter Antenna

The main consideration for RF transmission is the proper design and use of a reliable antenna. Antenna design is a finicky area of study and many properties, such as styles, shapes and sizes can be changed in order to optimize the transmission for a particular application. Unlike typical applications involving RF transmission, our application requires the range to be limited within a fixed radius, rather than to be maximized. This can mean one of two things. We can either create an antenna that is inefficient, thus limiting the range, or we can create an efficient antenna and simply reduce the output power of the transmitter. Since we are trying to minimize the total current use in an effort to have a long-lasting product, the latter is the obvious choice.

Antenna efficiency is a matter of creating a matching antenna load, and from the Linx module documentation, we know that the antenna should ideally be 50Ω. We noticed from testing that this was only a requirement for efficiency and not an absolute requirement to produce reliable transmission. Instead, the consistency of the antenna resistance was much more important. For example, when using a simple loop of wire as the antenna, shaking the antenna or even the slight movements of our hand would affect the transmission. The reason is that any movement in the wire changes the effective cross-sectional area at different segments of the wire, thus slightly changing the resistive load seen by the transmitter module. Another reason is that the movement of the wire changes the position of the antenna with respect to the ground plane, which is important in quarter-wave antenna design. The conclusion from this discussion is that for our application, we needed an efficient antenna that would not move or shake with respect to the ground plane when the cat runs around.

An efficient way of achieving this was to create an internal antenna on the PCB itself, known as a trace antenna. The total length of the trace, L_{ant}, also has a large effect on the efficiency of the antenna. This ideal length is based on the transmitter carrier frequency (f = 418 MHz) and is given by

$$L_{ant} \cong \frac{7125}{f} \cong 17.1cm \text{, [4]} \qquad (3.2.1)$$

where f is given in megahertz. By etching away the copper in certain areas of the copper clad board, we constructed three different antenna styles, each with a total effective length of 17.1cm, as shown in figure 3.2.1.

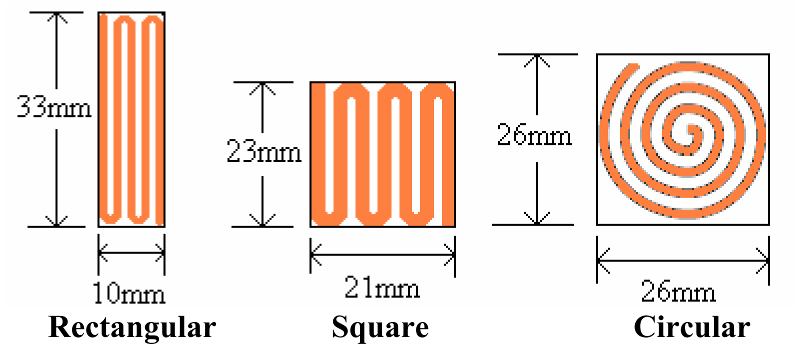
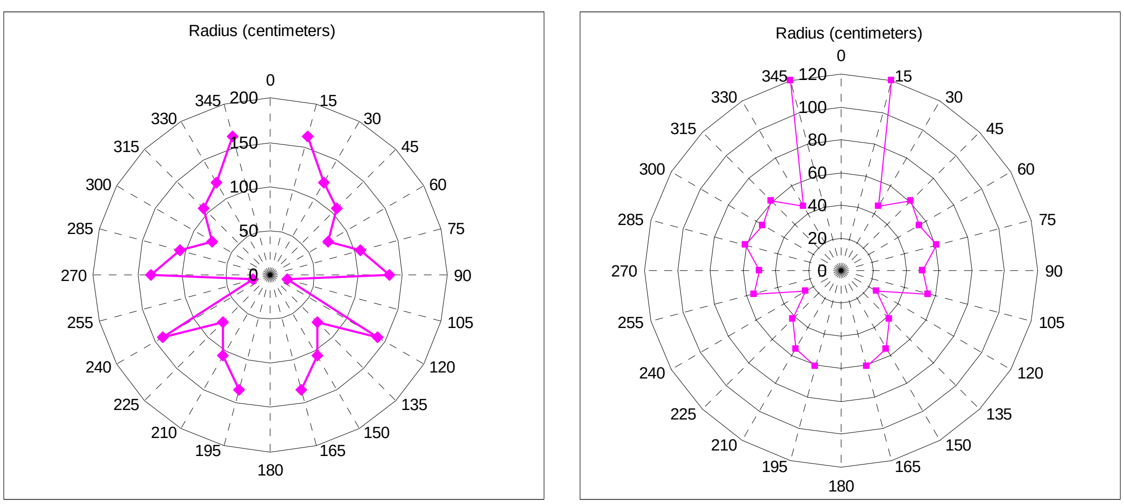


Figure 3.2.1. Antenna styles and dimensions (L_{ant} = 17.1cm)

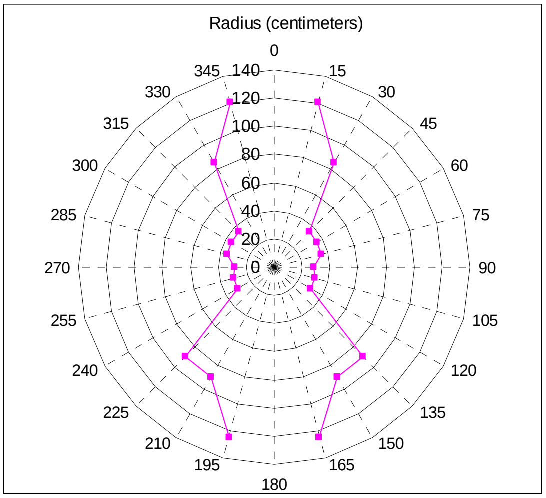
We performed experiments to test the range capability as well as the dependency on the orientation with respect to the receiver module. The square antenna was the most omnidirectional of the three while the rectangular antenna was more dependant on the angle of the antenna. Even though our initial assumption was that the circular antenna would be the best choice for our application, it would not transmit at any distance from the receiver. As a result, we chose to continue testing with the square antenna.

To understand the range capability at different angles, a polar plot for the square antenna was constructed. We repeated the test the following day so that we could also understand the discrepancies that could result from day to day or from different positions of interfering objects. Figure 3.2.2 and figure 3.2.3 summarize these polar plots for day 1 and day 2, respectively (note that all radii are given in centimeters).



Antenna perpendicular to ground **Antenna parallel to ground**

Figure 3.2.2. Range measurements at different angles for the square antenna with level adjust resistor at 230 Ω (day 1).



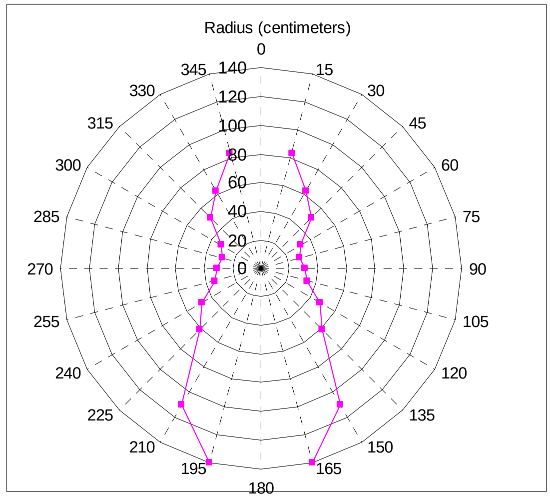


Figure 3.2.3. Range measurements at different angles for the square antenna with level adjust resistor at 230 Ω (day 2).

By comparing the plots from day 1 and day 2, we can see that there are slight differences in the range, yet the angular dependency seems to be repeatable. The difference in range can be attributed to several factors, such as the proximity of nearby interfering objects. Most importantly, we are able to detect the presence of the transmitter reliably. In fact, the differences in range that occurred from day to day will add to the randomness of the toy and will contribute to the desired effect of simulating a live mouse.

3.3. Pulse Generation and Power Requirements

As discussed in section 3.1, the current drawn from the transmitter (V_{CC} = 3V) should be 1.5mA during transmission and 1.5 µA in standby. We measured the actual current while transmitting a signal at 2.3V to be $I_{transmit}$ = 3.541 mA and during standby to be I_{idle} = 1 µA. Comparing these current levels, we can see that the transmitter requires 3541 times more current while transmitting. The purpose of the pulse generation circuit is to minimize the transmitting time in order to conserve power.

For our application, it is not necessary to output specific data to the ball. Instead, all we need to do is transmit a pulse so that once it is detected the ball will know that the cat is nearby. Although we were reasonably flexible to choose any frequency at which to output, our application required a minimum frequency, which we determined based on the speed of a typical cat. The justification is that we wanted to ensure that the cat would not be able to run past the ball or attack the ball before the microcontroller was able to detect the cat's presence. At top speed, a cat can run at approximately v = 20 km/hr (5.6m/s) and the detection radius of the ball is roughly 1m. So the ball has 1/5.6 seconds to detect the presence of the cat, which can be thought of as the period of the transmitted signal. Thus, the frequency of the signal must be at least 5.6 Hz. To create a safety boundary, we rounded the frequency up to 10 Hz (T = 100 ms).

The other variable that can be adjusted is the duty cycle of the signal, which is given by

$$dutycycle = \frac{T_H}{T_H + T_L} * 100\% = \frac{T_H}{T} * 100\%, \tag{3.3.1}$$

where T_H, T_L, and T are the high time, low time and total period, respectively. By adjusting the duty cycle, we can limit the transmitting time, thus limiting the average current drawn by the transmitter. The datasheet for the TXM-418-LC module states that it is capable of handling signals at a maximum of 5000 bits per second (BPS). This equates to a minimum T_H of 1/5000 = 0.2 ms. Again, to create a sufficient safety boundary, we chose $T_H \approx 2$ ms. Using equation 3.3.1, this equates to a duty cycle of 2%. With this duty cycle, the average current drawn from the transmitter module is given by

$$I_{avg} = 0.02 * I_{transmit} + 0.98 * I_{idle} \tag{3.3.2}$$

Using equation 3.3.2 with the current values stated previously, this equates to I_{avg} = 71.8 μA. The actual average current was measured to be 58 μA. The next step in the design was to construct a low-current astable multivibrator. After considering circuits using op amps, 555 timers, as well as CMOS logic, we found that the CMOS logic circuit consumed the least current. In fact, the final circuit, shown in figure 3.3.1, consumed only 2 μA. A TC4011 chip was used for the NAND gates, as shown below.

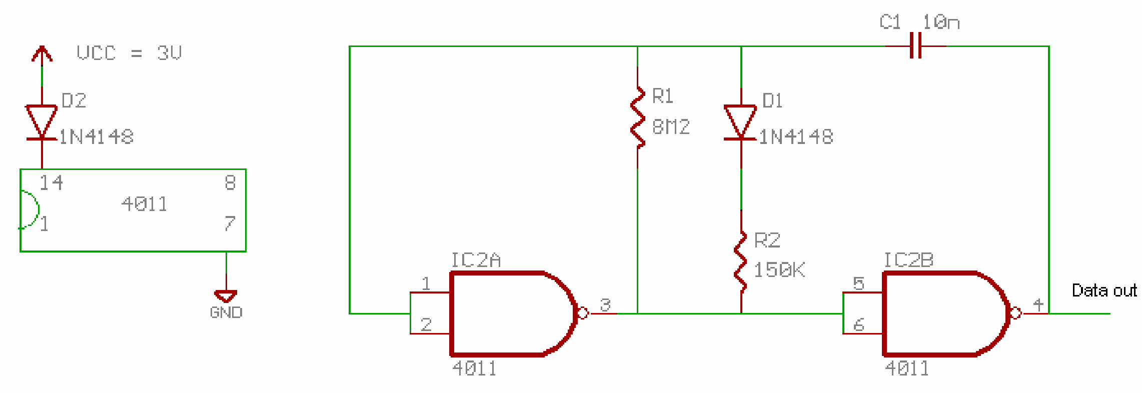


Figure 3.3.1. Low-current astable multivibrator circuit diagram

The actual specifications for the circuit are compared to the expected values in table 3.3.1.

Table 3.3.1. Astable multivibrator - measured and expected values

	Expected	Measured
Frequency	10Hz	10.91 Hz
Period, T	100 ms	91.66 ms
High time, T_H	2 ms	1.58 ms
Low time, T_L	98 ms	90.08 ms
Duty cycle	2 %	1.72 %

Connecting this circuit as the input to the transmitter encompasses the entire circuitry for the collar. Table 3.3.1 summarizes the measured current values of this system at different power levels (i.e., changing the level adjust resistor on the transmitter module).

Table 3.3.2. Collar supply current for different level adjust resistors

Level adjust resistor (Ω)	Current (μA)
0	100
50	86
100	74
150	66
200	61
250	53
300	50
350	48
400	45
450	42
500	40

From our measurements from the antenna section, we found that a resistance of 230 Ω was ideal to achieve the 2-4 foot detection radius. In our functional specifications, we noted that the battery life of the collar should last at least 2 months. With the ultra-low current circuit that we have designed, we can attain battery life many times greater than this. We will use a 3V lithium coin cell for the collar and the nominal capacity ranges from 25 – 1000 mAh for different size cells. We will likely use the CR2354 model made by Panasonic that is rated at 560 mAh. Using the CR2354 with a total current of 60 μA (rated at 230Ω level adjust resistor), we can calculate the expected battery life to be

$$batterylife \cong \frac{560mAh}{0.06mA} = 9333hours = 389days = 13months \qquad (3.3.3)$$

It is important to note that even though the battery is rated at 560 mAh, it will not be able to supply this total capacity. However, our design outperforms our expected value stated in our functional specifications, so we will still meet the requirement. The measured specifications for the final collar circuit are tabulated below for easy reference.

Table 3.3.3. Measured specifications for the collar

Specification	Measured value	Units
Supply voltage	3	V
Supply current	60	µA
Frequency	10.91	Hz
Duty cycle	1.72	%
Battery life	9333 (13)	Hours (Months)

3.4. Receiver Chip

The receiver we are using is the Linx RXM-418-LC-S. We choice this particular chip for its low power consumption and its ease of use. The RXM-418-LC-S requires no external RF components and is capable of demodulating the transmitted signal of the TXM-418-LC effectively. The receiver detects the carrier frequency and generates an output square wave depending on the presence or absence of the carrier. Figure 3.4.1 shows the circuit configuration used in our design. Although the RXM-418-LC-S has 16-pins, only six pins actually have physical connections.

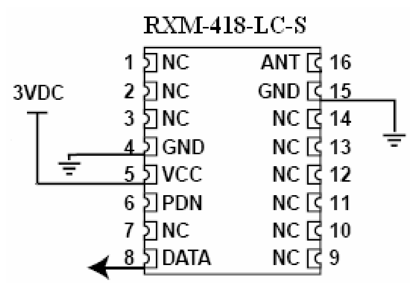


Figure 3.4.1: Receiver Circuit Schematic

Note that in Figure 3.4.1 there is no antenna attached to pin 16. This design decision was made after our test results indicated that there was negligible difference in the range and signal quality due to the absence of an attached receiver antenna. Therefore, to reduce space the antenna was taken out in our final design. Using the configuration shown in Figure 3.4.1, we tested the receiver chip's current parameters, which are summarized in Table 3.4.1. These current values are negligible relative to the motor current and are not a dominating factor of the battery life of the ball.

Table 3.4.1. Receiver Chip Current Parameters at 3.0V

Parameters	Typical	Max	Units
Current (Receiving Continuous)	6.3	6.34	mA
Current (Receiving Pulse)	6.8	6.86	mA
Current (Idle)	6.8	6.86	mA
Current (Power Down)	0.9	0.97	mA

4. Jerk Sensing Unit

The jerk sensing unit is comprised of the jerk sensor and the pulse stretching circuit. When the ball is either hit by the cat, or runs into a wall, the jerk sensor will detect the input in the form of an unstable pulse. This unstable pulse is turned into a single pulse using the pulse stretching circuit and is used as an input to the microcontroller.

4.1. Jerk Sensor

The jerk sensor is comprised of a spring and a pin, with ground connected to the spring and the pulse stretching circuit connected to the pin. When the ball is hit, the spring will move, making contact with the pin. It is desired for the spring to make contact only in the circumstance when the ball is hit. Thus, the ball's rolling should not make the spring contact the pin. Further, since the ball will be physically abused, the pin must be strong enough that it will not bend or break during the use of the toy. The final design for the jerk sensor can be seen in Figure 4.1.1.

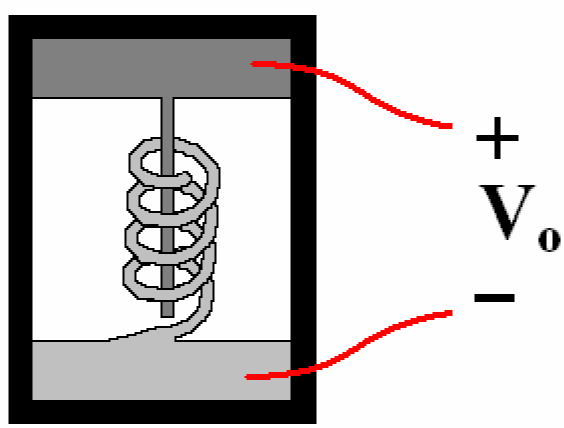


Figure 4.1.1. Jerk Sensor

4.2. Pulse Stretching Circuit

When the spring makes contact with the pin, the voltage at the input of the pulse stretching circuit drops from three volts to zero volts. The pulse stretching circuit is shown in Figure 4.2.1.

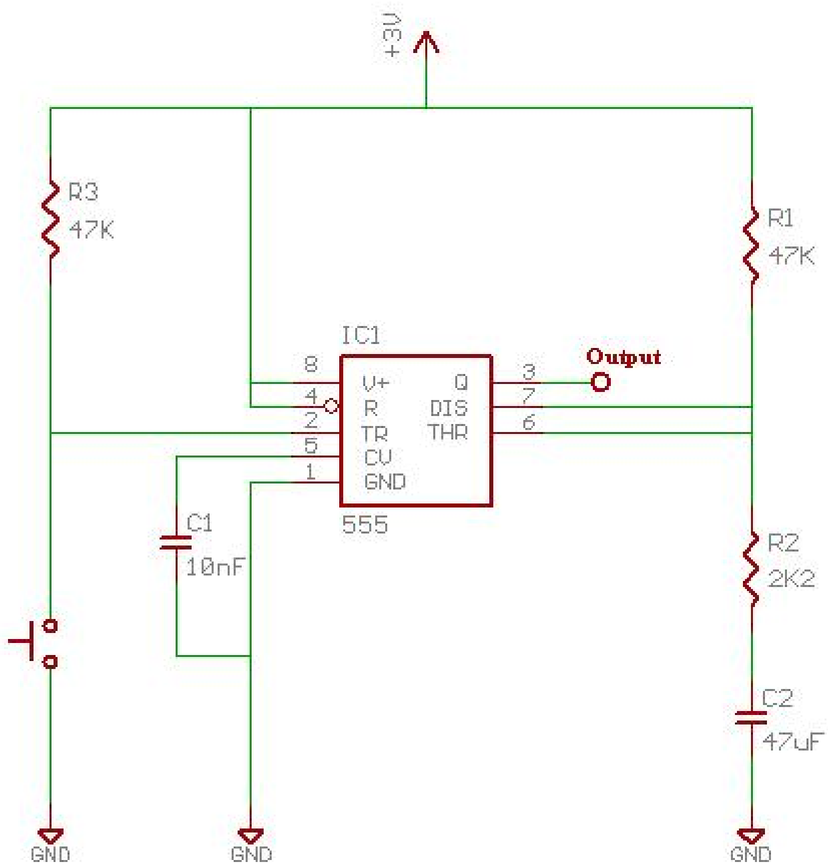


Figure 4.2.1. Pulse Stretching Circuit

This circuit utilizes a low power 555 timer, the 7555 chip. The input of the timer, pin 2, is held at a high until the force sensor triggers a low. Once the first falling edge is detected the 555 timer holds the output pin at a high for approximately two seconds. From laboratory testing, two seconds is a sufficient length to hold the output at a high because during this period, the spring will dampen and return to its steady state. By creating only one pulse, we can ensure the microcontroller does not have to filter the jerk sensor input. By doing so, we use less internal timers of the microcontroller, thus allowing for more timed patterns of movement for the ball. If we do not need to save these timers for programming the balls movement, we can replace the pulse stretching circuit with an RC circuit. This circuit would filter the oscillations to a point that the microcontroller's software would be able to interpret them easily.

The final design of this circuit uses minimal power. When the jerk sensor is not active, the circuit draws 0.16 mA. Once the sensor is active, and the output is held high, the circuit draws 1.25 mA.

5. Motor Unit

The motor unit controls the entire motion of the cat toy, and is controlled by the microcontroller using the H-Bridge. Depending on the state applied to the H-Bridge, the motor will spin either clockwise or counter clockwise. The actual configuration of the motor within the ball is described in the section entitled "Mechanical Construction."

5.1. Motor

The motor selected for this product is the RF-370CA-15370 made by Mabuchi Motors. With a supply voltage of 3V, our experiments have shown this motor to draw 28 to 32 mA when it is loaded. The dimensions of the motor are shown in Figure 5.1.1.

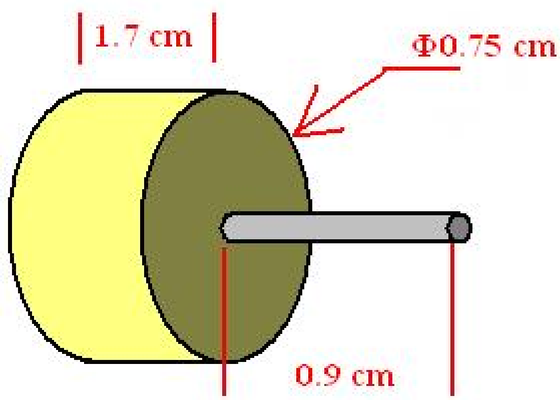


Figure 5.1.1. Motor Dimensions

5.2. H-Bridge

The H-Bridge unit is used to control the motor using only two outputs from the microcontroller. This circuit allows for the microcontroller to output either a high or a low, thus eliminating the need for digital to analog converters. The circuit schematic is provided in Figure 5.2.1.

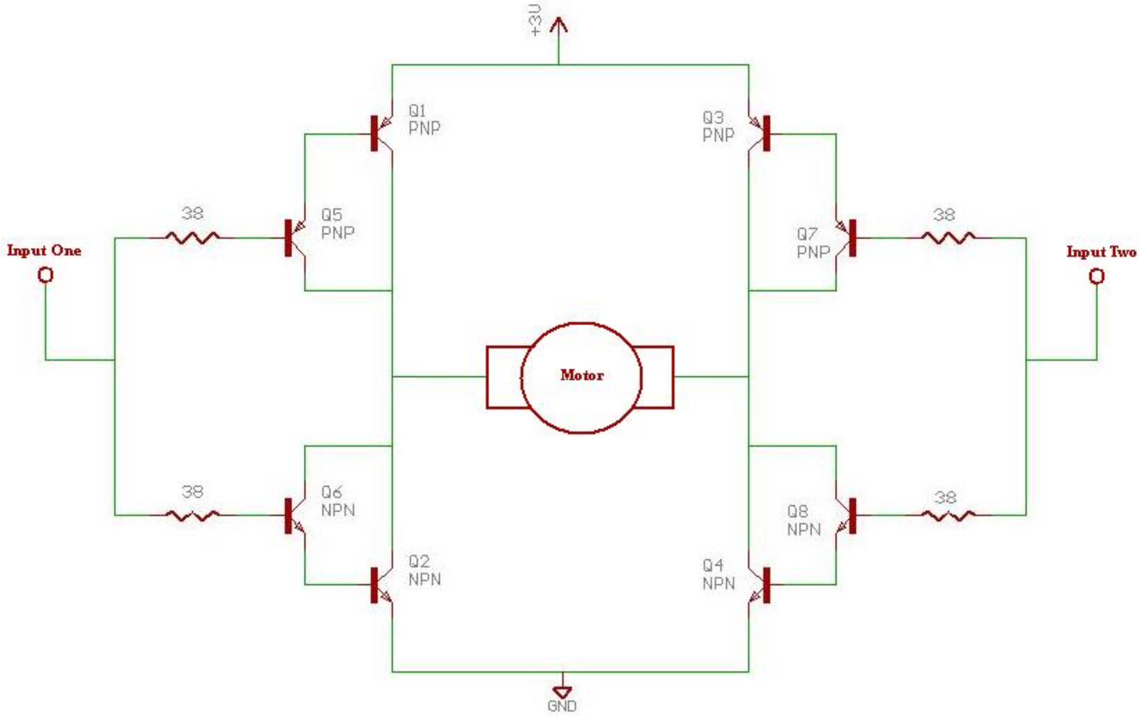


Figure 5.2.1. H-Bridge Circuit

This circuit uses four NPN transistors and four PNP transistors; Fairchild's 2N3904 and 2N3906, respectively. These transistors have a maximum collector current of 100mA, which will suffice for our motor's current requirements. Other parameters for the 2N3904 and 2N3906 are provided in Table 5.2.1.

Table 5.2.1. Transistor Parameters

Parameter Name	Value	Unit
Maximum Collector Current	200	mA
Maximum V_{CE}	40	V
Maximum V_{CB}	60	V
Maximum V_{EB}	6	V
Response Time (Rise)	35	ns
Response Time (Fall)	50	ns

The states of the motor for different inputs from the microcontroller are shown in Table 5.2.2. Note that the microcontroller should never output a high on both inputs of the H-Bridge because this will cause a short between the power supply. This issue will be resolved using the software of the microcontroller.

Table 5.2.2. H-Bridge States

Input One	Input Two	Motor Direction
0	0	OFF
1	0	ON, Counter clockwise
0	1	ON, Clockwise
1	1	N/A

Eight transistors were used instead of only the four main transistors, Q_1 toQ_4 in Figure 5.2.1, because without the extra transistors, the base current is 30 mA. This would indicate that 30mA must be drawn from the microcontroller, yet the microcontroller is only capable of outputting 15 mA. Using eight transistors reduces the current drawn from the microcontroller to 8 mA.

Table 5.2.3 shows the operation currents for the H-Bridge and motor combined.

Table 5.2.3. Motor Unit Operation Currents

Motor State	Current (mA)
OFF	8.1
ON, Counterclockwise	33
ON, Clockwise	33

6. Microcontroller Unit

The microcontroller module is the heart of our toy. It processes the RF input and jerk sensor input and outputs a motor sequence in order to entertain a cat. The microcontroller unit (MCU) used is the 68HC908QT4 from Freescale. The MCU is an 8-bit processor with high performance and low power consumption. The control logic is written in assembly language under the integrated development environment (IDE) of Motorola Modular Evaluation System 08Z (MMEV08Z) provided by the M68EML08QTQY emulation board package that aids in the development of the control software.

6.1. Microcontroller

Due to our design needs, we are looking for three main features in a microcontroller. The device must be small in size and with 16-pins or less. The power consumption needs to be low and the cost must be low. In addition to the properties mentioned above we are also looking for interrupt capabilities, memory, and processing power. The 68HC908QT4 is an 8-pin device with an 8-bit processor. Figure 6.1.1 shows the physical pin layouts of the QT4 chip. At 3.0 V supply the microcontroller is rated with a 2.5 mA current draw. This current rating is as low as 0.67 mA while in sleep mode [6].

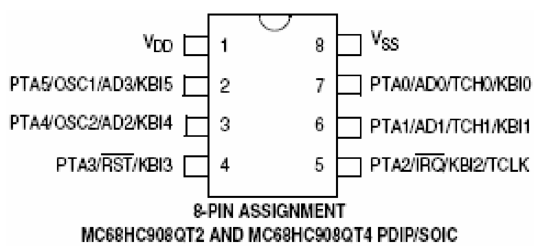


Figure 6.1.1: MC68HC908QT4 chip layout

Other attractive features of the QT4 are [6]:

- 4K Bytes of in-application reprogrammable Flash and 128 Bytes of RAM
- 2 Channel 16-bit timer with selectable input capture, output compare and PWM
- 4 Channel 8-bit analog to digital converter
- 5 bidirectional input/output lines
- External asynchronous interrupt pins

The CPU of the QT4 is the Motorola CPU08 which has the following features [6]:

- 16-bit stack pointer
- 16-bit index register
- 64-Kbyte program/data memory space
- Low-power stop and wait mode.

The QT4 is USD0.99 for orders of 1000 or more in quantity and it is available in PDIP package [6]. This microcontroller effectively meets the requirements of our project and provides us with a cheap solution to our computation needs.

6.2. Emulation Module

The Emulation Module is a valuable tool for the testing and debugging of the microcontroller programming process. The M68EML08QTQY Emulation Module is capable of emulation and debugging microcontrollers of the MC68HC908QT/QY families. Its main function is to receive the control software we have developed, and simulate the performance of a particular microcontroller running the control software. This makes for easy testing and debugging since changes to the source code can be made quickly once the problem is realized and reloaded on to the emulation module again. The greatest advantage of the emulation module is that it is capable of simulating two families of microcontrollers. Therefore it is easy to test our control code on a different microcontroller if the need arises. The emulation module can also help us determine the microcontroller that optimizes our design.

6.3. Software

Our control software will be developed in assembly language under the MMEV08Z environment. We choice assembly language over other higher programming languages such as C and C++ because we believe by using assembly language we can write more efficient codes.

The control software is a series of decision making process that determines a course of action depending on different inputs from the RF or jerk sensor. The actions taken are motor movements in one direction or another. For a more efficient code that saves processing time and power, we will make use of internal timer and external interrupts. Different states will be set up and at any given time the software will be waiting for an interrupt in one of the states. A high level flowchart of the software is shown in Figure 6.3.1 and Table 6.3.1 give descriptions of the four states shown in the flowchart.

Table 6.3.1. Control Software State Descriptions

State	Description
Shutdown	- receiver in power down mode - motor off - waiting on timer interrupt
Idle	- receiver turned on - motor off - wait on timer, pulse, or jerk interrupt
Motor Direction 1	- receiver in power down mode - motor on in forward direction - waiting on timer or jerk interrupt
Motor Direction 2	- receiver in power down mode - motor on in reverse direction - waiting on timer or jerk interrupt

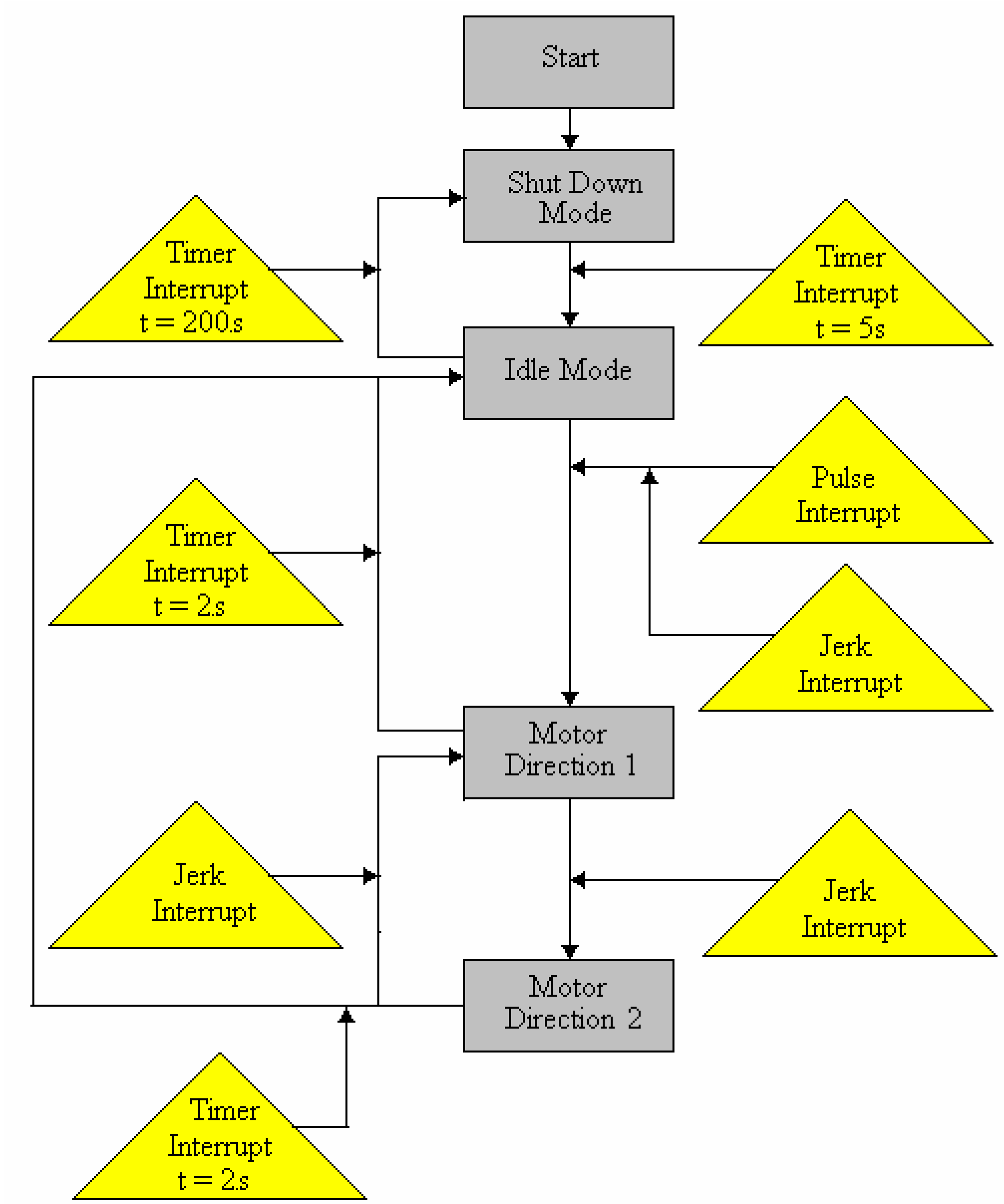


Figure 6.3.1: Control Software Flowchart

7. Mechanical Construction

The final mechanical construction of the toy must be robust and small. The casing we are using for the prototype is made of a very thin plastic, and is shaped as a spheroid. The dimensions of the spheroid are 5 cm in diameter in the minor axis, and 8 cm in diameter in the major axis. For production, the shell will be made of a thicker, more robust shell that would be able to withstand the abuse from a cat.

As shown in Figure 7.1, the motor will be securely attached to one end of the shell and the weight will spin freely in the center. The other end of the spheroid will house the RF modules, microcontroller, jerk sensor, battery, and H-Bridge. If these components do not offset the weight of the motor, a counterweight will also be included in the lighter end of the spheroid.

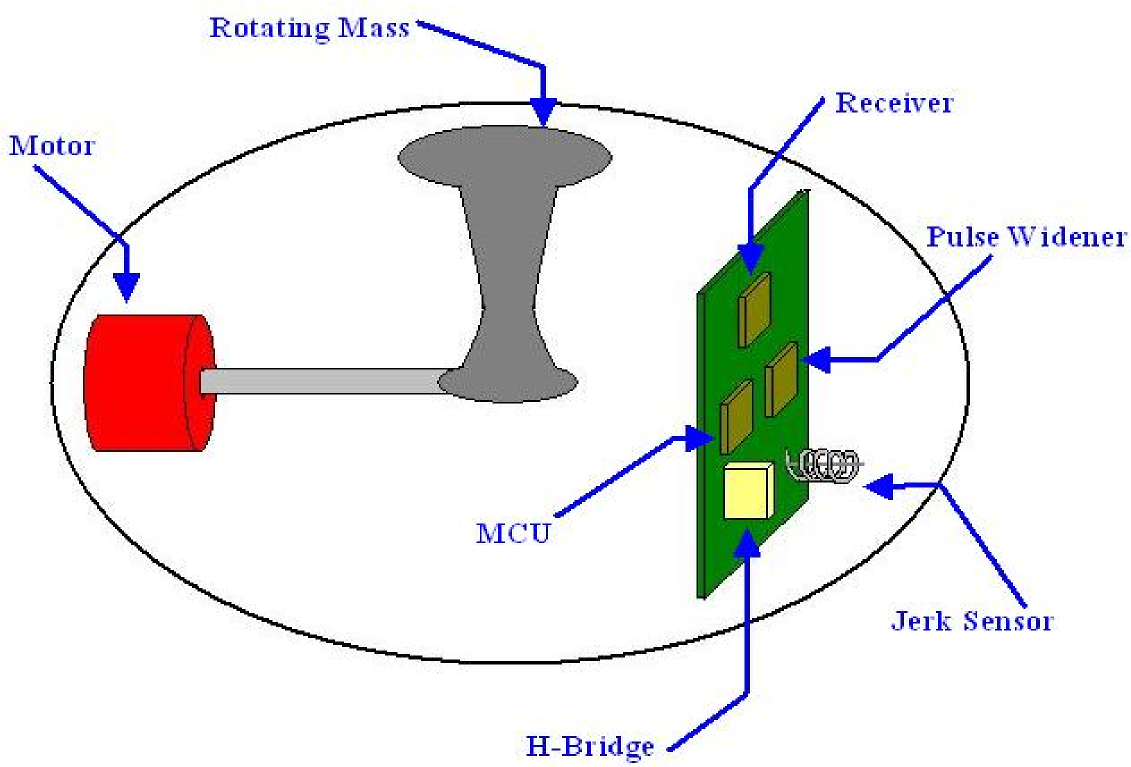


Figure 7.1. Mechanical Orientation

8. Test Plan

In order to perform the testing for this product we will first separate it into smaller sections. Each section will be tested individually to ensure the functionality as separate systems. The sections that will be individually tested will be the motor and h-bridge, the jerk sensor, the microcontroller, and the RF transmission. Once this testing has been confirmed the system will be integrated and tested as a whole unit.

As a stand-alone unit, the RF transmission will be tested for range and reliability. The point at which the transmitter fails to communicate with the receiver should be between 60cm and 120cm. This will be tested by sending a periodic square waveform from the transmitter, and the output of the receiver will be monitored at different ranges. This test will be performed for intervals of fifteen degrees, throughout a full circle, in order to obtain polar plots. These plots will be performed on several different days to ensure that the transmission is reliable.

The microcontroller will be tested using the emulation board. The interrupts of the microcontroller will be tested to ensure that they are received, and that they trigger the correct outputs to switch between their high and low states.

The jerk sensor will be tested for its sensitivity and its reliability. The sensor should not trigger by the force caused by the movement of the motor and shell. Ideally, the sensor should only trigger due to a force equal or greater than the ball hitting into a wall. Since the ball is desired to roll at 25cm/s we can test the sensor by hitting it at that speed. Also, the sensor will be shook to ensure that it will not trigger. These tests will be performed on several different days to ensure the reliability of the device.

Finally, the h-bridge will be tested to ensure its functionality as an individual unit. The unit must be tested to ensure that the motor can be controlled to change directions, depending on the state of the inputs. Also, when the motor is running, the inputs cannot draw more than 15mA. Finally, the entire h-bridge should not draw more than 75mA.

Once all the separate units have been tested they can be integrated and tested as a whole unit. Once combined the product will be tested to ensure it functions as expected.

9. Conclusion

The design specification for an innovative gyro cat toy has been provided in this documentation. Included in these specifications are detailed designs of each component of the gyro call ball, namely: RF Units, Jerk Unit, Microcontroller Unit, and Motor Unit. Each individual system also includes testing procedures to ensure that the product is functioning as stand-alone units. Finally, testing of the entire unit will be completed to ensure the product is functioning properly and that it meets all requirements as provided in the *Function Specifications for a Gyro Cat Toy* documentation.

10. References

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