Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

April 23, 2003

RE: Post Mortem for an Automatic Cat Feeder

Dear Lucky,

The attached document is Nekotek's Post Mortem for the Automatic Cat Feeder, MEO. This document outlines the design and implementation processes of MEO that we experienced during the course of ENSC 440.

Furthermore, this document describes the current state of the MEO, problems encountered during implementation, deviations from our original plans and future plans to improve our current system. This document will also discuss the budget, timeline and individual contributions from each team member.

Nekotek consists of five creative and talented engineering students: Benjamin Wang, Jason Chang, Leung Hoang, Christian Losari and Eric Huang. If you have any questions or concerns, please contact us by sending an email to ensc440-nekotek@sfu.ca.

Sincerely,

Benjamin Wang

Benjamin Wang
Chief Executive Officer
Nekotek

Enclosure: Post Mortem for an Automatic Cat Feeder

Post Mortem for Automatic Feeder System

Project Team

Benjamin Wang
Jason Chang
Eric Huang
Christian Losari
Leung Hoang

Company Email

ensc440-nekotek@sfu.ca

Date Issued

April 25, 2003

Revision

1.0

Submitted to

Lakshman One - ENSC 440
Steve Whitmore - ENSC 305
School of Engineering Science
Simon Fraser University, Canada

Table of Contents

List of Figures

List of Tables

1 Glossary

1.1 Acronyms

AC	Alternating Current
A/D	Analog to Digital
DC	Direct Current
DTMF	Dual Tone Multi Frequency
IC	Integrated Circuit
LCD	Liquid Crystal Display
MCU	Microcontroller Unit
MEO	Product name of Automatic Cat Feeder

1.2 Definitions

A/D Converter	A converter with internal sample and hold circuitry used to translate an analog signal to a digital signal.
Auger Bit	A drill bit characterized by a helical rotating shaft.
Bipolar Stepper Motor	A stepper motor with 2 identical and non-electrically connected coils.
DTMF	A method used by the telephone system to communicate the keys pressed with dialing.
Microcontroller	A single integrated circuit intended to be operated as an embedded system.
Operation Amplifier (op-amp)	A general-purpose, closed loop, amplifier used to implement linear functions. Its performance and function are defined by external components (feedback network or

	loop) surrounding it.
Optical Relay	A device that uses a short optical transmission path to accomplish electrical isolation between elements of a circuit.
PIC	A family of microcontroller from the company Microchip.
Proximity Sensor	A device that detects the presence of metal and non-metal objects (wood, plastic, liquids, etc.) without physical contact.
Solid State Relay	A relay that switches electric circuits by use of semiconductor elements without moving parts or conventional contacts.
Strain Gauge	A measuring element for converting force, pressure, tension, etc., into an electrical signal. A strain gauge is a thin metal foil that changes resistance with applied strain.
Transformer	An electrical device that steps up voltage and steps down current proportionally (or vice-versa). Transformers only work with AC only.

2 Introduction

MEO, an automatic cat feeder, has sparked the interest of 5 talented individuals (Benjamin Wang, Jason Chang, Leung Hoang, Christian Losari and Eric Huang) and brought them together to design and implement the idea.

The MEO system is an automatic feeding device that can be set to feed cats at predetermined times with predetermined amounts and can be operated remotely with telephone calls. The MEO system can be viewed as four modules. While the Controller module acts as the brain of the system, each of the other modules has its own function and communicates with the Controller module in order to complete the required tasks. Figure 1 shows the prototype of the MEO.

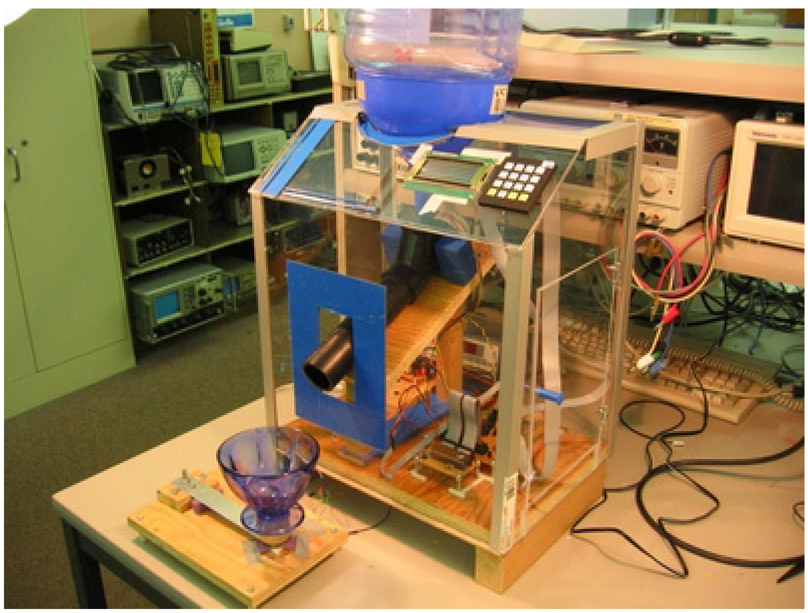

Figure 1: Prototype of MEO

3 System Overview

The MEO system overview is shown Figure 2 below.

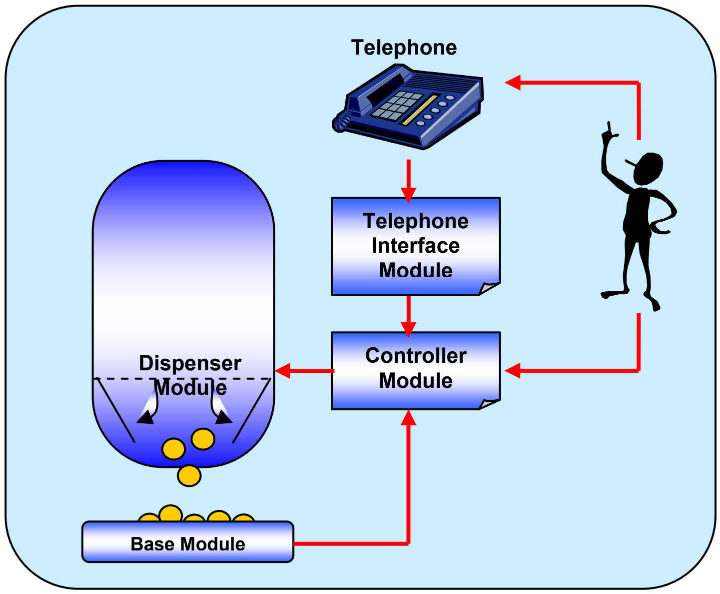

Figure 2: System Overview Block Diagram

The MEO system consists of five modules: Controller, Telephone Interface, Dispenser and Base. The user interacts with the MEO directly through the Controller module or indirectly via a telephone call through the Telephone Interface module. The Controller module receives real time signals from other system modules, processes the signals and sends appropriate control signals to relevant modules for actions such as dispensing food and displaying information on the LCD.

3.1 Signal Flow of MEO

Figure 3 shows the signal flow of MEO system.

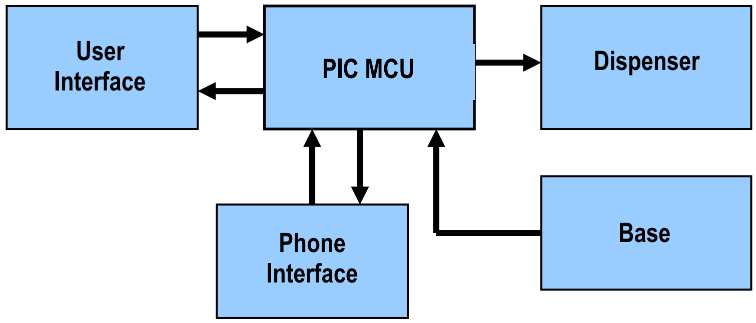

Figure 3: Signal Flow of the MEO System

3.2 Features

3.2.1 Programmable Auto Feeding Times

MEO offers the users programmable feeding times when the auto feed mode is activated. Users can program up to three feeding times per day.

3.2.2 Easy to Use Phone Interface

In order to dispense food remotely, users just have to make a phone call. MEO will pick up the phone after a specified number of rings. After the phone is picked up, users just have to press a 4-digit password to tell MEO to dispense a specified amount of food. Number of rings and the password are programmable.

3.2.3 Weight Food for Diet Tracking

MEO is able to track the diet of users' cats. MEO can display the average amount food eaten by cats and number of feeding from previous day.

3.2.4 LCD and Keypad Interface

MEO uses keypad and LCD to offer cat owners an easy-to-use as well as a user-friendly interface. In the MEO interface, users can check cat's diet and also can configure the MEO system.

4 Controller Module

MEO uses a PIC16F877 microcontroller to centralize the processing of incoming signals from the user, Telephone Interface Module and Base Module. Outputs are generated accordingly to the LCD and Dispenser Module.

4.1 Software

The Nekotek engineers chose to develop the software of MEO using PIC assembly language on the MPLAB IDE. Additionally, a development board was used to expedite the learning curve associated with programming in an unfamiliar language.

4.2 User Interface

When a user is physically in front of the MEO system, the user can interact with MEO through a 4x4 keypad and 20x4 LCD.

Originally, all 16 buttons were to be used. However, 13 buttons were sufficient to implement the functions of MEO. The 13 buttons used are:

#0-9:	Data Entry, Menu Select
[<]:	Back
[>]:	Next
[Manual Feed]:	Dispense Food

In the initial design of the MEO system, a 20x2 LCD was to be used. However, a 20x4 LCD had became readily available. The LCD provides visual feedback to the user by displaying menus. The menu hierarchy is simply modified from the initial planning. The hierarchy of the menu system of MEO is shown in Figure 4.

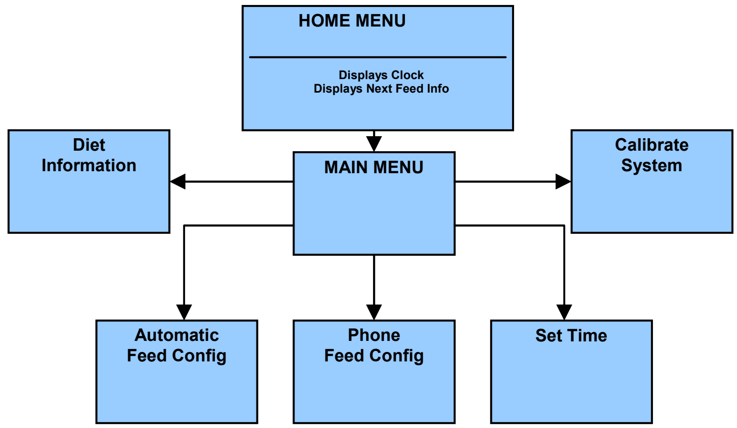

Figure 4: Menu Hierarchy of the MEO system

4.2.1 Home Menu

When MEO is started, the user is brought to the Home Menu. The home menu displays the current time, whether auto feed is on or off, and the next programmed feed time and amount.

4.2.2 Main Menu

From the Main Menu the user can navigate to any of the following 6 submenus.

4.2.3 Diet Information

The Diet Information Menu displays the total number of feeds and average feed amount for the previous day of feeding. The statistics are updated daily at approximately midnight (23:59).

4.2.4 Auto Feed Configuration

An available option for the user in the Auto Feed Config Menu is to turn on/off the auto feed feature. If Auto Feed is turned on, up to 3 feed slots can be programmed, each one with a different feed time and amount. The feed times must follow the 24-hour clock convention (eg. 22:00 instead of 11:00PM). Also, the user can easily delete feed slots in the Auto Feed Config Menu.

4.2.5 Phone Feed Configuration

In the Phone Feed Config Menu, the user can enter a 4-number password, the number of telephone rings before MEO answers the phone, and the corresponding feed amount. If the user enters '0' for the number of rings, the phone feed feature is deactivated.

4.2.6 Set Time

The user can set the time of the day in Set Time Menu. Like the Auto feed times, the time must follow the 24-hour clock convention.

4.2.7 Calibrate

By calibrating the system, the weight measuring feature used by MEO can be ensured to be accurate. However, the user must first ensure that the bowl is empty before proceeding. If not calibrating, an approximated calibration is used instead.

4.3 Problems Encountered

In regards to software development, the difficulties encountered were associated with the older Microchip PIC hardware architecture and the interpretation of the PIC16F877 datasheet.

If some internal features of the PIC16F877 are used, certain I/O pins of the PIC16F877 become reserved and unusable. For example, if the Timer1 of the PIC is used, a pin of PORTC will contain the output of Timer1. Moreover, if Timer1 is used, other features such as the input capture will no longer be available. Consequently, MEO's initial approximation of needed I/O ports was in danger of being underestimated. The design of MEO was modified in some areas to cope with the shortage of I/O pins. The LCD uses a 4-bit serial/parallel data communication instead of a simplified 8-bit parallel method. The generation of the stepper-motor's input waveform was also changed.

The PIC16F877 microcontroller has an 8-level deep hardware stack. Coupled with a 4 subroutine deep LCD code source, the depth of the stack limits code abstraction to the remaining 4 levels. Therefore, care was needed when programming the main programming and interrupt service routine.

Next, the program memory of the PIC16F877 is not contiguous, but is separated into 4 pages of memory. Therefore extra instructions are needed to call subroutines in different pages of memory. Combined with the vagueness of the PIC datasheet, which specifies that an interrupt push/pop and RETURN does not require such instructions, random resets were encountered. The problem was solved through numerous simulations.

5 Telephone Interface Module

The Telephone Interface Module governs the remote control aspect of the MEO system through telephone calls. The function of the telephone interface module is to detect incoming phone calls and relay remotely entered messages to the microcontroller for future actions.

5.1 Design

In the current design, we used an optical relay and a DTMF decoder as the basic component for this module. The diagram in Figure 5 shows the interaction between the phone interface module and the microcontroller.

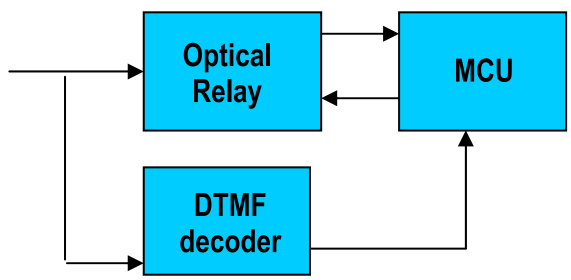

Figure 5: Block Diagram and Signal Flow of Telephone Interface Module

The incoming phone calls are detected by the optical relay, which then notifies the microcontroller of such an event. The microcontroller will then pick up the phone call by sending another signal to the optical relay. It will cause the optical relay to simulate an off-hook condition of the phone line. Once the phone call connection is established, the remote user can enter numbers through his/her telephone remotely. The DTMF decoder will then pass the decoded number to the microcontroller for password verification.

5.2 Ringer Equivalent Number

The REN in all telephone related products govern the amount of power it draws when the phone rings. A REN of 1 is equivalent of the power required to ring an AT&T standard telephone. The larger the REN, the fewer other telephones you can connect to the same telephone lines. The MEO system has a calculated REN of 0.55. This essentially means that it requires very little power from the phone line in order for it to operate and does not affect the operation of other telephone products if MEO is connected to the same phone line.

6 Container Module

This module has been removed from the current design. The proximity sensor is no longer used in the design. The module only contains a simple container.

7 Dispenser Module

7.1 Electronic Design

The Dispenser Module transfers food from the food container to the bowl in a controlled manner. Figure 6 shows the signal flow of the Dispenser with respect to other modules.

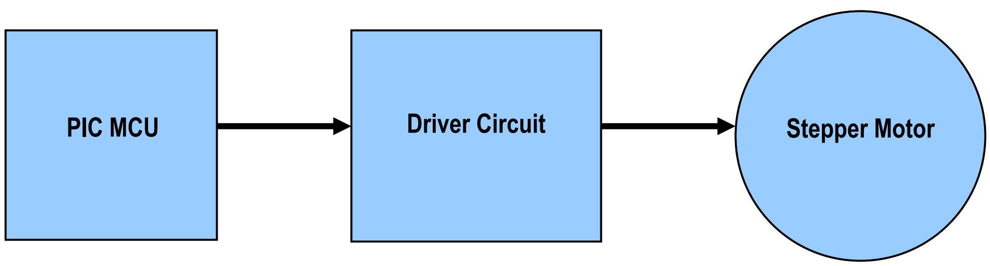

Figure 6: Signal Flow of Dispenser Module

The PIC produces the correct sequence of waveforms needed to drive the stepper motor and outputs the waveforms to the driver circuit. The driver circuit isolates the mechanical components (ie. stepper motor) from the electronic components (ie. PIC). The driver circuit also provides the necessary current needed to turn the stepper motor.

7.2 Mechanical Design

The mechanical design of the Dispenser Module includes an auger (spiral) bit attached to the shaft of the stepper motor. The auger bit is placed into a tube with a diameter slightly larger than that of the auger bit. As the motor turns, the auger bit will gradually push the cat food out of the tube and into the bowl. Figure 7 shows the mechanical design of the Dispenser module.

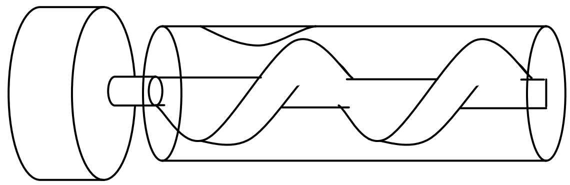

Figure 7: Mechanical Design of Dispenser Module

7.3 Problems Encountered

7.3.1 Driver Circuit

The driver circuit requires 4 inputs from the PIC in order to turn the stepper motor. The 4 inputs are grouped into pairs. Within each pair of signal, the two signals must be complements of each other. Since the available number of I/O pins on the PIC is limited, Nekotek engineers decided to use a BJT NOT gate to complement one of the signals in each pair and thus only used 2 I/O pins on the PIC for generating the necessary waveforms.

Another problem encountered with the driver circuit is heat. Since the stepper motor drains about 1A of current, the driver circuit gets hot really quickly. But this solution is easily remedied with the use of a heat sink.

7.3.2 Mechanical

A mechanical problem encountered during the design of the Dispenser Module is the alignment between the shaft of the stepper motor and the auger bit. If the shaft and auger bit are not aligned perfectly in a straight line, the auger bit will wobble as the stepper motor turns. Since the auger bit is enclosed in a tube with a diameter only slightly larger than that of the auger bit, the bit may occasionally become stuck since the motor does not have enough torque to overcome the friction. The solution to this problem is to have better craftsmanship and tools during construction.

8 Base Module

The task of the MEO Base Module is to measure the amount of food in the bowl. It operates in conjunction with the Dispenser Module, so that the system can dispense the desired amount of food. In addition, MEO is able to prevent overfeeding by using the weight information provided by the Base Module.

8.1 Design

The signal flow of the Base Module is described in Figure 8. The force sensor will detect the food weight and output a corresponding voltage. Next, it passes the voltage to the MCU through a difference amplifier and an amplifier circuit.

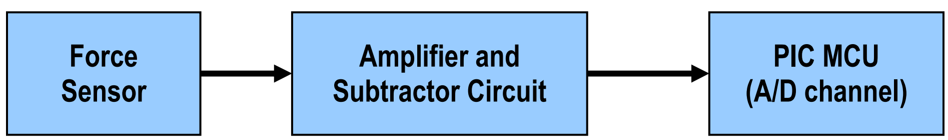

Figure 8: Signal Flow of Base Module

8.2 Force Sensor

MEO uses a Honeywell force sensor. The reason for choosing this sensor is because it is very easy to use and it provides high accuracy (i.e. ± 5 grams). The output voltage of the force sensor is linear with respect to the weight.

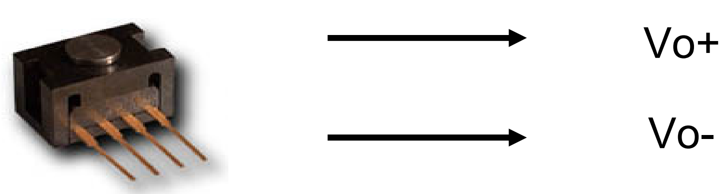

Figure 9: Honeywell Force Sensor

8.3 Difference amplifier

A difference amplifier is implemented for subtracting the two output voltages from the force sensor. It is possible to subtract the signal under software control; however, using a hardware subtractor will reduce the number of I/O pins used as well as minimizing the complexity of the code. Therefore, instead of passing two analog voltages to the PIC MCU, only one analog voltage will be passed.

8.3.1 Op-Amp

The output signals from the difference amplifier are very small; therefore, it has to be amplified before feeding it to the A/D converter of the PIC. The non-inverting op-amp is used to amplify this low signal.

8.3.2 Low Pass Filter

A low pass filter is implemented for filtering the unstable outputs from the force sensor. When the motor of Dispenser Module rotates, it will cause vibrations to the whole casing. The vibration causes oscillation on the output of the force sensor, which will make the output voltage unstable. Therefore, a low pass filter is required to remove this phenomenon.

8.3.3 Weight Scale

The weight scale is designed using a cantilever beam method. The mass will be placed at the end side of the beam and the sensor will be placed underneath. Figure 10 shows the diagram of the weight scale implemented on the Base Module.

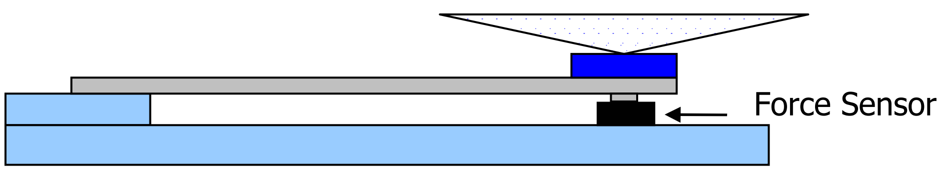

Figure 10: Weight Scale in Base Module

In addition, the shape of the bowl is also chosen to be cone-shaped, so that the food dispensed will always move toward the center of the bowl.

8.4 Problems Encountered

During the design period of the Base Module, two major problems are encountered: the choice of the weight sensor and the bowl.

8.4.1 Sensor

At first, strain gauges are used as the weight sensor for the Base Module, because it is very cheap in terms of cost. However, strain gauges keep producing an inconsistent initial voltage offset, which makes it hard to characterize. Furthermore, strain gauges are very temperature dependent. Slight changes in temperature will affect the resistance value of the gauges. Lastly, mounting issues became a problem. Mounting one gauge requires half an hour and it has to be done very carefully. A small mistake in mounting will decrease the performance of the strain gauges.

Due to the reasons mentioned above, the strain gauge approach was abandoned. The Honeywell force sensor is used to replace the gauges, although the cost of one force sensor is much more expensive than the cost of one strain gauge.

9 Deviations

During the development of the MEO, Nekotek changed some of their design parameters due to limitations such as time constraint, implementation feasibility and need.

9.1 5 Day Diet Tracking

In the current implementation, the diet tracking information is retained for the previous day rather than a 5-day period. This change is due to the time involved in developing additional math routines for the PIC.

9.2 Average Time for Automatic Feeding

The current implementation requires that the user specify the time and amount for automatic feeding. The average time was not computed due to the reduced importance of the feature after serious consideration and discussion.

9.3 Force Sensor

After experimentation, Nekotek found that if the strain gauge system was used for weight measurement, the reliability of the MEO system would be compromised. Thus a force sensor was used to replace the strain gauge implementation in measuring weight.

9.4 Proximity Sensor

The proximity sensor in the Container Module was removed due to the low usefulness of the feature.

9.5 Phone Feedback Tones

To reduce system complexity without compromising the remote control functionality, the feedback tones were not implemented.

9.6 Calibration

Due to a small deviation in the voltage produced by an empty bowl, a calibrate menu was added to ensure that the user will receive accurate weight measurements.

10 Future Plans

Since the MEO system is still at the prototype stage, there are many areas for improvement in the future. First, the software can be improved on calculating the dieting information. In the future, the diet information can be calculated over the last 7 days instead of just the previous day in the current design. Also, it would be ideal for the MEO system to have a battery backup for the 24-hour clock. In terms of usability issues, the MEO system can be improved to provide more obvious user feedback during remote control mode. In the current design, the person calling the MEO system only knows that he has entered the correct password to activate feeding if he hears the phone hang up. In the future, we may use DTMF transceivers instead of just the DTMF receiver to provide the user with feedback tones.

11 Budget

The cost for developing the MEO system was first estimated to be $785. Table 1 shows the cost estimation proposed in the infant stages of the MEO system.

Table 1: Initial Estimated Cost of MEO

Components	Estimated Cost
Power source (AC adaptor, batteries)	$50
LCD	$75
Keypad	$10
Sensors	$150
Microprocessors, clock, memory	$200
Mechanical Components	$150
Miscellaneous	$50
Contingency Fund	$100
Total Cost	**$785**

The actual development cost of the MEO system is shown in Table 2.

Table 2: Actual Cost of MEO

Components	Estimated Cost
Power Source (AC adapter)	$7.20
LCD	FREE (borrowed)
Keypad	$22.19
Sensors	
Optical Proximity Sensors	FREE
Force Sensor	$83.08
Microprocessors	
PICDEM-2 Demo Board	$170.72
PIC16F877 MCUs (x5)	FREE
Crystal Oscillator	$5.14
Mechanical Components	
Stepper Motor	$32.56
Clare Opto Relay	$19.20
California DTMF Decoder	$4.62
Casing	$67.11
Miscellaneous	$131.46
Total Cost	**$543.28**

After development was completed, the cost of the MEO system was lower than the original estimate. Initial over-estimation of the power source and mechanical components, as well as borrowed or free samples offset the under-estimation of the miscellaneous and casing costs. The contingency fund was used for the replacement of the strain gauge with a force sensor to measure weights.

12 Timeline

The progress of MEO did not go according to the timeline proposed initially. This was due to an underestimation on the research time required for the Telephone Interface Module. In addition, the time spent on trying to use a strain gauge system for weight measurement and later choosing to use a force sensor also delayed Nekotek. Figure 11 shows the timeline for bringing the MEO system into prototype.

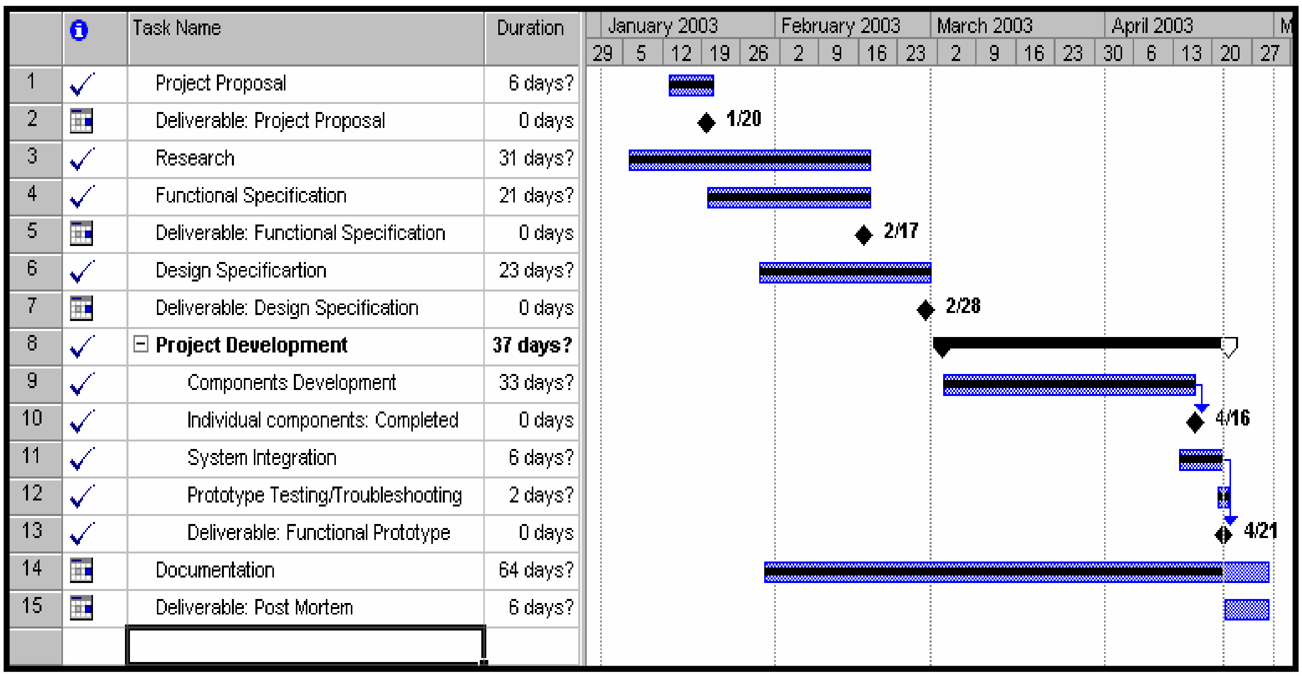

Figure 11: Timeline of Project

Even though Nekotek was behind schedule, its engineers were still able to finish the prototype on time through everyone's hard work and dedication to the project.

13 Primary Roles of Members

Each member of Nekotek is primarily responsible for each separate module. However, there are significant overlaps of responsibility to ensure minimum debug and redesign times.

Benjamin Wang

Ben is the leader for the Nekotek engineers. Ben was significantly responsible for electronics design of the phone circuitry. He researched and implemented the DTMF decoder, ring detector, phone off-hook switch, and phone line power isolation. The design and construction of the Telephone Interface Module was carefully inspected and tested by him for reliable operation.

He also implemented the power management for the MEO using voltage regulators and standard AC adapter sources. Ben is also responsible for entire board design, soldering all components onto the circuit boards, and testing the circuits. Alongside Christian, Ben also helped to modify the amplifier circuit to be powered by a simple 10-volt power supply.

He also wrote some codes for the PIC including EEPROM reads and writes, and assisting Jason in writing the code for DTMF decoder. Ben helps to develop algorithm to efficiently compare A/D values.

Ben also came up with the design of the MEO casing and dispenser piping to minimize clogging. Towards the end, he helped on testing of the overall system performance.

Eric Huang

Eric was responsible for the initial research of the design on choosing the appropriate components as well as software support through the course of the project development stage.

At the beginning of the design stage, Eric was responsible for understanding the PIC16F877 architecture and its assembly language. Eric was responsible for writing the A/D conversion code for the base module. Eric also helped on the algorithm on how to calculate the average weight of food dispensed in the bowl as well as on how to code math functions such as 16 bits by 16 bits multiplication. He also helped with some soldering of the hardware.

Additionally, Eric assisted Christian in the construction of the prototype casing. In the end, Eric was responsible for designing Nekotek's webpage as well as some overall testing.

Christian Losari

At first, Christian was helping Ben with the research on the components and design that will be used for the Telephone Interface Module.

Christian was involved in all stages of designing the MEO weight measurement system. Christian is also responsible for researching on the components used for the Base Module. First struggling with the strain gauge approach, he experimented with numerous mechanical setups. When Nekotek opted to go with the force sensor, Christian remained as the developer of the Base Module. Again, he tested different apparatus, including flat versus cone-shaped bowls, and fitted-hole method versus cantilever beam methods. Christian worked with Jason to characterize the force sensor and also to develop an algorithm for converting the A/D value to the weight.

Additionally, Christian developed subroutines for the MEO system including interrupt generation, display of current time and assisting Leung in LCD routines. Christian helps Leung with understanding the PIC16F877 architecture. Towards the end of the project, Christian was involved in the construction of the prototype casing and overall system testing.

Jason Chang

Jason was responsible for the Dispenser Module. His choices of motor, driver, and auger bit are used in the implementation of MEO's dispensing mechanism. He ensured that the motor did not draw current unnecessarily, ensuring the safety of the dispenser circuitry. Jason also tested a variety of dispenser tubing to wrap around the auger bit to minimize the number of clogging incidents. Furthermore, Jason also gave some assistance to Christian in developing the Base Module.

Alongside Ben, Jason assisted in DTMF electronics circuitry. He also suggested using a 555 monostable timer to count the number rings reliably. Jason also coded subroutines to be used for MEO, including stepper, DTMF decoder, and diet information (converting A/D value to grams, understanding math function).

At the end, Jason does some overall testing for functionality and reliability.

Leung Hoang

Leung was the primary software developer for the PIC16F877 microcontroller and developed the majority of the code. Leung managed the overall program flow and hence he helped integrate the routines written by the other members of Nekotek. The code written by Leung includes menu selection and display, user preference management, keypad button routines, and the activation of auto, phone and manual feed. He resolved issues with the PIC16F877 architecture include memory paging, 8-level stack, and ISR push/pop. Leung was responsible for gradually testing software components throughout the project.

Before the abandonment of the proximity sensor, Leung tested the sensor with a variety of transparent and translucent materials.

Leung was helping Christian in designing the base by suggesting adding some external circuitries that will increase the performance of the base. Leung also assisted Christian in the construction of the prototype casing.

14 Conclusion

By the April deadline, the engineers of Nekotek managed to complete MEO with slight modifications from the design specifications. MEO is capable of feeding by programmed times and amounts, feeding by a phone call and limited data collection of a cat's feeding habits. The automatic cat feeder works reliably, feeding with adequate accuracy and at precise times.

Nekotek feels that by developing an automatic cat feeder from the initial concept to the final implementation, its engineers were able to derive worthwhile knowledge and experiences. The project was invaluable to the growth of the Nekotek engineers.