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

March 3, 2003

RE: Design Specification for an Automatic Cat Feeder

Dear Lucky,

The attached document is Nekotek's design specification for an automatic cat feeder, MEO.

We are designing and building an automatic feeding device, MEO, that helps cat owners alleviate some of the daily feeding chores involved in owning a cat. MEO will give cat owners the ability to feed their cats even if they are not home. MEO has a telephone, keypad and LCD user interface for easy access of functions.

The design specification document details the reasons for choosing the components and the functionality of the components used to implement MEO. Test plans for the individual modules will also be discussed since they are key to the successful completion of the project in April.

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

Sincerely,

Benjamin Wang

Benjamin Wang
Chief Executive Officer
Nekotek

Enclosure: Design Specification for an Automatic Cat Feeder

Abstract

At Nekotek, the primary goal is to develop an automatic cat feeding system, MEO, capable of remote access and diet monitoring. Cat food can be dispensed through the MEO system via a telephone call, automated scheduling or manual override. MEO will be compatible with the standard RJ11 telephone jack and will not interfere with existing home appliances such as answering machines. User feedback will be provided through a LCD display.

A large spectrum of solutions to building MEO exists. Various mechanics, sensors, application specific integrated circuits and micro-controller units may be required in the construction of the MEO system. The objective of the design specification document is to present a design solution, which meets the requirements listed in the functional specification. Some alternative design approaches will also be summarized in this document.

Like the functional specification, the design specification document will separate the MEO system into five modules: Controller, Telephone Interface, Container, Dispenser and Base. Design details of each of the five modules will be explored to guide the engineers of Nekotek in meeting the project deadline of April 2003. Additionally, user interface designs and test plans will be outlined.

nekoTEK

Design Specification for Automatic Feeder System

Project Team

Benjamin Wang
Jason Chang
Eric Huang
Christian Losari
Leung Hoang

Company Email

ensc440-nekotek@sfu.ca

Date Issued

March 3, 2003

Revision

1.0

Submitted to

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

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1. Glossary

1.1. Acronyms

AC	Alternating Current
A/D	Analog to Digital
DC	Direct Current
DSP	Digital Signal Processor
DTMF	Dual Tone Multi Frequency
IC	Integrated Circuit
I/O	Input/Output
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MCU	Microcontroller Unit
PC	Personal Computer

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.

Digital Signal Processor	A semiconductor that turns analog signals, such as sound or light, into digital signals, which are discrete or discontinuous electrical impulses so that they can be manipulated.
Gage Factor	The fractional change in resistance to the fractional change in length (strain) along the axis of a strain gauge.
Hysteresis	The lagging of an effect behind its cause.
Operational Amplifier (op-amp)	A general purpose, closed loop, amplifier used to implement linear functions. Its performance and function are defined by the external components (feedback network or loop) surrounding it.
Optical Isolator (optoisolator)	A device that uses a short optical transmission path to accomplish electrical isolation between elements of a circuit.
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 Gage	A measuring element for converting force, pressure, tension, etc.,into an electrical signal. A strain gage 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 work with AC only.

2. Introduction

The MEO system is an automatic feeding device that can be set to feed cats at a predetermined time and amount, and can be operated remotely with telephone calls. The MEO system can be viewed as 5 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.

2.1. Scope

This document outlines the design specification of the MEO automatic cat feeder that will adhere to the requirements described in the functional specification document. The overall system design will be discussed followed by the 5 modules that make up the system. In each module's section, the possible solutions, proposed solutions, implementation and test plans will be discussed. The hierarchy of the user interface menu will also be discussed in this document.

2.2. Intended Audience

Design engineers will use this document to develop and test the individual modules for functional requirements and integration into the overall system. This document can also be used determine the progress of the project.

3. System Overview

The MEO system overview is shown Figure 1 below.

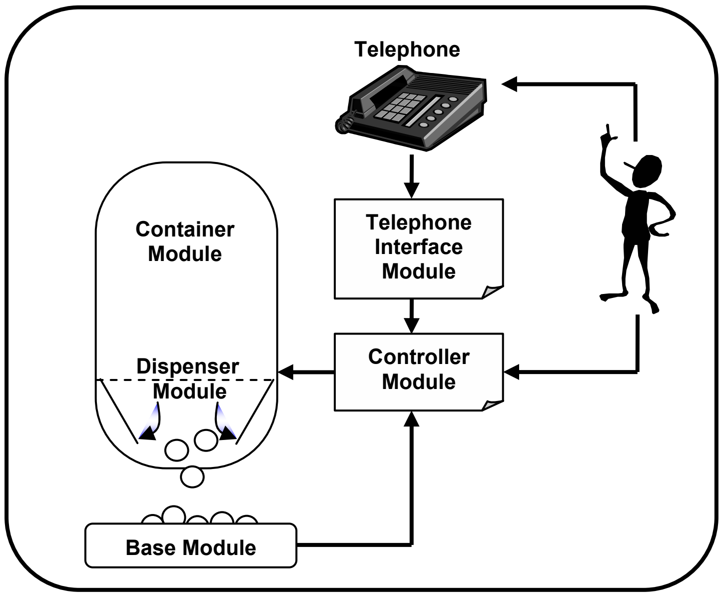

Figure 1: System Overview Block Diagram

The MEO system consists of five modules: Controller, Telephone Interface, Dispenser, Container 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.

4. System Modules

4.1. Controller

The primary function of the controller is to provide means for processing all signals from other modules and receiving user inputs.

4.1.1. Possible Solutions

4.1.1.1. Controller

The possible solution is to find a micro-controller unit (MCU) that has moderate processing speed, sufficient internal memory, and low cost. Suitable MCUs for the design include the Motorola 68HC11 and Microchip PIC micro-controllers. Digital Signal Processors (DSP) can also be used as the system's controller.

4.1.1.2. LCD

There are two LCD devices to be considered for interfacing with the user: LCD from PIC demo board and LCD DMC-20434N-B. LCD DMC-20434N-B is preferred because it can display 2 additional lines compared to the LCD on PIC demo board.

4.1.2. Proposed Solution

4.1.2.1. PIC16F877

The MCU that will be used in the design is the Microchip PIC16F877. The MCU is chosen because it is relatively inexpensive, has a large number of I/O pins for peripheral devices and control signals. The PIC16F877 has 35 single word instructions available for programming.

The PIC16F877 is a CMOS Flash-based 8-bit MCU. The MCU consists of an 8K CMOS flash memory space, 256 bytes of EEPROM data memory, and 368 bytes of RAM. The operating voltage for the PIC16F877 is between 2.0V to 5.5V.

The main program will be written in the flash memory. The flash program memory is available for use in the development process since it is erasable. Software development will be done on a PC and programmed onto the MCU via the PICSTART Plus programmer. Program code will be written in assembly language.

The PIC16F877 MCU has 40 pins. Among these 40 pins, 33 are available for I/O usage, each with individual direction control. Figure 2 shows the pin diagram for the micro-controller.

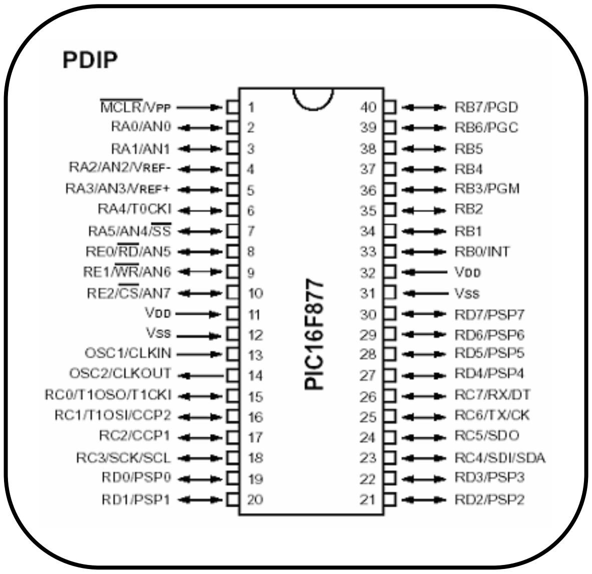

Figure 2: Pin Diagram of PIC16F877

Table 1 shows the number of pins that are required for the different devices to be interfaced with the MCU.

Table 1: Pin Assignments of MEO system

Devices	Pins Requirements	I/O Pins Direction
Motor	4	Output
Off hook relay	1	Output
DTMF decoder	7	Input/Output
LCD	11	Output
A/D converter	1	Input
Proximity sensor	1	Input
Ring detector	1	Input
Keypad	4	Input
Empty Status LED	1	Output
Total	**30**	

4.1.2.2. LCD DMC-20434N-B

The LCD is able to display 20x4 characters (i.e. 4 lines and 20 characters at each line). Table 2 summarizes the I/O pins of the LCD needed to interface with the MCU.

Table 2: LCD I/O Pins to MCU

Data Bus	8
Start Signal for R/W Operation	1
R/W Line	1
Register Select Line	1

Figure 3 shows the functional block diagram of the LCD. V_{cc} is to be connected to a 5V source.

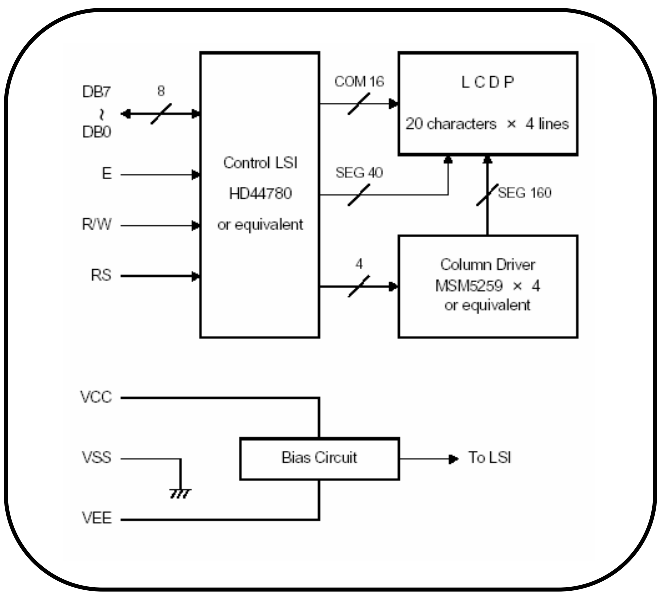

Figure 3: Functional Block Diagram of LCD

The contrast of the LCD can be adjusted by using potentiometer, as shown in Figure 4.

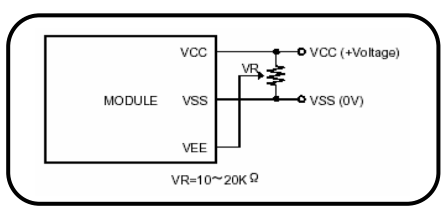

Figure 4: Adjusting the Contrast of LCD

4.1.3. Implementation

The LCD will be programmed to display the status of the overall system. The function of the keypad is to provide an interface between the user and the device.

The MCU will be implemented through an assembly-based program. The other modules will interface with the MCU I/O pins.

The Telephone Interface module receives phone calls and uses a ring detector to send a signal to the MCU. Based on this signal, the MCU will count the number of rings and activate the MEO system. The Container acts as the storage facility for the dry cat food and uses a proximity sensor to detect the status of cat food. The empty status of the container will be sent to the MCU and a LED will be activated accordingly. The Dispenser will receive instructions from the MCU to initiate transferral of food from the Container to the Base. The Base consists of the bowl that the cat eats from and a sensor to determine the amount of food in the bowl. The food information is fed back to the MCU for monitoring the cat's diet and controlling the Dispenser. The cat's diet will be displayed on the LCD.

4.1.4. Test Plan

- The MCU can be tested using the pre-programmed code provided by Microchip.

- The functionality of the MCU will be tested gradually as different module's software is being developed.

4.2. Telephone Interface

The Telephone Interface module is required to perform functions such as ring detection, phone off-hook, and DTMF decoding.

4.2.1. Possible Solutions

4.2.1.1. Protection Circuitry

Since the voltage across the pair of the line can be as high as 150V during ringing, the module will have to be isolated to protect electronic components such as the MCU and DTMF IC. Possible solutions are to use optoisolators, solid-state relays and transformers as protection circuitry.

4.2.1.2. DTMF Decoder

To decode remote user commands, a standard DTMF receiver IC can be used.

4.2.2. Proposed Solution

4.2.2.1. TS117 Optocoupler and Relay

Clare's TS117 IC contains an optocoupler and a solid state relay in a single 8-pin package. The internal circuit diagram of the IC is as shown in Figure 5.

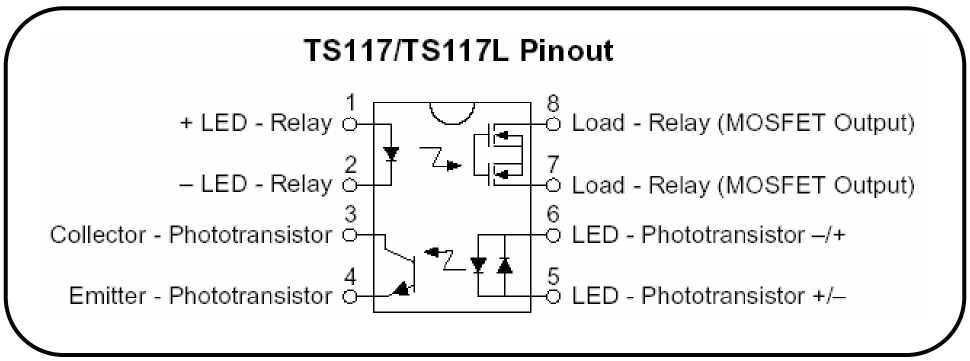

Figure 5: TS117 Circuit Diagram

The TS117 chip will serve two functions. The bottom half is the optocoupler, which will be used in the ring detection circuit. The upper half of the IC will be used as the relay that will be controlled by the MCU to pick up phone calls. When a phone call is picked up, the phone line is in the off hook condition.

4.2.2.2. Hybrid Transformer

A one to one hybrid transformer will be used to transfer voltage signals to the DTMF decoder. The purpose of the transformer is also to isolate the telephone line from the rest of the electronics.

4.2.2.3. M-8870 DTMF Receiver

Once the phone is off hook, the Telephone Interface module needs to decode tones that represent the numbers pressed by the user. The M-8870 DTMF receiver IC, which is also made by Clare, is a standard design and is suitable for use in this module. Figure 6 shows the pin configuration of the IC.

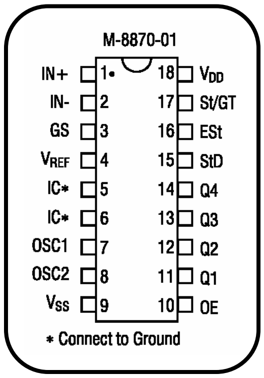

Figure 6: Clare M-8870-01 DTMF Receiver

4.2.3. Implementation

Figure 7 shows the block diagram of the Telephone Interface module and its communication with the Controller module.

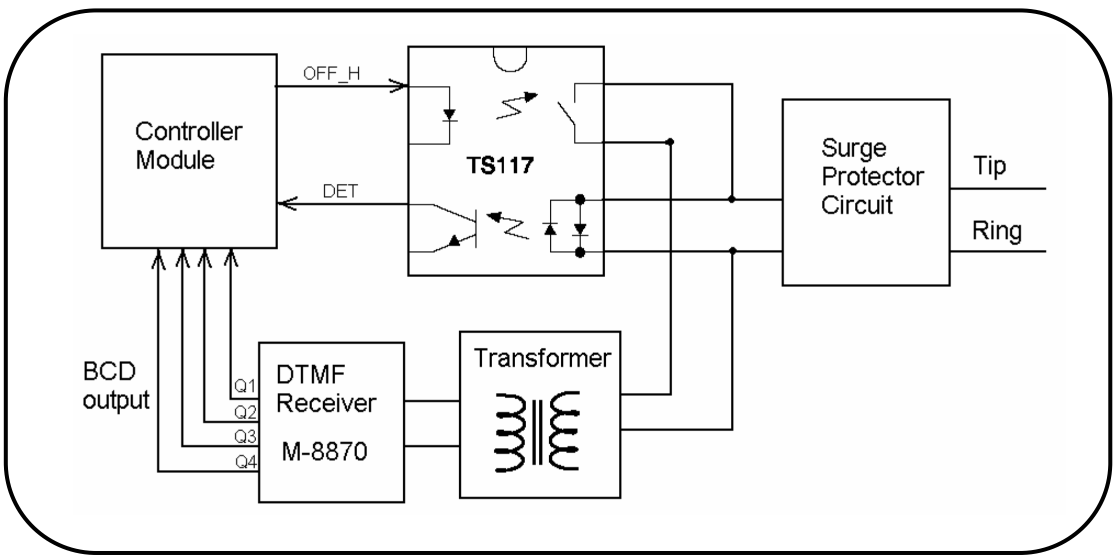

Figure 7: Block diagram of telephone interface module

In Figure 7, the tip and ring are the two telephone wires. A surge protector circuit will be used to prevent accidentally triggering the ring detection circuit by sudden surges in the signal. When an actual phone call comes in, the ring detection circuit will be triggered and generate pulses on the DET signal line. The Controller module will then set OFF_H signal high after several rings to close the relay switch and simulate the off hook situation of the phone. Once the call is established, the DTMF tones sent by the users are passed to the M-8870 DTMF receiver through the hybrid transformer. The decoded number will be output to the controller module in BCD format on lines Q1 – Q4.

4.2.4. Test Plan

4.2.4.1. TS117

- Apply AC current to pin 5 and 6 and measure whether the phototransistor on pin 3 and 4 conducts with some passive components such as LED or resistor. Use a function generator instead of the actual phone line to drive pin 5, 6 to avoid shock or damage to electronics equipment.

- Apply 5V DC across pin 1 and 2 and detect whether the switch across pin 7 and 8 closes.

4.2.4.2. Transformer

- Apply an AC signal on the primary windings and measure the voltage waveform that appears on the secondary windings.

4.2.4.3. M-8870 DTMF decoder

- Supply DTMF tone signals to pin 2 and observe whether the output appearing on pin 11 – 14 represents the correct number in BCD format.

4.3. Container

The container functions as the main storage area of cat food to be dispensed to a pet's bowl. If the container is empty, feedback will be provided through the MCU controlled LED.

4.3.1. Possible Solutions

4.3.1.1. Materials and Shape

The possible materials that can be used to construct the container unit include plastics, metals and ceramics. Workable container shapes range from pure rectangular, pure cylindrical, cone and hybrids of the three.

4.3.1.2. Proximity Sensor

A proximity sensor will be used to detect if the container is empty. The proximity sensor can either be mounted such that the beam points horizontal towards the bottom of the container or attached to the lid of the container having the beam pointing downwards. Analog or digital proximity sensors can be used for the design. Sharp has a variety of proximity sensors such as the GP2D12 analog and GP2D15 digital sensors.

The output of the proximity sensor (full/empty status) can be used to provide feedback to the user via a LCD or LED. In the case of the LED, the full/empty status can be connected directly or can be MCU controlled.

4.3.2. Proposed Solution

4.3.2.1. Plastic Container

The container will be constructed from plastic because it is cost-effective, non-conductive and maintenance friendly. The shape will predominantly resemble a cylinder with cone features toward the bottom of the container. With such a shape, food residual will be minimized.

4.3.2.2. GP2D15 Digital Proximity Sensor

To eliminate the overhead associated with analog to digital converters, a digital proximity sensor will be used. The proximity sensor's beam will point horizontally such that when the container is detached for cleaning, the sensor will remain intact in the main system. A vertical mount would require waterproofing the sensor to prevent damage when maintenance is performed.

Sharp's GP2D15 digital proximity sensor will use a factory set trigger point of 24cm (±3cm). The trigger point can be set to a different value when ordered for manufacturing.

A block diagram of the internal details of the GP2D15 is shown in Figure 8. Note that an external 12KΩ pull-up resistor is needed at the output of the sensor.

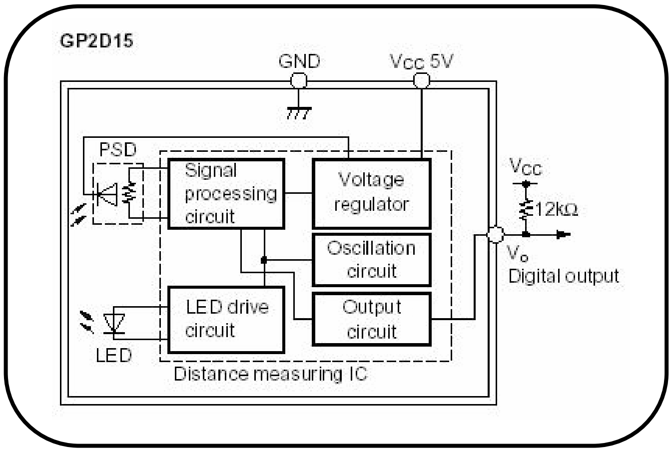

Figure 8: Internal Block Diagram of GP2D15

Also, the GP2D15 has hysteresis of 1cm to prevent output toggling. The distance characteristic of the GP2D15 is shown in Figure 9.

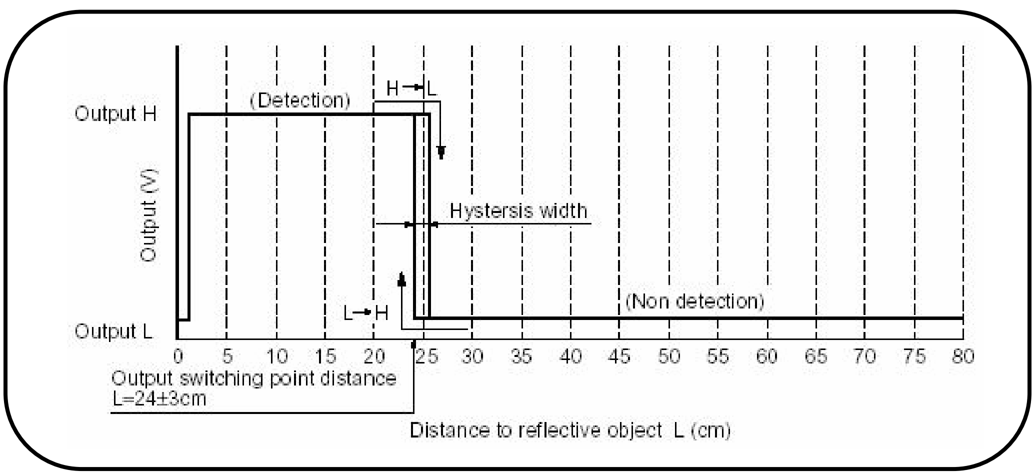

Figure 9: Distance Characteristics of GP2D15

A LED will be used for user feedback. The lumination of the LED will be controlled by the MCU in order to enclose the management of the system in the Controller module. Additionally, if the hysteresis of the sensor is not sufficient in delivering a stable LED output, the MCU can help alleviate the problems.

4.3.3. Implementation

Figure 10 shows a representation of the details of the container module.

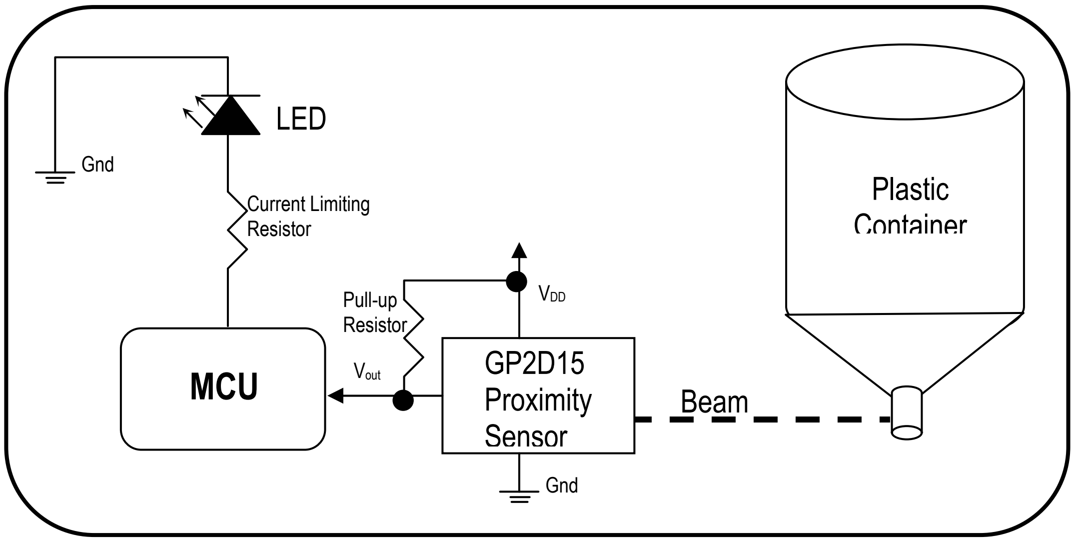

Figure 10: Implementation Details of Container Module

The pull-up resistor is needed for the proximity sensor's internal output logic. The current limiting resistor is used to protect the LED.

Among the components in the container module, only the proximity sensor requires power in order to operate. The supply voltage can range from –0.3V to 7V. Therefore, the proximity sensor can derive its power from the same source as the MCU. The output of the sensor will be connected directly to an I/O pin of the MCU. Based on the sensor signals, the MCU will be able to determine if the container is empty. The operating temperature of the proximity sensor is –10 to 60°C.

4.3.4. Test Plan

- Connect the GP2D15 proximity sensor pins as follows:
  VDD to 5V
  GND to 0V
  V_{out} to cathode of LED
  Gradually move your hand towards and away the sensor lens while observing the distance in which the LED illuminates. Ensure the distance is approximately 24cm.

- Connect the proximity sensor, MCU and LED as shown in Figure 10. Now block the passage at the bottom of the plastic container. By doing so, food cannot be transferred from the Container module to the Dispenser module. Open the lid of the container. Fill the container to maximum capacity. Check that LED is off. Gradually remove food from the container until the LED is illuminated. Measure the food removed and the food remaining in the container. Check if the leftover food in the container does not exceed 5% of the original amount deposited.

4.4. Dispenser

The primary function of the Dispenser module is to transfer cat food from the container to the bowl. In order to perform the task of transferring food, the module must have a mechanism that physically moves the food from the container to the bowl and respond accurately to the Controller's instructions.

The Dispenser module will use gravity as the driving force to transfer the food from the container into the bowl. A motor will be used in conjunction with an auger shaped bit to transfer the food.

4.4.1. Possible Solutions

4.4.1.1. Motor

Some of the types of motor that can be used are AC motors, DC motors and stepper motors. AC motor is rejected in the design because of the complexity associated with the operation of the AC motor. Although DC motor provides a lot of torque, it does not allow precision control by the Controller to dispense the required amount of food accurately without adding the overhead of a braking system. Finally, the stepper motor is the chosen motor in the design because it can be easily controlled with high precision by a MCU. The stepper motor has a lower torque output than the AC or DC motor but because an average of 50g of cat food is dispensed at a time, the low torque output of the stepper motor is adequate.

4.4.1.2. Auger Shaped Bit

Nekotek engineers can make the auger shaped bit out of a large diameter wood dowel. However, this may not be wise since the wood may interact with the cat food. The alternative is to use off-the-shelf auger bits that can be easily integrated into the design. Some of the auger bits are made of stainless steel and thus do not react with the cat food.

4.4.2. Proposed Solution

4.4.2.1. Bipolar Stepper Motor

The bipolar stepper motor is used as the driving force to transfer the food from the container to the bowl. The torque output of the stepper motor must be sufficient to overcome frictional and rotational acceleration loads.

The shape of the load (i.e. the auger bit and the cat food) is assumed to be cylindrical with different centre and outer masses. The centre mass is that of the auger bit and the outer mass is the cat food. The inertial load is calculated using Equation 1.

Equation 1: $I = \frac{1}{2}M_1R_1^{\ 2} + \frac{1}{2}M_2R_2^{\ 2}$

I = Inertial load (kg-m^2)
M_1 = Auger Bit (kg) = 0.5kg
R_1 = Radius 1 (m) = 0.01m
M_2 = Cat Food (kg) = 0.3kg
R_2 = Radius 2 (m) = 0.025m

Equation 2[1] is used to calculate the required torque.

Equation 2: $T = \frac{2I\omega}{t} \times \frac{\pi\phi}{180} \times \frac{1}{24}$

T = Required torque (oz-in)
I = Inertia load (lb-in^2)
ϕ = Step angle (°) = 7.5°
ω = Step rate (steps per second) = 48
t = Time (seconds) = 1s

Thus the calculated required torque of the stepper motor is approximately 0.212 oz-in. The Thomson 55M048D1B bipolar stepper motor is chosen for the application and has the specifications shown in Table 3.

[1]http://zone.ni.com/devzone/prenticehall.nsf/webmain/FC873A0E31F13E928625683F006D5803?opendocument

Table 3: Specifications of Thomson Bipolar Stepper Motor (55M048D1B)

DC Operating Voltage (V)	5
Resistance per Winding (Ω) ±10%	5.2
Inductance per Winding (mH) ±20%	9.6
Holding Torque* (min, mNm/oz-in)	236/33.5
Detent Torque (max, mNm/oz-in)	38.8/5.5
Step Angle	7.5°±5°
Steps per Revolution	48 Steps
Rotor, Moment of Inertia (gm^2)	5.56×10^{-3}
Insulation Resistance at 500Vdc	100 MΩ, min
Lead Wire Type	AWG #26, UL1430 (105°C, 300V)
Bearing Type	Sintered Bronze Sleeve
Max Operating Temperature	100°C
Ambient Temperature Range	Operation: -0°C to 60°C Storage: -40°C to 85°C
Dielectric Strength	650±50Vrms, 50Hz, for 1 to 2 seconds
Weight (g/oz)	270/9.5

* Measure with 2 phases energized

4.4.2.2. Driver

Figure 11 shows how the MCU, stepper motor and auger bit will be interfaced together.

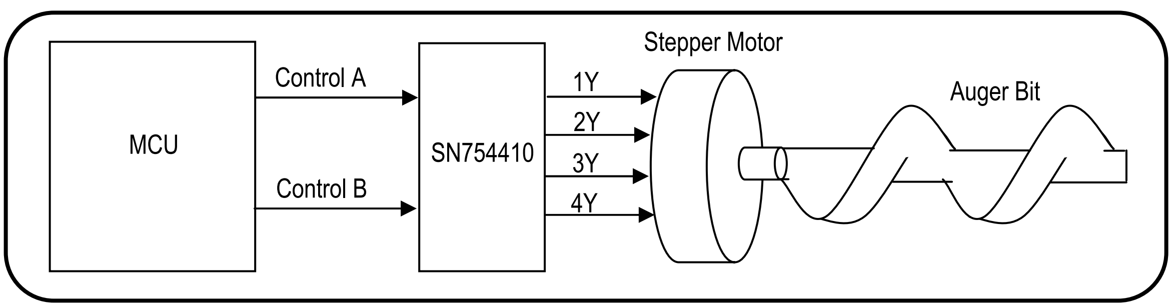

Figure 11: Implementation of Dispenser

The SN754410 driver will interface to the bipolar stepper motor as shown in Figure 12.

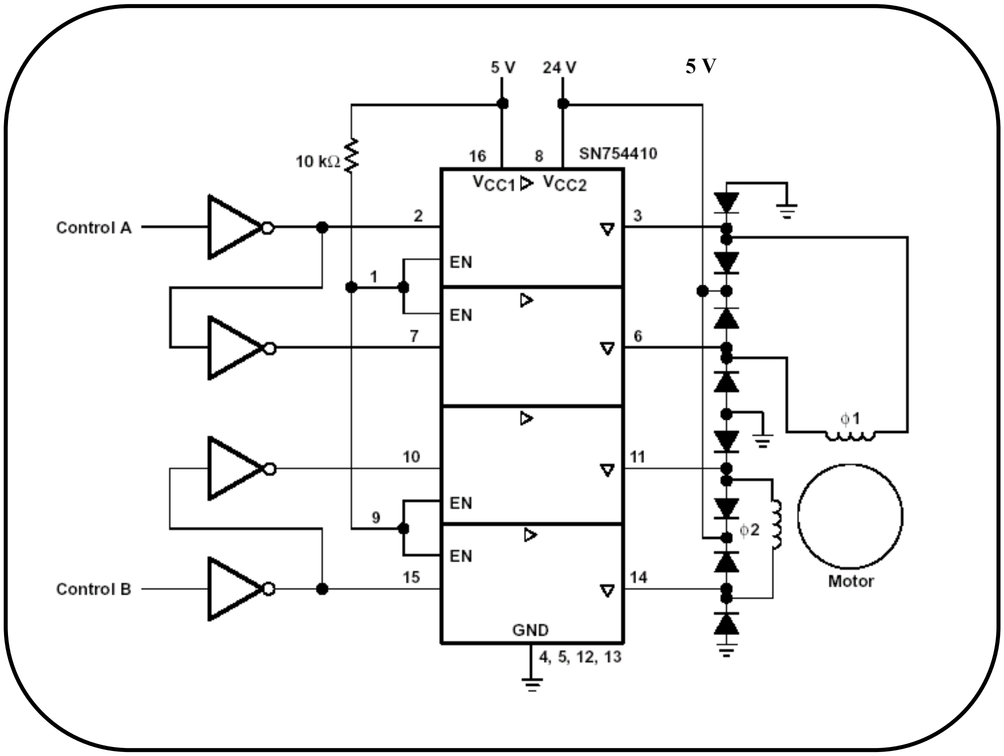

Figure 12: Connection Between SN754410 and Bipolar Stepper Motor

Control A and B are connected to the MCU of the Controller module. The MCU is responsible for sending the correct sequence of instruction to the SN754410 driver to correctly step the motor. Table 4 shows the sequence for stepping the motor.

Table 4: Instruction for Stepping Motor

	Step	Control A	Control B	
CCW Rotation ↓	1	High	High	CW Rotation ↑
	2	High	Low	
	3	Low	Low	
	4	Low	High	
	1	High	High	

4.4.3. Test Plan

4.4.3.1. Bipolar Stepper Motor

- Without powering the stepper motor, observe the torque required to manually turn the shaft.

- Apply 5V to the 2 phases of the motor and observe the torque required to manually turn the shaft. If a greater torque is required to turn the shaft while energized, then the stepper motor is working.

4.4.3.2. SN754410

- Connect a 5V source to V_{cc1} and V_{cc2}. Enable the driver by applying 5V to pins 1 and 9. Input a square wave into pin 2 and observe output on pin 3. If the input and output square wave matches, then the half driver is working.

- Repeat the procedure of inputting a square wave and observing the output to ensure the other 3 half drivers are working.

4.5. Base

The Base module consists of two parts: sensors for detecting amount of food in the bowl and op-amps for amplifying the signal from the sensor. There are several considerations in choosing the parts used for the design of the Base module.

4.5.1. Possible Solutions

4.5.1.1. Weight Sensors

Proximity sensors can be used for detecting the amount of food in the bowl. The sensor beam will check if the amount of food has reached a certain level. However, the proximity sensor can only detect one specific location in the bowl. If the amount of food in the sensor area has reached the required level, the sensor will send a signal to the MCU to stop the dispensing process. A problem will arise when the food in other areas has not reached the required level, and the dispensing process already stopped. Resultantly, error in detection will occur. Proximity sensors do not provide the required precision in measuring the weight of the food in the cat's bowl.

Weight sensors can provide improved precision in food measurement required for the diet-monitoring feature of MEO. There are two types of weight sensors to be considered: pressure sensors and strain gages. Strain gages are preferred because it is more cost-effective and two members of Nekotek have prior experience in mounting and using strain gages.

4.5.1.2. Operational Amplifier

The signal from the weight sensor has a very low voltage output for direct input to the MCU; therefore, it has to be amplified first. Standard operational amplifiers may not be able to amplify the low-level signal produced by strain gages due to noise voltage. Additionally, the offset voltage associated with standard op-amps may be substantial with respect to the strain gage output.

Chopper-Stabilized Amplifiers are an ideal choice for implementing MEO's Base module, because it can provide extremely high DC precision and reduce noise voltage significantly in low-level signal processing application.

4.5.2. Proposed Solution

4.5.2.1. Strain Gages CEA-Series

Strain gages are used for detecting any material deformation, which could be used to acquire weight information of the material. The strain gage works like a resistor, but its resistance is changed when deformation takes place. The initial resistance of the CEA-Series strain gage is 120 Ω and the gage factor is 2.055. Figure 13 shows the shape of the strain gages used for MEO.

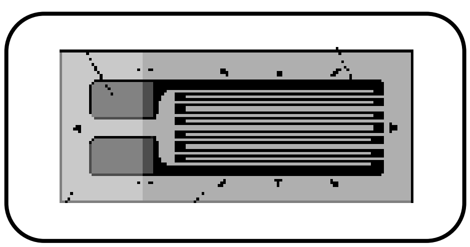

Figure 13: Strain Gage Diagram

In order to detect material deformation, the strain gage has to be mounted on the material.

4.5.2.2. Chopper-Stabilized Amplifier TLC2652

Chopper-Stabilized Amplifiers will amplify the low-level signal produced by strain gages effectively and send the signal directly to the MCU. Figure 14 shows the functional block diagram of TLC2652.

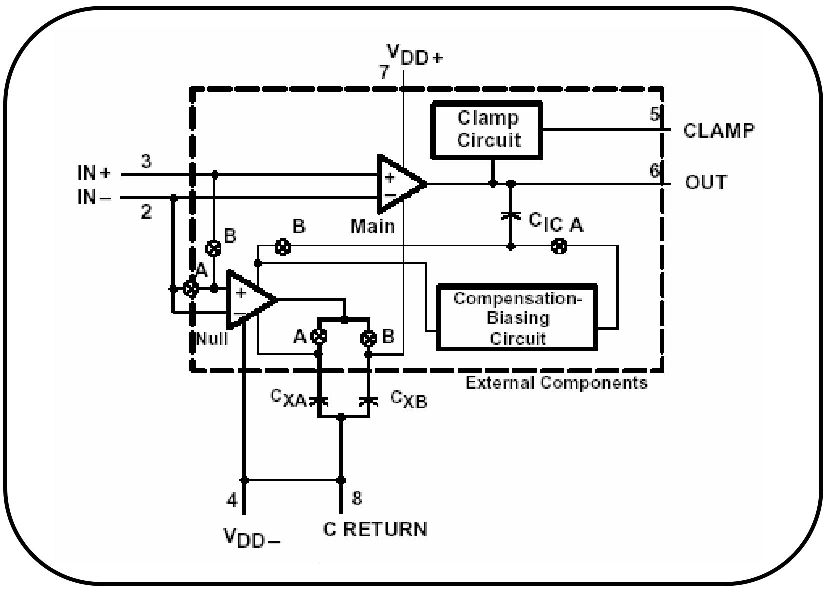

Figure 14: Functional Block Diagram of TLC2652

4.5.3. Implementation

The strain gages will be mounted on an aluminium cantilever beam. Using the Wheatstone Bridge Null Imbalance method, weight measurement can be accomplished. The method works as shown in Figure 15.

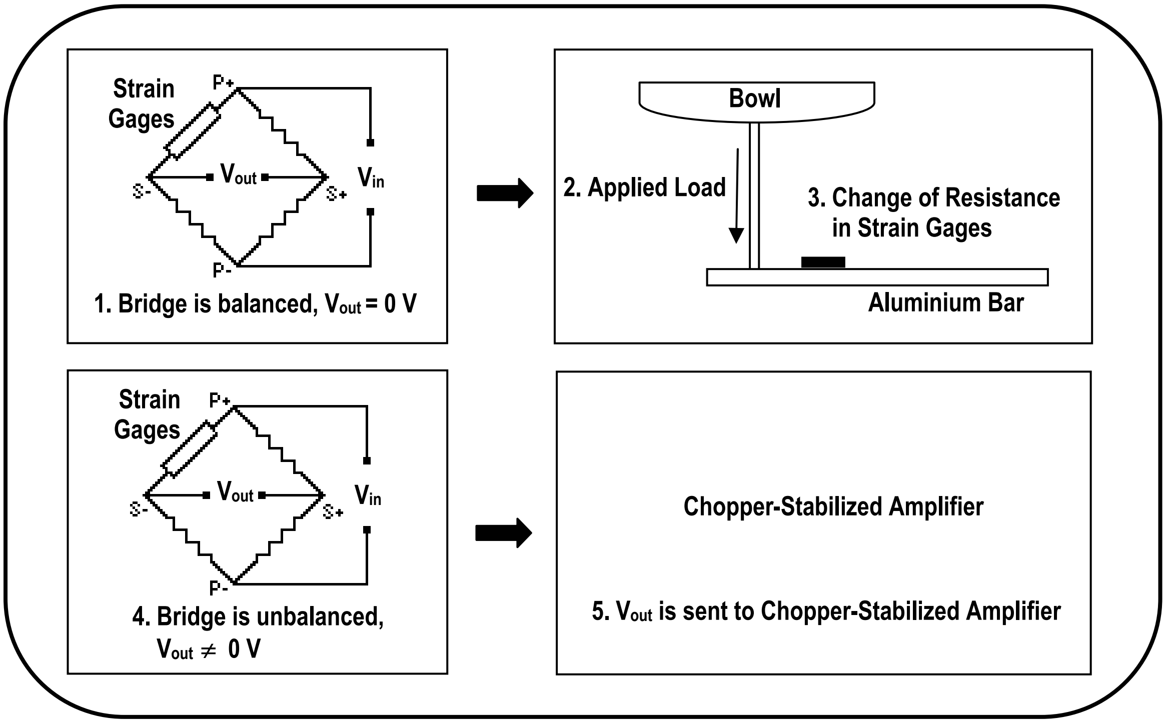

Figure 15: Wheatstone Null Imbalance Method

First the bridge has to be balanced carefully, so that $V_{out} = 0$. Once the load is applied to the aluminium beam, the resistance of the strain gage will change, resulting in an unbalanced bridge. The unbalanced voltage will be sent to the amplifier for further processing. Finally the amplified voltage will be transmitted directly to MCU.

The amplified voltage is in an analog form, which means that it has to be converted to a digital form to be processed by the MCU. The MCU has 10 bit A/D converters that will handle the conversion process. Inside the MCU, the digitized voltage value will be computed for finding the weight value. Using the weight value, the MCU will decide whether it will stop the dispensing process or not.

4.5.4. Test Plan

- The strain gage is connected with three 120 Ω resistor to form a wheatstone bridge (i.e. wheatstone bridge is shown in Figure 15). Then, V_{in} of the bridge will be connected to a 5V source. When no load is applied, the value for V_{out} is constant. Next, a load is applied to the bar. A change in V_{out} indicates the strain gage is working.

- The op-amp will be powered by supplying an 8V source. The voltage from the strain gage is connected to the input of op-amp. Then, the output and the input values of op-amp should be compared. An output is larger than the input indicates the op-amp is working.

- The bowl will be put on top of the aluminium bar, as shown in the Figure 15. The value of V_{out} and the weight of bowl and the bowl-holder will be recorded as the initial value. Cat food will be put in the bowl gradually to increase the weight. For every increase in weight, the value of V_{out} will be recorded. The test is performed in order to find a linear relation between V_{out} and weight.

5. User Interface

One of the goals of Nekotek is to provide MEO with user-friendly interface, so that the user can interact with the system without encountering any problems. The user interface in Figure 16 is designed to meet this requirement.

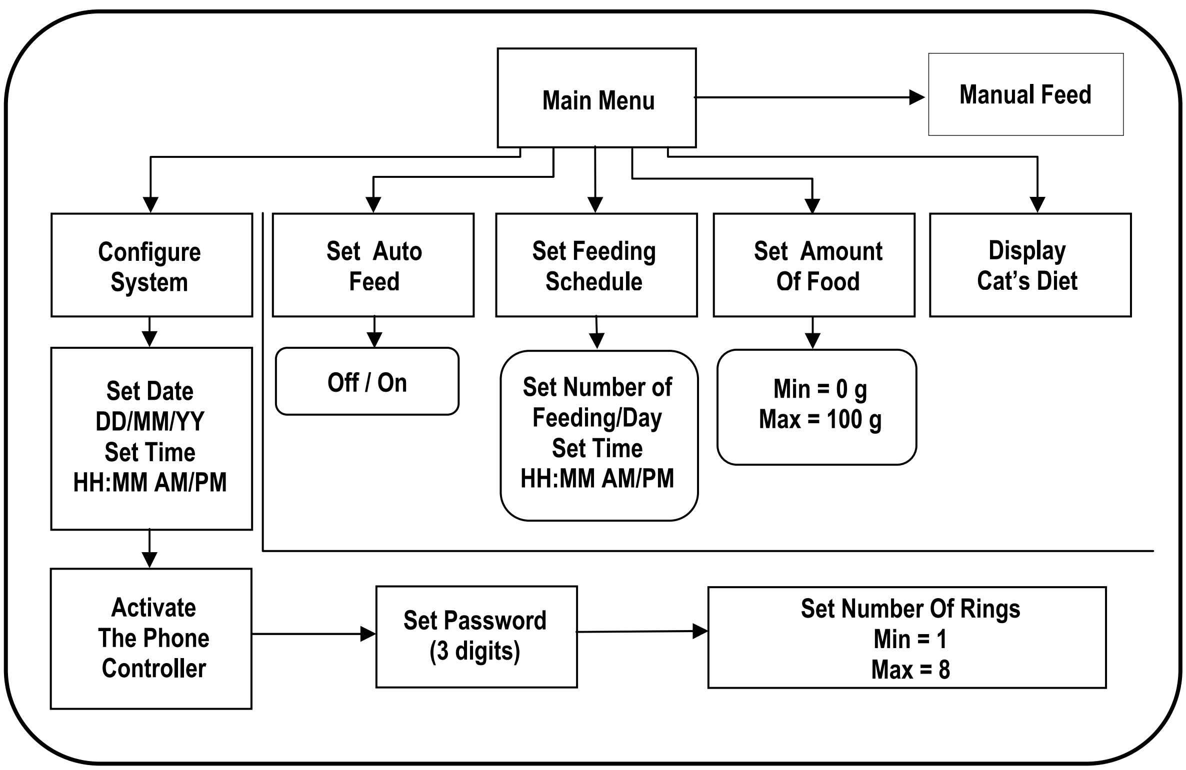

Figure 16: MEO's User Interface

5.1. Test Plan

- Each of the 5 submenu programs under the main menu will be written in assembly language and tested separately.

- After each submenu program is verified to be working correctly, it will be integrated into the main menu program and the main menu program will be tested thoroughly.

6. Conclusion

This design specification document outlines the detailed implementation of the MEO automatic cat feeder device. This document also provides Nekotek engineers with a good foundation and clear understanding of the design process. Each individual module is designed to meet the requirement listed as in the functional specification document. Test plans are also provided for each module to ensure correct functionality and smooth integration of the final product.