EEL 5666: Intelligent Machines Design Laboratory

The PET PAL

Author: Seth Reed Lakritz
Student #: 1520-7760
Due Date: 8/7/03
Instructor: A.A. Arroyo & Dr. E. Schwartz

Table of Contents

Abstract----------

The pet pal is an autonomous robot built to feed and entertain a bored pet while its owner is not at home. At certain user programmable times during the day/night, the PET PAL autonomous pet playmate comes alive and calls for the pet using very high frequencies that only a pet can hear. While emitting this high frequency sound, the PET PAL plays a recording of the owner saying something such as "Come here" – this way the pet associates the PET PAL with the his/her owner. After "seeing" the pet, the PET PAL dispenses tasty treats for the pet to consume. After consumption, the PET PAL plays with the pet using three of its built-in entertainment modules. First it throws a ping pong ball and plays "fetch" with the pet (something a dog would love). After playing "fetch" for a user programmable set of "throws/returns", the PET PAL releases string behind it and then proceeds to run around the room dragging the string behind it (cats are fond of this). Lastly, the string is retracted and an on board laser pointer is turned on. This emits a laser dot onto the wall which pets can chase. The PET PAL then runs around the room projecting the laser in front of it everywhere it goes. After a certain amount of time, the PET PAL will then enter hibernation mode, where it "sleeps" until next time. Hopefully the pet will sleep as well at this point – happy and with a full stomach.

Executive Summary----------

The PET PAL performs all the necessary functions required by the Intelligent Machines Design Lab. It performs object avoidance and incorporates special sensors in its functionality (CDSL, IR beacon/receiver, Voice Chip).

The PET PAL's behaviors are as follows:

- At certain programmed intervals during the day the PET PAL will emit high frequency noise to get the attention of the pet as well as playback a pre-recorded message from the owner asking the pet to "Come here" for example. It will then perform basic object avoidance while "looking" for the pet.
- As soon as the pet gets close enough, the PET PAL will dispense tasty treats for the animal while playing another message from the owner.
- After the pet is finished eating, the PET PAL will "play fetch" with it by throwing ping pong balls around the room and then let the pet fetch and return the ball.
- Following the "fetch" routine, the PET PAL will release a set amount of string behind it and then perform basic object avoidance while the pet chases the string from behind. After a set amount of time the PET PAL will "reel" the string back.
- The last phase involves the PET PAL turning on its on-board laser pointer and then performing object avoidance while the pet chases the laser which will be projected on the nearest wall in front of the PET PAL.

The ability to perform these activities consistently shows that the robot, while not perfect in design by any means, is indeed capable of exhibiting "intelligent, autonomous" behaviors. Therefore overall the PET PAL project is a success.

Introduction----------

The Pitch:

Hey all! Welcome to the next generation in pet care technology! Meet the PET PAL – a revolutionary pet care device developed to provide your dog or cat with the ultimate at home experience while you're not at home!

Pets can get lonely too! This is the perfect tool to combat the "pet blues" as well as a great device to make an owner's life easier – especially since the PET PAL feeds and entertains the animal for them when they are not at home. Overall, this robot will lead to a happier pet.

The PET PAL performs various tasks to accomplish the above. What it actually does and how it performs the tasks can be found in the following report.

Integrated System----------

Main "brain" of the PET PAL is Atmel Atmega 128 microcontroller on a *Let at Work* development board.

The Atmega 128 connects to:

- 5 servo motors that perform various tasks such as movement, feeding, ball throwing, and string releasing
- 5 IR devices (including IR rangers and receiver) used for object avoidance as well as pet "detection"
- 4 bump switches used for object avoidance
- Serial connection used for computer debugging and robot feedback
- Voice Record/Playback chip used to playback user recorded messages to the pet.
- Laser pointer which is used as an entertainment device
- CDSL sensor used to detect a "ball return" during the fetch stage.
- Piezo speaker used to emit "high frequency" noise to get the pet's attention (similar to a dog whistle)
- 8 LED array used for debugging and feedback purposes.

The following is a simple block diagram illustrating the connections between various devices and the Atmega 128. These allow the PET PAL to perform the actions discussed in the abstract and the executive summary.

PLEASE SEE HARD COPY FOR DIAGRAM

Figure 1: Block diagram of system connections.

Initially, the PET PAL's systems were integrated on a protoboard so that functionality could be quickly achieved. Eventually the wiring became chaotic and it was suggested that Protel be used to design a board to help get rid of the "bird's nest". Here is the attempted Protel design.

The Schematic:

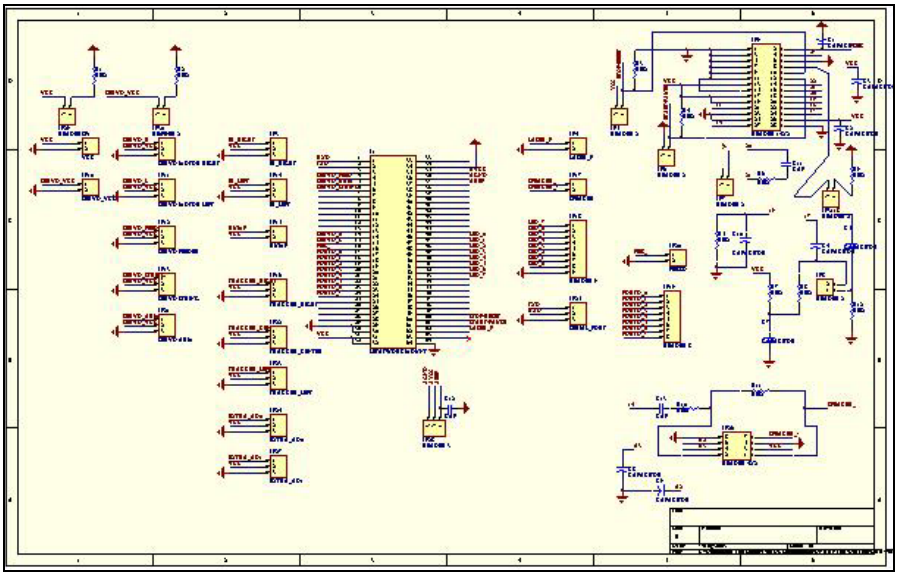

Figure 2: Protel schematic design

The PCB layout.

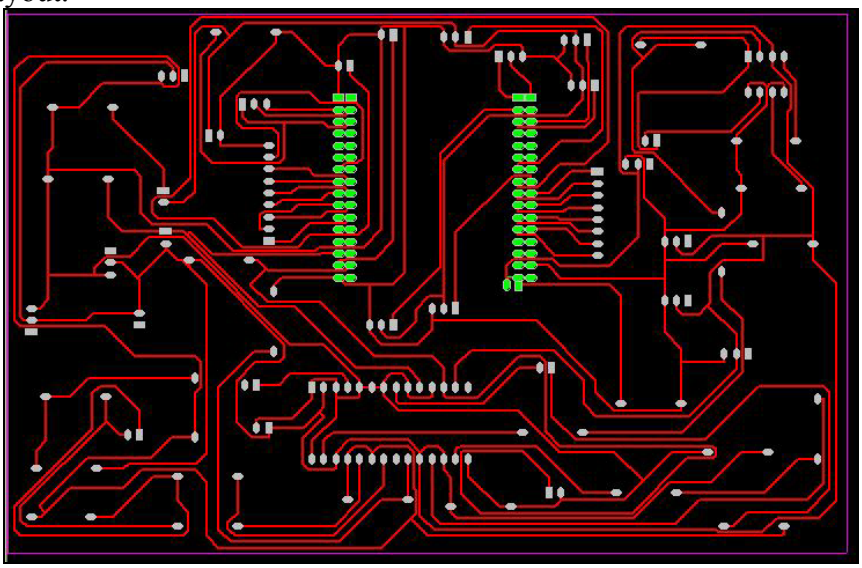

Figure 3: Protel PCB layout

Unfortunately, the Protel design did not perform as well as expected and it was abandoned. The final demo of the PET PAL was conducted using a protoboard again. However, the "birds nest" was significantly reduced since appropriate length wires were used. Labels were also utilized to assist in connecting and debugging components.

Mobile Platform----------

A basic mobile platform was initially utilized for the PET PAL. The platform consisted of mainly 1/8" thick wood provided by the IMDL lab. The design of the platform was performed on AutoCAD and 2 versions were constructed. The first revision consisted of a one level platform with a semi-circle front and a rectangular rear. Wheel holes were cut inside the platform and servo "braces" were also designed. Small rectangular holes were made behind the wheel holes to provide easy pass-through for the servo motor wires. Here is the initial design:

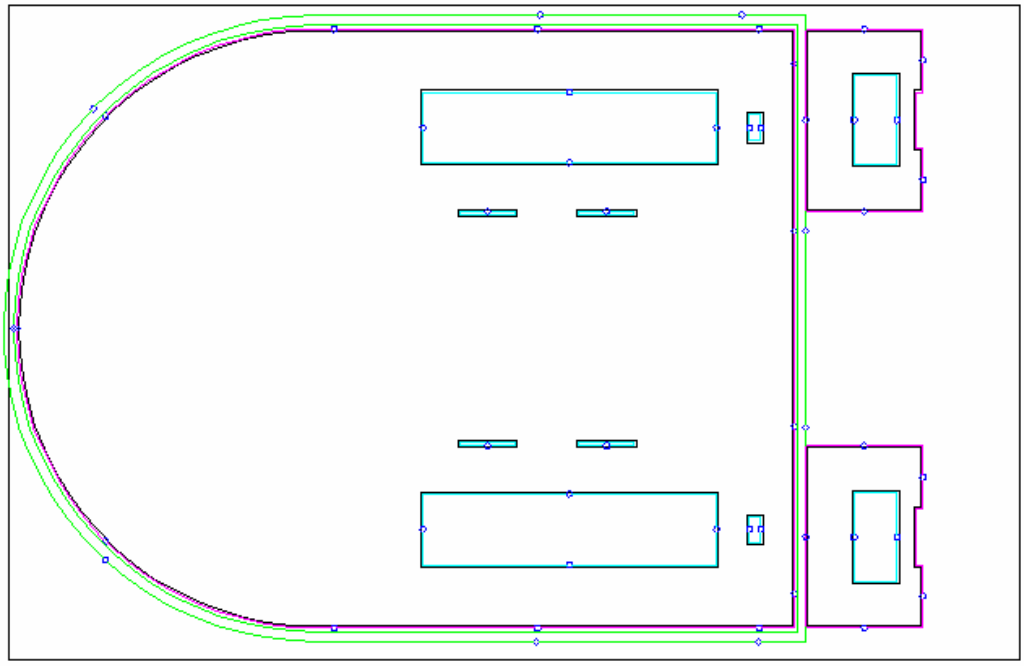

Figure 4: Initial Platform Design

At first, this design was meant to be very simple and very large, so as to provide as much space as possible for the extra components that were yet to be designed at the time. However, as the process of PET PAL development continued it became obvious that a simple one level platform would not provide enough room for all of the robot's modules as well as the controlling electronics. Therefore a second, two level, version was designed. This design allowed for the somewhat unsightly electronics to be concealed underneath the second level- where most of the modules would be attached (such as the feeder, and "fetch" mechanisms). Other improvements were made to the initial design, such as increasing the size of the wheel holes and providing extra support to the wheels by adding 2 more servo "braces". On the second level, many rectangular cuts were done so as to allow easy passage of wires to the modules positioned on that level to the first level electronics core. Also, the second level was designed to be easily detachable from the first, making it easy to work on the electronics underneath. This ease of access saved much time throughout the development process.

Here is a view of the two levels of the 2nd version of the platform.

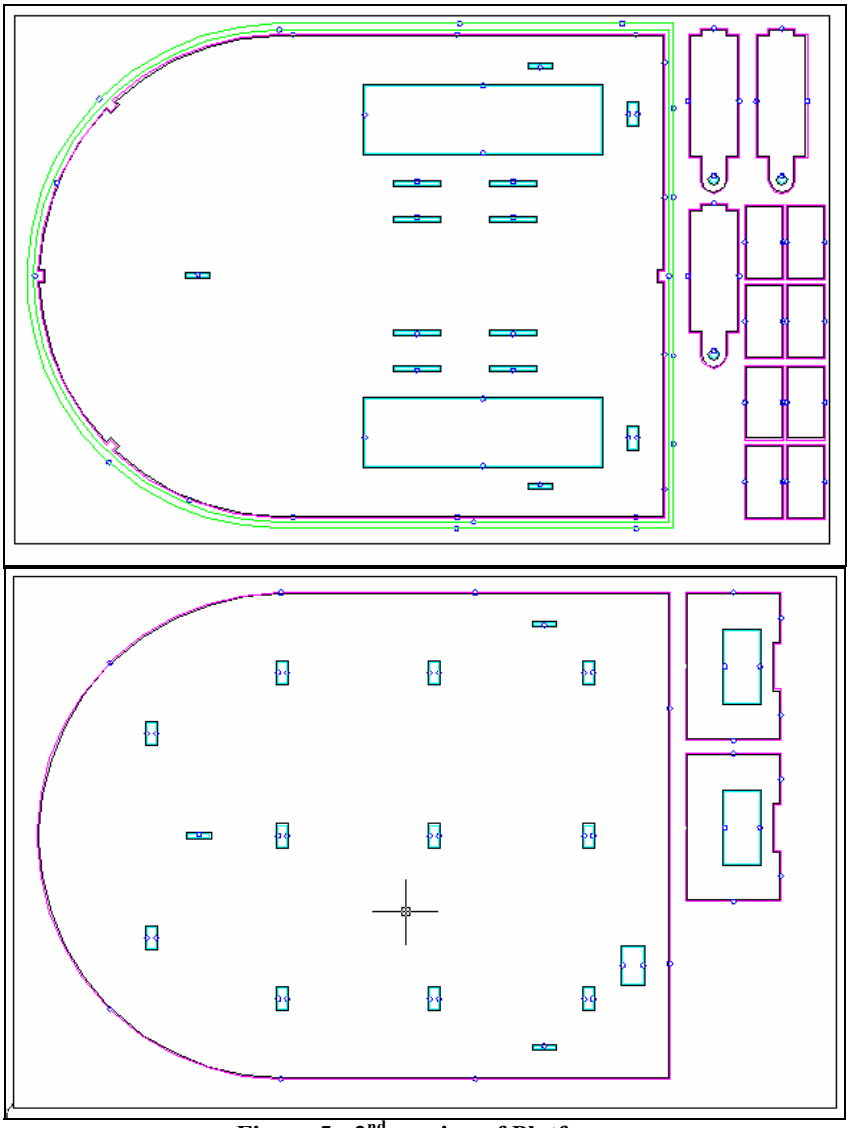

Figure 5: 2nd version of Platform

Actuation----------

The PET PAL features a great deal of "actuation" apart from the basic "object avoidance" behavior required from all of the IMDL projects.

As far as basic robot movement is concerned, the PET PAL utilizes 2 servo motors that are directly connected to tires on the first level of the platform. The PET PAL utilizes "3 point" movement and has a long screw with rounded top at the front of the robot. The two back servos connected to wheels provides the necessary forward and turning motions that the PET PAL needs.

The PET PAL also features movement in it's ping pong ball fetch "module" This module is equipped with a servo motor that powers it's "arm" that throws the ping pong ball.

The custom made PET PAL feeder also features a servo motor which is used to dispense a set amount of treats to the pet. It does this by turning a pipe clockwise and counterclockwise. This pipe has a compartment cut into it which holds the pet food. By turning this pipe, the servo is able to pour the food down a small ramp and onto the floor for pet consumption.

The "string" module present on the rear of the PET PAL also features a servo motor. The simple operation of this servo motor is to release and then reel in "string" from the PET PAL during the "string play" phase of PET PAL's entertainment program.

All of the motors found on the PET PAL are controlled by signals from the microcontroller. All of the servos were obtained in the "default" configuration meaning that they could only turn approx 180 degrees. The servos that needed to provide FULL rotation (wheel and string servos) "were" hacked to allow for complete 360 degree functionality. Servos were used instead of DC motors because they were equipped with their "control" electronics and did not need any extra circuitry such as a motor driver.

Sensors----------

The PET PAL utilizes many sensors to perform its goals of feeding and entertaining pets. Each sensor will be discussed as well as its relationship to robot performance.

Sensor: IR Ranger
Part Number: Sharp GP2D12
Vendor: Acroname
Quantity Utilized: 2
Application: The IR rangers are positioned at the "front" of the PET PAL and serve as the "eyes" of the robot and allow it to perform a basic but essential function - object avoidance. The rangers emit and receive IR. The IR is reflected off nearby objects, allowing the ranger to "gauge" how far away objects are. The output of these rangers is a varying voltage output which is connected to an A/D channel on the PET PAL's Atmega microcontroller. In short, the closer an object to the PET PAL, the higher that A/D values produced in the controller. By using these IR rangers, code was written to allow the PET PAL to avoid objects by turning left, right or backing up.

Sensor: Bump Switches
Part Number: N/A
Vendor: IMDL Lab
Quantity Utilized: 4
Application: Bump switches are used in conjunction with the IR rangers to perform object avoidance. The IR rangers have a limited "sight" area and therefore bump switches are utilized to allow the robot to sense if it has run into an object that the IR rangers did not see. Since there are limited A/D channels on the Atmega 128, a special circuit was constructed to so as to allow the bump switches to only take up 1 A/D channel. Here is the circuit.

PLEASE SEE HARD COPY FOR DIAGRAM

Figure 6: Bump switch circuit

Each switch, when pressed provided different voltages back to the processor so that it is easy to distinguish between which switch was pressed. These switches work together with the IR rangers to allow the robot to move left, right, or back up when necessary.

Sensor: IR Receivers
Part Number: LITE-ON LTM-9034
Vendor: Jameco
Quantity Utilized: 3
Application: The three IR receivers utilized are placed on the second level of the PET PAL platform. They allow the PET PAL to detect when a pet is in the room so it knows when to dispense food. The receivers were initially configured for a digital output but were "hacked" to provide analog signals to 3 A/D channels of the microcontroller. The "hack" was performed as follows (provided by Michael Hattermann – Spring 2002 IMDL student).

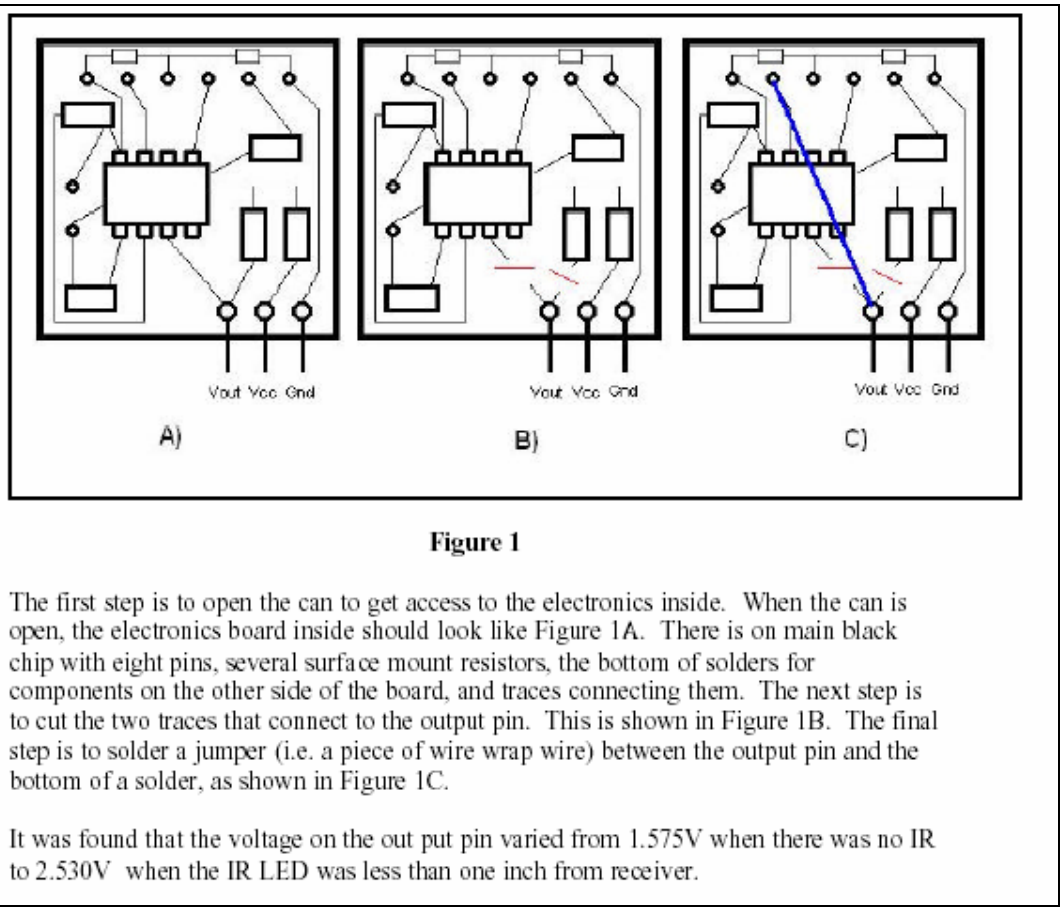

Figure 1

The first step is to open the can to get access to the electronics inside. When the can is open, the electronics board inside should look like Figure 1A. There is on main black chip with eight pins, several surface mount resistors, the bottom of solders for components on the other side of the board, and traces connecting them. The next step is to cut the two traces that connect to the output pin. This is shown in Figure 1B. The final step is to solder a jumper (i.e. a piece of wire wrap wire) between the output pin and the bottom of a solder, as shown in Figure 1C.

It was found that the voltage on the out put pin varied from 1.575V when there was no IR to 2.530V when the IR LED was less than one inch from receiver.

Figure 7: LITE-ON hack procedure

While a pet wears an IR emitting device – such as a TV remote control or IR beacon – on their collars, the PET PAL can detect when it is in the area. It is very important to note that this type of IR does NOT interfere with the IR rangers mentioned above. These IR receivers work at a frequency at 56.8KHz, much different from the rangers frequency. The "remote collar" also works at 56.8kHz, therefore also not affecting object avoidance capabilities. Like the rangers above, when a pet is in the area, the A/D values produced rise from their "low" values. This corresponds to an approx. .5V voltage change in the

output signal of the receivers. Simple code was written to correspond to the "sensing" of the pet.
Sensor: CDSL
Part Number: N/A
Vendor: IMDL Lab
Quantity Utilized: 1
Application: Utilizing a CDSL sensor in the "fetch" module of the PET PAL. The primary function of this sensor is to alert the PET PAL to a returned ping pong ball so that it can continue to play fetch with the pet. This sensor works by changing resistances based on the amount of light hitting its surface. In the design of the "return chute" the CDSL is somewhat "covered" from above lights that would make readings somewhat inaccurate. Also, an LED was place opposite the CDSL inside the shaft to further make the readings more accurate. Resistors and voltages were applied to the CDSL so that when less light is applied to the surface of the sensor, the voltage output decreases. This signal is also connected to an A/D channel on the microcontroller. When the ping pong ball goes down the chute, it rolls between the CDSL and the LED, therefore significantly reducing the amount of light shining on the sensor. This voltage change causes the written code to throw the ball again to continue the game of "fetch"

Sensor: Voice Playback/Record Chip
Part Number: ISD2590
Vendor: Jameco
Quantity Utilized: 1
Application: Used to record and playback messages from the pet's owner. Easy to use by itself or with a controller. Please read special "sensor" report for more details.

Behaviors----------

Simplified Actions in Order:

- At certain programmed intervals during the day the PET PAL will emit high frequency noise to get the attention of the pet as well as playback a pre-recorded message from the owner asking the pet to "Come here" for example. It will then perform basic object avoidance while "looking" for the pet.
- As soon as the pet gets close enough, the PET PAL will dispense tasty treats for the animal while playing another message from the owner.
- After the pet is finished eating, the PET PAL will "play fetch" with it by throwing ping pong balls around the room and then let the pet fetch and return the ball.
- Following the "fetch" routine, the PET PAL will release a set amount of string behind it and then perform basic object avoidance while the pet chases the string from behind. After a set amount of time the PET PAL will "reel" the string back.
- The last phase involves the PET PAL turning on its on-board laser pointer and then performing object avoidance while the pet chases the laser which will be projected on the nearest wall in front of the PET PAL.

Experimental Layout and Results----------

Experimental Results for LITE-ON 56.8kHz:

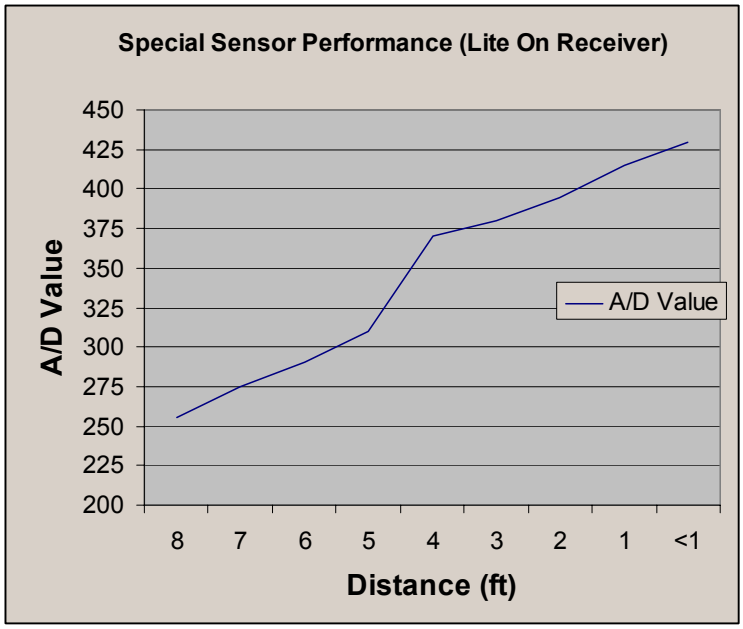

Figure 8: Special Sensor data for IR Receiver

As shown in the above figure, the A/D value increases as the "pet" with the IR source gets closer.

Experimental Results for CDSL:

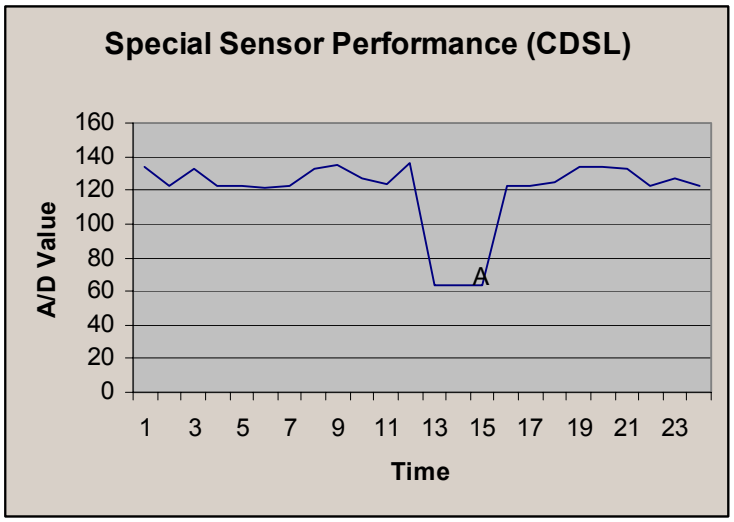

Figure 9: Special Sensor data for CDSL

The A/D value of the CDSL remains approx. constant until the ping pong passes between the sensor and the LED. At that point a value of approx "63" can be seen on the A/D for a short period of time.

Conclusion----------

The PET PAL performs the two main tasks it was designed to do – feed and entertain a pet. It would be nice to actually try the PET PAL with a real pet. Unfortunately that will have to wait until sometime in the future. For now, I don't mind be the acting "pet" for the demonstrations.

Although I consider my PET PAL robot to be a success I wish I still had more time to improve on its functionality. The feeder design could possibly be improved as well as the cat detection devices (possible switch to RF or sonar instead of using IR). The return "shaft" of the "fetch" module could definitely be designed in the future with better materials (something other than a paper bowl and a toilet paper roll). Eventually I hope to finally mill a working board. This will help get rid of a lot of cutter on the first level of the platform as well as make future debugging a great deal easier. I'd also like to add some more entertainment "modules" to the PET PAL such as a feather duster toy and possibly a dog bone play toy.

If I started the project over again I would make sure that I would have not taken any other classes during development. This project was by far the most time consuming project I have ever undertaken. I have never pulled this many "all-nighters" before for a class in my life.

However, given the chance I would not change any of the project specifications. I appreciated having so much freedom to make whatever project I desired. The few requirements that were given, such as weekly demos and reports, were reasonable and helpful in keeping me on track to finish in time for demo day.

Looking back on what I have accomplished, I can honestly say that this class was the best learning experience I've ever had. This is my first graduate school class and I feel that by taking it, I was forced to revisit and learn some topics from my undergraduate classes that I did not understand fully. I feel that I'm a much better engineer as a result.

Documentation----------

Atmel Atmega 128:
http://www.atmel.com/dyn/resources/prod_documents/doc2467.pdf

Let At Work Development Board:
http://www.bergmann-electronics.com/english/shop/letatwork.php

Sharp GP2D12 IR Ranger:
http://www.acroname.com/robotics/parts/R48-IR12.html

LITE-ON IR Receiver:
http://www-inst.eecs.berkeley.edu/~ee40/calbot/sensor_datasheets/ltm-9034.pdf

LITE-ON IR Receiver HACK:
http://www.mil.ufl.edu/imdl/papers/IMDL_Report_Spring_02/michael_hatterman/hacked_ir.pdf

ISD2590 Voice Record/Playback Chip:
http://www.jameco.com/Jameco/Products/ProdDS/120660.pdf

Appendices----------

Program Code --- Please see attached