GPS Dog Shock Collar

Final Report
December 12, 2012

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Introduction

Concept : Most pet owners appreciate the safety of knowing where their pet is at all times. A modern pet containment solution is a Shock Collar. A user sets up magnetic posts or buries a wire in their yard which serves as an invisible boundary against a pet's movement. When the pet crosses the threshold between two posts, a sensor in the collar is alerted and a training pulse causes displeasure to the dog. One problem with this design is that a stubborn dog could cross the threshold and be free of its perimeter. Another problem with this design is that only one perimeter can be set up for the pet, and it must be set up using a cumbersome outdoor fence system. Our idea is to replace the standard "fence" idea with GPS coordinates as set by the user. Not only is there no physical fence setup, but now multiple user locations can be specified for different occasions such as the user's home, office, or favorite park. Multiple perimeters can be saved on the collar and chosen for the proper occasion, and the boundaries apply beyond the limits of the physical fence setup.

Behind the Concept : Instead of the standard magnetic sensing on current dog collars, ours will use GPS coordinates to achieve the same affect. The GPS module will receive the current location from GPS satellites; transmitting the data via the NMEA-0183 serial protocol to a microcontroller. The microcontroller is in charge of interpreting all of the data given to it; determining whether the shock mechanism should be activated and making sure that the shock collar works only over certain intervals so as not to unjustly punish the pet. These coordinates will be written to RAM in the microcontroller using a couple possible methods:

- Instant: Triggering of a barrier with a certain radius as specified by a dial on the computer. A dial on the collar with selectable radii and an activation button will trigger an instant perimeter. This feature is beneficial when on vacation somewhere such as the beach and you want an instant perimeter for your pet. Good for small/medium portable perimeters.
- Corner Set Point: A user will put the collar into set mode upon which time he/she will walk around the perimeter to set the various corners of the perimeter. Pressing the corner activation button will trigger a new corner point for the perimeter. Good for medium/large perimeters.

In addition to GPS, there are a few other features that we planned on implementing, but due to the time restraints of this class have only chosen one for the time being: detection of nearby pets wearing the same type of collar. A small transceiver antenna in the collar will transmit each dog's unique I.D. to a small proximity radius. The same transceiver antenna in another pet's collar will pick up the I.D.'s of other pets in the near vicinity and determine whether contact is allowed between these two pets. The factor of whether two pets are allowed to interact or not comes from the user's selection to put certain pet's I.D. tags on a "No-Contact List" within the RAM on the pet's collar. The prohibited list will be programmable via the computer user interface. The option of preventing contact with all dogs wearing this collar will also be available. Some other features that could possibly be implanted into the collar include barking & jumping detection, and a possible GPS locator in case of a missing pet. The barking detection and GPS locator already exist as stand-alone products, but if all of these are implanted in one collar, then we could see potential in having an all-in-one training solution. Users could even select different models with different amounts of features at a lower cost to suit their needs

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The shocking mechanism is not a novel factor to the concept. In the sense of avoiding "reinventing the wheel", the shocking portion will not be implemented at this time. An analog output on the Microcontroller will be left open for future shock addition. Instead, two LED indicators and activation sounds will be implemented to provide warning to the pet and owner of an infraction before and during the shock. The collar will go into Warning Mode whenever an infraction is being committed such as being outside of a boundary or interacting with a prohibited pet. In Warning Mode, the LED and an associated buzzer will flash at roughly 1 Hz, much like when a garbage truck or school bus goes in reverse. This Warning Mode will serve as an indication to refrain from such activity before the shock occurs. Ivan Pavlov's Classical Conditioning proved that dogs can be trained to react to a stimulus when repeated multiple times preceding a constant result. Why shock when a simple buzzer sound will do? After a predefined amount of time (currently five seconds) without proper reaction to the Warning Mode, the pet will be shocked and a separate sound buzzer will go off simultaneously. The Pavlovian conditioning will take over and the pet will eventually learn to react before the shock. Another preventative measure to over-punishment is our method to prevent too many shocks. Instead of blindly shocking the dog for hanging around his barrier, the internal software will have delays between shocks and will eventually stop after too many consecutive shocks in case of an improperly set boundary. This will prove to be another advantage over the current shock collars on the market today which have no method of preventing repeated shocks.

Features :

- GPS-based perimeter detection for pet confinement
- Multiple user-programmable perimeters
- Multiple perimeter entry modes including Instant and Set-Point perimeters
- Prevention of unwanted contact with other pets as specified by the user
- Adjustable shock levels
- LED/sound shock indicators
- Battery powered
- Connects to computer via USB
- Computer user interface

Benefits :

- GPS Accuracy (the Venus model has 2.5m accuracy with up to a 20 Hz refresh rate)
- No physical fence setup which allows for larger and more diverse boundaries
- Multiple, configurable, and switchable perimeter locations
- Preventative measures beyond the theoretical boundary
- Usable by dogs, cats, exotic animals, and even flying animals.
- Inter-pet contact prevention

Design

Component Diagram :

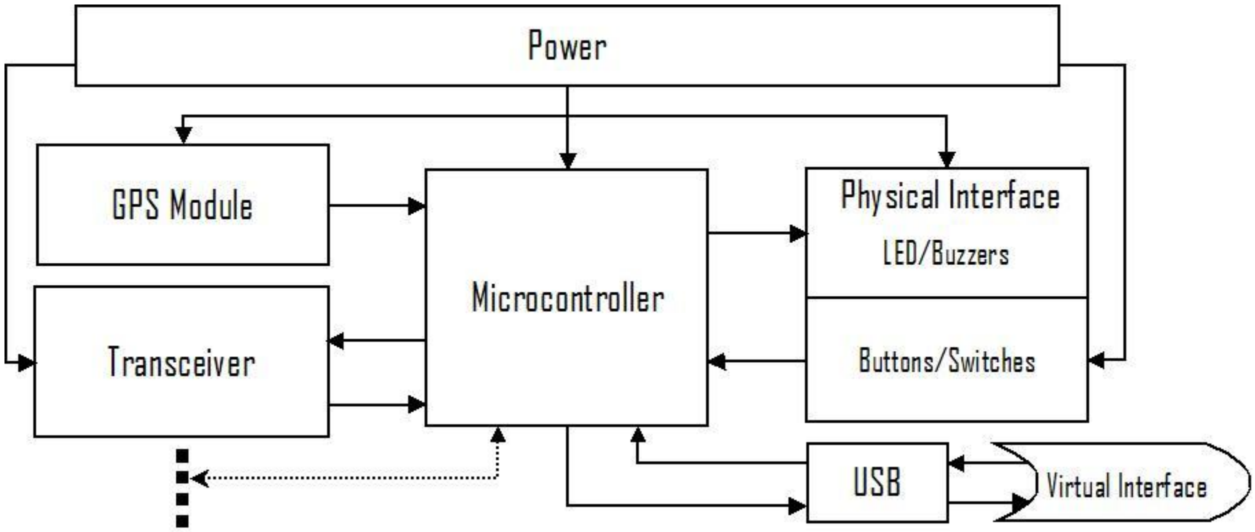

Figure 1

Component Descriptions :

- Power Source – Battery/Power Source for all other components in the project. This is run via 4 AAA batteries for 6V power. Immediate reason for use of AAA battery power is ease of use for consumers.
- GPS Module – Receives and transmits current coordinates to the Microcontroller portion for cross-reference against non-allowed zones. The Venus GPS-11058 transmits current coordinates via the NMEA-0183 protocol, has a 20Hz refresh rate, and is accurate within 2.5 meters.
- Transceiver – Sparkfun nRF24L01+: Transmits the unique ID of the pet collar and identifies others in the near proximity.
- MicroController – An Arduino-based ATmega-328P microcontroller: Takes input from the various detectors and references the physical interface buttons, switches, and knobs to determine if a violation is in progress while transmitting the unique pet I.D. through the Transceiver. It controls the alert/shocking system, stores GPS coordinates in its onboard RAM, and communicates to the Virtual Interface via the USB hub to receive programmed perimeters and prohibited pet I.D.'s. Will be programmed mostly in C with some additional subcode provided by the Arduino community. Refer to Software Flow Chart in Figure 3.

- Physical Interface: LED/Buzzers – As described in the introduction, the alert/shocking portion will be represented by two sets of LED's and sound buzzers. One buzzer will be in sync with the yellow LED and the other buzzer with the red LED. The yellow combo will appear in a repeating pattern for Warning Mode i.e. whenever the pet is concurrently infracting on either its perimeter or prohibited interactions and will only stop whenever returning to an area without infraction. The red combo will appear whenever the physical shocking should occur. The shocking mechanism will not be implemented at this time but a Microcontroller analog output will be left open for the future addition.
- Physical Interface: Buttons/Switches – The physical interface will feature a button, switch, and rotary knob configuration as approximated in Figure 2. This will be the interface for human interaction with the device when it is in use.
- USB – The USB interaction circuit with an outboard TTL Serial port for connecting to a USB port on a standard home computer. Data will transfer between the microcontroller and the virtual interface via the USB hub.
- Virtual Interface – A program installed on the pet owner's computer that communicates with the collar via the USB. Will be capable of input of pet I.D.'s and GPS coordinates. Hopefully, a future implementation would allow for a user community for sharing of opinions, common perimeters such as local parks, and their unique pet I.D.'s. It will be programmed in Microsoft's Visual C# 2010 Express.
- Extension Space – Room in microcontroller for further pet-training additions such as barking correction, jumping correction, and location of lost pets.

Project Requirements :

- Portable and compact, i.e. able to fit on a pet's collar.
- Consumer-friendly, easy to use, and marketable to a pet-owning community.
- Easily powered. AAA battery method preferred for now for ease of use.
- GPS accurate to a reasonable proximity, preferably 10 feet or less within perimeter.
- GPS functions in a vast majority of locations.
- No false infractions.
- Accurate transmission and detection of pet ID's through transceiver.

- Reasonable pet interaction distance for transceiver propagation must be achieved.
- Reprogrammable microcontroller capable of storing user's information.
- User interfaces, both Physical and Virtual, are intuitive to the average consumer.
- Controllable shocking mechanism that proves to not continuously shock, or shock in between intervals of 3 seconds. Needs to stop after a reasonable amount of time so as not to potentially shock pet for more than 5 iterations.
- Warning sound before shock with LED status indicators (yellow for out of proximity and red during the actual shock) and buzzers (different sound for each).
- Safe testing (probably on ourselves at first).
- Safe to all pets (dogs the main consideration at the moment).

Equations :

Besides the simple electrical circuit equations used in the design of our circuit specifically for finding needed resistor sizes, the most important equations or calculations we needed were for determining the distance between two coordinate points and equations for determining if the current point is inside the box.

The tinyGPS Arduino library provided a distance between function which would calculate the distance in meters between two points returning a float or decimal number. This made the instant radius setting much easier to accomplish without any lengthy code.

In order to find if the current point is inside a box determine by four corners, we first used an algorithm that checked to make sure the point was above two of the lines, determined by the sides, and below two of the lines. This algorithm would work as long as the box was a parallelogram. We wanted a better range of input boxes so with some investigation we determined that by using the four triangles made by connecting two adjacent corners and the current point, we could determine if the dog was inside or outside. We did this by first determining the area of each triangle using the equation:

$$A_t = \sqrt{s(s-a)(s-b)(s-c)} \qquad s = \frac{a+b+c}{2}$$

Where a, b and c are the side lengths. We then added up the area of the four triangles and compared this to the area of the box determined by:

$$A_b = \frac{1}{4}\sqrt{4p^2q^2 - (a^2 + c^2 - b^2 - d^2)^2}$$

IF the sum of the triangles is greater than the area of the box, then the dog is outside the box. If it is equal then the dog is inside the box.

Diagrams

Physical Controller & Interface :

Mounted as part of the physical device on the collar, the controller offers an array of buttons, switches, and knobs. Allowing for direct contact proves to be more useful for the average consumer, and the ability to set both instant-radius and corner perimeters requires a portable interface that travels with the GPS so it makes sense to attach it to the actual collar for ease of use and portability. The collar module will be the same size as the battery holder for aesthetics. In Figure 2, the switch sizes and layouts are approximated but they should easily be able to fit into the space provided with extra room for the logo.

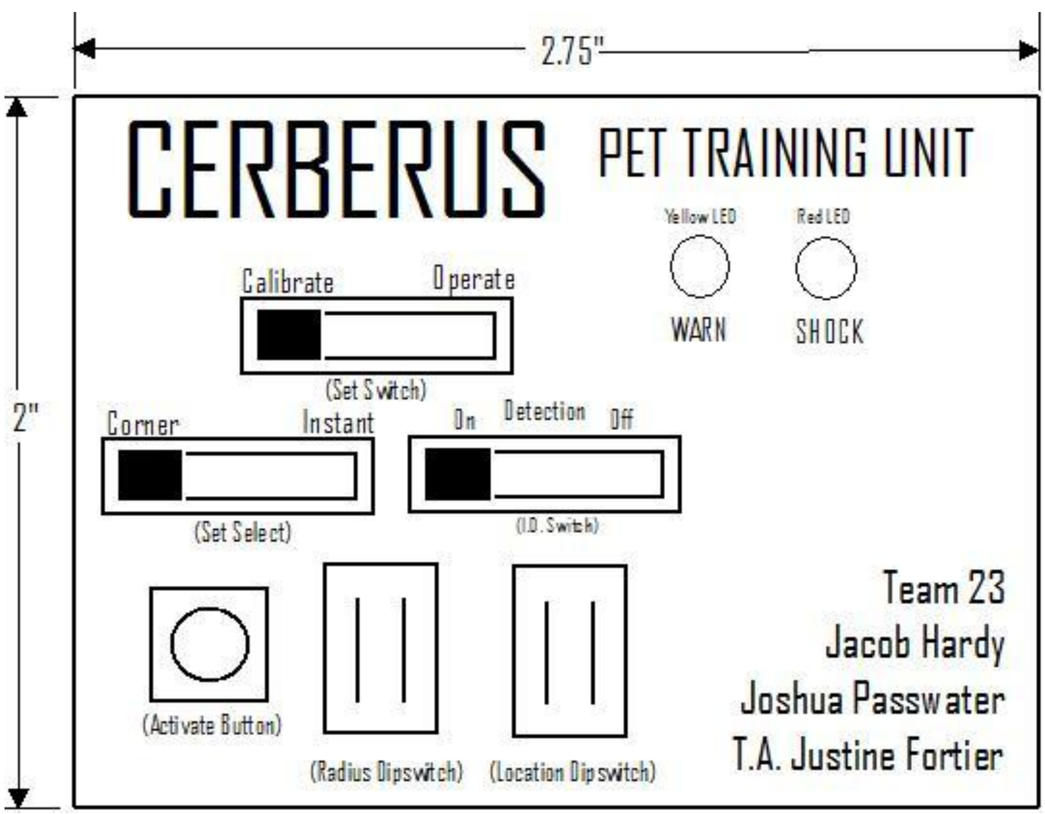

Figure 2

- Set Switch – Operational switch that allows user to define whether they will be setting up a perimeter or using an existing one. It switches between the Calibrate mode where the locations are set and the Operate mode which puts the collar into operation using the currently set location.
- The Location Knob is a user-selective rotary switch that chooses between four locations: Off, A, B, and Instant. Off specifies that there is no current perimeter so the dog is free to roam wherever. Off would prove useful for users only looking for the pet interaction prevention. A and B are perimeters put into the RAM using the Corner-Set input method. They are both over-writable, reconfigurable, and able to be stored even when the collar is turned off. The instant location refers to the last location set up using the Instant-Radius input method.
- The Set Select switch allows the user to specify whether they will be updating perimeter using the Corner-Set or Instant-Radius input method. The Location Knob must be set accordingly as it specifies what location in memory will be over-written. The Set Select switch is only relevant when the Set Switch is set to Calibrate.
- The Radius Radius selects the radius size for an instant perimeter when the Set Select is put into Instant.
- The Activate Button works for both Set Select Modes. In Instant Mode, it activates a radius-based perimeter around the current location at whatever radius is currently selected by the Radius Knob. The Instant Location is then over-written. In Corner Mode, the Activate button selects each corner location into memory, in order, as a user walks around the outside of whatever perimeter they choose. As the user traverses the perimeter, they will press the button at each corner they reach. After four corners, the internal software will determine the GPS coordinates for the perimeter and over-write either A or B depending on which is currently selected by the Location Knob. While the user traverses the perimeter, warning mode is enabled to let the user know that he/she is not yet finished entering the four corners.
- The I.D. switch allows the user to specify whether they would like to use the pet identification feature on the collar.

Software Flow Chart :

Figures 3, 4, and 5, located in the appendices, are overall and detailed views of the software flowchart. The programming for the microcontroller follows these.

Schematics

Figure 6, located in the appendices, is a simple EAGLE implementation of the physical component outlay/PCB we plan on creating for the actual device imbedded in the pet's collar. Each component is reasonably small for portability. The only concern might arise when certain interconnections impede a certain placements of components, like the switches, that will alter the physical look of the physical interface.

Schematics of each module we have used including the transceiver, GPS and microcontroller are also included in the appendices.

Verification

Power :

We started our verification process by assembling our PCB. The first requirement we checked was the power module. We needed it to supply power to all the necessary parts. This means the 5 V and 3.3 V regulators need to be supply the correct voltages. We used a volt meter to measure the output voltage of the regulators and discovered them to be correct.

Microcontroller :

After insuring the components were powered up correctly, we tested the microcontroller to insure it was working properly. We first verified that it could communicate with the switches as these were the easiest to communicate with. We ran a simple program that displayed the logic levels of the switches on the serial monitor while it was connected to the computer. We verified that all the switches were giving us the intended data. This also told us the micro was programmable. We verified the microcontroller's ability to communicate with the transceiver and GPS modules while verifying those modules themselves.

GPS :

The next section we verified was the GPS as this was our most necessary component. We did this by running an example code included in the tinyGPS programming library that we were using. This program would ask for GPS data every second and display all possible data points on the serial monitor. We walked around the Engineering quad and saw that points were changing as we expected when we walked in known directions. As far as accuracy goes, without knowing what the exact GPS locations are, we have no way to prove that it is as accurate as stated so we will simply have to take the manufacturers word on it for the time being. Some of the data output from this test is included in the Appendices.

Transceivers :

We then ran our test code for the transceivers. In order to do this, we assembled a 2nd collar on a breadboard which would transmit a bad listed dog ID. Our main collar was running a program that first checked if any dog IDs had been received or not. If an id was received, it was compared to the bad list of IDs and then it displayed the results of the serial monitor. Using this test, we were able to get the communication distance down to less than 4 meters. If necessary, we could do some antenna shielding in order to reduce this more but for our purposes, we considered this good.

Overall Project :

After verifying that each module of our project was working as expected, we then tested the project as a whole. At this point we could verify the physical interface was working as intended by selecting different combinations of calibrate/operate, 4 corner/ instant radius, and ID detection on/off and seeing what subroutine the program called. Knowing this was working, we took the project outside and verified the instant radius was working. We set our radius to 10 meters and started walking until the collar displayed that it was warning or shocking. We estimate that we were approximately 10 meters away when this happened. We then tried the same test for 5 meters and 25 meters and the distance we needed to travel decreased or increased as expected. We then verified the 4 corner setting was working by setting our 4 corners to be the corners of the engineering quad. We then walked around inside to verify the dog wouldn't be shocked inside. After that we stepped outside and quad and were immediately warned that we were outside the boundary. The last subsection to test was the ID detection. We again grabbed our second collar that transmits a bad listed dog ID. We moved it in and out of range of our main collar and found that our collar would recognize when the second collar was too close.

Part Statistics :

::Unit::	::Relevant Statistics::
Venus 638FLPx GPS	20 Hz refresh rate 9600 bits/second 2.5m accuracy Separate Tx and Rx I/O Optional Internal Flash 1.15" x 0.7"
GPS Antenna	VSWR < 2 26 dB amplifier gain & 3 dB antenna gain Roughly 1" x 1" antenna with a 6" cable
nRF24L01+ Transceiver	Built-in antenna 2400-2525 MHz (125 selectable channels) Separate MISO and MOSI I/O Data MISO/MOSI select, chip enable, clock, and interrupt On board regulator (3.3-7V) 32 Byte separate FIFO for Tx and Rx 0.8" x 0.7"
ATmega328P Microcontroller	Speed : Up to 20 MHz 6 Analog I/O 15 Digital I/O
Magnetic Buzzer (2400 Hz)	0.46"Diameter x 0.35"Height
Piezo Buzzer (4000 Hz)	0.54"Diameter x 0.27"Height
AAA Battery Holder	Holds 4 Alkaline AAA Batteries 2.5"x 1.9"x 0.6"
Physical Interface	2.5"x 1.9"x TBD"

Cost/Labor

Labor :

Name	Hourly Rate	Total Hours	Total = 2.5 * HR * TH
Jacob Hardy	$40.00	200	$20,000.00
Joshua Passwater	$40.00	200	$20,000.00
Total		400	$40,000.00

Total Hours = 20 hours/week * 10 weeks

Parts :

Part	Price/Part	Quantity	Cost
Dog Collar	$10.00	2	$20.00
Venus GPS : GPS-11058	$49.95	1	$49.95
GPS Antenna	$11.95	1	$11.95
Transceiver nRF24L01+	$19.95	4	$79.80
Barebones Arduino Kit	$14.95	2	$29.90
AAA Battery Holder	$1.45	2	$2.90
Button Single-Throw	$0.29	10	$2.90
Slide Switch	$0.39	4	$1.56
Dip Switch	$0.85	4	$3.40
LED – Yellow	$0.15	10	$1.50
LED – Red	$0.12	10	$1.20
Buzzer – Magnetic	$1.49	2	$2.98
Buzzer – Piezo	$1.25	2	$2.50
5V Regulators	$1.45	4	$5.80
Tupperware (Enclosure)	$5.99	1	$5.99
PCB	$0	1	$0
Shipping (So Far)	$30.64	N/A	$30.64
Total			$252.97

Labor	$40,000.00
Parts	$252.97
Total	$40,252.97

For One Collar :

Part	Price/Part	Quantity	Cost
Dog Collar	$10.00	1	$10.00
Venus GPS : GPS-11058	$49.95	1	$49.95
GPS Antenna	$11.95	1	$11.95
Transceiver nRF24L01+	$19.95	1	$19.95
Barebones Arduino Kit	$14.95	1	$14.95
AAA Battery Holder	$1.45	1	$1.45
Button Single-Throw	$0.29	1	$0.29
Slide Switch	$0.39	3	$1.17
Dip Switch	$0.85	2	$1.70
LED – Yellow	$0.15	1	$0.15
LED – Red	$0.12	1	$0.12
Buzzer – Magnetic	$1.49	1	$1.49
Buzzer – Piezo	$1.25	1	$1.25
5V Regulators	$1.45	1	$1.45
Tupperware (Enclosure)	$5.99	1	$5.99
PCB	$10 est.	1	$10 est.
Total			$131.86

Considering bulk part purchases and the redundancies of various components listed above, we estimate that a collar's parts alone would cost roughly $50.

Conclusion

Accomplishments :

We were able to meet all of our requirements we put forward during our design review including GPS barrier using instant radius or four corner method and ID detection. We have a finished project that is operating as intended and user friendly. The ID detection currently works at a range of slightly less than 4 meters and is able to detected dog IDs and verify if the dog is bad listed or not.

Uncertainties :

Most of our uncertainties lie in the GPS module. Without knowing the exact locations of a certain area, we have no idea if our GPS is actually accurate to the amount of 2.5 meters that is stated. This could mean that saved locations drift slightly and dogs could end up traveling out of the wanted boundary or be shocked while in the current boundary. We also could run into problems where this accuracy isn't close enough for smaller areas such as less than 10 meters. The only other uncertainty at this moment is that the transceiver might be detecting at too far of a range. This could easily be fixed by shielding the antenna to reduce transmission power and receiving abilities.

Future Work/Alternatives :

Some possibilities for future work and improvements are as follows:

- Location known and retrieval of lost pet through added communication with possible host station
- Jumping detection
- Barking detection
- Different punishment mechanism such as spray
- User community with uploadable, shareable perimeters such as local parks
- Rechargeable battery

We would also like to figure out the accuracy of our gps and the effect of interference from poor visibility cause by buildings and trees. The physical appearance of our project could be upgraded greatly with some design work in that area but it was not as important as getting the project working in this amount of time. We would also look into some higher quality PCBs and parts.

Ethical Considerations – IEEE Code of Ethics

1. *To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.*

One ethical concern that arrives from the onset of our project is that it is essentially a "punishment device". Its sole intention is to cause harm to an animal, and while that sounds harsh, it is for the good of all parties involved. We ourselves will not be implementing the means of punishment, but current shocking devices have been approved by the CVM (Center for Veterinary Medicine, part of the FDA) as a humane alternative training measure. Certain shocking regulations are in place that ensure the safety of the pets involved. The device itself (with shocking or not) will be entirely safe for use with no infractions to the safety, health, or welfare of the general public or their associated pets.

2. *To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist.*

There might be some conflicts of interest with certain animal rights activists that do not approve of this method of pet training. One of America's greatest rights is that to protest, by boycott or otherwise, and it is understood on our part if people choose not to purchase our product. Our product will be entirely safe and all safety issues, if any arise, will be addressed to the general public.

3. *To be honest and realistic in stating claims or estimates based on available data.*

All of our stated claims and estimates are based entirely out of factual component data As the product nears completion, estimates will be updated to exact statistical and experimental models. No false claims will be made.

4. *To reject bribery in all its forms.*

While no bribes have been offered as of yet, we swear to reject all briberies in all of their forms.

5. *To improve the understanding of technology; its appropriate application, and potential consequences.*

We are proud of the work we achieve as we strive for the best product we can create. Using other subsidiaries' products to achieve that goal requires a certain understanding of each borrowed component and we swear to fully justify the use of every piece of technology. Understanding each component is the first step in assembly and we will knowingly take the time to fully understand each.

6. *To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations.*

We will make sure our technical knowledge not only applies, but is also up to the modern standard in all tasks undertaken. This applies to everything we do ourselves and for all other projects upon which our assistance is requested.

7. *To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.*

We will openly accept, acknowledge, and correct for all honest criticms. All contributions will be honored.

8. To treat fairly all persons regardless of such factors as race, religion, gender, disability, age, or national origin.
9. To avoid injuring others, their property, reputation, or employment by false or malicious action.
10. To assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

We promise to follow these three codes without question as they are already embedded in our very personalities.

We also realize that there may be ethical dilemmas that extend outside of the reach of the IEEE Code of Ethics. Whenever they arise we will properly consult an appropriate authority, and with accordance to IEEE Ethics Code 7, we will accept honest criticism and advice leading to a solution.

Approval from the UIUC Institutional Review Board for animal testing is not yet confirmed, but should be shortly.

Selected Resources

http://en.wikipedia.org/wiki/Classical_conditioning
http://en.wikipedia.org/wiki/Shock_collar
http://www.jameco.com
http://www.sparkfun.com/
http://www.arduino.cc/
http://www.ieee.org/about/corporate/governance/p7-8.html