Doggy Pal Collar

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Abstract — **Doggy Pal Collar is a device that can be attached to a collar that is designed to monitor the heart rate, temperature, location, and position of any dog by Bluetooth communication. The collar is also equipped with an alert system that can notify the owner when the dog is suffering and needs immediate attention. All this information will then be displayed on an Internet of Things website created for the owner for easy access. By monitoring and tracking the information gained veterinarians can look for any patterns or important signs that can later help treat the dog.**

Index Terms **— Animal behavior, body sensor networks, event detection, global positioning system, lithium batteries, microcontrollers, optical sensors**

I. Introduction

The idea for this project was inspired by one of the members of the group. His dog has a medical condition that unfortunately results in the dog having erratic seizures. He explained how this condition induced constant fear because he never knew when a seizure could happen. A seizure could occur when he was away; preventing his dog from getting the required attention until it was too late. The Doggy Pal Collar was created in the hopes that by monitoring and tracking the dog the information gained will be able to show any patterns or important signs that a veterinarian can later view and use to help treat the dog. The collar was also equipped with an alert system that can notify the owner when the dog is suffering from a seizure in real time so that the dog can get the immediate treatment he/she needs. By adding in more sensors we expanded the collar into a device that can monitor several different data points about the dog. That way the owner or a veterinarian could get a lot of data about the dog from the collar instead of just the heart rate. The goal for this project became to create a collar that could monitor the heart rate, temperature, position and location of the dog. Then allow the owner or veterinarian to see the data from these sensors in real time on a device that is connected to the internet. The final goal is to have the collar send a message to the phone of the owner and be equipped with a buzzer that will go off should there be any negative signs that the dog is in need of help.

II. System Overview

The Doggy Pal Collar is a smart collar designed to monitor a dog that is wearing the collar around the neck. The smart collar is user friendly and will allow the user to monitor several important aspects about the dog at any given time. The collar will be powered by lithium-ion polymer batteries. The Doggy Pal Collar will monitor the heart rate of the dog, the temperature of the dog, the location of the dog with GPS and the position of the dog with an accelerometer. All these sensors will be on the collar around the neck in a 3D printed case that protects the components from outside elements. A microcontroller will be used to connect with each sensor to process the data that is collected from each sensor. The Doggy Pal Collar will have a Bluetooth chip on the collar that will send the data from each of these sensors to the cloud. The Bluetooth chip will send data to a computer with Bluetooth capabilities. Once the computer receives the data from the Doggy Pal Collar, another program running on the computer will send that data to the cloud to be processed and displayed. The Internet of Things platform will be used to process and display the data in real-time using a specially designed website called ThingSpeak. This website is part of the Internet of Things platform and allows for easy data collection, manipulation and visualization. The temperature and accelerometer data will be displayed as numeric data. The GPS data will show the location of the collar. The heart rate data will be displayed as a graph showing the pulse of the heart. If the heart rate data is abnormal and outside certain boundaries, ThingSpeak will send a message to the user’s phone alerting the user of the strange data. ThingSpeak will also send a message if the temperature data for the dog is outside set boundaries and abnormal. This will help alert the owner that there is an immediate concern with the dog. The Internet of Things platform also allows for the owner and any other interested party to view the data from the Doggy Pal Collar on any device that has internet connectivity. By having the Internet of Things platform work in unison with the hardware components, the Doggy Pal Collar can be an efficient tool for both dog owners and veterinarians to monitor and track data about a dog.

III. Standards and Constraints

As this project is designed for a dog the constraints are unique. First and foremost the Doggy Pal Collar needs to be durable, a.k.a. Dog-proof. To be durable the collar has to reach the standards placed on electric devices that face outdoor elements.

A. Standards

Dirt/Dust: Dirt can have anything from little to catastrophic effects on the project. If dirt gets in the collar it can cause electrical shorts which can be permanently damaging to integrated circuits (ICs). Dust can contain conductive material like water, oils, and metallic elements which can then cause signal errors and abrupt part failure. High/Low Temperatures: Cold - Under very hot or cold conditions electronic device can suffer shut-downs, malfunctions and/or permanent component damage. In some cases components may even crack rendering them useless. Electronic devices will generate heat simply by operating. This means when devices are exposed to outside heat sources the temperature inside can reach and easily surpass the device's limits. Batteries are particularly sensitive to high temperatures. Heat, like cold, can shorten the battery's life-span or in extreme cases melt and warp plastic enclosures and cases. Water resistant: Any way an electrical device comes in contact with water can be devastating. Humidity can cause damaging static charges and condensation which can then lead to corrosion.

A. Design Constraints

Size: As this device is marketed towards dogs the size of the Doggy Pal Collar will be to be small. This smart collar cannot be uncomfortable for the dog to wear. Weight: Like the size, the weight of this smart collar needs to be light so as to be comfortable for the dog to wear for long periods of time. Component placement: Some of the Doggy Pal Collar’s sensors need specific placement for the device to work properly. For example, the temperature sensor needs to be placed close to the body of the dog. No animal/human testing: The University of Central Florida does not allow both human and animal testing. Because of this all of the testing done for the Doggy Pal Collar will be done on other objects. For example, to test the temperature sensor was working the temperature of a block of cheese was measured. Shaving the dog: The thick fur of a dog is natures design to keep the dog warm in the winter and protected from the sun in the summer. This thick fur may be an element that the pulse sensors cannot penetrate. Even though this cannot be tested at this stage, a note was made moving forward that the skin may need to be exposed to detect heart rate.

IV. ThingSpeak IOT Data Communication

The Doggy Pal Collar has four sensors that are constantly collecting data. These sensors include the GPS, Pulse sensor, Accelerometer and Temperature sensor. In order to make the data from these sensors easy to understand and update in real-time, it was decided to go with an Internet of Things platform called ThingSpeak. The ThingSpeak platform allows for the transfer of data from the Doggy Pal Collar to a website that can be viewed from anyone anywhere with an internet connection. Furthermore, the data can be updated constantly with only a 15 second delay so the owner of the collar is always getting accurate readings from the Doggy Pal Collar.

However, before the data can be displayed an intermediate step is needed between the Doggy Pal Collar and ThingSpeak. The reason this was necessary was because the Doggy Pal Collar communicates to the computer using Bluetooth technology. A Processing Sketch was created to take the data sent over Bluetooth from the Doggy Pal Collar to the computer and send that same data again to the ThingSpeak website to finally display the data for the owner. This means the Doggy Pal Collar can only work properly with a computer with the Processing Sketch and Bluetooth connectivity to send data. Likewise, the Processing Sketch needs to be on a computer that has Bluetooth to connect to the Doggy Pal Collar to receive data. Without this intermediate step, the Doggy Pal Collar will not be able to send data from the Bluetooth device to the Internet of Things platform.

ThingSpeak was chosen as the Internet of Things platform for this project because of several advantages. The first advantage was the easy programming configuration. The programming code necessary to connect the Doggy Pal Collar to ThingSpeak and constantly send data was easy to implement. Several loops were used to constantly loop for new data from the collar while also constantly looping to send data to ThingSpeak. This allowed for more code space on the microcontroller for other sensor programming code. ThingSpeak also has an advantage of coming with built-in data processing tools. These tools include graphs, charts and other plugins and apps that can clearly display data. Each sensor data can have their own unique way of displaying data which allows for a better user experience because each data point can be displayed in a manner that gives the most information to the user. With all these advantages and more, including a free price point, ThingSpeak was a great Internet of Things platform to use for displaying the data from the Doggy Pal Collar sensors for the owner to easily view.

V. SYSTEM COMPONENTS

There are seven components that make up this smart collar. Each component was carefully chosen to fit the previously stated design constraints.

A. GPS

For the Doggy Pal Collar the GPS needs to meet specific requirements. As this device is going to be warn around a dog's neck it needs to be small and light weight which includes the GPS chip. It also need to have high-sensitivity because the dog may travel in places where signal interference would be a factor. It also needs to be cheap due to budget restraints. The Adafruit MTK3339 chip meets all the requirements and more. Its low power consumption mean less battery power is needed with leads to a smaller battery; inadvertently lowering the overall weight of the device. It uses UART interface and Adafruit tested this GPS chip themselves and found the time-to-first-fix to be 45 seconds in Downtown Manhattan, New York. This chip was capable of tracking them as they traveled through New York's underground caverns, which is impressive. Even though the MTK3339 is small and therefore has a small flash there is an option to program the chip to only log information when moving which saves flash space. For these reasons the Adafruit's MTK3339 GPS chip was chosen to be implemented into the smart collar.

B. Pulse Sensor

The pulse sensor component of the Doggy Pal Collar will be used to measure the heart-rate of the dog. The normal heart-rate of a dog is from 60 to 140 beats per minute for a resting dog according to Dr. Marty Becker DVM at Vet Street. The pulse sensor will be attached to the back of the Doggy Pal Collar to get accurate heart-rate readings from around the neck. It will be necessary to start by getting a correct heart-rate reading for the dog wearing the collar because dogs of different ages, different sizes and different fitness levels will each have different heart-rates. Once the owner knows their dog's own heart-rate average it will be easier to tell if the dog is having any problems such as a seizure because the owner will be aware if the heart-rate is getting too high or too low away from the average. The Doggy Pal Collar will monitor the heart-rate of the dog, and if the data is found to be outside normal heart-rate boundaries, the Doggy Pal Collar can alert the owner by sounding an alarm.

An optical heart-rate sensor was chosen for the Doggy Pal Collar from Sparkfun. This sensor uses pulse oximetry to measure the heart-rate. The sensor uses an LED to shine light into the tissue and an APDS-9008 photo sensor to capture the light that bounces back from the tissue. The sensor also has built-in amplification and noise canceling designs to help get accurate pulse readings and minimize errors. The optical heart-rate sensor from Sparkfun runs at 4mA current draw at 5V and also has an option to run at low voltage at 3V. The dimensions of the sensor include a 0.625'' diameter and a 0.125'' thickness. The dimensions and power usage of the Sparkfun sensor make it a great fit for the Doggy Pal Collar requirements. The small size will help keep the Doggy Pal Collar small and light weight and the low power usage will help keep the collar long lasting. The overall package of the Sparkfun sensor was a good fit for the Doggy Pal Collar.

C. Temperature Sensor

The temperature sensor is a crucial component for the seizure-detection aspect of the Doggy Pal Collar. The normal body temperature for a dog is in the range of 99.5 to 102.5 degrees Fahrenheit according to the American Kennel Club, however it is known that during a seizure episode, a dog's body temperature increases above this range. A body temperature of 106 degrees Fahrenheit or higher is known to be dangerous for dogs, but any increase above the normal range can be a good indicator of a seizure episode occurring. While a rise in heart rate could be due to excitement, and sudden changes in acceleration could be caused by the dog scratching or moving in some other way, a body temperature reading that increases above the normal range is highly unlikely to be due to non-seizure activity. It is for this reason that the primary trigger for the seizure alarm will come from the temperature sensor.

The sensor chosen was the Texas Instruments TMP007. The TMP007 is an infrared IC temperature sensor which can take accurate temperature readings from a target object. During testing, the TMP007 gave accurate temperature readings up to twelve inches away from its target. The TMP007 has an operating temperature range of -40 to 257 degrees Fahrenheit and operates with its listed accuracy in the range of 32 to 140 degrees Fahrenheit with 14 bits of resolution. The TMP007 also features an integrated math engine which allows temperature data to be pulled directly over the I2C lines with no additional calculation required. The primary reason for using the TMP007 is its ability to take readings at range. Keeping a sensor in contact with the dog's skin at all times is a challenging proposition at best, and the TMP007 completely circumvents this issue.

D. Accelerometer

The accelerometer used is an InvenSense 9 Axis Accelerometer labeled the MPU-9250. The team looked into many other accelerometers but it was decided that this one fit the needs of the project. The constraints involved in selection were weight, size, functionality, and cost. The InvenSense accelerometer device performed well, weighed very little, and was very small so overall its performance was a plus. This component required moderate levels of coding but still was easy to use.

Within the device there are 3 sets of 3 axis control units containing 9 axis total. The first die contains a 3 axis gyroscope and a 3 axis accelerometer, the other die contains a 3 axis magnetometer.

For digital to analog conversion this device contains nine 16 bit analog to digital converters of digitizing the gyroscope outputs, accelerometer outputs, and for the magnetometer outputs.

The temperature range for precision device outputs ranges from 40 Celsius to 85 Celsius. The operating voltage range (VDD) is from 2.4v to 3.6v. The MPU-9250 includes a support module for AAR, automatic activity recognition which includes built in software that can detect when a user is walking, running, sleeping, etc. It was found that this kind of built in technology is perfect for the Doggy Pal Collar. Although the integrated software was designed for humans walking and running, it gave this project an ideal starting point to change and integrate the software for the collars needs.

It was found that this device was suitable for the design. Not only is the device able to meet the required specifications it is designed and durable for this type of application. This device is low cost, reliable, space efficient, and high quality.

E. Bluetooth

For the communications component it was decided to use a Bluetooth module. The one selected is the Bluefruit EZ-Link. This device was found to be satisfactory because of its ease of use in conjunction with our microcontroller in addition to the amount of power and size. The Bluefruit EZ-Link can connect to any computer using Bluetooth with the exception of Linux machines but can be used on android smart phones. All of the most common baud rates are available for use. With this device the connecting device will automatically configure its ports for ease of use. This device automatically adjusts baud rate and select the DTR pin as needed. For the design of the Doggy Pal Collar the dimensions of the component is 20mm by 41mm by 4mm and weighs 4.35 grams and was found to be satisfactory. Another feature of this Bluetooth module is it's built in connecting antenna which contributes greatly to the size of the device. There are two LED's on the board that indicate whether information is being sent or received. The LED's also allows the user to know if the MCU is receiving data when a code is uploaded, in addition this device also indicated if it was being properly powered. Overall this communications device made it very easy to complete the Doggy Pal Collar given its compatibility with our MCU and easy interfacing.

F. Power Supply

The battery's amp hour needs to exceed the max current draw needed to run the smart collar enough to last at least a day. Even though the smart collar may not reach or stay at the maximum current it is best have a power overhead so as not to tax the battery and for safety reasons. The current draw for each component is shown in Table 5-1.

Components	Max Current Draw	Max Voltage
Microcontroller	**25mA**	**4V**
Heart Rate	**.17mA**	**3.6V**
Temperature	**.27mA**	**5.5V**
Bluetooth	**40mA**	**16V**
GPS	**25mA**	**4.3V**
Accelerometer	**11.83mA**	**3.6V**
Conclusion	**Total max current draw is 102.27 mA**	**Cannot exceed a Voltage of 3.6 V**

Table 5-1: Maximum Power Needed

Using the information from the table and due to this projects design constraints the power supply for this smart collar is Adafruit's Lithium Ion 3.7V 4400mA battery which comes with a pre-attached 2-pin JST-PH connector. This battery is small with a size of 2.7" x 1.5" x 0.71" and has a light weight of 3.5 oz. This battery also comes with a protection circuitry which keeps the battery's voltage from becoming too high (this can over-charge the battery) or becoming too low (this will over-use the battery). The battery will cut-out when completely dead at 3.0V. This protection will also prevent output shorts.

One major drawback for these types of batteries is they're not durable and require extra care during use and charging. This disadvantage was counterbalanced in the design stage by securing the battery in a sturdy casing.

G. Microcontroller

The microcontroller used for the Doggy Pal Collar is the Atmel ATmega328. The microcontroller programming and system prototyping was done using an Arduino Uno board and the Arduino IDE. The ATmega328 features 32 KB of flash memory, one Serial USART, one I2C interface, and multiple digital and analog I/O pins. It operates at a clock speed of 16 MHz and comes in a 28-pin DIP package.

The ATmega328 was selected for a variety of reasons. The 16 MHz clock speed is sufficient because a high sample rate is not necessary for this project. The DIP package was desirable due to being easy to mount and replace if necessary. The Arduino UNO board was extremely useful in prototyping thanks to its easily accessible and clearly labeled headers. Finally, the Arduino IDE was appealing due to its lightweight nature and intuitive interface, as well as plentiful examples, libraries, and community support.

The system is configured as follows: The Bluefruit EZlink Bluetooth adapter is connected to the serial USART on pins D0 and D1. The TMP007 and MPU9250 are connected to the I2C lines on pins A4 and A5. The MTK3339 GPS module was connected to digital I/O pins D2 and D3 which were configured as a second serial communication port via software. The ADPS-9008 is connected via analog I/O pin A0. The ATmega328 is powered by the 3.7 V battery.

The ATmega328 code runs it through a loop which requests data from each sensor one-by-one and prints it serially via the Bluetooth module. During testing these prints were configured for human interpretation for debugging purposes. In the final build, the raw data is printed consecutively to be interpreted and cleaned up by an intermediate Processing Sketch. This Sketch will take each part of the raw data and send the data to the IOT platform ThingSpeak.

VI. Initial Design Architectures and Related Diagrams

The initial design architecture of the smart collar system features two sensors and a communication module connected to the microcontroller via I^2C, one sensor connected to the microcontroller via UART, and one sensor connected to the microcontroller via a proprietary digital communication connection. The basic communication layout of the smart collar system is shown in Fig. 6-1.

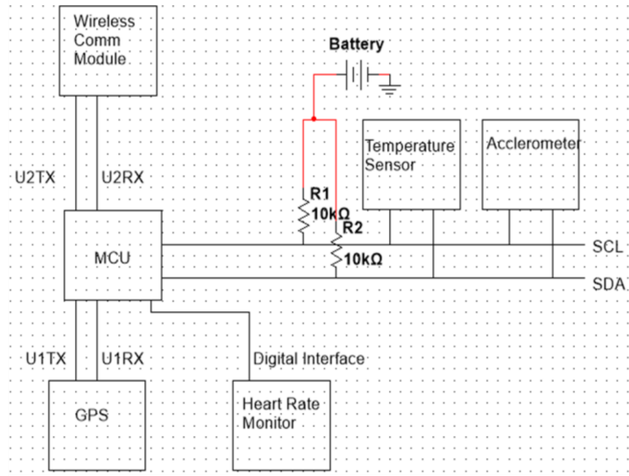

Figure 6-1: Communication Configuration of the System

Each sensor will collect data from the target object- the dog wearing the smart collar. The data collected will include temperature, position, acceleration, and heart rate. The data will be aggregated by the microcontroller and then sent to the wireless communication module for wireless transmission through a local wireless connection to the web. The end user will be able to view the data in an easy-to-read format on a website. A signal flow block diagram for the smart collar system is shown in Fig. 6-2.

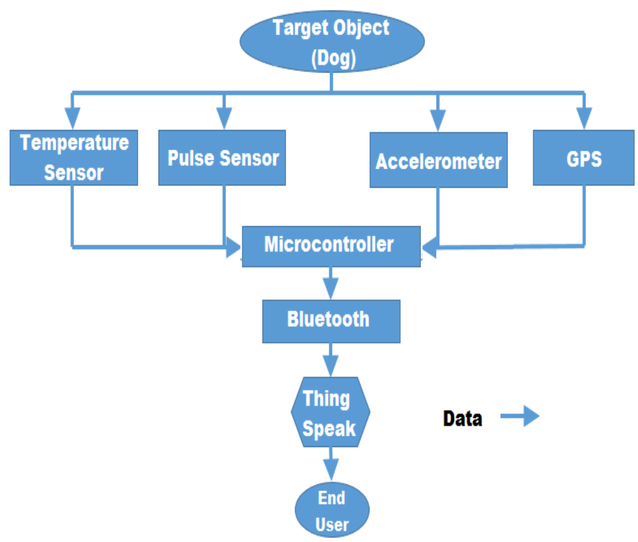

Figure 6-2: System Flowchart

VII. Subsystems

A. Temperature Subsystem

The temperature subsystem will gather temperature data from the target object, and can operate from -23 to 127 degrees Celsius. The temperature subsystem will consist of the TMP007 Infrared Temperature sensor which will be connected as a slave via I^2C bus to the TM4C123GH6PM microcontroller. Pin A1 of the TMP007 will be connected to digital ground. Pin A2 will be connected to analog ground. Pin A3 will be connected to a 3.3 Volt supply source. Pin B3 will be connected via the I^2C serial clock line to pin 47 of the microcontroller. Pin C3 will be connected via the I^2C serial data line to pin 48 of the microcontroller.

The TMP007 will be positioned on the printed circuit board as shown in Fig. 7-1 such that its sensor is facing upwards through a small viewing port on the interior side of the smart collar directly at the target object. Using its internal thermopile which can be seen in Fig. 7-2, it will calculate the temperature of the target object and communicate that data to the microcontroller via the I^2C bus. The TMP007 will continuously gather temperature data and send it over the I^2C bus at a rate of 100 kHz whenever the microcontroller requests it. The TMP007 is capable of sending alerts from pin C2 at certain temperatures, however as of this writing, the alert feature will not be used in this project.

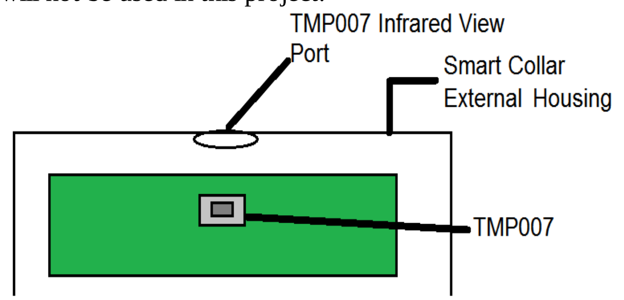

Figure 7-1 TMP007 Infrared Viewing Port

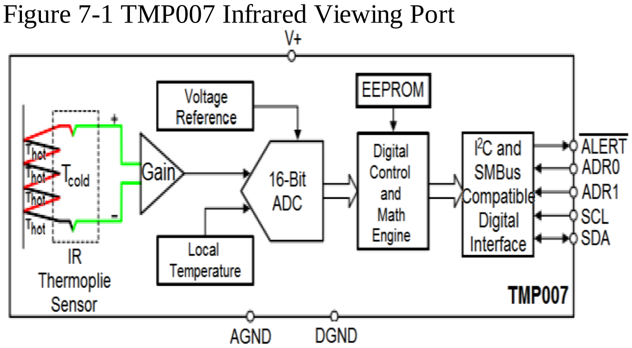

Figure 7-2 Functional Block Diagram of the TMP007 (Courtesy of Texas Instruments)

B. GPS Subsystem

This high-quality, quick-to-fix, -165 dBm sensitivity receiver will make tracking the dog's location simple and the small size will make implementation effortless. When the microcontroller is wired to the RX and TX pins it can the command the GPS to start. This chips works by using the built in antenna to send and receive signals. How the GPS system will work with the microcontroller is shown in the Fig. 7-3.

When installed the MTK3339 chip should quickly find a fix and send out the echo signal. This GPS chip will then decode the raw data that is received from the located satellites and automatically log this data. Since the data does not log unless there is a fix, this decreases the chance of confusing or inaccurate information. This GPS also comes with software that can take this logged data and create a google-map-like graph with the path that was taken highlighted for easy viewing.

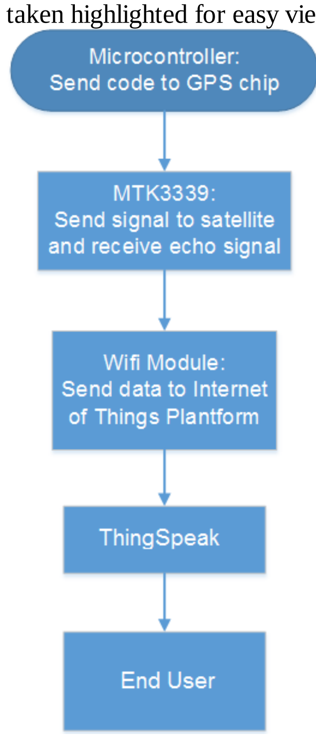

Figure 7-3: GPS System Flowchart

C. Pulse Sensor

The pulse sensor subsystem consists of the pulse sensor and three main connections to the microcontroller as well as special code that monitors the pulse sensor data and will trigger an alarm if the pulse sensor data falls outside certain boundaries. The pulse sensor will connect to the microcontroller Pin A0. This pin will be used to receive the pulse data. The pulse sensor will also connect to digital ground and also connect to a power supply of 3.3 Volts. The alarm system will consist of a piezo buzzer. This buzzer will be connected to digital ground and also have a power supply of 3.3 Volts.

VIII. Casing Design

The design idea for this project is to create an attachment that could be used with any collar and any size dog. The material used to create the Doggy Pal Collar would need to be strong and light weight to fit the design constraints. 3D printing was chosen to be the ideal way to create a collar as the University of Central Florida has a 3D printer that they allow their students to use free of charge for educational purposes and learning to design in AutoCAD will be a valuable asset to have. The design for the casing will a hollowed box, Fig. 8-1, that will have an area on one side that will allow the owner of the dog to pass a rope collar through so that the attachment can work for any size dog.

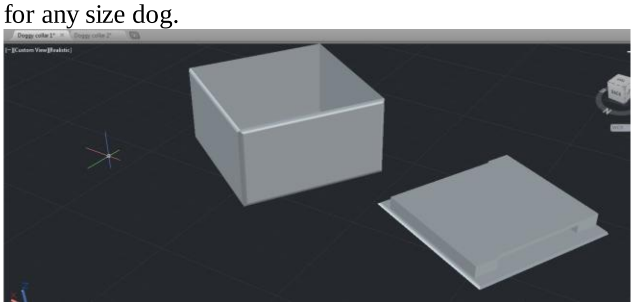

Figure 8-1 Box

VIII. PCB DESIGN

Using EagleCAD two designs were created for the Doggy Pal Collar. The first design, shown in Fig. 8-1, was for the Atmel ATmega328. This design consists of the ATmega328 chip, one 10k resistor, two 0.1uF capacitors, one 16 MHz resonator, one MPU 9250 Invensense acelerometer and several mounting pads for connections. This board will be the brains of the Doggy Pal Collar.

The second design, shown in Fig. 8-2, is for the temperature sensor component of the Doggy Pal Collar. This design consists of one 10uF capacitor, five 10K resistors, one TMP007 chip and several mounting pads for connections.

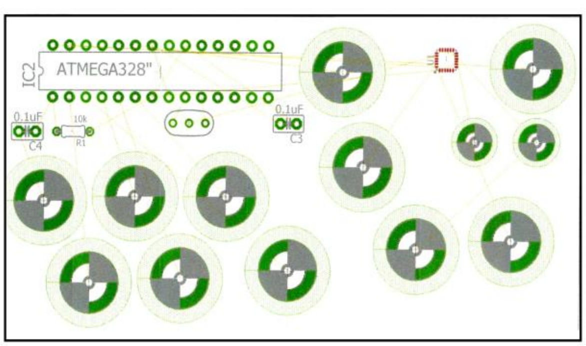

Figure 8-1: First Design

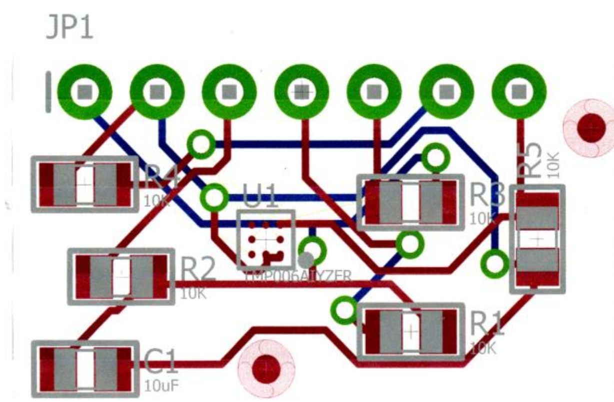

Figure 8-2: Second Design

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance and support of Dr. Samuel Richie, Dr. Lei Wei and the University of Central Florida.

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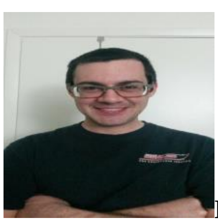

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Stephanie Heagney is currently a senior at the University of Central Florida and will graduate with a Bachelor’s of Science in Electrical Engineering in August 2016. Her goals are to participate in an Externship in May and then work as an intern over the summer. She hopes to start working after graduation, and may pursue a Master’s degree in the future.