ECE 445 Design Document

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TA: Ruhao Xia

Pet Guardian

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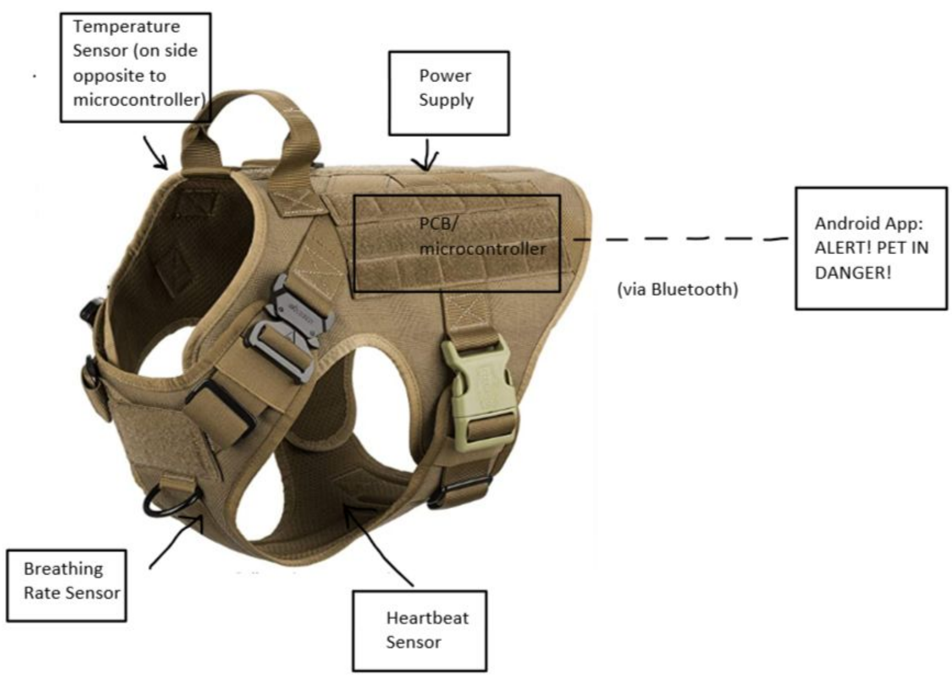
Introduction

Environmental conditions pose as one of the biggest threats [1]. In certain areas and neighborhoods, environmental factors and changes can be an even bigger threat than encounters with other animals, especially in fenced or gated communities. There are many scenarios in which pet owners (especially owners of larger pets/dogs) let their pets outside for long periods of time, or even have their pet reside outside, if the conditions are suitable. However, knowing whether these conditions are suitable or not can be tricky for the owner to identify, and long enough exposure of that pet in the wrong conditions could leave the pet in a life-threatening situation [2]. In order to ensure that an individual's pet is never left outside in the wrong conditions, we are creating a *Pet Guardian* harness that can detect if a pet (testing on a dog) is being adversely affected by its surrounding environmental condition/temperature, and send that information to the owner via a mobile application. Our outfitted harness would be able to obtain information about the surrounding environment temperature, the pet's respiratory activities, and the pet's heart rate, all of which are factors that can be used to tell whether a pet is at risk of a heatstroke, hypothermia, or any other other life-threatening condition.

Visual Aid



The physical design above is a high level overview of our *Pet Guardian* design. It includes the sensors, power supply, and microcontroller, as well as the software interface. For budgeting purposes, we can make use of already owned Rabbitgoo size large dog harnesses if needed. However, we are planning to use a tactical dog harness in order to have enough area to fit the sensors, power supply, and microcontroller of our choosing.

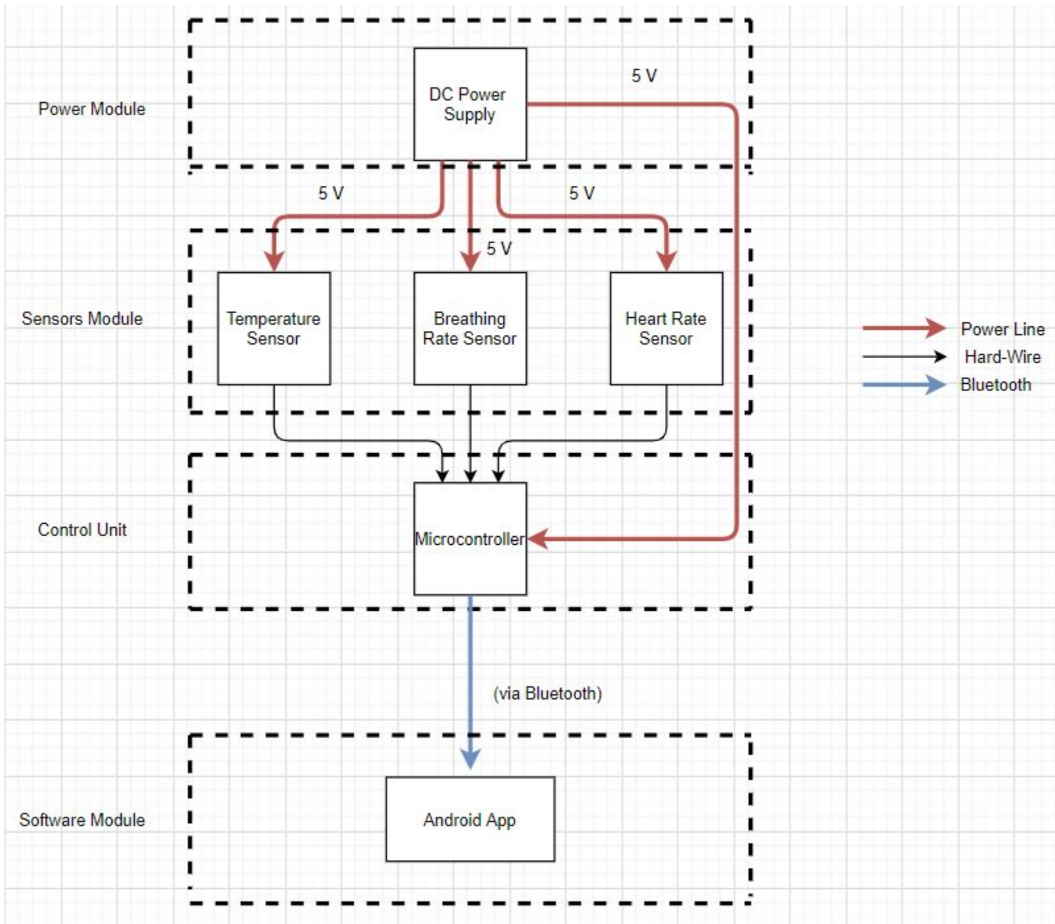
High-Level Requirements

1. All electrical components must be operable well within temperature ranges safe for dogs (about 15-100° F), and must be operable for 12 hours (assuming fully charged).

2. Our design must fit on a size “Large” harness for dogs (50-80 lbs), and weigh less than 5 pounds (weight limit to ensure the dog is not weighed down too much).

3. Microcontroller must be able to send a custom message to the Android App within less than 30 seconds of detection of unsafe conditions for the dog, with a maximum range of 45 meters.

Block Diagram



The modular design of our block diagram ensures that all components that will be used will be able to fit on a size “Large” dog harness. We made sure to include only the components that were crucial to the monitoring of the dog’s well-being, as any miscellaneous component that does not further our monitoring needs would only act as a hindrance and add bulkiness to the overall product. The power supply provides power to all sensors and the microcontroller, while the microcontroller takes the data received from the sensors as input and outputs a message via bluetooth to the user android app. The data transmission protocol via Bluetooth will depend on what microprocessor we ultimately decide on using. We are planning on using the ATMega328P so we will need to utilize UART protocol for data transmission.

Subsystem Descriptions and R&V (includes supporting material)

Sensors Module/Subsystem

This subsystem is responsible for collecting all the vital information needed in order to analyze the level of risk the pet is experiencing. This includes ambient temperature, heart beat rate, and breathe rate. Since the information we collect will be in a range of conditions/temperatures, we have to ensure that all sensors within this module can operate within these conditions/temperatures so that no vital information is missed or no circuit failure happens. This will guarantee overall success at a high level. All this vital information will be passed to the processor module, which will analyze this information and decide the risk intensity level. This module (sensors) also communicates with the power module, as it will be receiving power via hardwire.

Temperature Sensor

Description: A temperature sensor can be used to detect if environmental temperature conditions are too extreme/outside the bounds of safe pet conditions (for dogs its 32° F - 85° F; dogs can experience hypothermia/frostbite in temperatures lower than 32° F and heatstroke in temperatures higher than 85° F). We need to be sure that this temperature sensor can operate in the temperature ranges that we will be exposing the electronics to. This sensor will be great for detecting unsafe weather conditions that are not reflected through the dog's heart or breathing rate (e.g. dog getting frost bite on foot but breathing does not change much). However, since temperature is not the only factor in determining the pet's health, we will need more data from other sensors.

Requirements	Verifications
● Must be able to detect temperature changes accurate to within ±1° F ● Must be able to detect temperature ranges well beyond 32 - 85° F (safe dog temperature ranges)	*Will make use of digital thermometer (have at home) to verify our temperature sensor ● Place both temperature sensor and digital thermometer in a controlled temperature environment (a car with working air conditioning/heating) ● Set the car temperature to 65° F using air conditioning and verify using a digital thermometer ● Turn off air conditioning and let inside temperature rise to 80° F ● While temperature changes from 65° F to 80° F, ensure temperature sensor and digital thermometer do not differ by more than 1° F ● To test temperature ranges, obtain readings with the temperature sensor

	inside a fridge/freezer (product specifications also state working temperature ranges beyond these bounds).

Respiratory/Breathing Sensor

Description: The goal of this sensor is to obtain the breathing rate of the dog. A piezoelectric sensor measures changes in mechanical stress, like pressure, and converts it into an electrical charge. We can make use of this to reliably monitor the respiratory activities of the pet, which changes based on prolonged exposure to unsafe weather conditions. Obtaining a functional sensor which monitors respiratory activity can prove challenging because breathing sensors are relatively new and could not be found on the market a few years back. Current respiratory sensors today go for around $300 [3]. We will most likely make our own circuit for much cheaper by making use of a piezoelectric transducer. This will help turn the movement of the dog's chest into a voltage signal. We will most likely also have to create a filter for ensuring the movement is due to breathing, and not due to ambient movement (tail wagging or dog walking).

Requirements	Verifications
● Must successfully monitor breathing rate of dog accurate to within ± 5 breaths per minute (normal is around 15-25 breaths per minute, while abnormal is around 35-40 breaths per minute) ● Must be able to detect temperature ranges well beyond 32 - 85° F (safe dog temperature ranges)	● Place our respiratory sensor around our dog's chest/diaphragm for 15 seconds, record breathing rate, and multiply by 4 to obtain BPM (breaths per minute) ● Use a stopwatch and count the number of times dog's chest rises in 15 seconds and multiply by 4 ● Compare these two measurements and ensure the readings do not differ by more than 5 BPM ● Piezo-transducer specifications: operating temperature -4° F to 158° F

Heartbeat Sensor

Description: This sensor will be used for detecting the heart rate, which is the most notable change in a dog when at risk of experiencing heat stroke or hypothermia. The easiest circuit to fabricate would be an electrocardiogram (ECG) circuit, which measures bio-potential generated by electrical signals which control expansion/contraction of the heart chamber. However, safety issues arise during testing such as accidental current being passed through the pet through skin-electrode contact points. An alternative due to testing hazards can be a photoplethysmogram (PPG) circuit which achieves similar information as the ECG, but instead uses changes in light to sense the rate of blood flow controlled by the pumping heart. This would need to be attached to the pet's ear, which could prove uncomfortable for the pet, so each design choice has its tradeoffs [4].

Our proposed PPG is made using ABS plastic, which has a melting point of about 220+° F. Based on the technical details of the product description, our PPG should have no problem operating within our testing temperature ranges, as we will also take measures to verify the operating temperature ranges.

*Well beyond is about ±15° F of safedog temperature ranges (17-100° F)

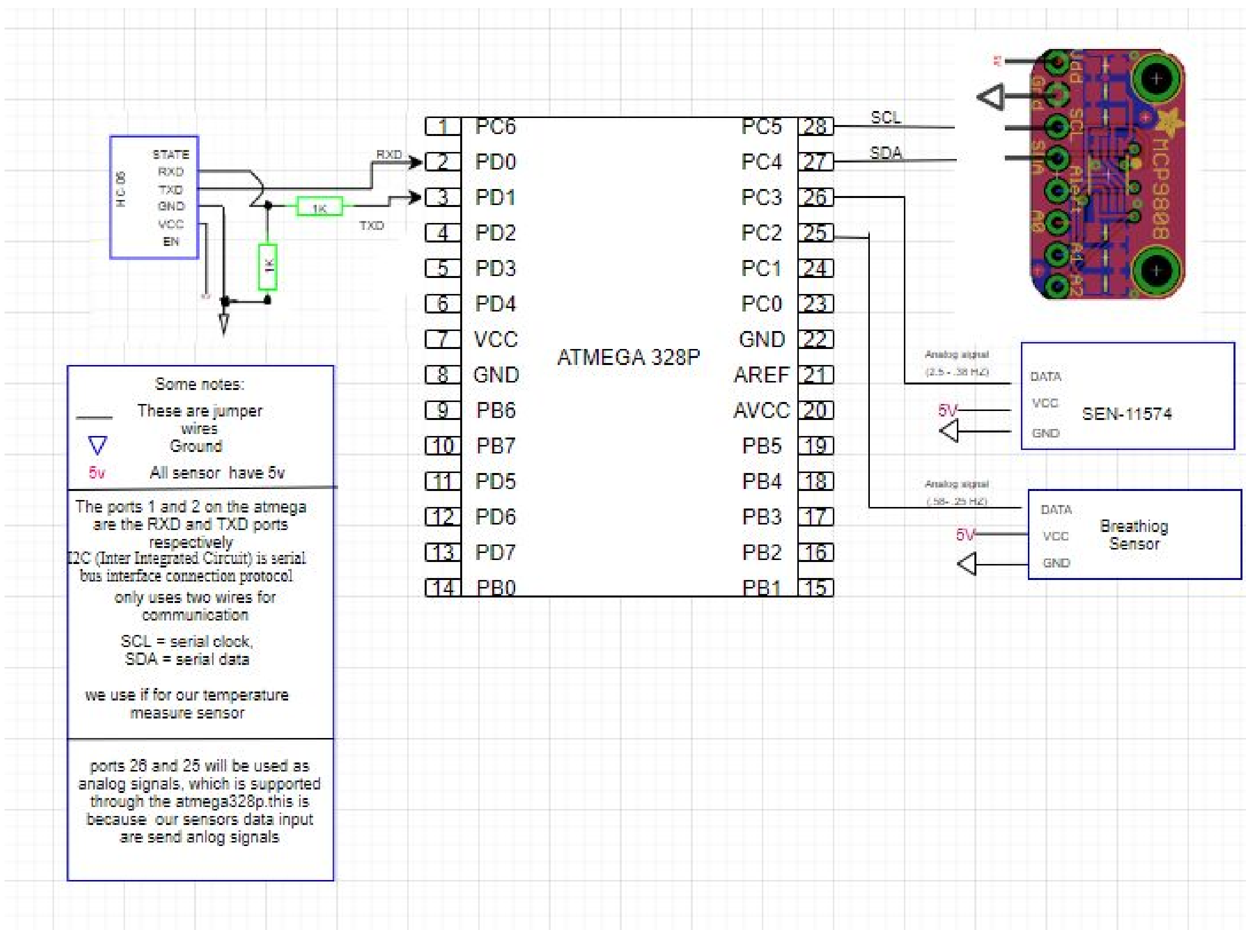
Requirements	Verifications
• Must successfully monitor heart rate of dog within an accuracy of ± 10 beats per minute (60-100 beats per minute is the average for large adult dogs, and above 140-150 is abnormal) • Must be able to detect temperature ranges well beyond 32 - 85° F (safe dog temperature ranges)	• Attach our PPG sensor to dog's ear for 15 seconds, record heart rate, and multiply by 4 to obtain BPM (beats per minute) • Place hand on dog's left side behind front leg or inside of the top of hind leg; use a stopwatch and count the beats felt for 15 seconds then multiply this result by 4 • Compare these two measurements and ensure the readings do not differ by more than 10 BPM • PPG sensor specifications: operating temperature -40°F to 185°F

<u>Processor Module/Subsystem (Control Unit):</u>
This module is essentially the brains in deciding the conditions and thresholds for what it means to be in either ‘Critical Danger!’, ‘High Risk’, or ‘Moderate Risk’. The information that will be analyzed will be collected and passed in through the sensors module. This module also communicates with the software module via bluetooth, as a message will be sent to the software module if unsafe conditions are detected. We need to make sure the message is rapidly sent so that we satisfy our third high level requirement, and to ensure the safety of the pet. This module will also be receiving power via hardwire from our power module.

Microcontroller
<u>Description:</u> We will be making use of a microcontroller in order to analyze the data received from the sensors. The inputs to the microcontroller will be the output of the sensors, and the output of the microcontroller will be an alert message. Rather than having just one ‘alert’ message, we plan on having three different alert messages (ranked High, Medium, and Low) so that the owner can be aware of the intensity of the situation their pet is in. For example, the ‘High Risk’ would be sent if the safe temperature conditions are well out of bounds, and a ‘Medium Risk’ would be sent if the temperature is within the bounds, but the heart rate is starting to increase more than usual.

Requirements	Verifications
● Must convert sensor voltage input into data which can be used to analyze risk intensity level ● Must be able to send one of three messages (three different risk levels) to the android app if unsafe conditions detected (temperature, heart rate, or breathing rate abnormal), and must not alert the app otherwise	● Attach each of the sensors to the microprocessor and simply print out the data readings ● Ensure the data printed out matches format of corresponding comparison threshold (frequency for respiratory/heart rate sensor, number value for temperature sensor) ● Set the testing threshold values reasonable for testing of all sensors (e.g. for temperature, use 70° F since it is easier to go above/below this value easily) ● Set sensor readings to outside of threshold limits and be sure the corresponding warning flags are 1 (on)

	• Set sensor readings to within threshold limits and be sure corresponding warnings flags are 0 (off)



Connection of Sensors and Microprocessor

<u>Power Module/Subsystem</u>

This module is responsible for providing the necessary power to all the other modules (sensors and processor module) except the software module. All our components, including the sensors and microcontroller, will most likely be running on 3-5 Volts. We need to ensure these components obtain the power they need for at least a 6 hour time period, which will fulfil our high-level requirement. We also want this subsystem to be as modular and convenient as possible, either through a rechargeable or easily replaceable power supply.

Power Supply

<u>Description:</u> The power supply will be used for making sure all components on the dog harness have power, including the sensors and microcontroller we will be using for analyzing the input data so that we can send a signal to the owner's mobile app if need be. As of right now, this power supply needs to provide constant power to the microcontroller and sensors for a prolonged period of time. Ideally, we would want the power supply to provide power for as long as possible to account for dogs that reside outside for long periods of time. We would like this harness to operate for weeks/months on end to provide ease of use for the owner, such that he/she will not have to replace the power supply every day. We also want recharging to be easy, such that all the owner has to do is remove the power supply and recharge is separately. To achieve this, a power bank might be ideal, since we are only powering sensors and a microcontroller and nothing that requires a great deal of power consumption.

Our power consumption will most likely be less than around 50 mW, but we will test with 100 mW to be sure our power supply can provide at least 100 mW of power for 12 hours.

Requirements	Verifications
● The power supply must provide power to the components and maintain successful operating conditions for at least 12 hours. ● Power supply must be rechargeable, as well as detachable to the rest of the system/product.	● Using a digital mulit-meter, measure the voltage across the power bank when it is at 100% charge and ensure output is within 5% tolerance of 5 V ● Connect fully charged power bank with a positive and negative terminal at VDD and ground respectively and discharge battery 100mA for 12 hours; ensure that the output is still within 5% tolerance of 5 V ● From discharge state, recharge power bank and use voltmeter to ensure power bank is again within 5% tolerance of 5 V

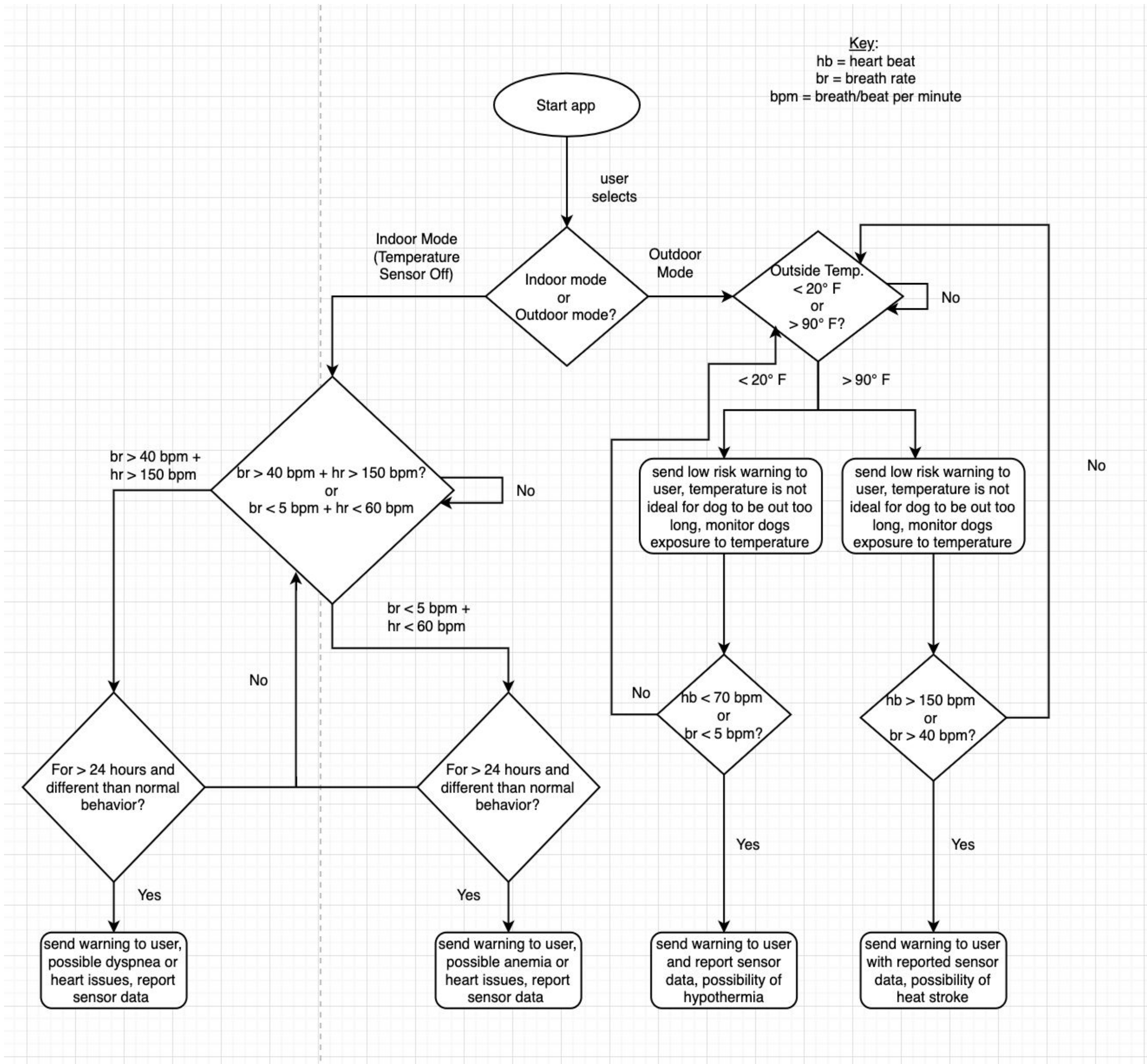
<u>Software Module/Subsystem</u>

This module will only be communicating with the processor module. In fact, the processor module only sends information and the software module only receives information via bluetooth. However, the software module should only receive any alert from the processor module if the dog is in an unsafe condition, and not otherwise. We do not want to constantly spam the user app with the condition the dog is in, rather only alert the user app when certain thresholds are passed (e.g. too fast heart rate or too high temperature).

Bluetooth Module/Android App:

<u>Description:</u> This subsystem will be used for allowing the *Pet Guardian* harness to send a message to the pet owner about the condition of his/her pet. Once the microcontroller detects a possible risk to the dog's health (hypothermia, heat stroke) will send a warning message to the user on the Android App wirelessly through bluetooth, since WiFi range would be limited dependent on the availability of a nearby WiFi source. The transfer of data will be through the UART protocol (Universal Asynchronous Receiver/Transmitter) in order to communicate with our microprocessor (AT Mega). Our android app will feature two modes, indoor mode (temperature sensor turned off since no environmental factors to detect underlying conditions like heart disease) and outdoor mode (with temperature sensor on and warnings sent if temp + heart rate or temp + breath rate pass safety thresholds), the flowchart can be found below.

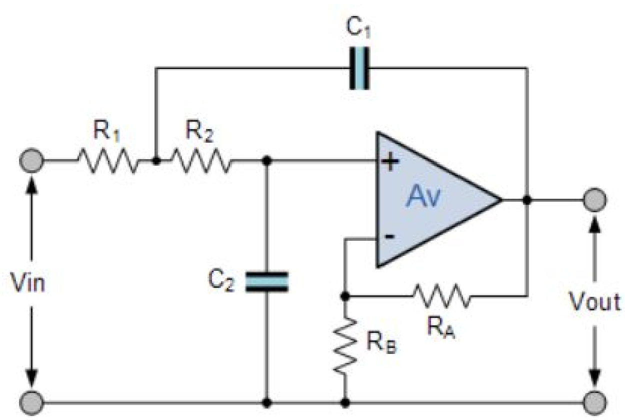
Requirements	Verifications
● The module is able to connect to the Android App and transfer data between phone and microcontroller via bluetooth over an open-air distance of about 45 meters ● The transfer of data must be done in a timely manner (less than 30 seconds) to ensure that the user can act accordingly once an alert is received ● Bluetooth module operates over UART interface with microcontroller to send and receive data	● Establish base bluetooth functionality in the Android App and pair with bluetooth module ● Pair with bluetooth module ● Send a test message from the module to the app at 45 meters ● Record the amount of time it takes for the app to receive the test message to ensure it is done with low latency (less than 30 seconds) ● If the app successfully receives the message, it will send a verification message stating "Message Received" ● Connect Bluetooth module to AT MEGA over UART, send test message, and check to see if received the same message back.



Logic Flowchart

Tolerance Analysis

Our most critical subsystem that poses the greatest risk to the completion of this project is the sensor module, in particular the respiratory/breathing sensor. The completion and accurate functionality of this sensor is crucial, as it will be one of the main data collected for analysis in order to decide whether a dog is in a healthy condition or not. If this sensor is faulty or inaccurate, this could completely throw off the signals being sent to the user's phone app, or even worse, not send a signal to the android app when a dog is detected in a critical condition. The challenging part for the breathing sensor is making a much cheaper alternative to the existing $300 respiration sensor in the market today, while still achieving similar accuracy. The hardest part in making this custom sensor for dogs will be making sure that we detect only changes in pressure due to breathing, and not due to other movement (e.g. Tail wagging or scratching ear). In order to ensure we detect only pressure from the chest/breathing movement, we are planning to create a second order low pass filter in order to detect just the chest movement from breathing. The filter we are choosing to construct is based on the Sallen-Key filter [5]. Through additional research, we found out we can easily create an active second order filter for increased accuracy by cascading two first order low pass filters together, or adding an additional R-C network within the feedback path. Our filter will be active rather than passive as we are using a gain of 3 to increase the output into a voltage that our microprocessor can analyze/work with while maintaining stability, since the output of the piezoelectric transducer by itself is too low [6]. As for the cut off threshold, the value we choose to use is 35 breaths per minute, which correlates to a frequency of 0.58 Hz.



Gain (Av) = 1 + (Ra/Rb)

Fc (cutoff frequency) = $1/(2\pi\sqrt{R1R2C1C2})$

*We can use that same resistor and capacitor values (R1=R2 and C1=C2) to further simplify our frequency cutoff equation to → Fc (cutoff frequency) = $1/(2\pi RC)$ where C = C1 = C2 and R = R1 = R2

Calculations for 2nd order active LPF:

*One design consideration is finding reasonable values of R and C such that we still obtain our desired RC time constant. In general, it will be much cheaper to make use of large resistance values and smaller capacitance values, rather than trying to find capacitors with large C values. Therefore, taking into account our allocated budget, we set our capacitance C at 100 nanofarads and find our resistance accordingly.

Gain = 3 → 2 = Ra/Rb → Ra = 20 $k\Omega$, Rb = 10 $k\Omega$

0.58 Hz = 1/(2πRC) [C = 100 nF] → R = 1/(1e-7*2π*0.58) → R = 2744.05 $k\Omega$

Final 2nd order active LPF values:

Av = 3
Ra = 20 $k\Omega$
Rb = 10 $k\Omega$
R1 = R2 = 2744.05 $k\Omega$
C1 = C2 = 100 nanofarads = 0.1 microfarads

Project Differences

Overview:

The biggest difference between our project (*Pet Guardian*) and the original project (*Pet Pest Protector*) will be the sensing of environmental factors on the dog's well-being, rather than other animals. As stated before, for certain communities and other groups of people (based on location, living conditions, etc.), environmental factors could prove as a greater threat to dogs than other wild animals. “There is no notion of *the best solution*, because *best* is relative depending on the community and group of people that are using the product” - Professor Jing Jiang. In other words, different solutions can be bad or good based on the consumers buying them. For example, because the *Pet Guardian* harness will detect environmental changes that pose as a threat, this product will appeal to a more niche market/community in which pets are often left outside for longer periods of time (e.g. Large Dog Owners who have their dogs reside outside because of size constraints/regulations/preferences). While the *Pet Pest Protector* excels in locations with consistently-moderate temperatures safe for animals (like in North California), the *Pet Guardian* excels in locations which experience varying weather conditions harmful for pets (rain, snow, extreme heat & cold) that can prove more hazardous than wild animals.

Analysis:

Our design of the *Pet Guardian* will definitely be an improvement in the area of pet monitoring, especially since our design will monitor the overall vitals when the pet is most vulnerable; unattended and outside. However, in order to analyze the level of improvement it will have in this area, we have to first define the core problem we are trying to solve and define which particular area our core problem corresponds to. At a more high level, both products (*Pet Pest Protector and Pet Guardian)* solve the issue of detecting if a pet (left unattended outside) is in danger and sends an alert to a user app of the pet owner. However if we go one level deeper and define the ‘danger’ parameter that is putting the pet at risk, we see that this core problem is broken into two: 1) *Detecting if a pet is in danger from other animals* and *2) Detecting if a pet is in danger from environmental factors*. It is clear through this distinction that the original project solution (*Pet Pest Protector)* only takes into account ‘other animals/creatures’ as the only threat to unattended pets left outside. However, upon further research into the ‘threats’ that pets can face while left unattended, we found that a bigger threat to unattended dogs left outside can be extreme environmental conditions [7]. People for the Ethical Treatment of Animals (PETA) have records of the amount of pet deaths per year due to either extreme cold or hot environments, but have no records of the amount of pet deaths due to other animals. The numbers only take into account the deaths, meaning the number of pets hospitalized or adversely affected in general by unsafe environmental conditions can be in the thousands (probably even more). Therefore, the core problem that we think is more relevant and we try to solve is *detecting if a pet is in danger from environmental conditions,* and here we clearly define our ‘danger’ parameter as the surrounding environmental factors rather than other animals. Analyzing now the improvement our product solution will have in the area of pet-related injuries/deaths due to extreme environmental conditions, there is no doubt our design will greatly improve this area since it will allow pet owners (who left their pets unattended outside whatever the circumstances) to obtain an understanding of the underlying vitals that comprise of a pet's overall well-being. No matter the scenario, the *Pet Guardian* will aid the pet-owner in deciding the level of risk the pet is in, either by acting as the first line of defense against an environmental threat by alerting the pet owner (if pet is unattended), or by helping the pet-owner analyze through additional information of the vitals other than physical just observations (if pet is attended).

Cost & Schedule

Parts

Part	Description	Manufacturer	Part #	Quantity	Cost
Tactical Dog Harness (Large)	-1050D Nylon with Pu Water Resistant Coating -Soft padded ventilate mesh -Alloy Metal Hardware -100% Nylon Webbing,thread	ICEFANG	ASIN: B01N1YVRC8	1	$38.99
Power Bank	- Features a special low-current charging mode -Battery Capacity: 5000mAh / 18.5Wh -Dimension of 4.02 x 1.18 x 1.18 inches - 4.80 ounces	AUKEY	ASIN: B07RJK8XH9 Model: PB-N54	1	$10.99
Pulse Sensor	-0.625" Diameter and 0.125" Thick -Pulse Sensor Board -24-inch Color-Coded Cable with Standard Male Headers -Ear Clip for Earlobe HR Measurement -Velcro Finger Strap Transparent Stickers to Protect Sensor	sparkfun	SEN-11574	1	$24.95
Piezo bender (transducer)	-Operating Temperature Range -20℃ to 70℃ -Plate Size 20mm -Element Size 14mm	sparkfun	7BB-20-6L0	1	$1.50

Temperature Sensor	-Up to 8 adjustable address pins - -40°C to 125°C range (0.5°C guaranteed max from -20°C to 100°C) -2.7V to 5.5V power and logic voltage range -Operating Current: 200 µA (typical)	adafruit	MCP9808	1	$4.95
Microcontroller	-Automotive temperature range: –40°C to +125°C -Low power consumption -37.4 x 6.76 x 3.28 mm	Microchip Technology	ATMega328P	1	$2.20
Male Jack 2 Pin 2 Wire	-5V USB 2.0 Male Jack 2 Pin 2 Wire Power Charge Cable Cord Connector DIY 1m Wire -Used for connection from power supply	PartsStorm	ASIN: B07Y45NV16	1	$7.73
Bluetooth Module	-Reference Distance: 80 meters -Can connect to android - Dimension: 26.9mm x 13mm x 2.2 mm - Working temperature: -20 ~ +75 Centigrade -Weight: 0.18oz (5g)	Smart Prototyping	HC-08 SERIAL BLUETOOTH MODULE CC2540	1	$7.99
Total					$ 99.30

Labor

For the salary, we assume the average salary per year for Engineering graduates from Illinois, which is $78,159/year [8]. We divide this by the total working hours in a year (2,080 hours) to obtain an hourly rate of $37.58/hour for each member. Using the equation below assuming four members:

4 (# of members) x ($/hour) x (hours/week) x (weeks to complete) x 2.5 = Total Labor Cost

Total Labor Cost = 4 x ($37.58/hour) x (10 hours/week) x (6 weeks) x 2.5

Total Labor Cost = $22,548

Combining parts and labor cost →* **Grand Total = $22,548 + $99.30 = $22,647.30

Schedule

Week:	**Didrick**	**Ming**	**Syed**	**Michael**
Week 1	-Determine improvements to Pet Pest Protector - Identify other possible sources of threats	-Work with Syed to brainstorm improvements for parking meter alert project	-Work on backup idea about parking meter app	-Work with Didrick to identify improvements to Pet Pest Protector
Week 2	- Determine if using PPG or ECG and trade offs - Determine what respiratory sensor we will use	-Determine the type of power supply needed for our application - Help Didrick research determine ECG/PPG tradeoffs	-Think of logic flow chart of what alerts we want to send depending on what signal - determine how to analyze sensor data going into processor	- Research bluetooth capabilities of microprocessors -Analyze ranges necessary for our application
Week 3	- Research custom filter for respiratory sensor - Decide on specifications for sensor parts	-Decide on power supply and analyze power/current consumption -Took ECE 342; will help with filter design	-Determine which microprocessor we will be using - Determine which pins sensor will connect to for chosen microprocessor	- Elaborate on Android App design - Research and finalize choice of microprocessor

Week 4	-Create piezo sensor PCB circuit/finish circuit schematic on eagleCAD -Help create slides for powerpoint	-Create slides for powerpoint about power and filter design - Practice presentation for Design Review -Test sensors and ensure power supply can support 100mA for 12 hours	-Create processor logic which analyzes data from sensors, compares it to threshold values, and raises the correct flag	-Begin working on frontend software code for user app - Prepare powerpoint for Design Review
Week 5	-Work with Ming to integrate power supply into PCB - Help syed to integrate/analyze data signal from sensor to ATMega328P	-Revise/include any parts criticized from Design review - Start on final report	-Work with Mike to finalize processor to app connection (ensure when flags are raised, the correct corresponding message is sent)	- Finalize backend and frontend software for Android App and UI/UX design
Week 6	-Work with Mike (and other members) to ensure phone app alerts work have correct functionality - Revise document/work on final paper and presentation	-Help debug processor logic and software code -Work on final report and finalize lab notebook for hand in	-Finalize final report, make any revisions commented by TA - Ensure final design working together, debug any issues that arise in either software or processor logic	- Help others on any parts needed and revise parts criticized - Prepare for final presentation

Ethics & Safety

Addressing ethical and safety issues is extremely important to us, especially considering that our final product is meant to be worn by a living household pet (in our case for testing purposes, a large adult dog), rather than an inanimate object. Therefore, because the health of a living animal can be at risk, I believe it is necessary to address liability issues that may inevitably occur.

To start, our product does NOT serve as a replacement to existing professional practices used to evaluate general pet health/well-being. As such, the owner of the pet using this product should still follow proper dog care techniques, such as twice-yearly veterinarian check-ups [9]. This product is initially intended for “Large” adult dogs (American Labrador Retriever will be breed used to set threshold limits), and though it can be used on other animals/dogs, *Pet Guardian’s* primary use will be on Large American Labs (50-80 lbs in weight); use on other animals and dog breeds might not guarantee same behavior/accuracy. It should also be noted that proper use of this product will require the awareness of the owner (owner must be aware and ready to act as soon as there is an alert message that his/her dog is in danger). To ensure safety of the dog used for testing, we have to be sure to test our product design in a safe environment and stable conditions when tested on the dog. Although we may test our components/circuit separately in other conditions, we must ensure safe conditions when testing with the dog. To prevent any discomfort for the dog, we will make sure to not alter the fitting or design of the harness. By doing this, we can ensure the dog’s safety (does not choke on harness or incur rashes) and also ensure safety of everyone during testing, as testing with an aggravated dog poses a risk to the dog, people around the dog, as well as the state of the overall product.

Moving forward, other safety and ethics issues arise when creating our design. In regards to the IEEE Code of Ethics first point [10], it is crucial that we make sure the materials we use for this harness are non-toxic to plants, people, and especially animals. The fact that this product will be used on a living animal makes this safety and ethics issue of very relevant and of utmost importance to us. This should not be taken lightly by any means, as we can be held accountable to liability issues that occur due to poisoning of a person or animal due to toxic materials. We have to also be sure to take into account the possibility that a certain component or material can become toxic when exposed to certain conditions (either too hot, too cold, rain, etc.), and be aware of what conditions create toxic effects, if any. Environmental conditions that can bring out any toxic hazards within the product components must be avoided.

One potential safety hazard that should also be addressed is hazards regarding the power supply. If using a simple Li-ion battery, we face the possibility of explosion of the battery due to thermal runaway [11]. This again is of huge concern to us, because the battery will be on the harness, which is connected to the dog. Any explosion or failure in the battery will result in damage to the dog, which is completely unacceptable. In order to ensure this does not occur, we need to utilize a protection circuit/mechanism. One way could be to use a thermistor, which changes its resistance based on temperature. Utilizing this can disconnect the battery from the entire circuit if high enough temperatures are detected. Another viable solution would be to make use of a power bank, which excels in drawing low current for long periods of time, perfect for our application. One benefit is that a power bank comes equipped with a protection circuit to limit current drawn.

Electrostatic Discharge

The issue of electrostatic discharge was previously unknown to us, as other harnesses equipped with electronics did not seem to regard this as an issue (e.g. Pet Pest Protector). However, this possible issue was brought to our attention from our TA, and upon further research, we found that electrostatic discharge could possibly be an issue in our specific application [12]. The causes of electrostatic discharge can be either through electrostatic induction, or through the triboelectric effect (tribocharging). In our case, our source of concern is through tribocharging (e.g. when you rub a balloon on your head and there is a difference in charge between your hair and the surface of the balloon). The reason tribocharging can be an issue is that if the pet were to come into contact with another surface which causes the fur to become charged, electrostatic discharge could occur between the fur and the electronic components. However, analyzing whether or not electrostatic discharge prevention measures need to be taken is tricky because the amount of discharge harmful for devices depends on the type of material the device is made out of, as well as the sensitivity classification of the device. On top of that, we would also need to know the maximum amount of charge fur can hold, which would differ greatly depending on pet/breed. Nonetheless, we do have some possible electrostatic discharge protection strategies within the budget if we find out later on that this is a major issue (depending on what protection measures are taken, it can become very costly) [13]. The idea behind any basic electrostatic discharge protection strategy is to ground the items that are possible sources of electrostatic discharge. This common ground ensures that there is no potential difference between the two sources, and therefore no possibility of electrostatic discharge. One simple and cheap solution would be to make use of an anti-static ESD wrist strap. This wrist strap would be attached to one of the dogs front upper legs, as their upper legs are around the size of humans wrists. It also comes with a jumper coiled cord that connects to ground. The only issue with this design choice would be the loose hanging cord. A more advanced design which solves the hanging cord issue while making use of the ESD wrist strap would be to attach/sew the wrist strap to the vest, and run the cord along the inside of the harness. A more expensive and complex design would be to make use of an anti-static mat, and customize the mat to make it fit and attach to the inside of the harness. However, this would be more costly and harder to design, as we would have to figure out how to attach the anti-static mat to the harness without the pet losing comfort.

References

[1] peta.org, “Animal Companions.” Heat-Related Deaths Since 2018. [Online] Available: https://www.peta.org/features/dogs-and-other-companion-animals-suffer-heat-related-deaths/. [Accessed: 2-April-2020]

[2] hillspet.com, “Important Tips.” Leaving Your Dog Outside. [Online]. Available: https://www.hillspet.com/dog-care/routine-care/keeping-your-dog-safe-outside. [Accessed: 2-April-2020]

[3] thoughttechnology.com, “Thought Technology Ltd.” Respiration Sensor - SA9311M. [Online]. Available: http://thoughttechnology.com/index.php/respiration-sensor.html. [Accessed: 2-April-2020]

[4] NeuroSky.com. ECG vs PPG for Heart Rate Monitoring. [Online]. Available: http://neurosky.com/2015/01/ecg-vs-ppg-for-heart-rate-monitoring-which-is-best/. [Accessed: 2-April-2020]

[5] electronic-tutorials.ws, “ElectronicsTutorials”. Second Order Filters. [Online]. Available: https://www.electronics-tutorials.ws/filter/second-order-filters.html. [Accessed: 15-April-2020]

[6] americanpiezo.com, “APC International, Ltd.”. What is a Piezo Transducer? [Online]. Available: https://www.americanpiezo.com/piezo-theory/whats-a-transducer.html. [Accessed: 15-April-2020]

[7] peta.org, “Animal Companions”. Animal Companions Are Dying in Cold Weather—These Are the Reported Cases. [Online]. Available: https://www.peta.org/features/animal-companions-winter-freeze-death/. [Accessed: 16-April-2020]

[8] ecs.engineering.illinois.edu, “Engineering Career Services”. Student Success - Undergraduate Success. [Online]. Available: https://ecs.engineering.illinois.edu/outcomes/. [Accessed: 16-April-2020]

[9] WebMD.com, “FETCH by WebMD”. How Often Should Your Pet See A Veterinarian. [Online]. Available: https://pets.webmd.com/features/your-pet-veterinarian#1. [Accessed: 2-April-2020]

[10] ieee.org, “IEEE Code of Ethics”, 2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 3-April-2020]

[11] BatteryUniversity.com. Lithium ion safety concerns. [Online]. Available: https://batteryuniversity.com/learn/archive/lithium_ion_safety_concerns. [Accessed: 3-April-2020]

[12] electronics-notes.com, "ElectronicsNotes Incorporating Radio-Electronics". What is Electrostatic Discharge: ESD basics. [Online]. Available: https://www.electronics-notes.com/articles/constructional_techniques/electrostatic-discharge/esd-basics.php. [Accessed: 16-April-2020]

[13] electronics-notes.com, "ElectronicsNotes Incorporating Radio-Electronics". ESD Protection. [Online]. Available: https://www.electronics-notes.com/articles/constructional_techniques/electrostatic-discharge/esd-protection.php. [Accessed: 16-April-2020]

[14] vetstreet.com, "Dr. Marty Becker". Normal Dog Temperature, Heart Rate and Respiration. [Online] Available: http://www.vetstreet.com/dr-marty-becker/what-is-normal-dog-temperature-heart-rate-and-respiration. [Accessed: 15-April-2020]

[15] usarveterinarygroup.org," Lori E. Gordon, DVM MA TF-1 US&R". Hypothermia and Frostbite in the Canine. [Online]. Available: http://www.usarveterinarygroup.org/docs/HypothermiaAndFrostbiteInTheCanine.pdf. [Accessed: 16-April-2020]