Robotic Animal Assisted Therapeutic Device

Team 13
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1: Introduction

1.1 Objective

Therapalz is in the process of creating a robotic therapy animal that will serve as a companion for Alzheimer's patients. Currently, the project needs to have a more realistic design where managing the electronics doesn't disturb user experience. Specifically, opening a robotic animal's stomach to replace batteries isn't ideal. Sensory input through capacitive touch on the current design has also proven to be ineffective and doesn't produce reliable stimuli to the system. Lastly, the device lacks a useful user interface for caregivers that would allow them to monitor and potentially control the animal for specific needs during periods of patient stress.

Our objective for this project is to improve on the current prototype, increase realism, and provide point-of-care abilities for caregivers. We plan on implementing wireless charging to make the device more realistic and using a microprocessor to improve on its convenience factor. The microprocessor can analyze data from sensors, change the purring habit of the device, and transmit data to and from the caregiver via a web app/mobile app. Wireless charging will be achieved by placing a primary coil in the pet bed and a secondary coil in the stomach of the pet and will use resonant inductive charging. The microprocessor will gather data from the accelerometer, gyroscope, and microphone sensors to determine general distress of the patient and adjust the purring output to the speaker. This data will be sent to a server which will relay the information to the corresponding caregiver's phone via a mobile app. The caregiver will then be able to read the data and send commands(such as increase purring) to the device.

1.2 Background

Currently, Alzheimer's is the 6th leading cause of death in the United States [1]. According to the Alzheimer's Association [1], 1 in 3 seniors dies with Alzheimer's or another dementia. There are 7.7 million new cases every year. Clearly, this is a very pressing issue.

Over the past few decades, researchers have been exploring alternative, non-pharmaceutical methods of treatment for patients with Alzheimer's and related diseases. Animal-assisted therapy(AAT) is gaining popularity and has been proven to be extremely effective on patients: it improves their apathetic state, decreases their irritability and depression, and boosts their social interaction[2]. Studies also show that AAT helps lower blood pressure and increase neurochemicals related with relaxation and bonding[2].

Therapalz aims to provide the benefits of AAT without the burdens: using robotics lowers the cost of animal care and reduces possible threat of abuse or neglect towards service animals. We intend to implement a cheaper option than the current AATs that cost several thousand dollars, so many patients are able to receive the benefits by using sensors and components that aren't more precise than are needed.

1.3 High-Level Requirements List

- The device must be able to charge using the embedded wireless charging circuit and a corresponding pet bed(that contains the transmitter) to charge a lithium ion battery that will be used to power the rest of the robot when it is not charging.
- The device must be able to process and route data from input sensors to output devices. Input from the touch sensor should cause the speaker to emit a purr sound. Sudden violent movement should be sensed by the gyroscope/accelerometer and continuous loud sounds(heard via microphone) will result with sending a distress signal to care givers via the WiFi module.
- The device's Wi-Fi module should be successfully able to connect to a WiFi network. It should also be able to transmit and receive data from services on the cloud. Data sent includes diagnostics on how many times the robot has been stroked, how often it has been interacted with(gyroscope) etc. Data received includes instructions to change default setting such as purring sound level.

2: Design

The entire system will be run off of a single cell lithium ion battery providing a constant voltage between 3.7 and 4.2 volts with a 6 AHr capacity. The system must last for a maximum of 10 hours and therefore must draw at most .6 [A] of current continuously. The four current drawing systems are the sensors, the microprocessor unit, the Wi-Fi module, and the voltage regulators to step up the battery voltage to 5 volts and step it down to 3.3 volts. The battery will be charged using resonant inductive wireless charging across a gap of about 1-2 cm and must charge the battery in less than 14 hours.

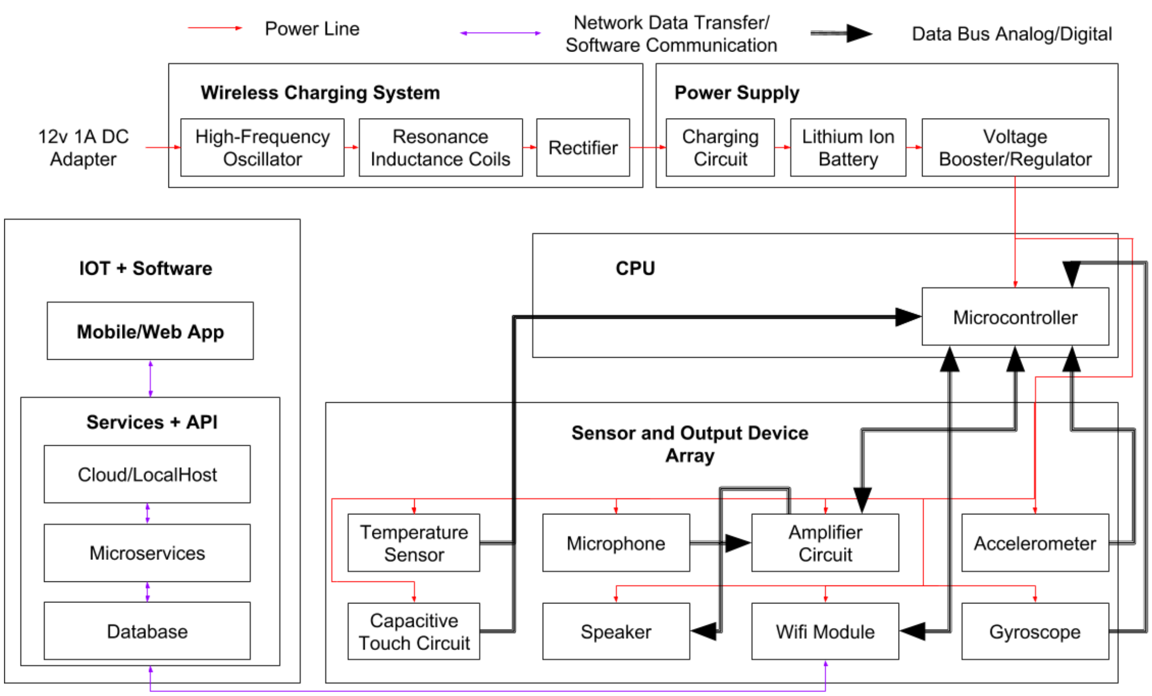

Figure 1: Block Hardware Diagram

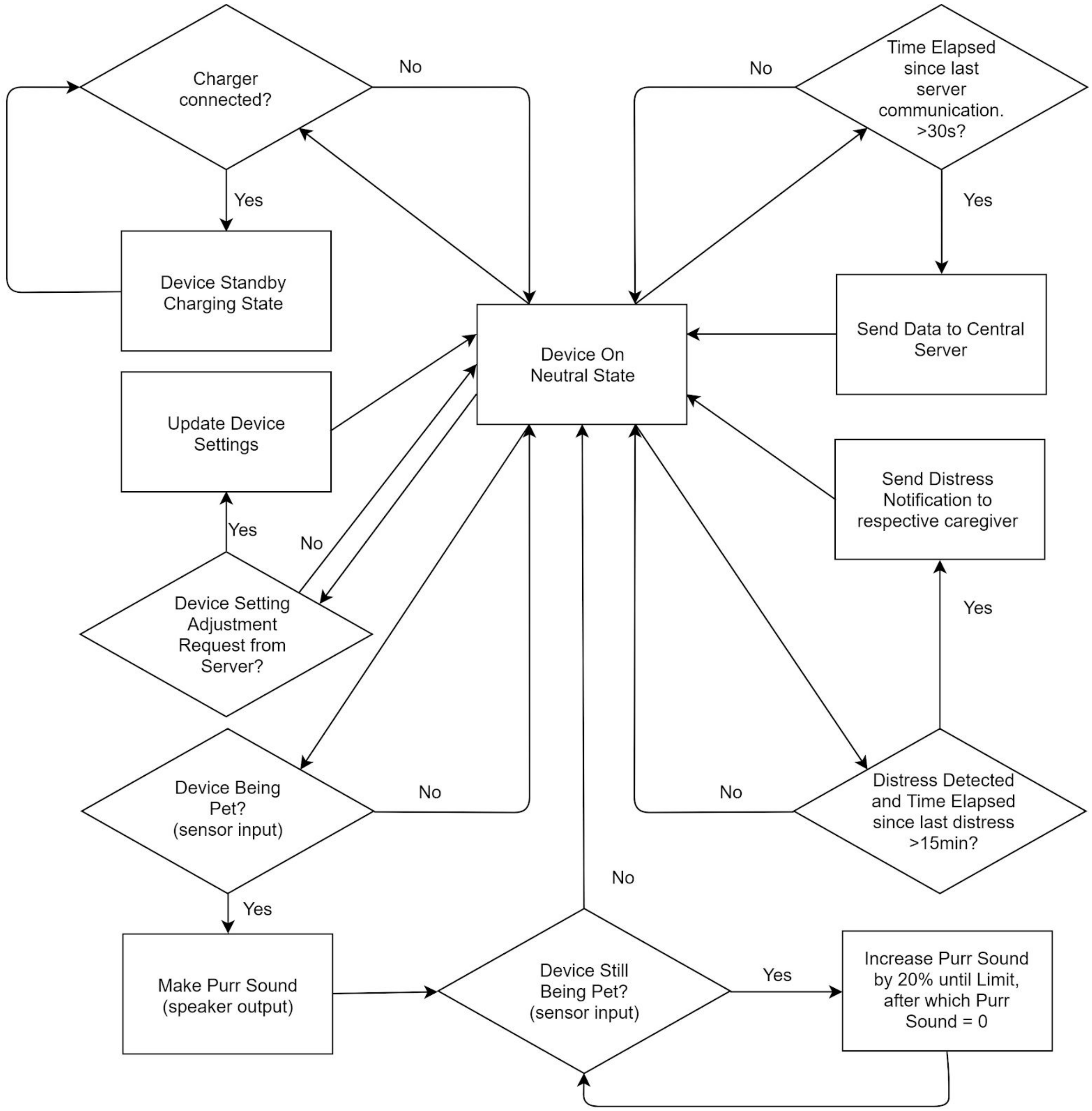

Figure 2: Software Control Flow Diagram

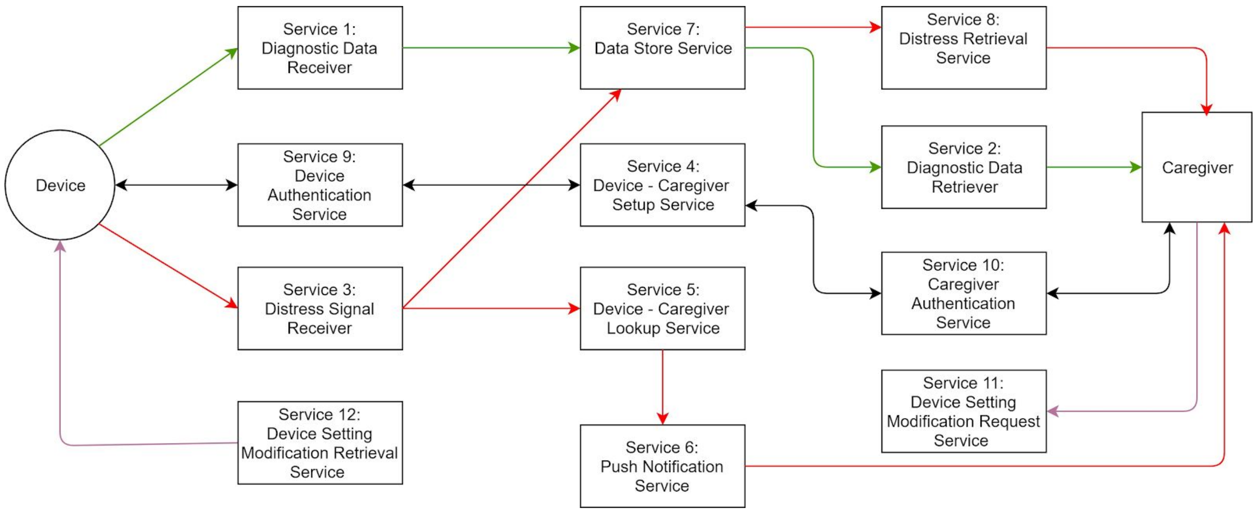

Figure 3: Services Control Flow Diagram

The block diagrams shown in Figure 1,2 and 3 satisfy the high level requirements:

The charging control flow will verify if the device is charging successfully or not. If it is successfully charging, device goes to Charging State. In this state, the device's lithium ion battery is charged through the embedded wireless charging circuit. Otherwise, the device runs on power supplied by the battery.

If input is received at the capacitive touch sensor, the device makes a purr sound. If it continues being pet, it makes a louder sound until it reaches its maximum threshold. Otherwise it stops purring. If the robot is violently moved(gyroscope + accelerometer) or large sound is heard(microphone), the robot will send a distress signal to the caregiver as shown in Figure 2. Every few moments, the device sends general diagnostic data to the server. This can be used by the caregiver to ensure that everything is okay. Non-sensitive information can be used to further improve software and hardware design.

Default settings of the device can be adjusted through the mobile app. This includes making the device louder for patients who are sensitive of hearing. Data is easily retrieved by caregiver after their identity has been verified. Services exist to setup caregiver-device relationship.

2.1 High-Frequency Oscillator

The high-frequency oscillator will convert the DC 12v 1A supplied from a purchased wall adapter into a high frequency signal (in the order of around 550-650kHz depending on the resonance frequency of the coils). A square wave is generated by a PICAXE microprocessor and will be used in a Class E type Inverter to create a AC voltage [11]. The AC wave is able to produce the alternating current to produce the magnetic field to induce current in the secondary coil. The right part of figure 4 depicts the high-frequency oscillator from the output of a square wave generator into an n-channel mosfet with a LC circuit to provide oscillations and change the square wave into a sine wave.

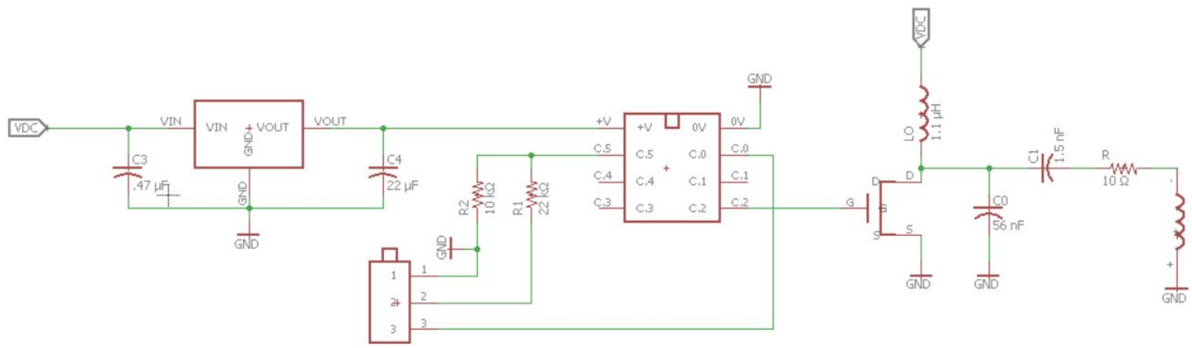

Figure 4: Circuit Schematic of Primary Side. Includes a 5v Voltage Regulator, a PICAXE Microprocessor for a Square Wave Generator, Class E Inverter, and Primary Coil.

The charging circuit is composed of two major parts the primary and secondary sides[9]. The primary side (figure 4) consists of a 12V 1A AC-DC wall adapter, a 5v voltage regulator, a square wave frequency generator (PICAXE), and a Class E Inverter to produce a sinusoidal current. The secondary side (figure 5) has a receiver coil that has an induced current and a full bridge rectifier to convert the AC wave into a DC voltage. It also contains another voltage regulator and a battery charging IC.

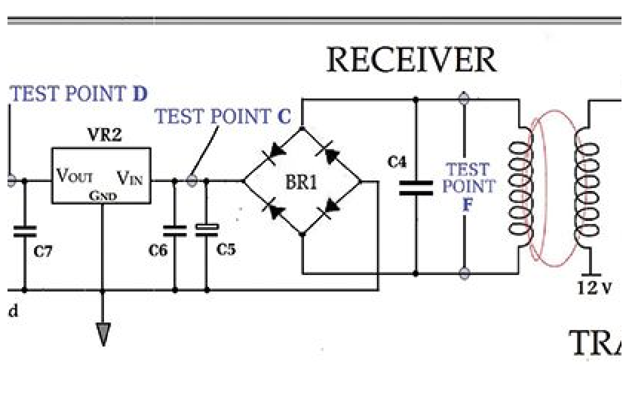

Figure 5: Circuit Schematic of Secondary Side. Includes the Secondary Coil, Full Bridge Rectifier, and a 5v Voltage Regulator

2.2 Resonance Inductive Coils

The resonance inductive coils are the portion of the wireless charging circuits that creates the magnetic field and induces the current in the secondary coil. There is a ~12sin(2**π**(f_c)*t) + 12 volt wave that enters the primary coil (where f_c = the resonance frequency = 550-650kHz). The change in current through the inductor L2 (47 μH transmission coil) in figure 6 (the blue curve) will create a magnetic field to induce current in the secondary coil (not shown in figure 6). We will need to perform experiments to confirm that the magnetic field produced by the primary coil is sufficient to induce a large enough current in the secondary coil. For the purposes of this design we will be treating the current induced in the primary coil due to the secondary coil as negligible. From the simulation we were able to estimate the current as $I(t) = .700 \cdot sin(2\pi \cdot 600,000 \cdot t)[A]$. The magnetic field can be calculated using equation 1.

Equation 1:

$$B(t) = \frac{\mu_0 I(t)}{2\pi r} = \frac{4\pi \cdot 10^{-7} \cdot .7}{2\pi \cdot .4} \cdot sin(2\pi \cdot 600,000 \cdot t) \approx 3.53 \cdot 10^{-7} sin(2\pi \cdot 600,000 \cdot t)[Teslas]$$

Equation 2:

$$\phi(t) = B(t) \cdot A = B(t) \cdot \pi \cdot (.01315)^2 = 1.97 \cdot 10^{-10} \cdot sin(2\pi \cdot 600,000 \cdot t)\ [Wb]$$

Equation 3:

$$EMF = -N\frac{d\phi(t)}{dt} = -11 \cdot 7.43 \cdot 10^{-4}\ cos(\ 2\pi \cdot 600,000 \cdot t) = 8.169 \cdot 10^{-3} cos(2\pi \cdot 600,000 \cdot t)[J/C]$$

Using the simulation to estimate the current flowing through the primary coil, estimating a distance of .4 meters between coils, using the area and turns of the secondary coil we are able to estimate that for the values in the simulation the max EMF would be significantly under the required EMF. For the rectifier to produce a large enough voltage we need the EMF to be about 1000 times larger. We will need to experimentally determine the values. A store bought coil will not contain enough turns (the store bought coil only contains 11) to produce a large enough EMF. After creating a coil we can measure the inductance and re-calculate inductor and capacitor values for the Class E Inverter as well as calculate the necessary capacitor in series with the primary coil to create an appropriate resonance frequency. We can then also create a secondary coil, measure that inductance and calculate another capacitor to match the resonance frequency of the primary side. A resistor (5 ohm in the figure 6) can be used to limit the current through the primary coil.

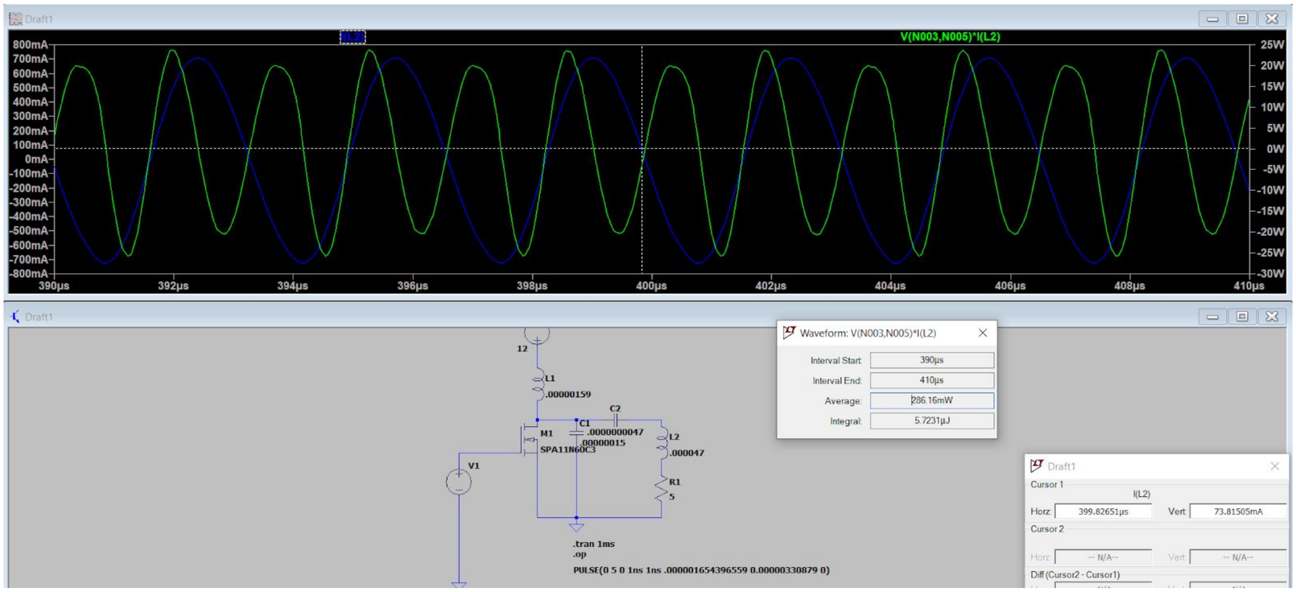

Figure 6: Simulation of Current through Primary Coil

The simulation (figure 6) provides an estimation of the current through the primary coil from the Class E Inverter. However, we are unable to model it at a high level of accuracy since the N-Channel Power Mosfet we will be using, isn't modelled completely accurately. The simulation has proved that increasing each inductor and capacitor by constant percentage will increase the current through the primary coil and will help us determine the required components while experimenting.

2.3 Rectifier

The Full-Bridge rectifier converts the AC voltage output from the secondary coil into a dc voltage, it is BR1 in figure 5. This voltage is used to power the charging circuit and the rest of the robot while the robot is on the pet bed. The voltage doesn't need to have the ripples completely attenuated since it'll be feeding into a Fixed Output Linear Regulator that can take any voltage from 6 [V] up to 24[V]. The Fixed Output Linear Regulator has a max current of 1[A]. We need the rectifier to convert the AC voltage induced in the secondary coil to a voltage greater than 6[V]. The equations 4 and 5 [12] calculate the voltage that would be required to be induced from the secondary coil and the capacitance to reduce the ripple voltage to be less than .1[V].

Equation 4:

$$V_{DC} = .637(V_{max,ac} - 1.4) \geq 6[V]$$

$$V_{max,ac} \geq 10.819[V]$$

Equation 5:

$$V_{ripple} = \frac{I_{load}}{2f \cdot C} \leq .1[V]$$

The max I_{load} could be is 1[A], and the frequency will be larger than 550kHz

$$C \leq 9.09 \cdot 10^{-6}[F]$$

2.4 Charging Circuit

The charging circuit regulates the charging of the Single Cell Lithium Ion Battery [13]. It maintains a constant current during the linear charge phase of the charge cycle and a constant voltage to finish charging the battery. It will also turn off the charging when the battery is fully charged. Figure 7 below shows the general circuit that will be implemented following the 5v voltage regulator on the secondary coil side of the circuit.

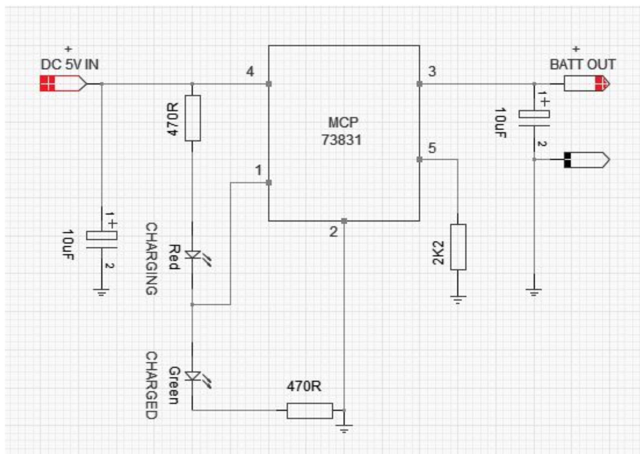

Figure 7: Circuit Schematic of Lithium Ion Battery Charger from 5v Voltage Regulator

2.5 Lithium Ion Battery

The lithium ion battery is the power source for the robot when it isn't on the charging pad. It must be able to last for 10 hours and supply voltage for the voltage booster circuit and step down voltage regulator to power the MPU and Wi-Fi module.

2.6 Voltage Booster/Regulator

A DC-DC converter to convert the 3.7-4.2v from the battery to a constant 5v to supply optimal voltage to the MPU. Must also step down the battery voltage to a constant 3.3v supply for the Wi-Fi module. Each of these devices are treated as a singular IC that will be implemented in the overall circuit.

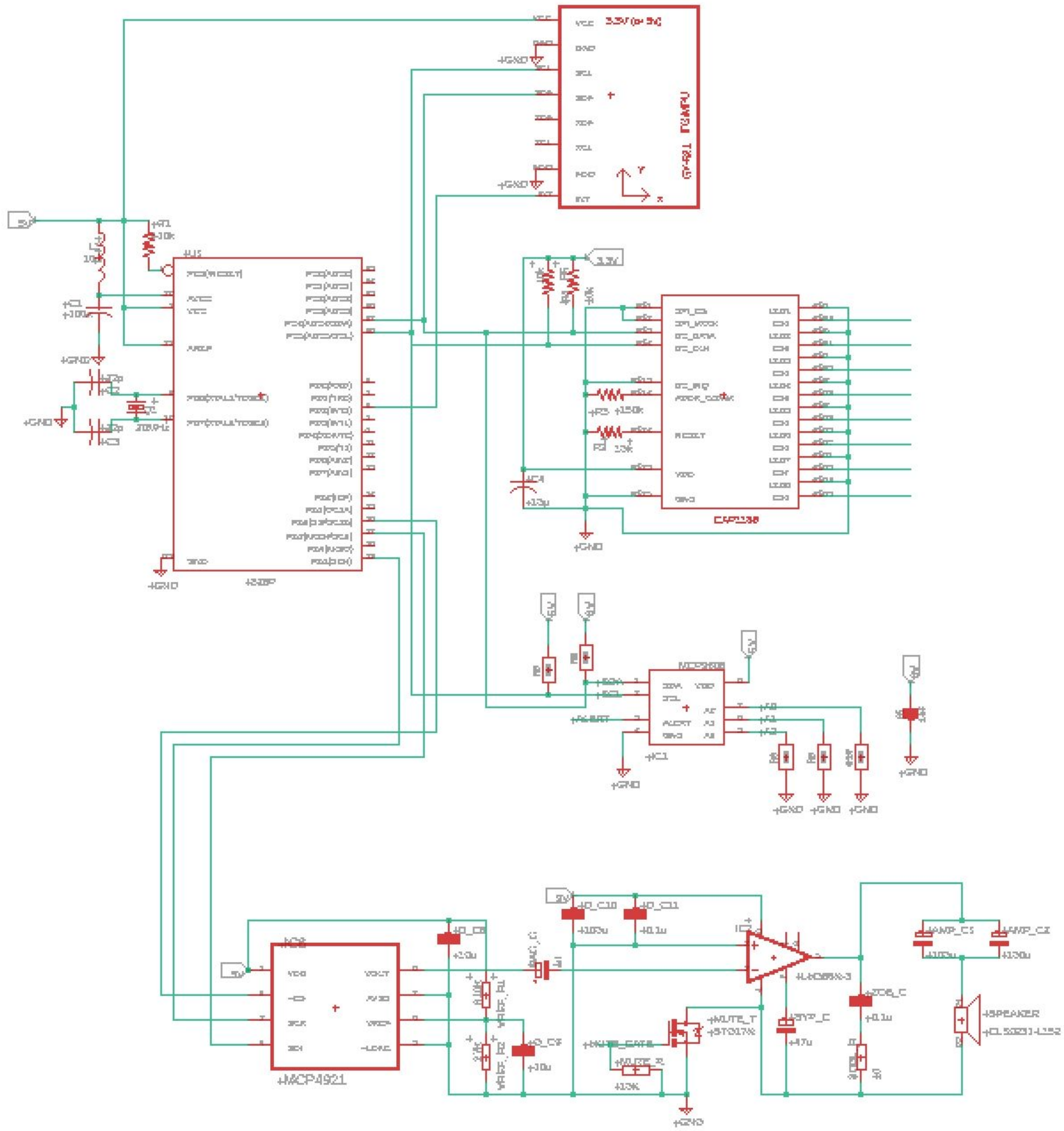

Figure 8: Layout Schematic

2.7 Microcontroller

The ATMega328P will be handling data acquisition, routing, and output from input sensors to output devices. The controller will be interfacing with analog and digital sensors as well as handling audio recording and behavioral logic to trigger audio playback in response to user interaction. The controller will also interface with a wifi module where it will send processed sensor data to be sent to a server.

2.8 Accelerometer

The accelerometer will track acceleration of the device to monitor possible stress events. Based on calculated thresholds, the accelerometer will be used to alert caregivers when the device is likely thrashed or thrown, indicating that the user might be in a panic.

2.9 Gyroscope

The gyroscope will track rotation of the device as a second means of monitoring patient conditions. By setting calculated thresholds, the gyroscope be used to alert caregivers when the device is likely being shaken violently, and also thrown, indicating that the user might be in a panic.

2.10 Microphone

The microphone will record speech as well as volume data as a third means of monitoring patient conditions. If alerts are triggered by accelerometer and gyroscope data, the microphone will start taking 5 second samples of speech and volume intensity which can be used with the rest of the sensor data to determine the state of the patient.

2.11 Speaker

The Speaker will be one of the output devices used for behavioral response to user interaction. Input sensors like the capacitive touch mechanism will trigger audio output to replicate common animal sounds such as barking/purring.

2.12 DAC/Amplifer

The Amplifier Circuit will have two sections. It will amplify audio waveforms coming from the microphone so that they can be read by the microcontroller, and amplify audio waveforms going to the speaker to achieve the desired specifications for our speaker.

2.13 Temperature Sensor

The temperature sensor will be used as a fail safe for the system. In case of overheating, the sensor will cut power to the system.

2.14 Capacitive Touch Circuit

The capacitive touch circuit will process data from touch plates on the surface of the device to be used as trigger signals for behavioral logic. The act of touching the device should trigger a response in the form of audio playback.

2.15 Wi-Fi Module

The wireless module is used to connect the robot pet to services on the Internet. This adds the ability to monitor patients, collect data on how they use the robotic animal, and adjust sensors, on the fly. We will be using a variant of ESP8266, which is an SOC WiFi module that also has a 1MB flash disk.

2.16 Software: Connected Services, Mobile/Web App

An entire software stack will be built, as shown in the block diagram. This involves managing a database, writing services, and hosting them on the web. A mobile/web app will also be built that uses the api (services) as its backend.

Table 1:

Requirement	**Verification**	**Verification Status**
2.1 High Frequency Oscillator $V_{out}(t) = Asin(2\pi * ft) + 12$ $A = 12\ [V] \pm 20\%$ $f = 600kHz \pm 10\%$ $I_{out}(t) = Bsin(2\pi * ft) + 2.1$ $B = 3\ [A] \pm 20\%$ $f = 600kHz \pm 10\%$	Verification Process: (a) Attach a 5.5Ω Resistor as load. (b) Attach oscilloscope across load. (c) Ensure the output voltage is sinusoidal in shape, periodic with a frequency of f and has an amplitude of A. (d) Attach the oscilloscope in series with the load and measure the current passing through the resistor. It should be mostly sinusoidal in shape.	
2.2 Resonance Inductive Coils $I_P(t) = Asin(2\pi * ft)$ $A = 700\ [mA] \pm 5\%$ $f = 600kHz \pm 10\%$ $EMF_S(t) = Asin(2\pi * ft)$ $A > 10.8$ $f = 600kHz \pm 10\%$	Verification Process: (a) Attach a 5.5Ω resistor in series with the primary coil. (b) Attach oscilloscope in series with coil and resistor. (c) Ensure the input current is sinusoidal in shape, periodic with a frequency of f and has an amplitude of A. (d) Attach an oscilloscope in parallel across the secondary coil/tuning capacitor. (e) Ensure the output voltage is sinusoidal in shape, periodic with a frequency of f and has an amplitude of A.	
2.3 Rectifier Provide between 6 and 24[V] with less than .1[V] ripple Current will be limited by the battery charger IC which draw	Verification Process: (a) Add an oscilloscope to the output of the rectifier. (b) Measure the average voltage. (c) Measure the peak to peak to ensure less than .1v.	

≤2[mA]	(d) Add an oscilloscope in series with the output of the rectifier to the charging circuit to test that the current isn't too high while being used	
2.4 Charging Circuit Using a LM2940T-5.0-ND 5v Fixed Voltage Regulator into MCP73831 3.7v Li-Ion Battery Charger $I_{out\ regulator} \leq 2mA$ $T_{charger} < 125$℃ but should be closer to 25℃	Verification Process: (a) Put a voltmeter in parallel with the output of the voltage regulator and battery charger. (b) Use an ammeter in series with the input of the battery charger. (c) No need to verify the Battery Charger IC and voltage regulator works within datasheet spec. (d) To measure the temperature of the charger, after 30 mins of charging the battery use an IR temperature thermometer.	
2.5 Lithium Ion Battery Provide 3.7-4.2[V] and at least 400[mA] to 600[mA] of current for 10hrs	Verification Process (a) Use a voltmeter across the terminals of the battery to measure voltage within range. (b) Connect an ammeter in series with the robot circuit while robot is in use to confirm current is within necessary levels. (c) Time how long it takes for the battery to die under normal use. (d) Battery must be a 6Ahr battery	
2.6 Voltage Booster/Regulator Booster: Provide a constant 5(±.1)[V] and at least 100[mA] for the sensors and MPU Regulator: Provide a constant 3.3(±.1)[V] and at least 215[mA] for the Wi-Fi module and additional sensors.	Verification Process Booster: (a) Place a 50Ω resistor from V_{out} to GND of the booster (b) Use a voltmeter across the resistor to ensure the voltage is within the proper requirements (c) Use an ammeter in series with resistor to ensure the current remains constant Regulator: (d) Place a 15Ω resistor from V_{out} to GND of the regulator	

	(e) Use a voltmeter across the resistor to ensure the voltage is within the proper requirements (f) Use an ammeter in series with resistor to ensure the current remains constant	
2.7 Microcontroller Provide Analog/Digital data processing for sensors and output devices. Support 4 Analog devices using I2C addressing. Use a clock frequency of 20 MHz.	Verification Process (a) Use a basic LED debug circuit connected to reserved digital ports and a blink program to test digital functionality. (b) Use function generator connected to Analog pins and check that digital conversion is accurate using step function chart. (c) Use an I2C scanner program to ping multiple devices over I2C bus and confirm detection of all devices. (d) Use a basic digital pulse program on one digital port and read the pulse on an Oscope to determine clock frequency.	
2.8 Accelerometer Must be able to detect acceleration up to 3g. Must have 3 axis detection.	(a) Read output of Accelerometer on Oscope and test 3 different axis for adequate signal. (b) Test that output signal remains stable at high acceleration (around 3g).	
2.9 Gyroscope Must be able to detect rotations up to 500 degrees / second.	(a) Read output from gyroscope on Oscope and test multiple rotational axis for consistent signal (b) Test that output signal remains stable at high rotation (around 500 degrees / second).	
2.10 Microphone Must have a sensitivity of at least -40 dB and a max frequency response of 20 KHz. Operates at a maximum of 0.5 mA.	(a) Have microphone output through amplifier into Oscope and test various sound types. For upper end of frequency response, human speech is a good test	

	case. (b) Have resistors in series with microphone and measure that current across it is consistent with operating maximum.	
2.11 Speaker Must have a sound pressure level of at least 70 dB. Has an operating power of 1 Watt.	(a) Measure power through speaker while active. Based on datasheet, approximately 2 watts should translate to 96 dB.	
2.12 DAC/Amplifer DAC: Must convert digital audio to analog output. Amplifier: Speaker amplifier must provide up to 2 watts to speaker.	(a) Examine digital waveforms alongside analog outputs and observe if analog conversion is consistent. (b) Measure power of output signals from dac on amplifier using Oscope.	
2.13 Temperature Sensor Must be accurate and function at temperatures above 100 degrees Celcius.	(a) Use a heat gun to bring sensor to 100 degrees celsius and take readings onto a serial console. Check that they are consistent.	
2.14 Capacitive Touch Circuit Supplies signal to controller when any sensor detects a capacitive change of approximately 20 femto Farads.	(a) Use an led debug circuit to test functionality of capacitive sensors. 20 femto Farads is the equivalent to contact with skin. Use fingers to test threshold.	
2.15 WiFi Module	Verification Process a. Use oscilloscope to ensure that V_in is 3.3V, and GND is 0V b. Connect microcontroller to computer and run initialization script on Wifi Module c. Open up serializer and look at responses for nearby WiFi access points d. Connect to WiFi access point with credentials	
2.16 Software	Verification Process a. Connect to WiFi access point as shown on step 2.15.	

	b. Run connect script to connect to MicroServices. c. Send test diagnostic to server d. Try to connect to server on computer. Check logs to confirm test diagnostic was received e. Go to phone/computer. Log into account corresponding to device. f. Confirm test diagnostic received g. Send “sound” command to device h. Confirm server receives command i. Confirm device receives command, device makes “sound”	

2.17 Risk Analysis

The block that poses the biggest is the wireless charging system. A group in the past tried and failed to create a wireless charging pad to charge a laptop. The biggest concern with the wireless charging pad is that it won’t be efficient enough to charge the battery. They tried to transfer a significant amount more power than we require. The battery for our system needs at most 3 W meaning allowing a low need for efficiency. The low need for efficiency enables a more simplistic design. The wireless charging depends upon the secondary (receiver) coil having an induced current from the magnetic field produced by the primary (transceiver) coil. We need to ensure that the resonance frequency matches in both coils as well as with the sine AC signal that is creating the magnetic field in the primary coil and inducing the current in the secondary coil. Ensuring these frequencies match can be difficult as many coils we would buy online don’t have complete datasheets to include the capacitance between the wires in the coil. This capacitance varies from coil to coil and could greatly affect the resonance frequency. Measuring the capacitance of the system and tuning the frequency by adding capacitors in parallel with the coils can help improve efficiency. Another issue with the wireless charging could be the distance between the coils while charging. Magnetic fields decrease as $\frac{1}{r^2}$, meaning that the further away the secondary coil is from the primary the more energy is lost. We need to ensure that the coils are close enough that the field doesn’t decrease so much as to reduce efficiency too much.

2.18 Tolerance Analysis

Wireless charging would greatly increase the realism of the robot. It reduces the need to manually replace the batteries which can be frightening to the patients who will use the robots. Wireless charging requires an alternating current to flow through the primary coil which generates an alternating magnetic field. The flux through the secondary coil generates an electromotive force and induces a current. A sinusoidal alternating current can be generated using a Class E Inverter. This inverter utilizes a N-Channel Mosfet, a square wave signal, and a LC circuit to produce an oscillation [14] (see right side of figure 4). Invert feeds directly into the capacitor (C2) and inductors (L2) in series for the primary coil. Each component needs to be tuned so that current through L2 is mostly sinusoidal and is sufficiently high enough to produce a large enough EMF in the secondary coil. Buying a 47μH coil means that the frequency of the square wave must be about 604kHz, and means we would buy C2 = 4.7nF ± 10%, C1 =150nF ± 20%, and L1 = 1.59μH ± 5%. Using the ideal values of each of these components results with an EMF of about $8.169 \cdot 10^{-3} cos(2\pi \cdot 600,000 \cdot t)[J/C]$.

This value isn't sufficient, but experimentation must be done to produce our own coils to increase the EMF. To provide the sufficient voltage for the voltage regulator on the secondary we need an EMF with amplitude of at least 10.8 [J/C]. Since we will need to make our own coils to increase the amount of turns and inductance of the coil in an effort to increase the EMF these values are very likely to change and the tolerances won't be accurate. This will show the calculations that we will be doing to ensure that this circuit works once we have tuned the coil correctly.

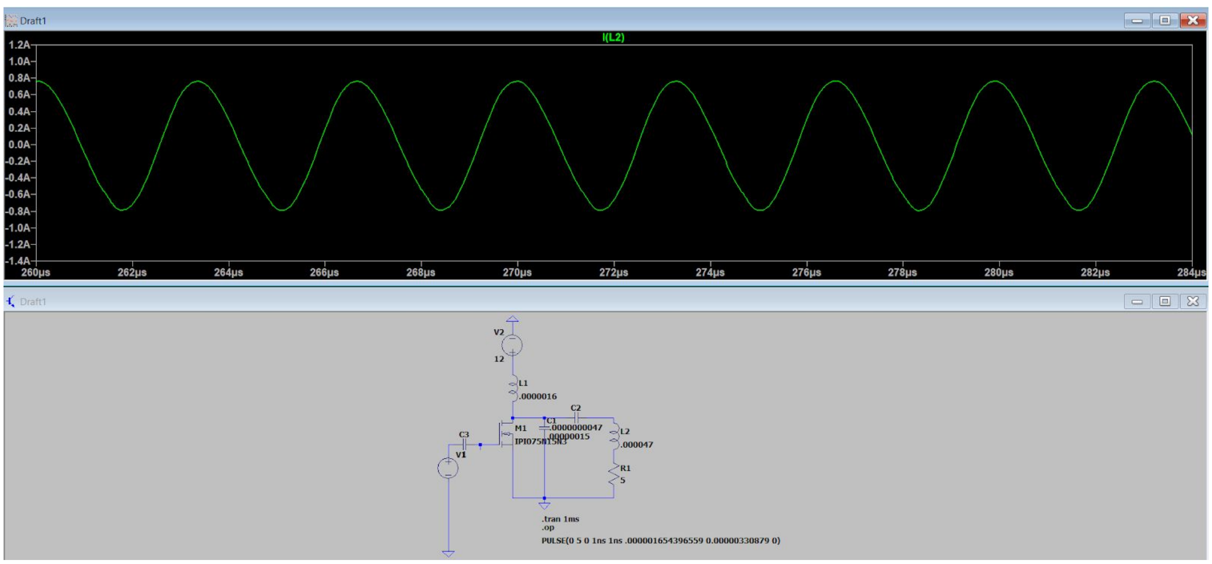

Figure 9: Simulation of Current through Primary Coil for Ideal Components

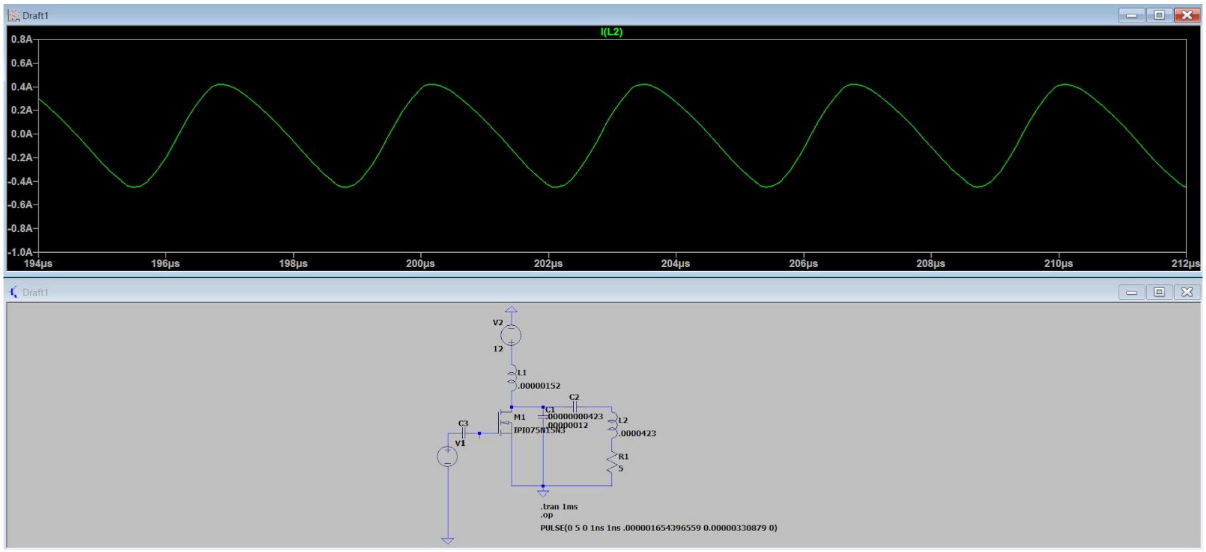

Figure 10: Simulation of Current through Primary Coil for Lower Extreme Tolerances

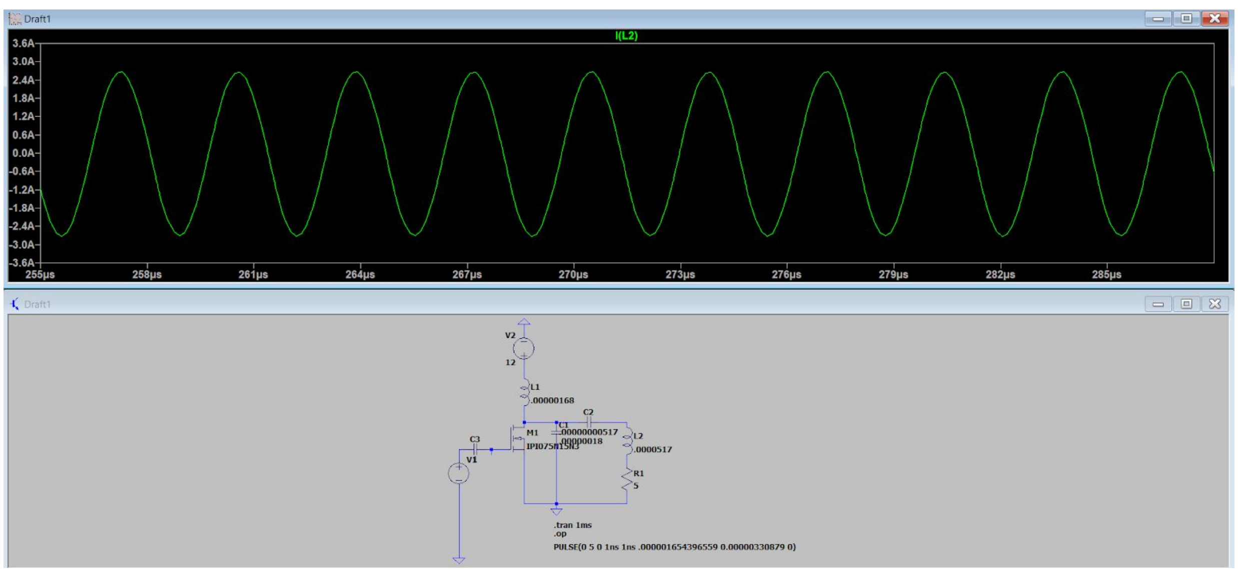

Figure 11:Simulation of Current through Primary Coil for Upper Extreme Tolerances

Changing the values can greatly affect the amplitude of the current through L2 and as a result change the EMF as seen in table 2.

Table 2:

Tolerance Extreme	EMF Amplitude [J/C]
Lower Extreme	$4.878 \cdot 10^{-3}$
Ideal	$8.169 \cdot 10^{-3}$
Higher Extreme	$3.090 \cdot 10^{-2}$

It can be seen that at the extremes of the tolerances the EMF can vary by about 0.0004 to 0.0022 [J/C]. We will need to keep this in mind once we have selected the final coil so that the EMF stays above the required 10.8 [J/C]. However, having an EMF above the requirement doesn't matter too much since the 5v voltage regulator that follows the rectifier can accept a voltage up to 24[v]. Increasing the number of windings for the coil and matching the new components for the new inductance of the coil should result with a better EMF. Furthermore, the simulation shows that the variance from tolerances isn't too high and tolerances of ~10% per component should be sufficient once the EMF is in the required range.

3 Cost Analysis

3.1 Labor

Table 3: Labor Costs

Name	Hourly Rate	Hours	Total	Total x 2.5
Brian Wilens	$40.00	300	$12,000.00	$30,000.00
Divij Nagpaul	$40.00	300	$12,000.00	$30,000.00
James Brown	$40.00	300	$12,000.00	$30,000.00
Labor Total				**$90,000.00**

3.2 Parts

Table 4: Parts Costs

Description	Quantity	Backup Quantity	Part Number	Manufacturer	Vendor	Cost/unit	Total Cost
WiFi Module - ESP8266	1	1	ESP8266	Makerfocus/Spark Fun	Amazon/Spar kFun	$6.95	$13.90
Logic Level Converter - Bi-Directional	1	1	BOB-12009 ROHS	SparkFun	SparkFun	$2.95	$5.90
Arduino Uno	1	0	Version 3	Arduino	Amazon	$18.16	$18.16
Lithium Ion Battery - 6Ah	1	0	N/A	SparkFun	SparkFun	$29.95	$29.95
Battery Babysitter - LiPo Battery Manager	1	0	PRT-13777	SparkFun	SparkFun	$19.95	$19.95
Wireless Charging Coils (47uH +- 10%)	2	0	710-760308101 303	Wurth Electronics	Mouser	$12.43	$24.86
Inductor (1.6uH +- 5%)	1	1	807-1782R-25J TR	API Delevan	Mouser	$2.44	$4.88
Capacitor (22uF +- 10%)	2	2	490-17935-ND	Murata Electronics North America	Digikey	$1.40	$5.60
Capacitor (.47uF +- 10%)	2	2	445-2643-ND	TDK Corporation	Digikey	$0.64	$2.56
Capacitor (.15uF +- 20%)	1	1	399-4343-ND	KEMET	Digikey	$0.36	$0.72
Capacitor (4.7nF +- 10%)	2	2	445-5250-ND	TDK Corporation	Digikey	$0.29	$1.16
Capacitor (6.8uF +- 20%)	1	1	565-4733-1-ND	United Chemi-Con	Digikey	$2.47	$4.94
Resistor (22kOhm +- 1%)	1	1	BC3259CT-ND	Vishay BC Components	Digikey	$0.24	$0.48
Resistor (10kOhm +- 5%)	1	1	10KQBK-ND	Yageo	Digikey	$0.10	$0.20
3.5 mm audio jack	1	1	490-MJ-3502N	CUI	Mouser	$1.24	$2.48
MOSFET 150V Vds 20V Vgs TO-220	1	1	78-SUP80090E -GE3	Vishay / Siliconix	Mouser	$3.09	$6.18
5v voltage regulator	2	1	926-LM2940T-5.0/NOPB	Texas Instruments	Mouser	$1.55	$4.65
Diode (.7v FW voltage)	4	2	641-1411-1-ND	Comchip Technology	Digikey	$0.54	$3.24

PICAXE 08M2 Microcontroller (8 pin)	1	0	N/A	SparkFun	SparkFun	$2.95	$2.95
Charger IC Lithium-Ion/Polymer SOT-23-5	1	1	MCP73831/2	Microchip Technology	Digikey	$0.58	$1.16
Pololu 5V Step-Up Voltage Regulator U3V12F5	2	1	U3V12F5	Pololu	Pololu/Amazon	$3.95	$11.85
Pololu 3.3V, 500mA Step-Down Voltage Regulator D24V5F3	1	1	D24V5F3	Pololu	Pololu	$3.95	$7.90
General Resistors TBD	1	0	N/A	N/A	N/A	$12.00	$12.00
General Capacitors TBD	1	0	N/A	N/A	N/A	$12.00	$12.00
2.2 X 6.5 Inch Breadboard	1	0	103-1100	N/A	ECE Supply Center	$14.07	$14.07
ATMEGA328P-PU Microcontroller	1	1	556-ATMEGA328P-PU	Microchip Technology	Mouser	$2.15	$4.30
Triple Axis Accelerometer and Gyro Breakout	1	0	MPU-6050 / SEN-11028	SparkFun	SparkFun	$29.95	$29.95
Capactive Touch Sensor	1	1	CAP1188-1-CP-TR	Microchip Technology	Digikey	$1.15	$2.30
Board Mount Temperature Sensor	1	1	MCP9808-E/MS	Microchip Technology	Mouser	$1.17	$2.34
DAC	1	1	MCP4921	Microchip Technology	Digikey	$2.03	$4.06
Amplifier	1	1	LM386N-3	Texas Instruments	Digikey	$1.01	$2.02
Speaker	1	1	CLS0231-L152	CUI Inc	Digikey	$4.64	$9.28
Electret Microphone Amplifier	1	1	MAX4466	Adafruit	Amazon	$8.99	$17.98
							$283.97

3.3 Total Cost

Our total cost is $90,000.00 + $283.97 = $90,283.97

3.4 Schedule

Our schedule is shown below in Table 5:

Table 5: Schedule

Week	Task	Responsibility
9/17/2018	**Project Proposal Due**	All
	Finalize project proposal	All
	Research Sensors, Microcontroller	Brian
	Research IOT	Div
	Research Wireless Charging	James
9/24/2018	**Eagle Assignment Due**	All
	Prepare for Mock Design Review	All
	Research Software Control Flow	Div
	Research Hardware Flow	James, Brian
	Research Wireless Charging	James
10/1/2018	**Mock Design Review & Design Document Due**	All
10/6/2018	Order Microcontroller, sensors, WiFi module, battery, components for wireless charging experiments	All
10/8/2018	**Design Review**	All
	Start building wireless charging circuit	James, Div
	Start programming microcontroller	Brian
	Start setting up JSON contract for data exchange	Div
10/15/2018	**Teamwork Evaluation 1 & Soldering Assignment due**	All
	Start programming web integration for diagnostics for microcontroller	Brian,Div
	Last day to prove wireless charging is a viable option	James, Brian
	Experiment with wireless charging efficiency, modify circuit, order more parts	James
10/22/2018	**First Round PCBway Orders due**	All
	Start programming sensor logic	Brian
	Test service, start implementing front-end application	Div
10/29/2018	Continue working on Wireless charging	Brian, James
	Continue working on expanding services, implementing front-end application	Div
11/5/2018	**Individual progress report due, Final Round PCBway Orders due, Last day for revisions to machine shop**	All

	Assemble all components, integrate parts	Brian
11/12/2018	**Start wrapping up project**	All
	Prepare for Mock Demo	All
	Run tests on project as a whole	James, Div
11/19/2018	Fall Break	All
	Prepare Presentation	James
	Ensure Functionality	Div
	Start Preparing final paper	Brian
11/26	**Mock Demo**	Brian
12/3	**Mock Presentation**	James
	Improve Presentation and Demo based on feedback	Div
12/10	Presentation and Final Paper due	All

4 Safety and Ethics

The biggest ethical concern we have correlates to guideline 1 of the IEEE code of ethics. That rule corresponds to the health and safety aspect of the rules. Transferring power in general, especially over the wireless coils, runs the risk of heating up the system. The robot is covered in fur and has very little air flow, therefore overheating and possibly catching on fire is a concern. We intend to reduce this risk by transferring relatively low amounts of power and by having heat sinks across the robot to redistribute the heat. Another fire concern relates to the charging of the lithium ion battery. Lithium ion batteries are great batteries in that they're able to charge and discharge many times, they're able to provide a good voltage, and be able to last for long periods of times. This risk can be minimized by using safe charging methods. There are many ICs that are able to monitor and control the charge of lithium ion batteries. By using one of these we are able to reduce the risk [3].

Another concern correlates to guideline #5 of the IEEE code of ethics, in that our robot is recording patient data in terms of temperature and speech to alert the caregiver. Additionally, the caregiver will be able to use an app to control the robot's animal noises. Care must be used to ensure that no data can be stolen and that the robot's controls can't be hacked. We intend to use RSA + AES standard that is commonly used in the industry[5]. This involves public and private key exchanges along with generation of an AES key that will be used to establish a secure session. This ensures that no man-in-the middle attack or eavesdropping can occur. We hope that by discussing and documenting our work we can demonstrate honest and just engineering practices and share the growth of knowledge.

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