Wirelessly Charged Nursery Light

DESIGN DOCUMENT

TEAM 22

CLIENT/ADVISOR: CHENG HUANG

JOSH HOLLOWAY / TEAM LEAD

THOMAS YOUHN / ELECTRICAL LEAD

WYATT RAYL / COMPONENT DESIGN

WILLIAM SNYDER / TESTER

LOGAN FARMER / FACILITATOR

ALEXANDROS PSOMAS / PRODUCT DESIGNER

sdmay24-22@iastate.edu

https://sdmay24-22.sd.ece.iastate.edu

Table of Contents

Table of Contents 1
1 Executive Summary 3
1.1 Development Standards & Practices Used 3
1.2 Summary of Requirements 3
1.3 Applicable Courses from Iowa State University Curriculum 3
1.4 New Skills/Knowledge acquired that was not taught in courses 3
2 Team 4
2.1 Team Members 4
2.2 Required Skill Sets for Your Project 4
1.1 Skill Sets covered by the Team 4
1.2 Project Management Style Adopted by the team 4
1.3 Initial Project Management Roles 4
2.1 Problem Statement 6
2.2 Requirements & Constraints 6
2.3 Engineering Standards 6
2.4 Intended Users and Uses 7
3 Project Plan 8
3.1 Task Decomposition 8
3.2 Project Management/Tracking Procedures 9
3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria 9
3.4 Project Timeline/Schedule 10
3.5 Risks And Risk Management/Mitigation 11
3.6 Personnel Effort Requirements 12
3.7 Other Resource Requirements 13
4 Design 14
4.1 Design Content 14
4.2 Design Complexity 14
4.3 Modern Engineering Tools 15
4.4 Design Context 15
4.5 Prior Work/Solutions 16
4.6 Design Decisions 17
4.6.1 Materials 17
4.6.2 Physical components 17
4.6.3 Features 17
4.7 Proposed Design 17
4.7.1 Design Overview 18
Design Visual and Description 18
Functionality 19
4.7.2 Design 1 20
Design Visual and Description 20

4.8 Technology Considerations 22
4.9 Design Analysis 22
5 Testing 23
5.1 Unit Testing 23
5.2 Interface Testing 23
5.3 Integration Testing 24
5.4 System Testing 24
5.4.1 Circuit Design 24
5.4.2 Software Design 24
5.4.3 Physical Design 24
5.5 Regression Testing 24
5.6 Acceptance Testing 25
5.8 Results 25
5.8.1 Touch Sensor Results 25
5.8.2 Arduino Nano Every Results 26
5.8.3 LED Strip Results 26
5.8.4 Battery Charging Unit Results 27
6 Implementation 28
7 Professionalism 29
7.1 Areas of Responsibility 29
7.2 Project Specific Professional Responsibility Areas 30
7.3 Most Applicable Professional Responsibility Area 30
8 Closing Material 31
8.1 Discussion 31
8.2 Conclusion 31
8.3 References 31
8.4 Appendices 31
8.4.1 Team Contract 31
8.4.2 Circuit Design Layout 36
8.4.3 Circuit High-Level Overview 36
8.4.4 Project Direction Sketch 37

1 Executive Summary

1.1 Development Standards & Practices Used

- Qi2
- IEEE 1855
- IEEE 370
- IEEE 1679.1
- IEEE 2700

1.2 Summary of Requirements

- Develop and test a nursery light product. Design needs to:
-
    - Be wirelessly charged.
    - Be battery powered.
    - Change brightness level by tapping on it.
    - Light auto dims and shuts off.
    - Light transitions smoothly on and off.

1.3 Applicable Courses from Iowa State University Curriculum

- CPRE 288
- EE 330
- Engl 314
- CPRE 281
- IE 305
- COM S 309
- EE 311
- EE 465

1.4 New Skills/Knowledge acquired that was not taught in courses

- CAD
- Arduino programming/testing
- Product design
- PCB Design

2 Team

2.1 Team Members

Thomas Youhn, Wyatt Rayl, Alexandros Psomas, Logan Farmer, William Snyder, Joshua Holloway.

2.2 Required Skill Sets for Your Project

- CAD
- Industrial design
- PCB design
- Circuit testing
- Circuit analysis
- Mathematics
- Microcontroller programming
- Circuit board prototyping

1.1 Skill Sets covered by the Team

- Josh: CAD, industrial design, circuit resting, mathematics, microcontroller programming, circuit analysis.
- Thomas: PCB design, circuit testing and analysis, mathematics, microcontroller programming, circuit board prototyping.
- Wyatt: CAD, microcontroller programming, mathematics, circuit analysis.
- Alexandros: Industrial design, mathematics, circuit testing.
- Logan: CAD, PCB design, circuit testing, microcontroller programming, circuit board prototyping.
- William: CAD, circuit analysis, power systems analysis, circuit testing, circuit board prototyping, microcontroller programming.

1.2 Project Management Style Adopted by the team

Agile project management.

1.3 Initial Project Management Roles

Project Manager: Josh Holloway

Electrical Lead: Thomas Youhn

Circuit Designer: Wyatt Rayl

Tester: William Snyder

Scribe/Facilitator: Logan Farmer

Project Designer: Alexandros Psomas

2.1 Problem Statement

The modern market of nursery lights is oversaturated with wired, large, and encumbering pieces of hardware. The goal of this project is to create a wirelessly charged nursery light that is easily used and easily integrates into any home. Normally, when you wake up at night to take care of your child you have to transport and carry a bright, harsh flashlight or turn on the room lights and hope its not too detrimental to your own or your child's future sleep after the bright lights fill the room. The goal of this project is to create a portable, easily accessible, and wirelessly charged nursury light for ease of transportation and usage.

2.2 Requirements & Constraints

Functional Requirements:

- Design must be battery powered and charged wirelessly.
- Design must be able to alternate between two brightness levels by tapping on it (constraint).
- Light must automatically dim and shut off after ten minutes (constraint).
- At all times when the light is turned on/off it must do so smoothly as to not wake the baby.

Resource Requirements:

- Project must utilize Arduino and remain programmable.
- Project must use a Lithium Polymer battery.

Qualitative Aesthetic Requirements:

- Design must be soft and easily approachable for children.
- Design must emit amber or other warm-levels of light.
- Design is not required to be commercialized or mass-manufactured.

Performance Requirements:

- Battery life lasts longer than three days during standard use (constraint).

2.3 Engineering Standards

Qi2 - The QI2 wireless charging standard is required to ensure we approach the wireless charging aspect of the nursery light properly and ensures proper efficiency and alignment.

IEEE 1855 - Standard for Fuzzy Markup Language, or Arduino code. As this project will remain programmable and be implemented with an Arduino Nano, this standard is needed.

IEEE 370 - Standard for printed circuit boards, which is planned to be utilized in this design as a shield to the Arduino Nano.

IEEE 1679.1 - Standard guide for characterization and usage of Lithium-Based Batteries in stationary applications, we plan to use a Lithium Polymer Battery so this standard is needed.

IEEE 2700 - Sensor parameters for touch-based applications, helpful for the touch sensors applied to this project for power/brightness level.

2.4 Intended Users and Uses

The main user of this project is the client, who has wanted a nursery light for personal use that follows the above requirements and constraints listed in Section 1.2. This means the light will often be in the proximity of nursing children, so keeping the design soft, safe, and simple on the outside to ensure the child's safety.

3 Project Plan

3.1 Task Decomposition

Task layout:

- Order the Components
  - Research each component and make sure that they are compatible
  - Send the component list to the supervisor to order through ETG
- Code: Turning on the Light
  - Test the current values at max brightness
- Calculate and source needed battery
  - Measure the current for this to occur
  - Using this current value, calculate the lifetime needed to run at max current
  - Find batteries to fit this criteria
  - Order the batteries
- Stress Test
  - See how long the battery can last for, but do not drain all the way
- Code: Brightness values
  - 3-5 separate dimming values, not including “light off”.
  - Test to make sure the touch sensor works.
  - Find the current for each brightness level
- Code: Dimming Over Time
  - Code and test to ensure onboard timer functions as designed
- Hardware: Wireless Charger and voltage control
  - See if the charger is working and at what rate it is charged.
  - Calculate how long it will take to charge to full.
  - Test to make sure the current will stop when the batteries are full
  - Make sure that the lamp does not heat up too much
- Full Test
  - Test the close to the full life of the battery
  - Make sure that the battery can be recharged at a reasonable rate
  - See if there is a reduction in battery life if it fully discharges
- Project housing
  - Design product casing to hold the fixture
    - Prototype project housing in SLA resin printing
  - Install and test project casing
    - Test thermal acuity
    - Ensure full project function over three days

Looking through the tasks, it can be seen that a majority of them are simply the requirements for the project. For instance, tasks such as “Code: Dimming Over Time” and “Code: Brightness Levels” are both just tasks to set up those two requirements from the design sheet. Besides those that are directly related to the requirements, the other tasks are about getting the components, running tests, or designing the housing for the nursery light. The components are obviously relevant since getting these are needed to set up and test the code that will make the light work. There are three test-related tasks, the first one acts as a stress test making sure that the battery can last the full time the consumer asked for. The next test was a full test making sure that all of the code was working as intended and seeing how the battery life varies with the dimming. It also will include charging the battery using the magnetic charger and seeing how long it takes to get to full battery. The final test will be doing the previous test within the housing to make sure that everything fits and works as intended inside it. The 2nd and 3rd final tasks of the project will focus on making an enclosure for the light fixture and the circuit controlling it. This enclosure then needs to be fitted to dim the light with an opaque amber-colored top and allow for the magnetic changer to work as needed.

Since the previous paragraph described the tasks that were not in the requirements, this paragraph will give a brief description of those that are in the requirements for the project. The first of these is the code to turn the light on. This is just making the code that will allow the microcontroller to turn on the installed light fixture. The next code is to make separate dimming levels. To do this the code will tell the controller to send different voltage values to the light fixture meaning that each voltage level has a different brightness level. The next requirement is making sure that the light will auto-dim after a set amount of time. The code does this by setting the voltage level of the light fixture to the brightness setting made in the last part. The level will change at set amounts of time until it is set to 0. This range will be around 5-10 minutes in total. The next task will be making the light not go to full brightness right away. This can be solved in a similar way to the dimming where the light will slowly turn on to the brighter settings. The final two tasks related to the requirements are creating the magnetic charger and a control for the charging voltage. The first one of these is just making sure that the charger is connected to the battery and allows the battery to charge. The second task is more important as it checks to see what the voltage level of the battery is and then checks to see if it still needs to be charged. If it is full it should stop the current from the charger to not waste power or heat the fixture too much.

3.2 Project Management/Tracking Procedures

For this project, we will be using agile project management. We have several smaller tasks that need to be completed; because of this, there won't be a lot of large sprints between check-ins but many small, individual sprints to push the project forward. To track our progress, we will use git, Google Drive, and Discord to organize sheets, notes, meeting minutes, and designs made throughout the semester.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

- Working code for Arduino
  - Three brightness levels
  - Timer to auto dim after 10 minutes
- 3D model of design that can hold required circuitry
  - Housing should survive drop test of 3 feet
- Test power draw to meet the power-on-time requirement
  - On max bulb brightness it should last three days on charge alone during regular use (three “on” cycles per night)

3.4 Project Timeline/Schedule

The basic task layout for this project is broken up into two semesters. During the first, the goal is to design and prototype each individual component and integrate it into the Arduino system. This involves sourcing and ordering components first, calculating the needed battery, then testing further using the now complete hardware list. The following semester revolves around CAD design and final testing/product assembly. The below Gantt chart is done with all tasks in necessary order with the color code of purple: testing, blue: hardware/software design, and green: product housing.

The deliverables for this project are separated into end of Q4 2023 and end of Q2 2024. Individual testing milestones are separated and specified within the Gantt chart.

Tasks	Start Date	End Date
Ordering components		
Component research	08/22/23	10/12/23
Component ordering	10/12/23	10/26/23
Software: Light		
Code Arduino to interact with light and turn it on	10/27/23	11/03/23
Battery		
Test current when light is at max brightness	11/06/23	11/08/23
Calculate lifetime and source battery	11/08/23	11/10/23
Order battery	11/10/23	11/17/23
Stress test		
Test battery life duration	11/27/23	11/28/23
Software: Brightness values		
Integrate and test touch sensor	10/27/23	11/03/23
Program brightness levels and test with touch sensor	11/06/23	11/10/23
Determine current requirements per brightness level	11/13/23	11/17/23
Software: Dimming over time	10/27/23	11/03/23
Program onboard timer and integrate	11/06/23	11/10/23
Hardware: Wireless charger		
Test charging components	11/28/23	11/30/23
Calculate charging time	11/30/23	12/01/23
Ensure charger does not overcharge	11/30/23	12/01/23
Ensure project heat management is within bounds	11/30/23	12/01/23
Project test		
Test full life of battery within operational parameters	01/15/24	01/26/24
Ensure battery charges at reasonable rate	01/15/24	01/26/24
Test function and recharging after fully draining battery	01/15/24	01/26/24
Design project housing		
CAD: Project housing	01/15/24	01/29/24
Print housing	01/30/24	02/19/24
Test thermal acuity	02/20/24	02/21/24
Assemble three products	02/21/24	03/01/24

3.5 Risks And Risk Management/Mitigation

When looking at some of the risks associated with each step in our planning process, there exists some risks but most have low probability and are avoidable by making sure of our research and testing components. With that being said there are some risks that are completely out of our control. To mitigate these risks, we have planned ahead and have other options ready in case these risks arise.

Ordering Parts: There is a chance that some parts that we order come with defects or not perform as advertised. Another possible risk is the parts being delayed or out of stock. This could slow down our prototyping process and may require us to find alternative parts or suppliers. To mitigate these risks we have done research on multiple options and have other parts options ready if the ones choses have issues. Probability: .2

Calculate and Source Needed Battery: A possible risk for calculating the battery and choosing one is that our calculations could be off due to missing an aspect of the system or there isn't a battery that fits our needs well enough. Probability: .1

Battery Stress Test: When Testing the battery, it is possible that the battery we chose would not meet our calculations and not perform how we expected. The other possibility is that the battery gets too hot which could result in a dangerous product or affect other components. Probability: .2

Code: Turning on Light/Brightness values/Dimming Over Time: When coding the lighting controls, a possible risk would be that the LED lights we choose to implement are not as programmable as we require for our project. This would force us to find a different lighting solution which could delay some of our steps. Probability: .05

Hardware: Wireless Charger and voltage control: A risk when working with wireless charging is that the hardware we chose might not provide enough power to charge the battery fast enough causing us to have to find different wireless charging hardware. Probability: .3

Full Test: When putting the entire system together there is always the possibility of components not working together as anticipated when they worked correctly on their own. This could force us to have to reconfigure our design or change some components to make everything work together. Probability: .15

Project housing: When creating the housing, we need to make sure that the outer material is thin enough so that the wireless charging and touch sensor work through it. This could be difficult depending on the material and method we use to create the housing. Probability: .4

3.6 Personnel Effort Requirements

Personnel effort estimates are approximated by the groups of people we have that have the ability to finish each task. Our team is separated into groups depending on skillset, project desires, and background. Through this, many tasks are team-based and will take less time than when a single member would tackle it. The following table separates each task listed in 2.1 and estimates the project time required for each portion. For reference for further breakdown on individual tasks, reference section 2.1. The longest task is printing time, which, although does not require direct input from the team, will be something to account for to ensure the project is completed on time. The estimated time is a reference and may change during development and testing.

Overall Task	Task Breakdown	Approximate Time to Finish (hours)
Ordering components	Component research	5
	Component ordering	0.5
Calculate and source battery	Turn on and measure the current	0.5
	Calculate lifetime based on current measurement	1
	Source batteries to meet the criteria	2
Component testing	Touch sensor light brightness changing	5
	Light dimming over time protocol	5
	Wireless charger	5
	Voltage control	1
Environmental testing	Stress test 1	6
	Stress test 2	6
Project Housing	Design project housing	12
	Print project housing	15
	Install and test project housing	4
TOTAL		*68*

3.7 Other Resource Requirements

Over the course of this project, there are multiple resources ranging from physical assistance to softwares required for this project to be completed. These are the sources we will be using to properly tackle the project requirements within IEEE standards:

- ETG (Ordering components and soldering tools)
- Fusion 360 (For 3D modeling)
- Arduino IDE (Code compiler for arduino)
- LT spice (For circuit simulation)
- KiCad (Circuit design)

4 Design

4.1 Design Content

For the design of our nursery light we are creating the housing and circuit that will be used. The housing will include the base shell for all the electronics as well as a cover for the light to deter damage. Our circuitry will mostly use arduino to control the finer aspects of the light including its ability to dim over time and run on a timer.

4.2 Design Complexity

This project can be split into 5 main challenges.

1. Dimmable LED using MOSFETs
2. Creating a PWM and Dimming Timers in Arduino
3. Battery Life and Choice
4. Wireless Charging
5. Physical Design

Focusing on them individually it can be seen that each one uses varying amounts of engineering principles. The first challenge is finding a way for the Arduino to control the brightness of an LED without it being directly connected to the LED strips. The reason for this is that the Arduino cannot output the current needed to light the strips in the brightness levels wanted. To solve this issue, a MOSFET was used, one of the core blocks of electrical engineering design. This MOSFET gate will act as an input for the Arduino pin while the battery provides the current and voltage in series with the LEDs. This MOSFET will then act as a switch allowing current through when the Arduino pin is high and cutting it off when it is low. To do this, a proper MOSFET had to be selected and currents had to be calculated to not overload the battery's life. This looked at the basic square law models and made sure that the threshold voltage was correct for Arduino's output pin voltages.

Looking at the dimming of the LED would be a different problem entirely. Dimming the LED can be done by lowering the flicker frequency. The easiest way to do this would be through pulse wave modulation (PWM). Using the Arduino timer, the output pin's frequency can be raised or lowered and in turn, the LED's frequency will be raised or lowered. This of course must still be higher than the human eye can see to make sure that the flicker is not bothersome. The lower the frequency, the dimmer the LEDs will be. This PWM also has to be able to be adjusted so that it will lower over set intervals, set by another timer, and changed due to buttons being pressed on the design. This means that the PWM must be adjustable through the Arduino software. This PWM must also be present when turning on the light since it needs to have a smooth turn on process.

Another challenge will be getting the correct battery life for the project. The goal of the project is to have a working battery life of about three days. The main draw for the battery will be from the LEDs as they need the most current. Next, it would be the draw from the Arduino. The battery must have the life to sustain the current drawn from it over a period of 10 minutes (the approximated dimming time). This 10-minute period will have different levels of dimming so the current draw will vary. Still, this must be calculated and to do this, the current draw at max brightness needs to be tested and gathered to pick out the correct life for the battery. Along with that, there needs to be a way to boost the battery voltage to 5 V to run both the Arduino and the LEDs. After that, the dimming currents should be tested so a battery with the correct AmpHrs is selected.

The next major issue is the wireless charging. This change is going to be done through magnetic induction. This needs to be researched and the correct coils need to be found. These coils then need to be tested to make sure that the input from a wall outlet will output the correct voltages to charge the battery without too much current flowing through it. Along with that, the heat needs to be managed as the induction coils can output a lot of heat as waste. Managing these two will lead to making sure that the charge rate is at a comfortable amount meaning that it does not take too long to change the battery while at the same time not making the current so high that it could rise to dangerous temperatures.

The final big part of the project is creating the physical housing for the light. This housing needs to be able to hold the LEDs, Arduino, circuit components, and the wireless charging coil. With that, the coil must also be able to interact with the other coil to start the charging process. The goal is to also have it fit comfortably and easily so that small adjustments will not stop the changing process accidentally. The design needs to be able to withstand any heat that might be output by the circuit without any damage. Finally, to help warm the light, a clear filament will be used to further dim the LEDs to not bother the children using the lights.

4.3 Modern Engineering Tools

What modern engineering tools were used for this design? Their roles.

- Fusion 360: Fusion's role in our project is a tool for designing the 3d components for our project we will personally design such as outer casings and housings.
- Arduino IDE: This is important because we will use it for our arduino code which will serve as the main area to control the light and its timer settings
- LT spice: This will be useful for testing a circuit before we use actual parts in the system as we do not want to ruin parts for an incorrectly calculated voltage or an unexpected surge while testing smaller individual parts.
- KiCad: The ability to create online circuits as a general plan is very useful to keep designs clear and easy to read for clients and creators, because looking at a breadboard and understanding what is going on is much more complicated.

4.4 Design Context

Our project may seem very simple and unassuming but nursery lights are a big part of having a child. Our project will address the societal needs of parents who are looking for a safe long lasting nursery light. There are a lot of cheap nursery lights on the market but we aim to do what none of the others can do we are going to make the light movable unconnected from the wall so you can bring it to any room in the house or even out of the house if you go on vacation or to the grandparents house. using wireless technology we will create a wireless charging station for this nursery light to be placed to charge. Then when it's fully charged parents won't have to worry about it for three days. Using the integrated battery and auto turn off timers our nursery light will have plenty of battery to last whatever event is keeping you from the wall.

List relevant considerations related to your project in each of the following areas:

Area	Description
Public health, safety, and welfare	Our product is made with safety in mind. we will design the light so that the diode will never get hot, giving peace of mind to the parents. With the wireless feature it also reduces chances of wires strangling young children.
Global, cultural, and social	The goal of this product is to be universal and simple, using simple design choices allow it to effortlessly fit into the average home.
Environmental	Our design will impact power consumption of a household, by reducing overall power consumption due to the wireless charging causes it to not always be plugged in and taking charge.
Economic	Our product is closed, meaning the final result will be used by our client and our client alone without moving to a secondary market. Because of this, the only economic impact we impose is paying for parts before assembly.

4.5 Prior Work/Solutions

When looking at other nursery and night lights available on the market today, there is a large variety of styles available and many come with a couple similar features. For example, there is a lot of options for different sizes and shapes. These include simple cylinders or spheres or more intricate designs like different animals and other non-standard shapes. While most other options have multiple lighting levels and touch controls like our design, there are a few features that are found in other products that we will not have. These include having different color options for the lights, a remote control, and some even have apps to control them. There are a few features we will have which seem less prevalent in the market today. Firstly is the wirelessly charging aspect. There seems to be a few options that have proprietary wireless charging docks whereas our design will work with any Qi charger that it can fit. Also, our design using an Arduino Nano which means that it is completely programmable and can be programmed to add more features and tweak some of the option that we will have.

Pros	Cons
Wireless Charging	No Remote Control
Completely Programmable	No Lighting Color Options
Auto Power Off	No App Control

4.6 Design Decisions

4.6.1 Materials

Housing will mostly be additive plastic with metal fasteners. This reduces lifetime due to constant wear on the places the fasteners are applied but as the product uses LEDs and is wireless, it should last a long time without needing to be opened up. We will use a mix of opaque and translucent plastics for our housing as well.

4.6.2 Physical components

We will utilize the following physical components to make our circuit:

- Arduino
- Li-Po battery
- Battery charging/protection module
- Touch sensors
- Fasteners
- Housing
- Wireless receiver
- Wireless charging board
- Solder/solid core wiring

4.6.3 Features

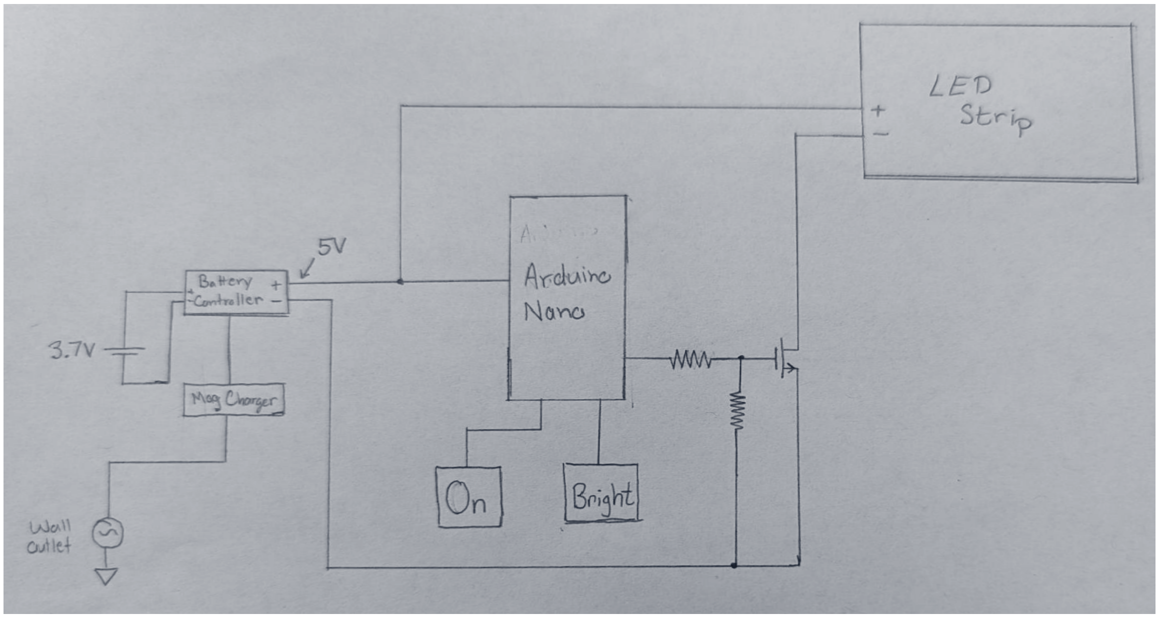
Our design features must hold to the requirements listed in section 1.2, while also following these basic tenants: Must hold battery, Arduino, and receiver. It also must have space for the touch sensors as well as something to diffuse the light from the LEDs.

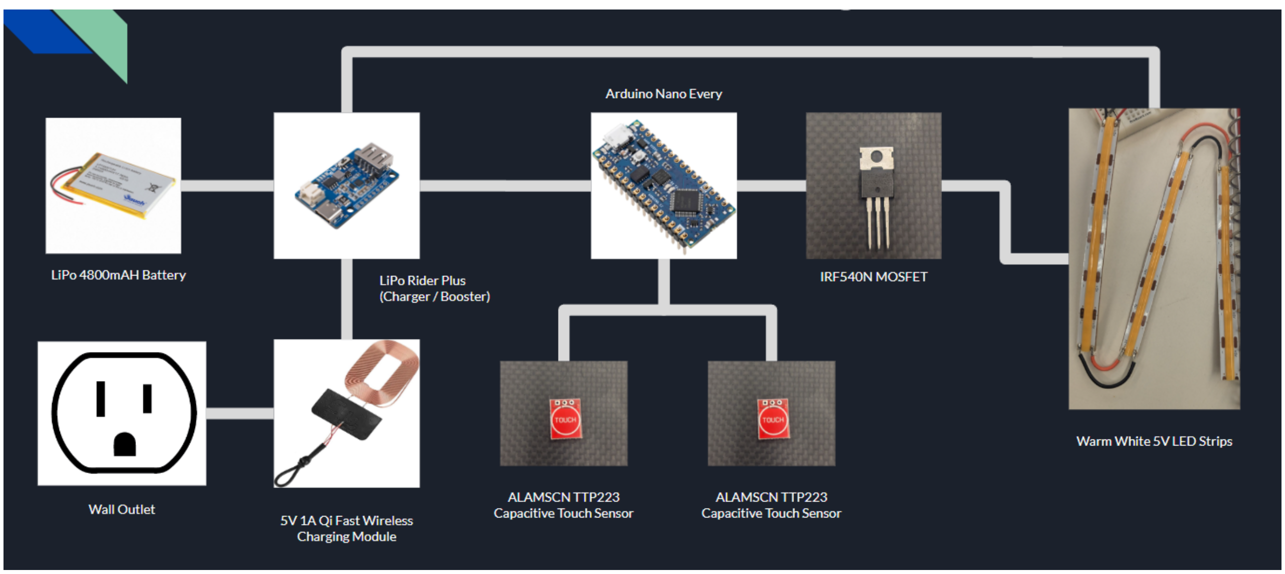
4.7 Proposed Design

Our design started from initial building blocks and isolating important components, and we've developed our ideas from there. By starting with the base requirements, we ordered and have begun testing what components work, how they integrate, and what the power requirements are. As we've begun this process, we've begun work on designing exterior components and shell designs to complete the project.

4.7.1 Design Overview

Design Visual and Description





Relation to Functional Requirements:

- Design is battery-powered and charged wirelessly.
- Design utilizes touch sensors to change brightness.
- Light must automatically dim and shut off after ten minutes using onboard timer from Arduino Nano.
- Using software, whenever the light is turned on/off it does so smoothly.
- Uses a nMOS transistor to act like a switch and controls the frequency of the light for turning it on and dimming.

Relation to Resource Requirements:

- Project utilizes an Arduino Nano Every to remain programmable during prototyping.
- Project uses a Lithium Polymer battery.

Main Function of Each Part

- Battery
    - The LiPo battery for three days of use
- Battery controller
    - Regulates coming and outgoing currents
    - Handles wireless charging compatibility
- Microcontroller - Arduino Nano Every
    - The microcontroller controls the current through the LEDs using a MOSFET
- LED strips
    - The LEDs were chosen on voltage and power constraints
- Wireless charging unit
    - Handles magnetic charging of LiPo

Functionality

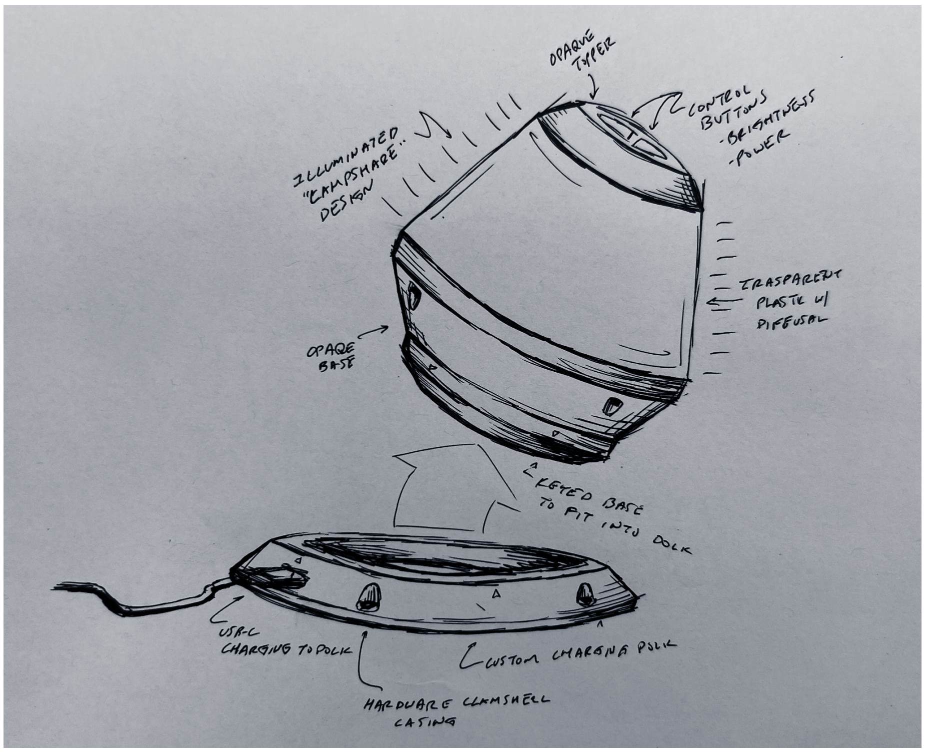
The design is currently optimized to be used in a family environment, close to and often operating within close proximity to young infants or children. Although our circuitry components fulfill all Functional and Resource requirements, we still need to design the outer casing that will fulfill our Qualitative Aesthetic requirements to ensure our design is safe to be operating within this environment.

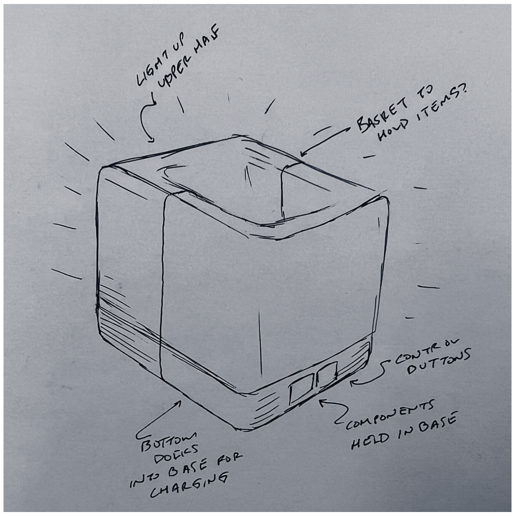
4.7.2 Design 1

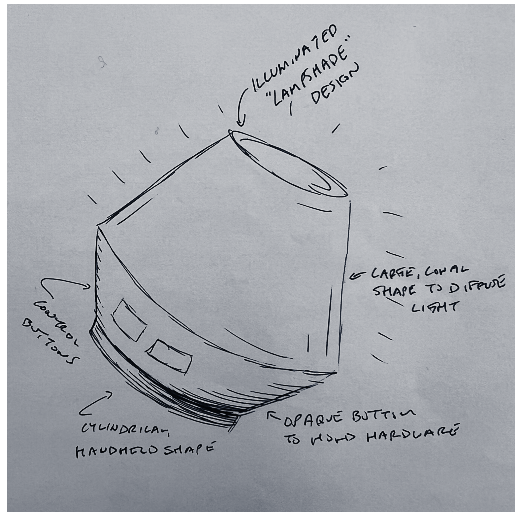
Design Visual and Description

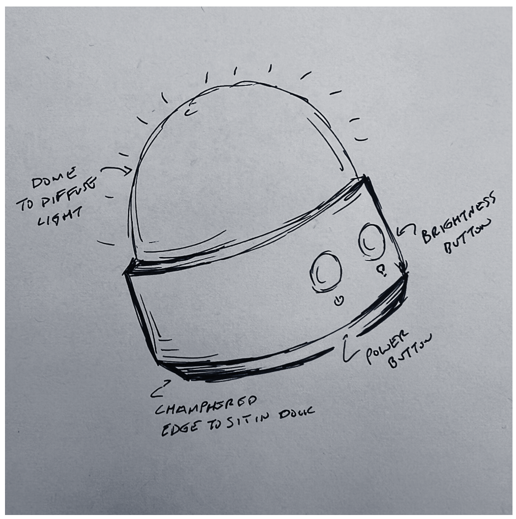
The goal after isolating the internal design was to begin external work. This is because the external design is informed and influenced by the internals, without much play in the opposing direction. Our goal was a simple, easy-to-understand, and functional design with very little moving parts that allowed for easy, seamless integration and testing.

This design iteration focused on the external design layout of the project. Utilizing the design choices from 4.7.1, we were able to isolate what components fit where, and design internals. The goal is for a two-part closer, one lower housing made of opaque plastic with a transparent plastic covering that fastens down to the main body. This is where light will shine from, creating a puck of light that allows for constant operation and ease of use. The design is simple, and safe so that a child cannot get accidentally hurt. One consideration we had to implement was the charging dock, which now resides as a separate component and plugs into a standard 120V wall outlet.









Relation to Qualitative Aesthetic Requirements:

- The design is soft and easily approachable for children, without sharp edges that could be dangerous.
- Design emits an amber or other warm-levels of light for a soothing effect.
- Design is not commercialized or mass-manufactured allowing for ease of rapid prototyping.

4.8 Technology Considerations

The main technology constraint we are working with is the battery. Considering battery life and ensuring the design meets specifications while also ensuring that the battery is not so large to dominate the design and make the final product a brick is a balancing act that requires a lot of testing. Also, our consideration of using an Arduino Nano Every helps ensure the design stays portable and easy to handle instead of using the larger, more cumbersome Arduino Uno.

On the other hand, we must consider the logistical pitfalls of 3d printing and ensure that our housing is easily printed with minimal supports and materials to keep costs within budget.

4.9 Design Analysis

After testing the design from 4.7.1, we have been able to test and verify that the design is sound. We have learned that too many lights can cause wavering in the light strips and that in the future we will need to order some battery connectors to wire into the battery control board.

Future designs we make will try to fit a custom PCB that will eliminate the separated components of the transistor, resistor,

5 Testing

The testing plan can be broken into six major parts, as seen in the sections below. Each of these tests focuses on a specific portion of the project. It starts with testing the physical design and then moving into the user interface. Once those are done, the focus shifts to integrating the two previous tests and ensuring they work together. With that finished, the testing moves onto the system as a whole and ensures that anything added does not damage the old process. Once these checks are done, the final tests make sure that the final prototype will pass all of the conditions given in the project procedure.

5.1 Unit Testing

1. Touch sensor
   - Tested by using a breadboard to connect a voltage source to an LED through the touch sensor and testing what materials and thickness can be used with it.
2. Light strip
   - Tested by connecting to a power source and measuring the current. Then, we will change the supplied voltage and read the change in current.
3. Wireless charger
   - Tested by connecting the transmitter to power using a USB cable, and holding the receiver over the transmitter while measuring the voltage and varying the distance between the coils.
4. Arduino Nano Every
   - Tested by connecting to the downloadable Arduino IDE, test run with the provided “Blink” code to ensure onboard LED functions as well as uploading functionality on the main board.

5.2 Interface Testing

1. Arduino -> Touch sensor interface
   - We will test the touch sensors through different materials like plastic to see which materials we want to make the shell out of. This information will help us ensure the sensor is always working properly and protected.
2. Arduino -> Light strip interface
   - We will test the ability to change brightness and dim the light over time in order to fulfill the requirements given to us to ensure optimal usage.
3. Wireless charger -> Lithium-polymer battery interface
   - We will test the connection between battery and circuit to bring the usage amount as low as possible to ensure the light can be used as much as possible between charges.

5.3 Integration Testing

The main integration for this project is the wirelessly charging battery circuit to the Arduino system, connecting to the touch sensors and the light strip. By completing integration tests, we know the individual circuits work, and combining them requires tests on voltage and current levels being input and output from the Arduino board itself. These voltage levels need to be consistent with the chosen battery. Along with that, the current draw from the battery should allow for up to three days of regular use. Everything must be connected to the Arduino, and the functionality should continue to work. This testing will be done through smaller modules, building on each previous part. These modules will be compiled into the working script that will allow the battery to be charged, turn on the LEDs, adjust the brightness, have a self-sleep mode, and so on.

5.4 System Testing

Our project will separate system testing into three different areas and individually test each section before integration. These sections and their respective strategies are listed below:

5.4.1 Circuit Design

To test the circuit design, we will measure the current draw and the temperature of all the components. To do this, we will use a temperature sensor and a multimeter to meet our target numbers: a temperature of 70 degrees and an overall current draw of 1.3 Amps.

5.4.2 Software Design

To test the software, we will use buttons and an LED strip to make sure the code is working properly. What the software needs to do is turn on the lights, turn off the lights, dim the lights over 10 minutes, have different settings for the lights, and be able to switch between them

5.4.3 Physical Design

To test the physical design, we will make sure that the design can fit all of the components, be able to be held for easy movement, have a space for a wireless charger, and be easy to assemble.

5.5 Regression Testing

To make sure that new additions do not break the old functionalities, we will make sure to test all of the features after each thing is added to make sure that they still work. If the new features affect an older one, then we will have to review the new functions to find out what is causing it before moving on to the next thing. The critical features we will need to ensure do not break are the touch sensor and the lights. The touch sensor is the user's interface to use the nursery light. If that function ever stops working, then the other functions won’t be able to work at all. So when writing code or adding components, we will make sure to check every function still works, and we will not move on until we know that they do.

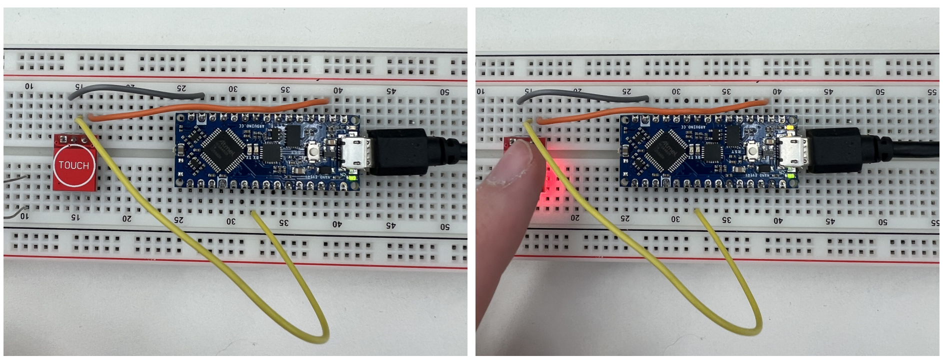
5.6 Acceptance Testing

Throughout the testing process, we aim to present and involve the client in ensuring all data meets standards and double-check that the requirements remain the same as the original meeting. The goal is to ensure that throughout the original testing procedure, we do not delve down a path that is not desired and also ensure that the client starts seeing tangible results.

- We will test to ensure that battery life lasts on normal use up to three days, minimum.
- We will test that the outer housing is easy to use and assemble.
- We will test programmability and the ability to easily scale values for operation changes.
- We will test heat output to ensure the light is "safe."
- We will ensure charging can function from 0% to 100%.
- We will test the individual functions of all components.

5.8 Results

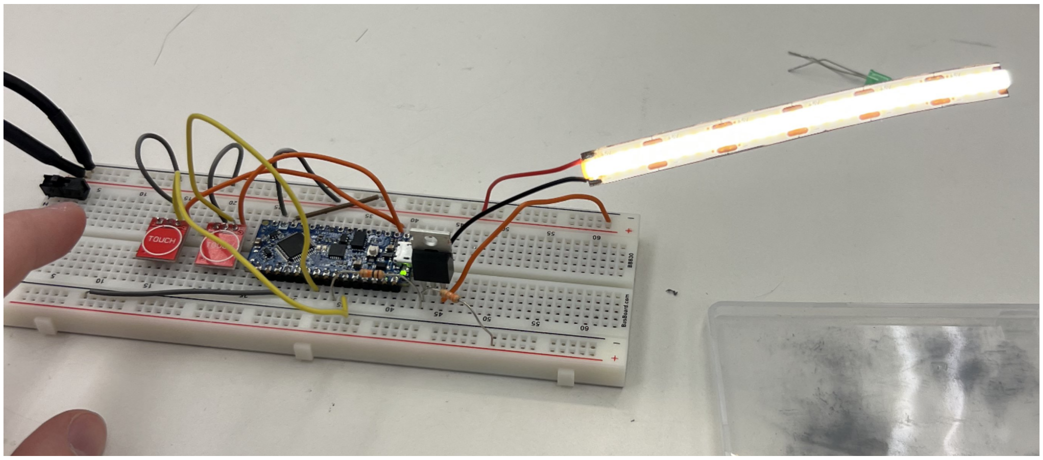
5.8.1 Touch Sensor Results



To test the functionality of the touch sensor, we developed a simplistic code system that, upon pressing the button, turned on the onboard LED (seen top right with a yellow glow) for one minute before turning it off. This doubled as a test for the Arduino's timer system we would need later.

We also concluded that the sensor functions with a 0.125" layer on top of it, allowing us to conceal it within the project casing while retaining functionality. We can wire two touch sensors in parallel to the Arduino's built-in 3.3 V power supply, which sends a digital signal to a digital receiver pin when pressed to start the built-in code.

5.8.2 Arduino Nano Every Results



The next test was finding the currents that would be drawn by the Arduino Nano and making sure that the outputs were working as intended. These need to be found so the overall current draw can be calculated to find the correct battery. Along with that, the output voltages of the I/O were also found.

This test also doubled as a total current test. This is because the Arduino Nano's current draw will vary based on the load. Testing this was very simple. The structure connects a DC power supply to the Arduino Nano's power supply and then the positive input of the LED strip. The negative port of the LED is then connected to a MOSFET's drain. The source of this nMOS is connected to the ground, and its gate is connected to a voltage divider powered by the PWM wave from the Nano.

With this test structure, the I/O pin voltage was found to be 4.6 V which is close to 5 V which is what the datasheet provided. This value is used to make sure that the voltage divider provides an accurate voltage and the MOSFET will be on for the selected brightness levels. After that, the load was disconnected from the Nano, and its base current draw was tested to be 27 mA. The load was once again added for three small LED strips and the current drawn by the Nano was found to be 30 mA. This current is much smaller than the LED currents found in the next section which is great as this should not be drawing much power.

5.8.3 LED Strip Results

The final test needed for battery calculations was the current drawn by the LED strips. These strips consume the vast majority of the power for this circuit. Getting these currents will give a much better idea of what battery could power this structure for 3 days. The difference between this test and the previous one was that the total current was found for each brightness level since as the PWM changes, the current controlling MOSFET will change the current and therefore the brightness of the LED strips.

Running this test once again used the DC source to provide 5 V to the circuits and a multimeter to test the currents. The light is planned to have 4 brightness levels and then the off state. During the off-state, it will only draw the 30 mA for the Nano as found in the previous section. During the other sections it will draw current from both the LEDs and the Nano's current will change with the load. This test was run a few times with the brightness levels varying to see what values would lead to a noticeable change in brightness and have a total power that would be feasible for a LiPo battery to supply. The first test was found to have currents of 1.989 A at max, 1.36 A at the next level, 0.8 A while dimming, and 0.43 A at the lowest level. This was done using the full strip and the total current for 3 days in high usage would be 7.95 Ahrs. This is much too high, but it was used as a benchmark as this test used the full LED strip.

After that, the LED strips were cut into smaller unit lengths such as the one seen in the figure in section 5.8.2. The test was then run for a single unit length. This results in values of 300 mA, 234 mA, 166 mA, and 99 mA. The total current draw for this was 2.19 Ahrs. This value is much smaller than the previous one and would work for many LiPo batteries. The issue is that one LED would not provide enough light, so to solve this issue, two more unit strips were added and the current was tested once again. These currents ended up being 730 mA, 556 mA, 385 mA, and 210 mA and had a total current draw of 4.58 Ahrs at high usage. This was an acceptable value in terms of current draw and it provided enough light to be useful in a dark room, so this LED design was chosen and a battery with 4.8 Ahr life was ordered.

5.8.4 Battery Charging Unit Results

NOTE: This section is not yet complete, will update when we have the battery on hand.

6 Implementation

We are currently working on making sure the battery meets our given requirements of total charge time, as well as total battery life over an average of three uses per day. Once this is done we plan on working on the design for the project housing. This includes coming up with a project housing that meets the customer's requirements and specifications, as well as ensuring it works around and functions with the current circuit we have spent Semester 1 building. We will prototype our design using 3d printing solutions to help finalize/test the design. As a group, we also plan on having a custom PCB designed for our circuit as this will be easier to install into the housing as well as create a more presentable look for the project. Durability and presentation of the final project are also at the forefront of our minds approaching this next design phase.

7 Professionalism

This discussion is with respect to the paper titled "Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", International Journal of Engineering Education Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

Chosen Code: IEEE

Work Competence	To ensure we are utilizing our technical competence fairyland only taking on tasks we are qualified to take on after listing our knowledge sets.
Financial Responsibility	To avoid conflict of interest as well as ensuring products are priced correctly.
Communication History	To properly communicate with others about work competency and contribution
Health, Safety, Wellbeing	Ensure proper safety measures are taken at all times when designing and marketing a product.
Property Ownership	Show respect for property of clients, consumers, and their ideas
Sustainability	To ensure proper measures are taken to continue as planned with no lasting impacts on other aspects of daily life.
Social Responsibility	To ensure you are not willingly putting other in harm's way by contributing to a project or idea

NSPE has a very clear cut distinction between each entry in the table while the code of ethics blends them together in different ways to reduce loopholes.

7.2 Project Specific Professional Responsibility Areas

For each of the professional responsibility area in Table 1, discuss whether it applies in your project's professional context. Why yes or why not? How well is your team performing (High, Medium, Low, N/A) in each of the seven areas of professional responsibility, again in the context of your project. Justify.

Work Competence	All members of our group are working on parts of a project that fall well within their current capable knowledge. So while it still applies it is not a huge concern. **Performance: High**
Financial Responsibility	The team is considerate of the budget and is not using it recklessly and instead meticulously plans before finalizing a purchase. **Performance: High**
Communication History	Our team holds regular meetings and check-ins both in person and online to ensure all members are properly able to do their jobs and ask for help if necessary **Performance: High**
Health, Safety, Wellbeing	All team members are ensuring proper safety measures are taken in the design process when soldering parts as well as plans are in place to test for consumer risks once the product is further along in development. **Performance: High**
Property Ownership	Team members show respect when in the design lab and do not rough house or risk breaking equipment. **Performance: High**
Sustainability	Due to the single customer nature of this request as well as the small scale of the project no issue with sustainability are in question **Performance: High**
Social Responsibility	The product fits clients desires and helps to fit a niche product line not commonly found and has no way to directly harm others unless misused **Performance: High**

7.3 Most Applicable Professional Responsibility Area

Financial Responsibility: Our product is not meant to be expensive and is instead supposed to be a reasonably priced product that was crafted to do a simple job. so pricing it appropriately is a must.

8 Closing Material

8.1 Discussion

So far, our results have met all expectations. We focused on meeting main circuit requirements first, as housing design comes later. We worked to ensure our product remained programmable, used small components, had smooth turn off/on, lasted three days minimum, varying brightness settings, touch sensors for control, and more. Overall, the base design has been proven, and now we need to tweak and finalize it to create a finished, professional product.

8.2 Conclusion

So far, our team has successfully designed, built, and tested the main circuit functionality of our project. We were able to keep the project simple, programmable, and fit within all given constraints from our client. In the future, our plan is to further simplify our design with custom PCBs, build and integrate a custom printed shell for the project, and make our own compatible wireless charging dock.

8.3 References

[1] Jauch Battery Solutions, https://www.jauch.com/downloadfile/5bf529a13146c840dc7ef8d1b712be114/4800mah_-_lp735977jh_1s1p_2_wire_70mm.pdf (accessed Nov. 30, 2023).

[2] TN0106 n-channel enhancement-mode vertical DMOS FET data sheet, https://ww1.microchip.com/downloads/en/DeviceDoc/TN0106-N-Channel-Enhancement-Mode-Vertical-DMOS-FET-Data-Sheet-20005932A.pdf (accessed Nov. 30, 2023).

[3] 5V/2.4a USB type C - mm.digikey.com, https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/338/106990290_Web.pdf (accessed Nov. 30, 2023).

[4] TTP223-BA6 TTP223N-BA6 tontouch - LCSC, https://datasheet.lcsc.com/szlcsc/TTP223-BA6_C80757.pdf (accessed Nov. 30, 2023).

[5] Arduino® Nano every, https://docs.arduino.cc/resources/datasheets/ABX00028-datasheet.pdf (accessed Nov. 30, 2023).

8.4 Appendices

8.4.1 Team Contract

Team Members:

1) Josh Holloway

2) Thomas Youhn

3) Logan Farmer

4) Wyatt Rahl

5) Alexandros Psomas

6) William Snyder

Team Procedures

1. Day, time, and location (face-to-face or virtual) for regular team meetings:

Monday of each week, 5-6 pm, face-to-face (Coover TLA) or virtual depending on current workload.

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

Virtual communication will be over a text chat, or discussed face-to-face during shared class times.

3. Decision-making policy (e.g., consensus, majority vote):

We will use a majority vote, with the team lead making the final say.

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

Logan will be our Scribe/Facilitator. The notes will be shared in a Google Drive folder

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:

Everyone is expected to attend all meetings either with the team or the TA unless communicated with the team that they are not able to attend. The team member unable to make the meeting should communicate their absence as soon as they are aware of a conflict.

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

Everyone is responsible for fulfilling team assignments, and keeping with timelines as close as possible. We will have a 3-5 day extension window permitted in case classwork outside of the team project interferes with team progress on an individual basis. However, we will keep the team on an Honor Roll to make sure deadlines are followed and communication to try and work with others to help finish off work to meet deadlines is encouraged.

3. Expected level of communication with other team members:

Team communication should be punctual to within the week the original message was sent. Also, any communication that affects a deliverable or progresses the project should be noted in the gitlab.

4. Expected level of commitment to team decisions and tasks:

All members have a say in every team decision, as noted above all decision making is done by majority vote. When it comes to tasks, all members are expected to commit time and effort to create the best project we can throughout the academic year.

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):

Team Lead, Client Interaction: Josh Holloway

Electrical Lead: Tommy Youhn

Component Design: Wyatt Rayl

Tester: William Snyder

Facilitator: Logan Farmer

Product Designer: Alexandros Psomas

2. Strategies for supporting and guiding the work of all team members:

The playing field within our team is flat. All members are encouraged to work with and communicate with other members during all stages of the process to ensure we are all comfortable with the progress and ensure that every step is in a positive direction for this project.

3. Strategies for recognizing the contributions of all team members:

Any member who had a hand in the design, testing, or attributed work during the general process will be credited for their work in all communication forms.

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.

Josh: CAD Design (Fusion 360, Onshape, AutoCAD, Solidworks), coding in Java and C, Industrial Design, Embedded Systems, Arduino, PCB testing, 3d printing and rapid prototyping workflow, AOI systems design. The perspective I believe I bring forward is my experience meshing product design and product function together to create a seamless final design. My experience with code, electrical design and testing, and Industrial Design come together to help with this perspective.

Tommy: Electrical Engineering, PCB design/testing/troubleshooting, Cadence Virtuoso, LTSpice, General Code knowledge in C, hardware implementation, soldering. Most of my experience comes from working on small projects making PCBs and designing things using small programming chips such as Arduino or Raspberry Pi.

Wyatt: Computer Engineering/Electrical Engineering, CAD, 3D printer work. Work with designing logic gates and smaller computer brains for simple processing.

William: Electrical Engineering, Power Systems, CAD design, Cadence Virtuoso, General Coding Experience, Component Testing. The experience I have is from working on projects and labs through the courses we have taken including virtual simulations and physical testing and design.

Logan: Electrical Engineering, Embedded Systems, PCB design/testing, Cadence Virtuoso, Python and C Code knowledge. The perspective I bring with me to this project is my experience working from beginning to end on a project including hardware and software design.

Alexandros: Electrical engineering, CAD, MatLab, C, LTSpice.

2. Strategies for encouraging and support contributions and ideas from all team members:

During weekly meetings we will isolate and discuss all current action items being done by the team. During that process, we will have group discussions on the current progress and how the future progress can begin and ways to move forward. Along with this, all work will have to be reviewed by either Thomas (Electrical) or Josh (Design), ensuring a final stamp before progressing forward with the project.

3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)

As a team we never want anyone to be stagnant in their work or feel they are not doing work they enjoy or are happy with their contribution to the team. During meetings, in private messages, or personal discussions team members are encouraged to voice their concerns to either Tommy or Josh so new tasks can be provided to help a member spread their wings, or communicate with all members to either back off or help to ensure we are all comfortable in our working environment.

Goal-Setting, Planning, and Execution

1. Team goals for this semester:

- Have product research and at least three project housing designs complete by the end of September.

- Have circuit math, design, and component choices done by mid-October.
- Have the 3D model done for circuit design by the end of October.
- 3D model design by mid-November.
- Large component testing (light, battery, battery charger) by the end of November.

2. Strategies for planning and assigning individual and team work:

- Each week during the meeting, any new assignments will be assigned at that point, and a timeline will be set for that assignment at the point of the assignment.
- If anything comes up that needs immediate action, a message will be sent either on Discord/text/email to the appropriate party.

3. Strategies for keeping on task:

The weekly meeting will have a section where each group member gives their account of what they have worked on and the overall progress.

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?

Warnings will be sent out by private message informing of concerns relating to a team member's adherence to obligations of the team contract.

2. What will your team do if the infractions continue?

Notes will be taken on the infractions, and if they continue the team will attempt to look into what issues may be happening keeping a team member from completing their work. If that does not work, concerns will be raised with the professor.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.

1) ______Alexandros Psomas____________________________________ DATE __09.05.23___

2) _______Wyatt Rayl____ DATE __09.05.23___

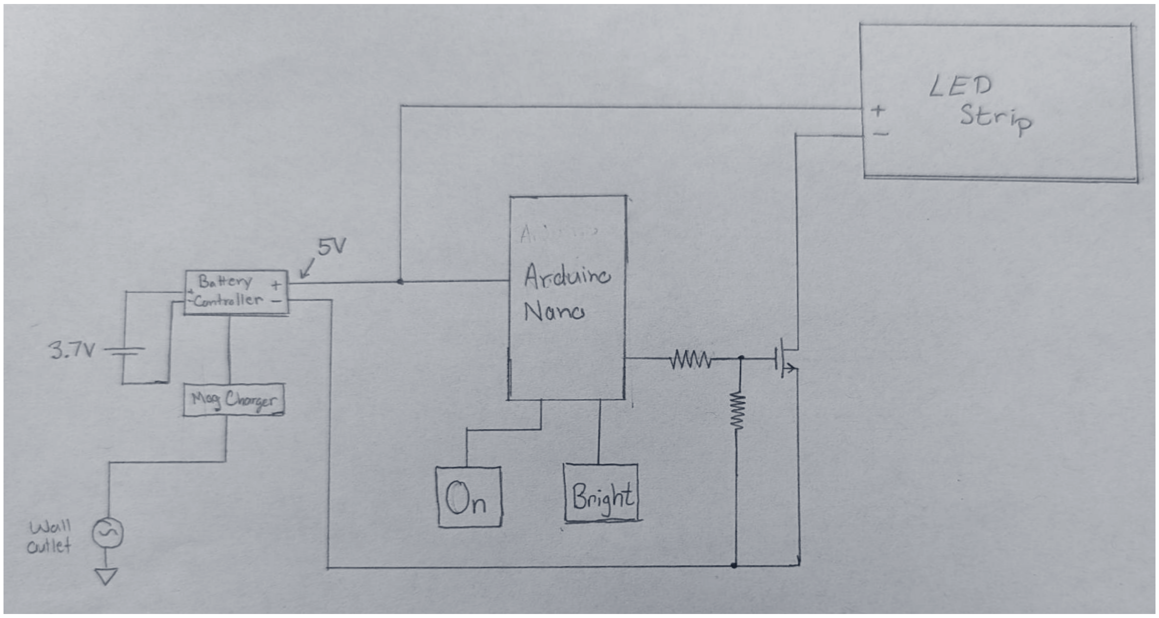
3) ________William Snyder____________________________________ DATE __09.05.23___

4) __________Logan Farmer____________________________________ DATE __09.05.23___

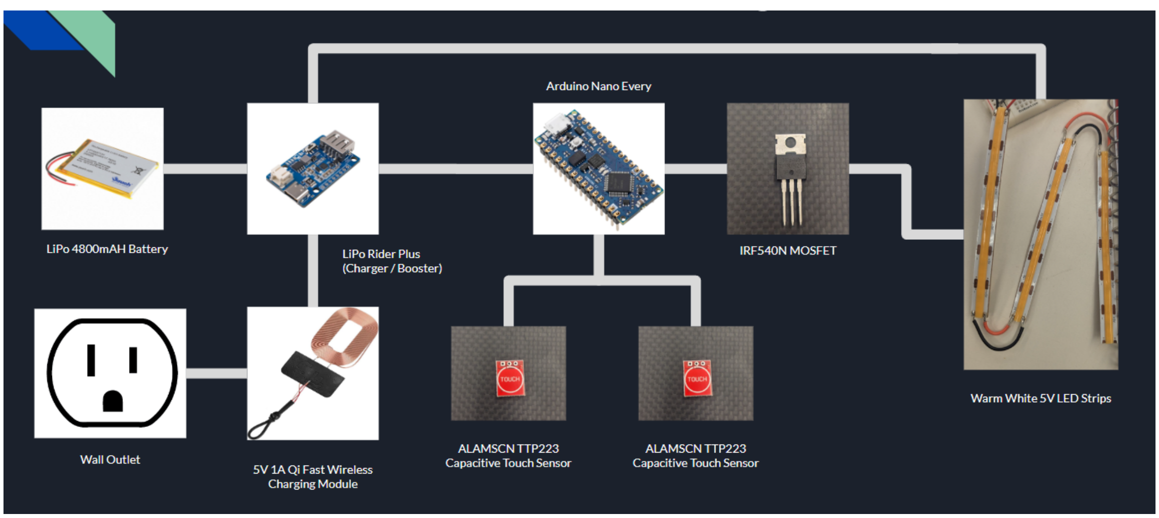
5) _______Thomas Yohn____ DATE __09.05.23___

6) _________Josh Holloway___________________________________ DATE __09.05.23___

8.4.2 Circuit Design Layout



8.4.3 Circuit High-Level Overview



8.4.4 Project Direction Sketch