Productivity Enhancement Device (TimeTable)

Team 47
Benjamin Xie
Pranav Goel
Hongru Wang

TA: Pooja Bhagchandani

Design Document
ECE 445 Spring 2022

2/24/2022

1. Introduction **2**

1.1 Problem 2

1.2 Solution 2

1.3 Visual Aid 3

1.4 High-level Requirements 3

2 . Design **4**

2.1 Block Diagram 4

2.2 Physical Design 5

2.3 Subsystem Overview 5

2.3.1 Power 5

Overview 5

Schematic 6

2.3.2 User Interface 7

Overview 7

Outputs 7

Inputs 7

Schematic 8

2.3.3 Sensing 9

Overview 9

2.3.3.1 Air Quality sensor 9

2.3.3.2 Temperature and Humidity Sensor 9

2.3.3.3 Motion Sensor 10

2.3.3.4 Ambient Light Sensor 10

2.3.3 Processing and Communication 11

Overview 11

2.3.4 Web App and Server 13

Overview 13

2.4 Supporting Plots 14

2.5 Schematic 19

3. Cost and Schedule **19**

3.1 Cost Analysis 19

3.1.1 Labor Cost 19

3.1.2 Parts Cost 20

3.1.3 Total Cost: 21

3.2 Schedule 21

4. Tolerance Analysis **22**

5. Safety & Ethics **24**

6. Citations **25**

1. Introduction

1.1 Problem

High productivity is something many people try to achieve with little success. One of the most powerful systems to optimize their productivity output is to make a to-do list. This system is often used via apps people access from many devices like phones, laptops, etc. However, these apps can ultimately lower productivity than increase it. Checking your to-do list can be a multi-step process that takes your focus away from your original task and results in you working on a completely different task. This makes it easy to forget to check the app or interact with it entirely. In addition, having your to-do list hidden on your tablet or phone makes it easier to ignore, especially when notifications are often dismissed for no reason other than cleaning up the lock screen. It can also allow you to get distracted since less productive apps become easily accessible. There could be many factors in one's working environment that can lower productivity, such as CO_2 levels [1], temperature [2], and humidity [3]. Many people don't even realize that something is wrong and will continue pushing onwards, attributing their lack of focus and concentration to factors such as lack of sleep or stress [4]. Boiling this down, we need a better method of keeping track of daily tasks. We also need something that continuously monitors one's working environment and informs them of issues affecting optimal productivity conditions.

1.2 Solution

To give people a better way to monitor their daily tasks, as well as their working environment, we propose building a desktop device that can display one's to-do list in addition to monitoring environmental factors such as CO_2 levels, temperature, and humidity. This provides a constant reminder of what needs to be done on your desk, making it easier to check and difficult to ignore. Being a physical device on a desk will also allow it to collect data about the environment. An integrated motion sensor will also allow it to track sitting time.

This device will use an e-ink screen to display tasks due to its readability and low idle power consumption. Because e-ink displays have low refresh rates, we will also include individually addressable RGB LEDs to communicate some information in real-time. We will use a speaker to alert the user non-visually of upcoming deadlines and environmental warnings. We'll include a rotary encoder and buttons to interact with the device physically. The primary function of these will be to change the status of the tasks between to-do, in-progress, and finished. The status for each task will be shown by the LEDs along the edge of the display. We will also include a variety of sensors in the device to measure the environmental factors that were outlined above. Everything will connect to an ESP-32 MCU which will handle controlling the device as well as communicating with a server that contains all of the tasks. The tasks will be sent to the server via a website.

1.3 Visual Aid

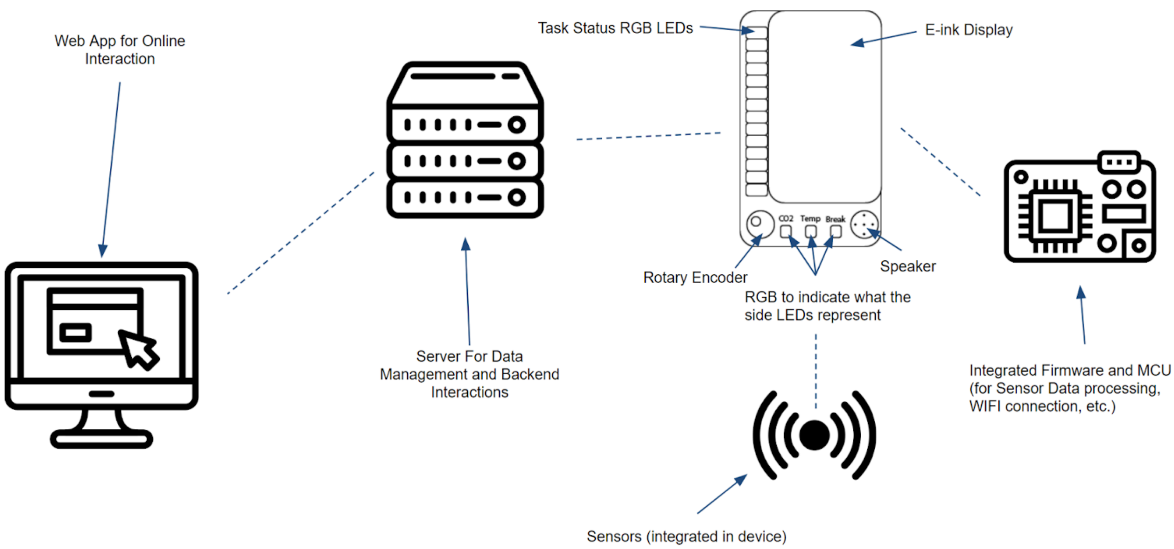

Figure 1. Abstract Representation of Device System (Visual Aid)

1.4 High-level Requirements

- ☐ The device must be able to display at least 12 tasks simultaneously with newly created tasks displaying on the device within 1 minute.
- ☐ The device must be able to measure and send the environmental CO_2 level, temperature level, and humidity level to a server at least once every 15 minutes.
- ☐ The device must be able to determine if the user is present or not within 5 minutes of the current status changing.

2 . Design

2.1 Block Diagram

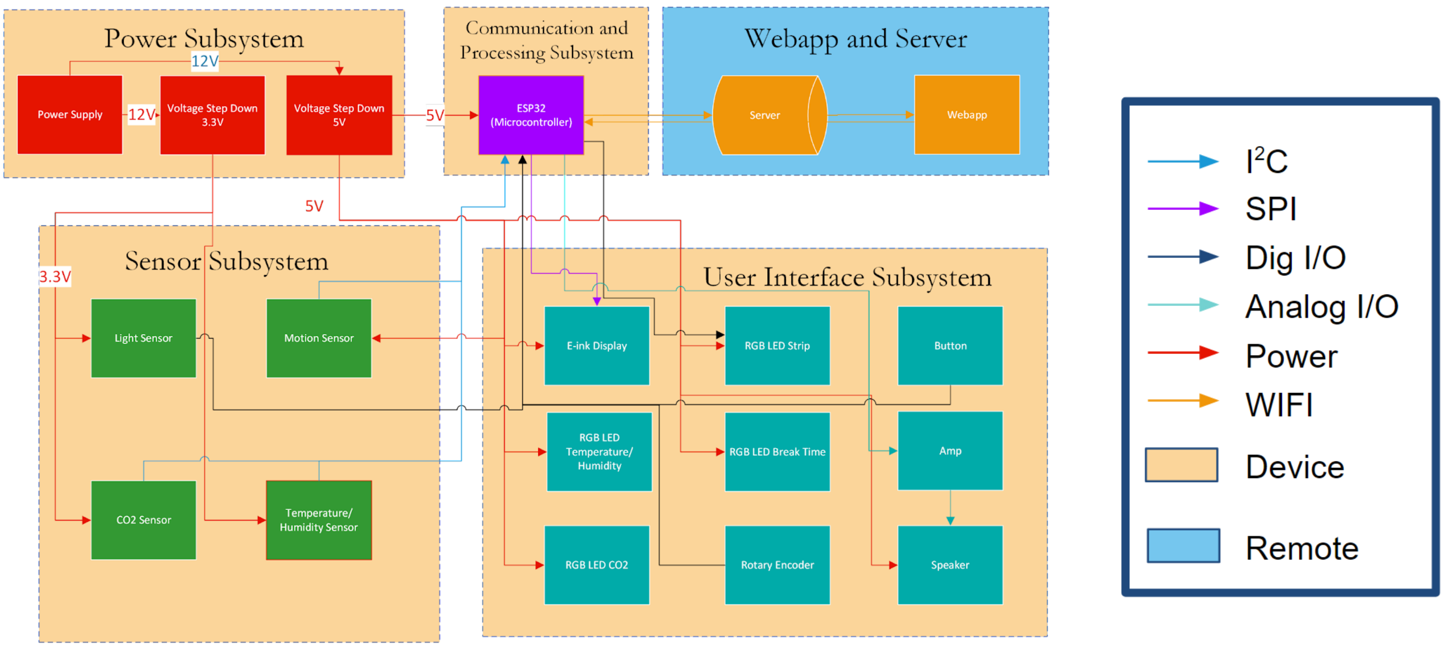

Figure 2. Block Diagram

This system has 5 subsystems - 17 of which are hardware components and 2 are software. The hardware components are powered by the Power Subsystem which ensures that the supplied voltages and currents are suitable. The MCU will work with the Sensor Subsystem to collect environment data and process it so that it's relevant to the user. It will specifically collect data from the light sensor to ensure that the LEDs in the User Interface Subsystem are at an ideal brightness. The motion sensor will be used to determine if a user is in their seat by sending movement data to the MCU for processing. The CO_2 and Temperature/Humidity sensors will be sending corresponding environment data to MCU which will be monitored and displayed via the LEDs when called for. The E-ink Display will primarily pull important task information from the Software components with the MCU being the middleman. The Button and Rotary Encoder will be sent through the MCU to the LEDs as well so that a user can interact with them. Lastly, the MCU will be using data from the Sensor Subsystem and the software components to determine when to make a sound to warn/get the attention of the user.

2.2 Physical Design

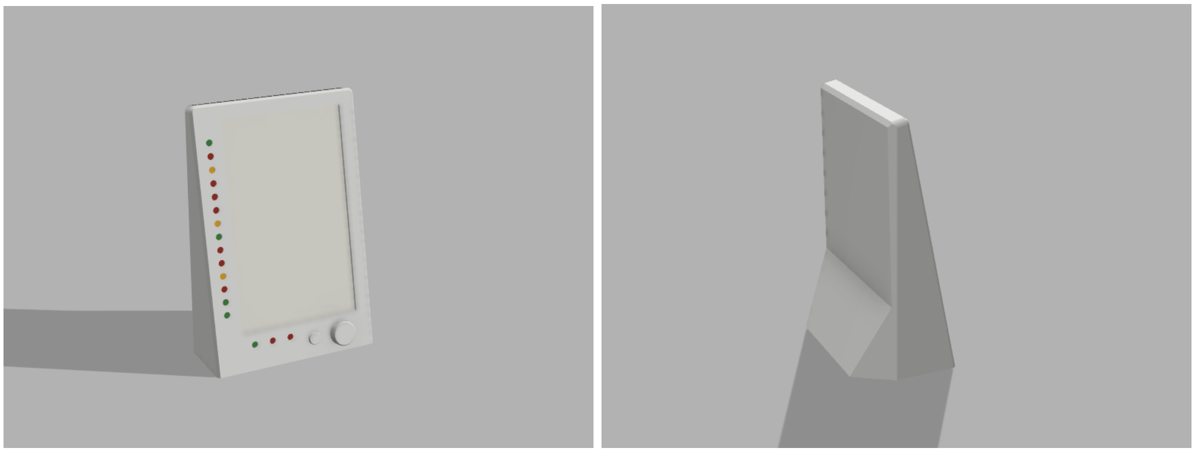

Figure 3. Preliminary Physical Design

The physical design of the device will primarily be based on the size of the E-ink display. We will have a strip of RGB LEDs along the left edge as that gives a lot of vertical space for tasks indications and other kinds of display that we can decide. There will also be three more RGB LEDs on the bottom that each will act as a status indicator. The rotary encoder and button will be next to those on the right. The casing from behind will be a bit thicker to give enough room for all the sensors with the speaker pointing to the back so it doesn't clutter the front design. The motion sensor has to be facing the front to detect if a user is at their desk.

2.3 Subsystem Overview

2.3.1 Power

Overview

The power subsystem will be responsible for providing power to the Processing, UI, and Sensing subsystems. It will have to step down $12V_{DC}$ provided from a standard AC/DC adapter to $3.3V_{DC}$ for the ESP-32, sensors, and e-ink display. It will also have to step down $12V_{DC}$ to $5V_{DC}$ for the RGB LEDs. This will be done with a $12V_{DC}$ to $5V_{DC}$ buck converter and a 5V to 3.3V linear LDO regulator. This is done in order to minimize power loss.

Requirements	Verification
The buck converter provides fixed 5.0V ± 5% from a 12V source	Measure the output voltage using an oscilloscope, test operations that can use power such as screen update and sensor usage and ensure the output always stays within the expected range.
The LDO regulator provides fixed 3.3V ± 2%	Measure the output voltage using an oscilloscope, test operations that can use power such as screen update and sensor usage and ensure the output always stays within the expected range.

Schematic

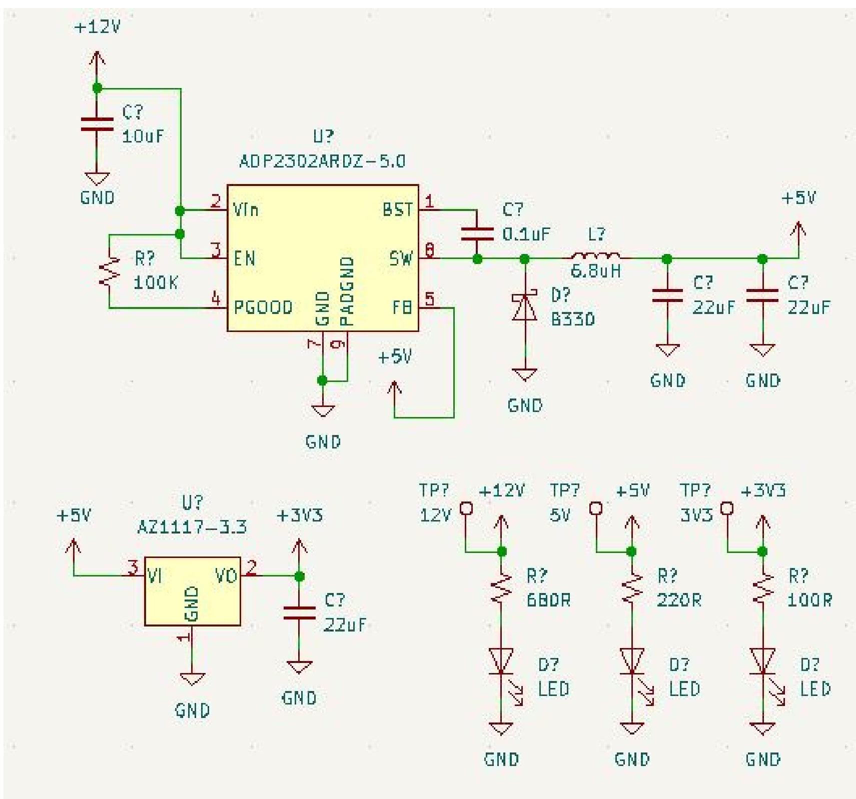

Figure 4. Power System Schematic

2.3.2 User Interface

Overview

The UI subsystem includes all the ways the user might physically interact with the device. This consists of ways the user will physically control the devices, as well as ways the device can display information.

Outputs

The primary way of displaying information will be on a 7.5 inch e-ink display connected to the Processing and Communication subsystem over SPI. Because e-ink displays have a slow refresh rate, a strip of RGB LEDs to the left of the display will be used to communicate information that is needed quickly, such as the task statuses, the currently selected task, relative temperature and humidity, and relative CO_2 levels. What's being displayed on these LEDS will be shown using a separate bank of LEDs under the display. There will also be a speaker that notifies the user of any incoming tasks

Requirements	Verification
The e-ink display must be able to completely refresh in under 15 seconds.	Trigger an update manually and measure the amount of time it takes to finish refreshing
The e-ink display must be able to show at least 12 tasks.	Add 12 tasks to the database, verify that all of them show up on the display
Each RGB LED needs to be able to show at least 6 colors (Red, Orange, Yellow, Green, Blue, Violet)	Run the sample NeoPixel code on the ESP-32 and verify that all colors show
The speaker must be able to produce a sound above 50 dB	Measure the volume of the speaker using a Decibel Meter

Inputs

The inputs will consist of a rotary encoder, and two buttons. This should allow the user to control the device and do things such as changing the task status or what information is shown on the RGB leds. These will connect to digital inputs on the ESP-32.

Requirements	Verification
The device must be able to detect each detent of the rotary encoder as it turns	Write a simple program that changes the LED that is lit based on the rotary encoder and verify that each detent changes the LED by one.
The device must be able to register button presses both from the encoder and the tactile button	Write a simple program that turns the LEDs on and off based on button presses, verify that each button works

Schematic

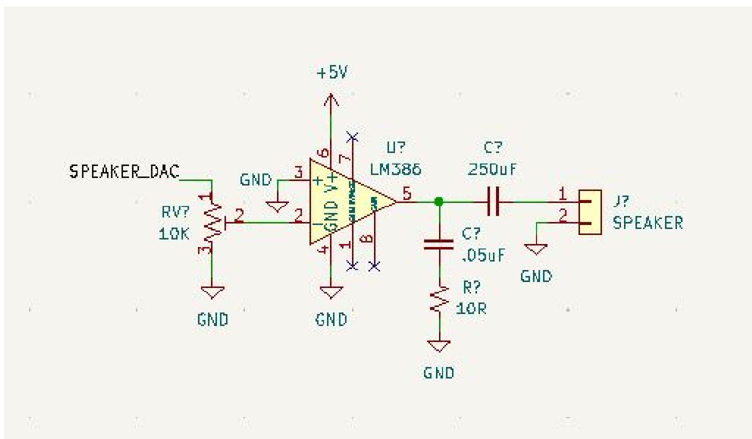

Figure 5. Speaker Op-amp Schematic

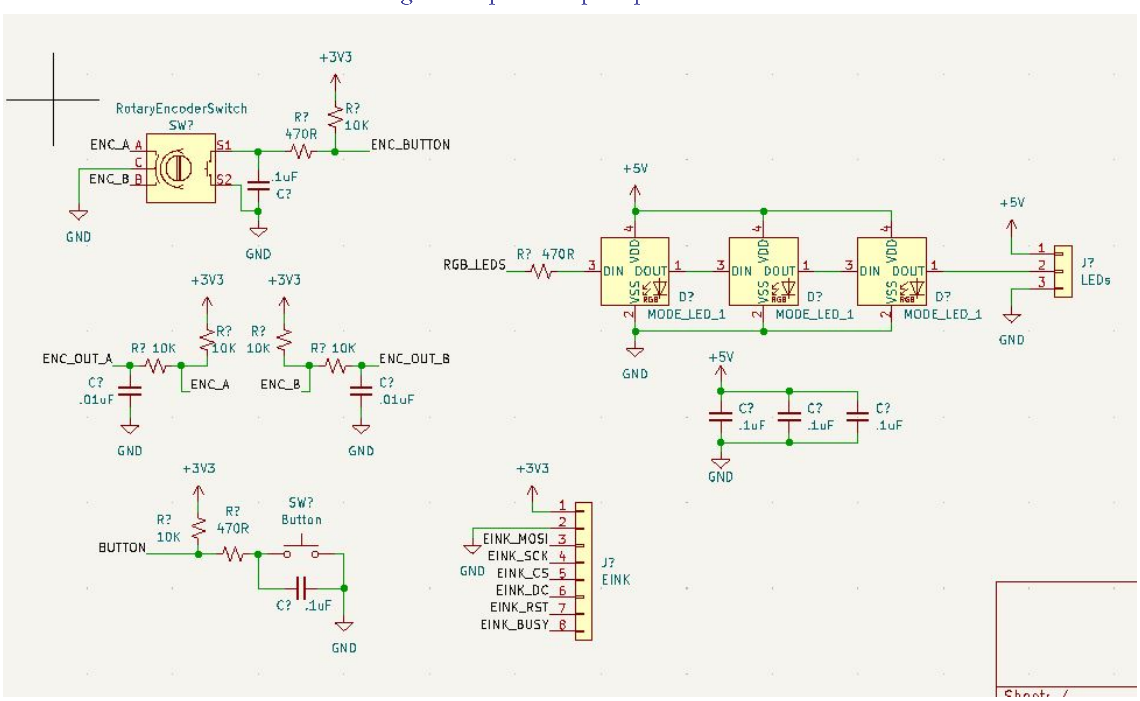

Figure 6. UI Subsystem Schematic

2.3.3 Sensing

Overview

The sensing subsystem will measure the environment around the device, and send that information via I^2C, SPI, or an analog signal to the Processing and Communication subsystem.

2.3.3.1 Air Quality sensor

The first sensor we will use is an air quality sensor. Normal CO_2 sensors are often bulky, expensive, and noisy, so we chose to use an air quality sensor like the SGP40 which measures the volatile organic compounds in the air, and calculates the approximate air quality based on that. The data will be sent to the Processing and Communication subsystem over I^2C.

Requirements	Verification
The air quality sensor must be able to detect changes in air quality that may affect humans. (A CO_2 change of 500 ppm.)	Bring the sensor outside, take a note of the readings. Bring it back inside, and verify it on the air quality scale (Figure 7). A normal CO2 reading outdoors is ~400ppm, and complaints of drowsiness start at around 1000ppm [1].

Table 4.

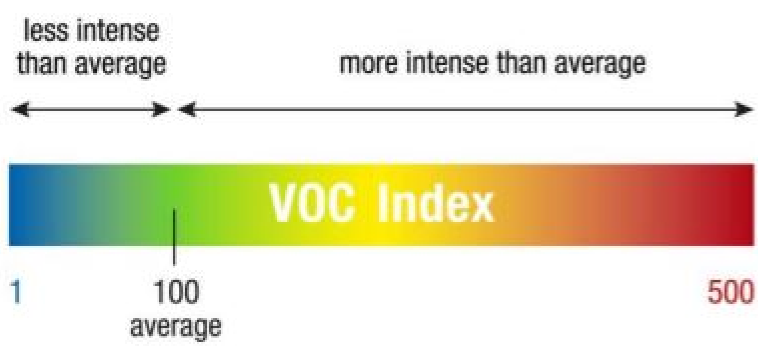

Figure 7. VOC Index Scale [16]

2.3.3.2 Temperature and Humidity Sensor

We also want to measure temperature and humidity. Many manufacturers combine these into one sensor, such as the SHT40, which will also communicate with the Processing and Communication subsystem over I^2C.

Requirements	Verification
The measured temperature needs to be within ±1°C of the actual temperature between 10°C and 40°C.	Compare measured temperature with a thermometer.
The measured relative humidity needs to be within ±3% between 25% and 75% relative humidity.	Compared measured humidity with a hygrometer.

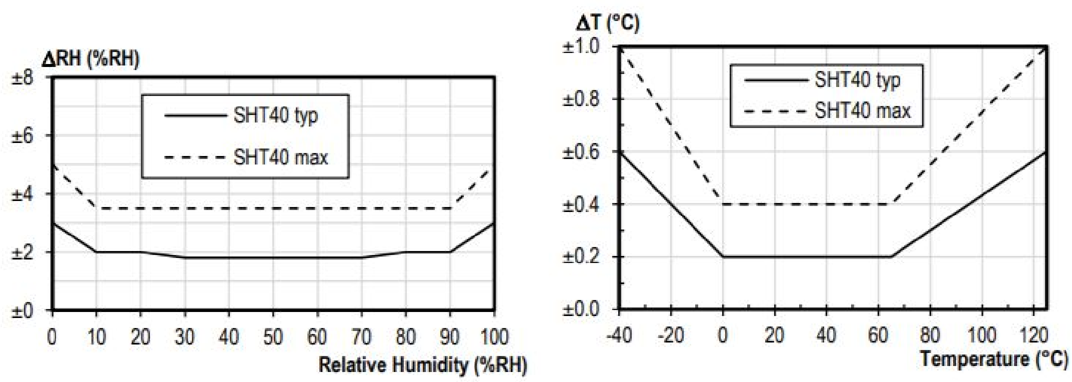

Figure 8 & 9. SHT40 Humidity and Temperature accuracy [17]

2.3.3.3 Motion Sensor

We plan to use a radar-based motion sensor to detect seat occupancy. We plan to use the RCWL-0516 [18] radar module for this. This sensor has an analog output, which will be read by an ADC on our ESP-32.

Requirements	Verification
The motion sensor must be able to detect movement within 2 meters of the device.	Output a message via Serial output when motion is detected. Verify that happens when someone moves within 2 meters of the device.

2.3.3.4 Ambient Light Sensor

We will also include an ambient light sensor to dim the LEDs to match the ambient light level, especially when the lights are off. This can be accomplished by using a phototransistor, which will use another ADC on the ESP-32.

Requirements	Verification
The ambient light sensor needs to be able to output a value proportional to the actual light intensity.	Put the device in a room with a dimmable light bulb. Output the ambient light level via serial output and ensure it changes as the light bulb dims.

Schematic

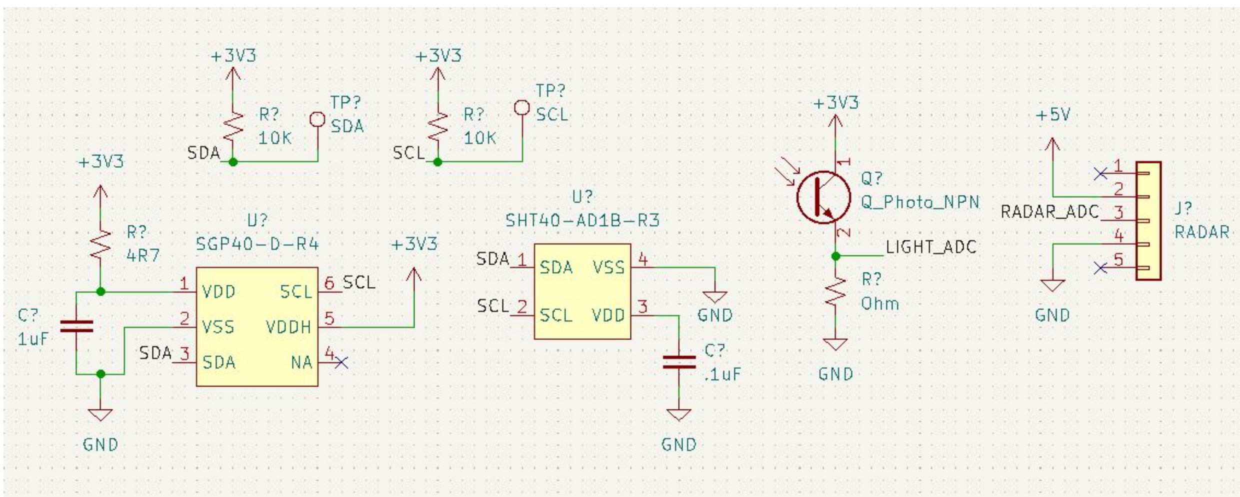

Figure 10. Sensing System Schematic

2.3.3 Processing and Communication

Overview

The Processing and Communication subsystem will gather information and disseminate it to the other subsystems. It'll also handle communication to the server over WiFi. It's primary focus will be taking information from the server and sending it to the display in the UI subsystem. It will also be tasked with sending the sensor information and any task updates done through the UI buttons on the device to the server.

Requirements	Verification
The MCU must be able to receive server information within 2 minutes of data sent	Write code so that the ESP-32 outputs any data received from the server over Serial and ensure it meets the time requirements
The MCU must be able to send relevant data to other subsystems within 2 minutes of it being called for	Ensure that the server updates within 2 minutes of a task status update on the device. Ensure that the e-ink display updates within 2 minutes of receiving new tasks.

Schematic

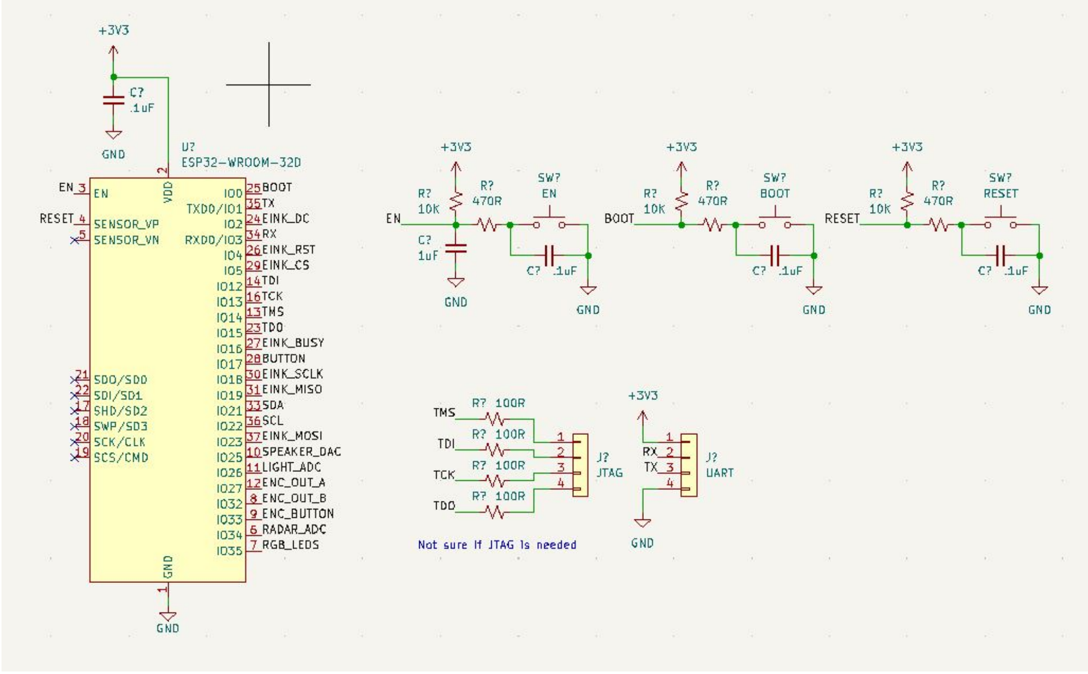

Figure 11. Microcontroller Schematic

2.3.4 Web App and Server

Overview

The Webapp and Server subsystem will primarily be used to input and store tasks. The user will be able to type in the task's name and the due date, and that information will automatically be sent to the server. The server will then send all the tasks to the device over WiFi to be displayed. The website will also need to read the stored environmental data from the server and provide an easy to interpret visualization. We will use React.js to build user interfaces of the simple page web application based on UI components from an established UI Framework. We also will use Node/Express as our server-side web framework. We will write our own API to retrieve and update data from servers. If time is an issue we will use the established Google Tasks API.

Requirements	Verification
The server must be able to store at least 12 tasks simultaneously.	Verify by performing adding tasks through the client-side and check if the tasks count is 12 in firebase.
The server must be able to store at least 24 hours of sensor data.	Check if the tasks are stored in the firebase real-time database or check the dashboard.

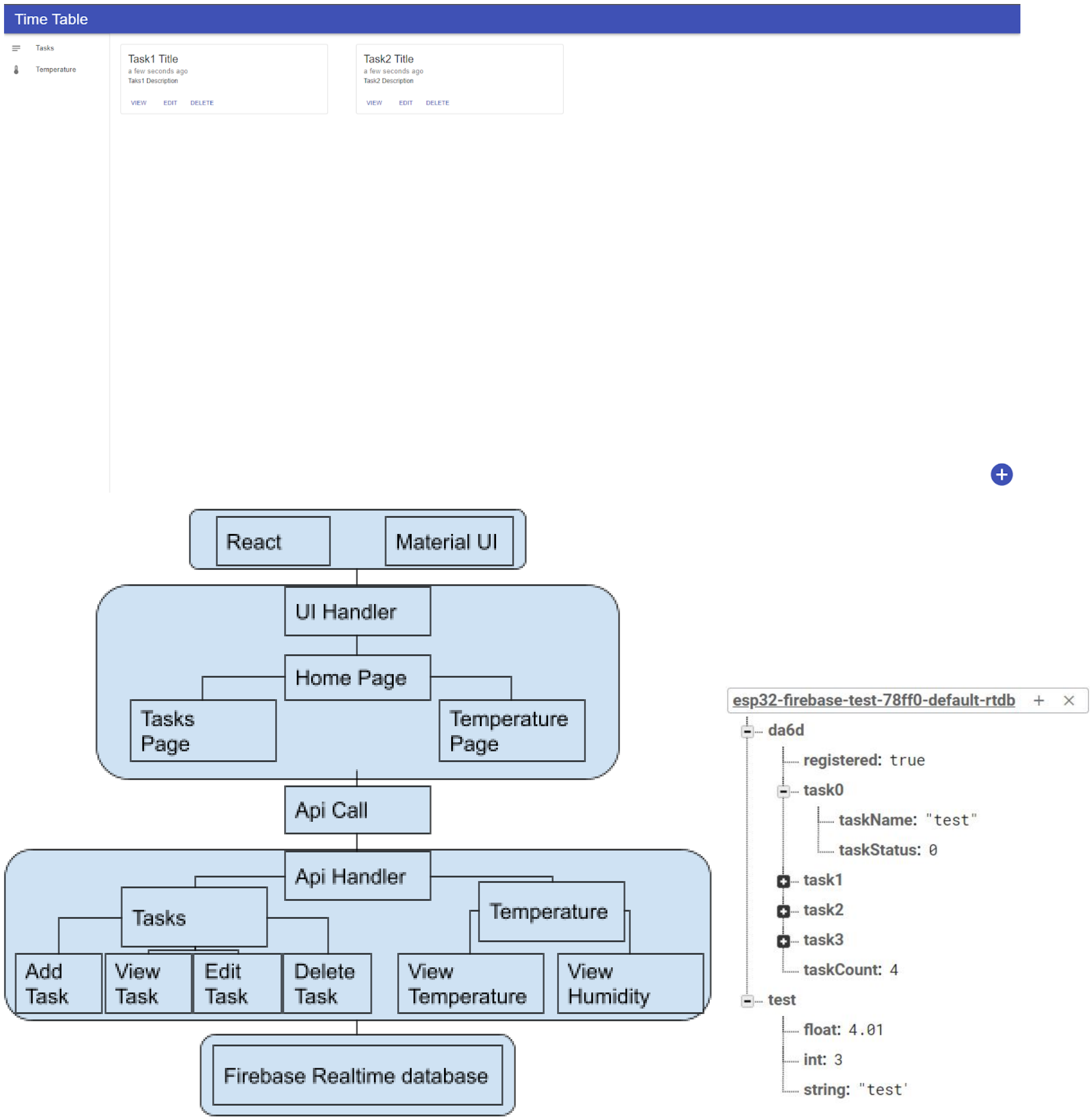

Figure 14. Draft of Task Page, Application Architecture, and Firebase Schema

2.4 Supporting Plots

Taking a deeper look at each of our sensors, we can determine the ideal readings based on current research into that environmental Factor. Firstly, with temperature, there is a lot of research on the effect of office temperatures on the effects of mental state and productivity. This particular research looks at 3 different temperatures: ~28°C, 21°C, and 17°C [10].

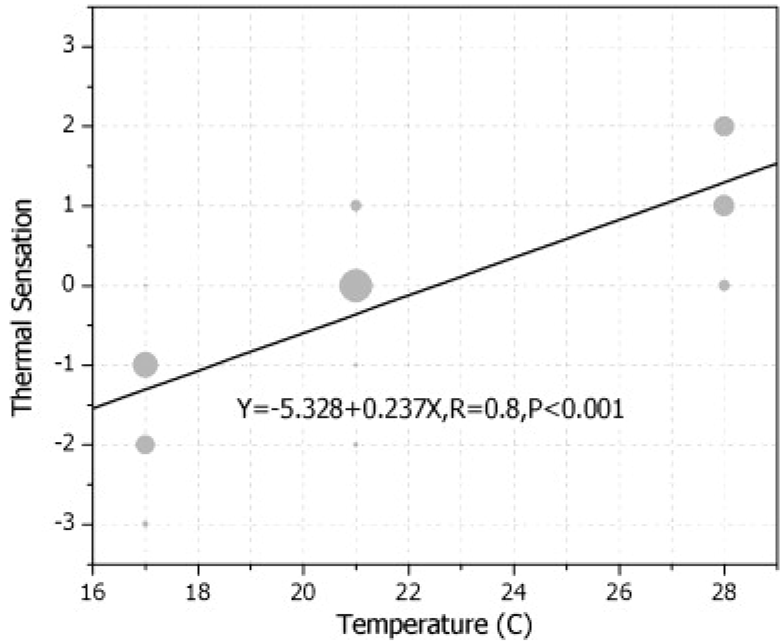

Figure 15. Graph Charting Subjects Sensation as Temperature Increases. [10]

There must be a determination that the different temperatures can be determined by people and according to Figure 15, we can see a clear linear correlation of "Thermal Sensation" and Temperature.

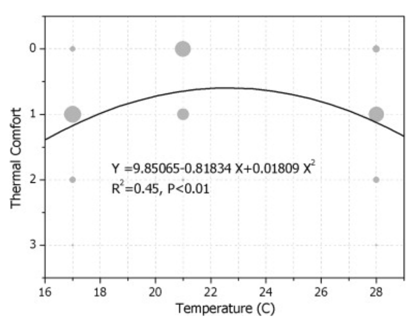

Figure 16. Subject Comfort as Function of Temperature [10]

In Figure 13 here we can see that the subjects are favoring temperatures around 22°C over the other extremes (16°C and 28°C). This study also took into account how the temperature was affecting subjects' emotional state as well as their perceived workload.

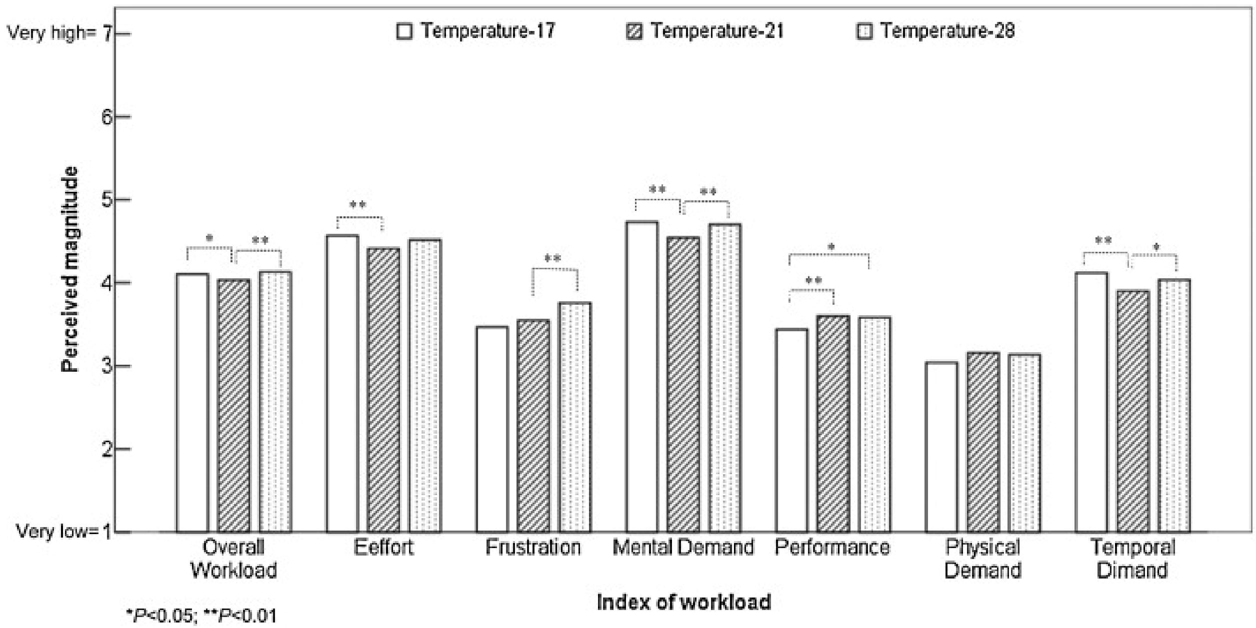

Figure 17. Graph Plotting Subjective Magnitude of Various Factors [10]

Figure 14, for example, clearly indicates that 21°C has a lesser perceived magnitude on the negative aspects of work such as workload, effort, and mental demand. In another study, they concluded that higher temperatures lead to decreased productivity. The important consideration to take into account was individual perceived warmth. Figure 14 shows that increasing temperatures are generally perceived to be warmer. However, this is still highly subjective to each person. If the person feels like 22°C is cold then their productivity might feel different than someone who perceives that 22°C as warm. That being said, we can initially generalize to 22°C with ± 2°C tolerance. Based on this study, make it optional for someone to lower or increase the core temperature with the maximum being 24°C and the lowest being 19°C. According to the other study, increases in temperature past 26°C will start decreasing productivity and 24°C + 2°C reaches that limit. 19°C was chosen because 19°C - 2°C reaches the 17°C limit. If we allow any more flexibility, then it would be difficult for us to say it's the ideal temperature as it no longer works according to the studies.

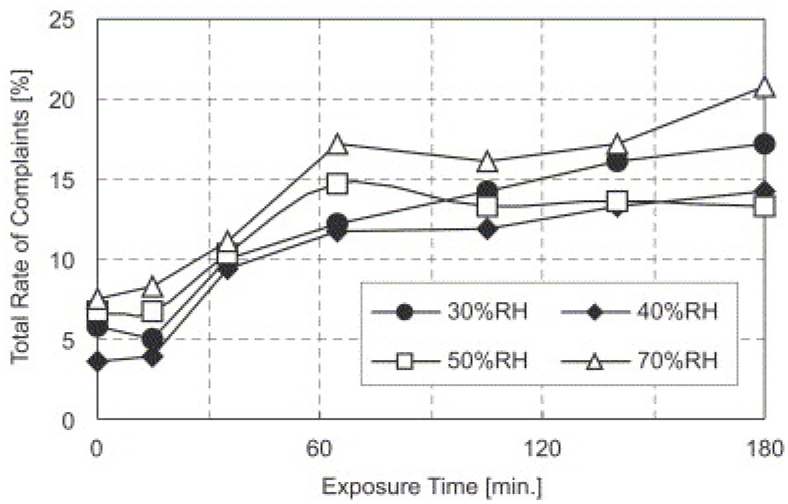

Figure 18. Complaints as a Function of Exposure Time at Various Humidity Levels [12]

Change in humidity isn't perceived between the ranges of 30% and 70%. Longer exposure to those humidity levels ends up having much more impact. According to Figure 18 [12], there is a clear increase in complaints as the time exposed to each relative humidity increases. This is a useful metric as we can make sure that we keep the humidity in said ranges but also can factor into our motion detection and when to take breaks. For example, there is a clear ramp-up in complaints in the first hour but after that, the complaints increase relatively little. So keeping the breaks to be around an hour each could keep down different feelings of irritation which overall will improve productivity.

According to a study on the impact of CO_2 on cognitive performance, there is a significant decrease in ability if exposure to CO_2 is > 1000ppm [13]. The study made several participants take a standardized examination that is considered to be of higher difficulty. They varied the ppm during each exam/simulated office work and used the results to measure performance.

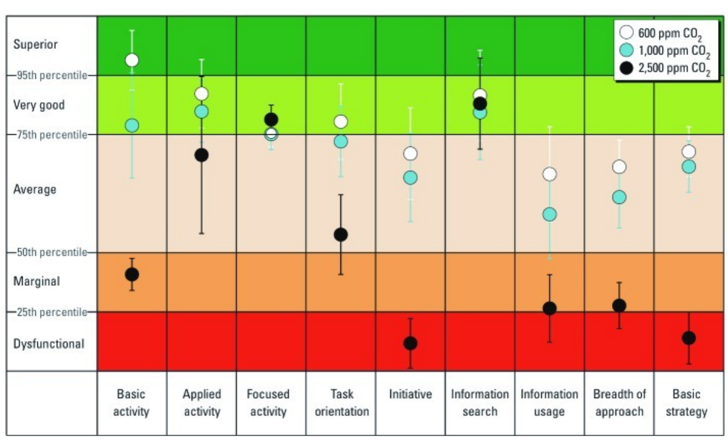

Figure 19. Effects of Carbon Dioxide on Various Categories of Productivity [13]

As you can see, in Figure 19 there is a clear decrease in performance for many of the categories as the ppm increases. Interestingly, the study specifically states that the change in performance is marginal from 600ppm to 1000ppm with a sharp impact happening at 1000pm. This is what leads us to use 1000ppm as an absolute max value in what we consider to be reasonable levels of CO_2. Now, considering we have a 20% accuracy goal, we can set that limit to be 800ppm so that at an absolute worst case it will still be 1000ppm. Since lower levels of CO_2 are ideal, we don't have to worry about the lower error threshold.

In terms of taking breaks, there are plenty of articles that support the 40-45 min of work and 15-20 microbreak model. However, there are a lot of problems with people determining when to take those microbreaks and failing to use them effectively [14]. Keeping track of these microbreaks will be the primary function of the motion sensor. We can take the subjectivity out of the decision-making by keeping track of your work (you are at your desk) and your breaks (you have left your desk). With this, we can effectively allocate work and break to keep productivity momentum up while limiting mental fatigue. At the maximum, we would want to keep the work period to an hour since, after that, the humidity has its greatest effect (Figure 18).

2.5 Schematic

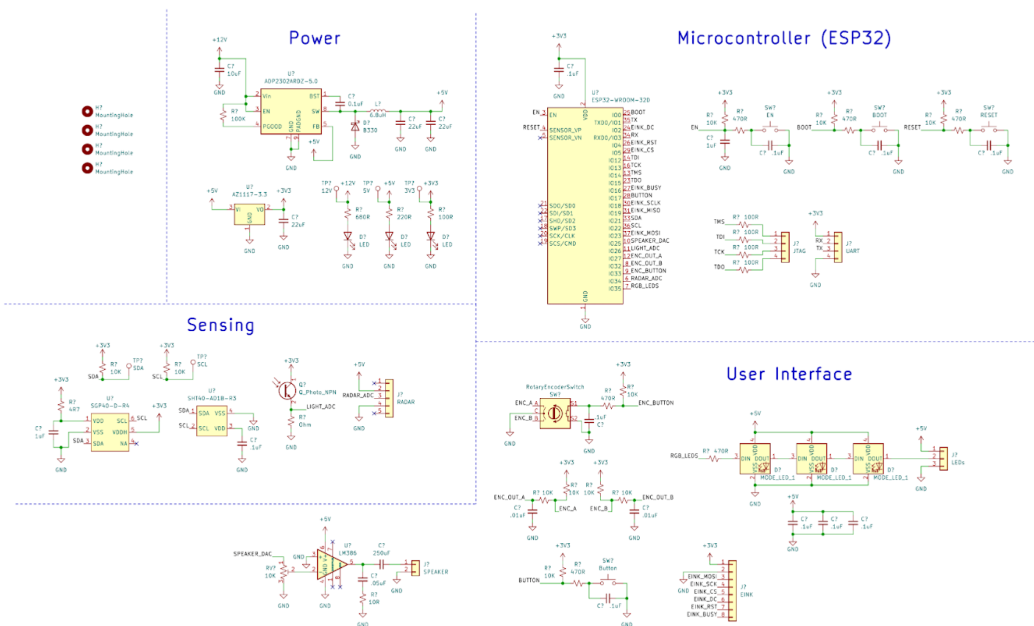

Figure 20. Complete Schematic

3. Cost and Schedule

3.1 Cost Analysis

The cost of this device comes mostly from the labor and the parts required to design and create it. The labor cost is the estimated cost for 3 electrical and computer engineers to design and build the device. The parts cost was based on prototyping cost, i.e., the cost does not factor in bulk pricing and bulk manufacturing discounts.

3.1.1 Labor Cost

Labor costs were based around an hourly salary of $40/hour which is the average salary of a new ECE graduate from UIUC. This was found based on the average UIUC Electrical Engineering salary of $76,079 and the average Computer Engineering salary of $92,430 [15]. It also assumes that each team member will work 10 hours per week for 15 weeks. Therefore, *3 team members * $40/hour * 10 hours/week * 15 weeks * 2.5 =* ***$45,000***.

3.1.2 Parts Cost

The parts cost was calculated without bulk discounts. This is the cost for exactly one prototype.

Part	**Cost**
7.5 inch E-ink display	$60
PLA filament	$20
12V power supply	$10
RCWL-0516 Radar	$3.59
ESP32-WROOM-32	$4.57
SGP40-D-R4 (eCO2 sensor)	$10.50
SHT40-AD1B-R3 (Temp/Hum Sensor)	$3.00
SFH 3711 (Phototransistor)	$0.76
PEC11R-4115F-S0018 (Rotary Encoder)	$1.75
506-FSM12JH (Tactile Button)	$0.30 * 4
SK6812 (RGB LEDs x10)	$4.50 * 2
SP-2306Y (Speaker)	$1.56
LM386MMX-1/NOPB (Speaker Amp)	$1.65
ADP2302ARDZ-5.0-R7 (Buck Converter)	$3.46
AZ1117IH-3.3TRG1 (LDO Regulator)	$0.50
Misc Resistors, Capacitors, Inductors	$10.00
PCB Fabrication	$5.00
Total	**$146.54**

3.1.3 Total Cost:

Adding the labor and parts cost, the total cost of the prototype is $45,000 + $146.54 = $45,146.54.

3.2 Schedule

Week	Ben Xie	Pranav Goel	Hongru Wang
01/31/2022	Brainstorm project ideas and write proposal	Brainstorm project ideas and write proposal	Brainstorm project ideas and write proposal
02/07/2022	Find parts for device and start preliminary BOM	Create the Block Diagram and Visual aid for Project	Create tolerance analysis
02/14/2022	Create schematic draft for main PCB	Gather supplementary materials (research) for Design Document and calculate requirement values	Start web front end developing
02/21/2022	Start working on Firmware - Get firebase/WiFi working	Create PCB Layout for main board	Create Schematics/PCB design for side LED module
02/28/2022	Create preliminary physical design	Verify PCB Layout with TAs	Order parts
03/07/2022	Get CO2 sensor working and test accuracy	Get LEDs to work with Sensor Readings/Modes	Connect front end to firebase, write APIs
03/14/2022	Spring Break- Catch up to schedule	Spring Break- Catch up to schedule	Spring Break- Catch up to schedule
3/21/2022	Design and fabricate enclosure, solder PCB	Get E-Ink display working, debug first circuit, solder PCB	Get Motion Sensor working
3/28/2022	Clean up codebase	Verify Design Document Requirements	Debug web app
4/04/2022	Polish/Clean up mechanical design	Polish Front End on both Device and Website	Polish client side for better user interface design
4/11/2022	Work on presentation, debugging	Work on presentation	Work on presentation
4/18/2022	Mock Demo - Fix last minute issues	Mock Demo - Fix last minute issues	Mock Demo - Fix last minute issues

4/25/2022	Demo/Mock Presentation/Start Final Paper	Demo/Mock Presentation/Start Final Paper	Demo/Mock Presentation/Start Final Paper
5/02/2022	Presentation/Final Paper	Presentation/Final Paper	Presentation/Final Paper

4. Tolerance Analysis

One of the most important parts of our design that could potentially affect the functionality of the device is the sensitive range of the RCWL-0516 radar sensor, which is a motion sensor to detect the data about the sitting time of users. It has a sensitivity of about 7 meters [5]. But the user usually would only be about 0.4 to 1.25 meters away from the sensor on the desk [6]. Generally, the preferred viewing distance is between 0.5 and 1m from the eye to the front surface of the computer screen (about an arm's length). We don't want the motion in the background to be detected by the sensor so we want to set a triggering threshold. Specifically, we want to control the sensitivity so it only goes on when there is very nearby movement, like 0.25 to 1.4 meters range. Except for the distance, another potential issue is that the sensor might not be able to detect slow body movement. For example, the sensor might not detect a very slight body movement so the sitting time of the user might be miscalculated. We will conduct multiple tests to solve the above issues by changing the value of a certain register to receive an optimal sensitivity range. According to the test result by a user who tested with this motion sensor, any object in the vicinity like walls, carpets, metal cups, porcelain or red paint with iron oxide/metals, etc. will have various degrees of reflection, interference, or attenuation [7]. According to his test results, we have to bring a linear tuning pot (fine-tuning) in series with a log pot (rough tuning) to adapt to the real world environment. Based on this, the corresponding logarithmic scale relation between the value of resistor R-GN(R3) and the reception limits is provided as follow:

$$f(x) = 0.1089e^{0.5375x} M\Omega$$

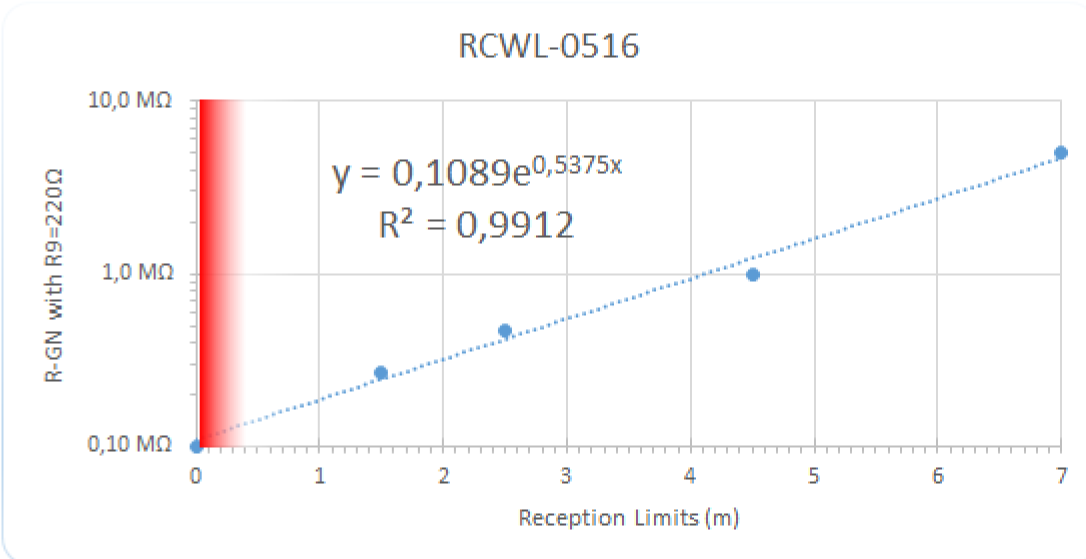

Figure 21. Relation between the value of resistor R-GN(R3) and the reception limits from [7]

According to Figure 18, there is extreme nonlinearity at small distances and quasi linearity at the furthest distance. Also, the red area is indicative of "ripples" in polar coordinate sensitivity around the receiver at distances 0-30cm [7]. So we should follow this formula and empirically adjust the corresponding resistor to 231,118.376106 ohms to filter out movements above 1.4 m for our project. In addition, according to the feedback from other users using the RCWL-0516 radar sensor, having a lot of other electronic devices such as a computer close by reduces reliability. We need to identify the equipment that may interfere with the sensor and move the sensor away from the interfering equipment.

Since we want the RCWL-0516 to detect small movement while keeping a relatively smaller reception limit than 7 m, we tested the sensor and found that setting the R-GN value to 1.2$M\Omega$ is optimal to satisfy our requirements because it's a good balance between the sensitivity to small body movement and reception limits. When R-GN is set to 1.2 $M\Omega$, we found that the motion sensor can detect small movements such as writing with a pen in 5 m range, which is very close to the result obtained from the formula $x = \frac{ln(\frac{1.2}{0.2089})}{0.5375} = 4.464\ m$. In addition, movements behind three layers of plastics and lateral movements can be detected with this resistor value.

5. Safety & Ethics

The user of our project will be directly involved with the operation of the device; We must adhere to the guidelines from Section I.1 of the IEEE Code of Ethics that "to hold paramount the safety, health, and welfare of the public. . . " [8] and the safety regulation in Sections 1910.302 - Electric utilization systems by Occupational Safety and Health Administration [9], so, it is important that we must ensure a safe and reliable product. There are several components in our product that, if mishandled or constructed poorly, might pose a risk to the user's safety. The power supply and circuits are some of the most important components to consider. The risks associated with the unstable power supply will be reduced by a rigorous power electronics design, and we would make sure that the users use our product in a safe environment. Furthermore, we must consider that our product will be available to everyone per Section II of the IEEE Code of Ethics [8] and that our users can equally operate our device. The mission of our project is to give people a better way to monitor their daily tasks and their working environment. We welcome everyone to use our product and we hope that our users could improve their productivity as well as the efficiency with our product.

6. Citations

[1] J. Allen, P. MacNaughton, U. Satish, S. Santanam, J. Vallarino, J. Spengler.(2016). Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. Environ Health Perspect 124:805–812.

[2] S. Lang.(2004). Study links warm offices to fewer typing errors and higher productivity. Cornell Chronicle. [Online]. Available: https://news.cornell.edu/stories/2004/10/warm-offices-linked-fewer-typing-errors-higher-productivity [Accessed: 10-Feb-2022].

[3] A. Hedge. (n.a.). Linking Environmental Linking Environmental Conditions to Productivity Conditions to Productivity. Cornell University Dept. Design & Environmental Analysis NYS College of Human Ecology. [Online]. Available: http://ergo.human.cornell.edu/Conferences/EECE_IEQ%20and%20Productivity_ABBR.pdf [Accessed: 10-Feb-2022].

[4] R. Henning, S. Sauter, G. Salvendy, E. Krieg. (1989). Microbreak length, performance, and stress in a data entry task. Ergonomics. 1989 Jul;32(7):855-64. doi: 10.1080/00140138908966848. PMID: 2806221.

[5] RCWL-0516 Microwave Radar Motion Detector. [Online]. Available: https://hobbycomponents.com/sensors/899-rcwl-0516-microwave-radar-motion-detector-#:~:text=detect%20moving%20objects.-,It%20has%20a%20sensitivity%20range%20of%20~7%20meters.,to%20its%20idle%20LOW%20state. [Accessed: 10-Feb-2022].

[6] Correct Sitting Posture: Working at a Desk. Physio Med. [Online]. Available:https://www.physiomed.co.uk/uploads/guide/file/22/Physiomed_Sitting_Guide_-_Working_at_a_Desk_Digital.pdf [Accessed: 10-Feb-2022].

[7] Question: Minimum range by R-GN adjustment? [Online]. Available:https://github.com/jdesbonnet/RCWL-0516/issues/11#issuecomment-771810294 [Accessed: 23-Feb-2022].

[8] IEEE Code of Ethics. IEEE. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 10-Feb-2022].

[9] Occupational Safety and Health Standards. Occupational Safety and Health Administration. [Online]. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.302. [Accessed: 10-Feb-2022].

[10] L. Lan, Z. Lian, and L. Pan, "The effects of air temperature on office workers' well-being, workload and productivity-evaluated with subjective ratings," *Applied Ergonomics*, vol. 42, no. 1, pp. 29–36, May 2010.

[11] S.-ichi Tanabe, N. Nishihara, and M. Haneda, "Indoor temperature, productivity, and fatigue in office tasks," *HVAC&R Research*, vol. 13, no. 4, pp. 623–633, Feb. 2011.

[12] H. Tsutsumi, S.-ichi Tanabe, J. Harigaya, Y. Iguchi, and G. Nakamura, "Effect of humidity on human comfort and productivity after step changes from warm and humid environment," *Building and Environment*, vol. 42, no. 12, pp. 4034–4042, Jan. 2007.

[13] U. Satish, M. J. Mendell, K. Shekhar, T. Hotchi, D. Sullivan, S. Streufert, and W. J. Fisk, "Is CO2an indoor pollutant? direct effects of low-to-moderate co2 concentrations on human decision-making performance," *Environmental Health Perspectives*, vol. 120, no. 12, pp. 1671–1677, Dec. 2012.

[14] R. O. B. E. R. T. A. HENNFNG, S. T. E. V. E. N. L. SAUTER, G. A. V. R. I. E. L. SALVENDY, and E. D. W. A. R. D. F. KRIEG, "Microbreak length, performance, and stress in a data entry task," *Ergonomics*, vol. 32, no. 7, pp. 855–864, Jul. 2010.

[15] I. Success Initiative, Illini Success Initiative, Champaign, Illinois, rep., 2018. https://ecs.engineering.illinois.edu/files/2019/03/IlliniSuccess_AnnualReport_2017-2018_FINAL.pdf [Accessed: 24-Feb-2022]

[16] Sensirion, "Indoor Air Quality Sensor for VOC Measurements", Datasheet SGP40, July 2020 [Revised: February 2022]

[17] Sensirion, "4th Generation, High-Accuracy, Ultra-Low-Power, 16-bit Relative Humidity and Temperature Sensor", Datasheet SHT4x, October 2020 [Revised: July 2021]

[18] IC Station, "RCWL-0516 microwave radar sensor module Human body induction switch module Intelligent sensor ", Datasheet RCWL-0516