Item-Tracking Backpack

Team 66

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ECE 445: Senior Project Design

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Introduction

Problem

A study conducted by Name Bubbles, surveying 400 parents, showed that around 80% of children lose their belongings at school [2]. 52% of the parents answered that the items lost included school supplies, while 36% stated that lunch boxes were among what was lost [2]. For most students, backpacks are their primary means of storing such items. With the ability of backpacks to store many items in various compartments, it is easy for students to lose track of what they have placed in them. It can also become inefficient and time-consuming for students to constantly check whether they have forgotten an item, especially when the number of items they have stored in their backpacks is typically relatively high. Moreover, the different compartments available for students to place their belongings in make it simple for them to become disorganized and lose track of a given item. This issue also results in students occasionally forgetting items at home, forcing parents to need to deliver them in cases where the items are important.

Solution

To solve this issue, our project will aim to provide users with the ability to track the items in their backpacks. RFID will be used to scan tagged items as they are placed and removed from the backpack. Students will be able to make lists of items they are planning on having in the backpack using a mobile application before their commute to school. Separate lists will be made for different compartments to assist users in keeping track of where the items are in the bag. The lists can be modified by adding and removing items, and the status of each item–present, missing, or misplaced–will be displayed for the user to see in real time. The present status will indicate that items are currently in the backpack and in the correct compartment; the missing status will show that an item is not currently in the bag; and the misplaced status will mean that an item is currently in the bag, but in the incorrect compartment. In addition, the time at which a missing item was removed from the bag will be indicated on the application to aid in locating it.

During school hours, many students will not have permission to access mobile phones, so LEDs will be used to allow for quick, but less explicit real-time tracking. Each compartment will have a red LED designated to it. These LEDs will turn on when the user has incorrectly placed an item in the compartment, or if an item is missing from it. The LEDs will turn off after the compartment zipper has been closed, or if they have been active continuously for 30 seconds. A green LED will be used to indicate that all items are present in the backpack and in the correct compartment, indicating that nothing has been forgotten. This LED will similarly turn off after being continuously on for 30 seconds, or after all compartments in the backpack have been closed. The application can then be used after school by parents picking up their children, or by the students themselves, to ensure that nothing is missing or forgotten.

High-level requirements

1. The mobile application shall enable the user to add and remove items to three separate lists, each corresponding to a compartment in the backpack. The user shall be able to track a maximum of at least five items per compartment.
2. The user shall be able to monitor the status of each item—present, missing, misplaced—using the mobile application, and they will be updated at least once every ten seconds. The application shall display what time a missing item was removed from the backpack.
3. The LEDs shall activate within ten seconds of a requirement being met. To conserve power, each red LED shall turn off when its corresponding compartments are closed, and the green LED shall turn off when all compartments are closed. Otherwise, all LEDs shall turn off after being continuously on for 30 seconds.

Physical Design

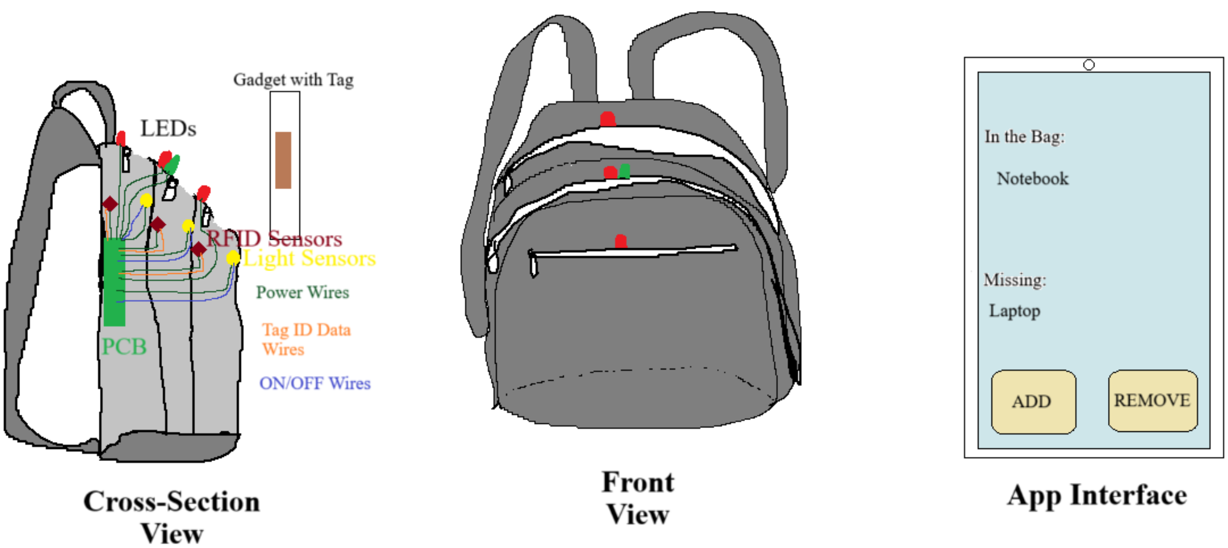

Figure 1: Visual Aid Diagram

The RFID readers will be attached to the interior walls of the backpack, towards the top as shown in figure 1. Tags placed on the items can be scanned in the process of placing and removing them. For protection from items being placed and removed, the readers will be placed in a case open from the side facing away from the wall. Each case will also have an LED extending to the backpack's exterior to allow users to directly view them. Moreover, a light sensor will be placed in the case to allow for the detection of when the zipper is closed. Finally, aluminum will be placed on the back wall of each case to prevent interference between RFID readers. Each of the three compartments will have a separate reader, light sensor, and LED. These will all be connected to the PCB, which will be placed at the bottom surface of the compartment at the center of the three compartments. To protect the PCB from the items in the backpack, it will be placed in a case for protection. Holes will be made in the walls of the backpack compartments to allow for wires to be connected to the devices in the cases. To prevent the wires from being exposed, they will be passed through tubes.

The block diagram is shown in figure 2. It has four main modules: the power module, the control module, the indication module, and the sensors module. There is also a sixth module which is the RFID tag module. It is outside the PCB, but it will interact with the RFID readers wirelessly. In addition, the phone app will interact with the microcontroller using Bluetooth 2.4 GHz.

All the power connections use a 3.3 V which is shown in green arrows. The data connections use dotted lines. The wireless connections use dual dashed lines.

The red dotted lines are the ON/OFF signals. They are responsible for turning the entire system on or off. They are obtained from ambient light sensors.

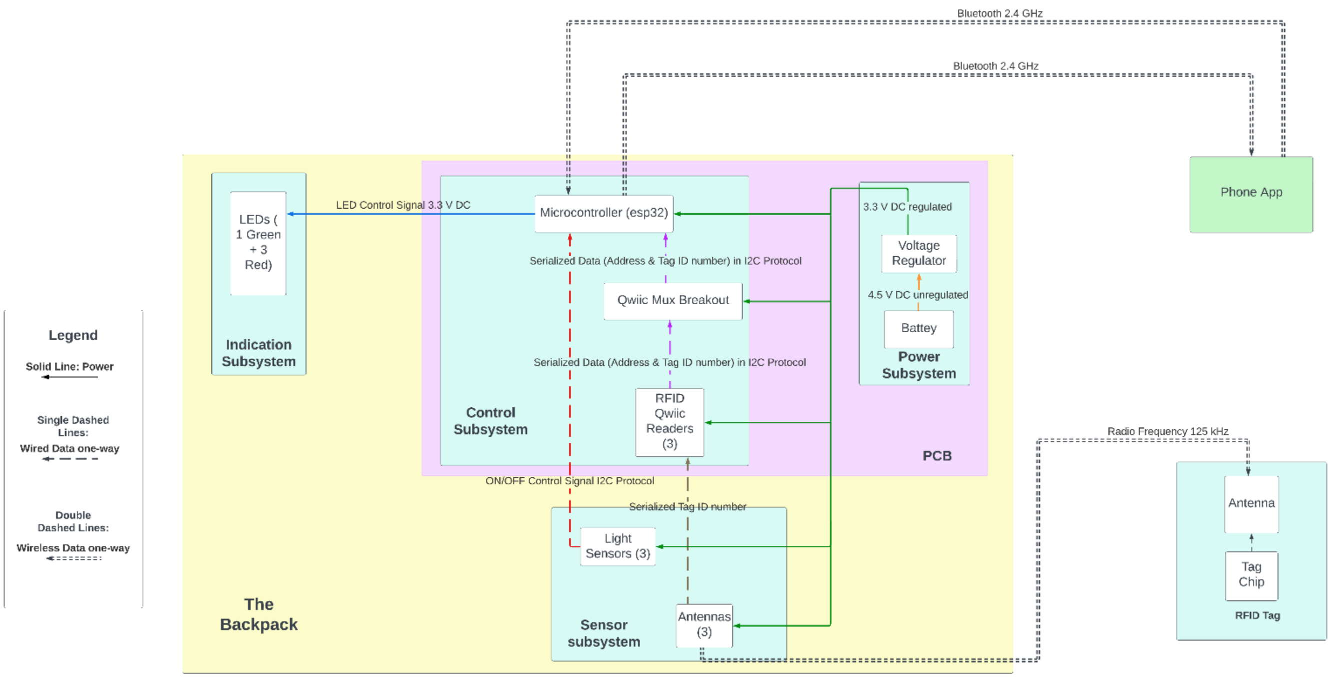

Figure 2: Block Diagram

Subsystems and Requirements

Sensor Subsystem

The sensor subsystem will be tasked with keeping track of what items are in the backpack and the compartments they are located in. It will also detect changes in the ambient light in each compartment to identify when the compartments have been closed. To carry out the item-tracking functionality, RFID ID-12LA readers, operating at 125 kHz, will be used to detect tagged items as they are placed in and removed from the different backpack compartments. These readers will be connected directly to RFID Qwiic readers, through which the data of scanned tags will be stored. To allow for detection of changes in ambient light in each compartment, TSL25911FN light sensors will be used, which will interface with the microcontroller through I2C. The RFID ID-12LA readers and light sensors will be supplied with 3.3 V from the power subsystem. It will be necessary to ensure that tags are scanned at least once per second. It will also be essential that the RFID ID-12LA tags do not interfere with one another. Finally, each light sensor must be capable of identifying when its corresponding compartment has been closed. To make certain that these conditions are met, the following Requirements and Verification table will be used.

Table 1: Sensor Subsystem Requirements and Verification

Requirements	Verification
• RFID readers must only scan the items of the compartment they are allocated to. The RFID readers must also not interfere with one another.	• Place two RFID ID-12LA readers, contained in the containers described in the Physical Description section, within 2 ± 0.1 cm of each other. • Connect a multimeter to measure the voltage across the “Tag in Range” pin of each reader. • Ensure that the voltage across this pin is 0.0 ± 0.1 V for both readers. • Place a 125 kHz RFID tag within range of one of the RFID readers. • Check if that reader was able to read the tag by confirming that the voltage across the “Tag in Range” pin is 3.3 ± 0.1 V. • Check if the other reader was not able to read the tag by confirming that the voltage across the “Tag in Range” pin is 0.0 ± 0.1 V.
• The light sensor must be able to determine when the backpack is open or closed by differentiating between	• Hold the light sensor in place near the top of an open backpack compartment. • Confirm that the light sensor was able to identify that the backpack is open by using an oscilloscope to measure its SDA and SCL waveforms.

the light intensity of these two states.	• Close the backpack compartment while keeping the light sensor near its top. Use a cloth to cover open areas if necessary. • Confirm that the light sensor was able to identify that the backpack is closed by using an oscilloscope to measure its SDA and SCL waveforms.
• The RFID readers must be able to scan a tag within two seconds of the tag entering its range.	• Connect a multimeter to measure the voltage across the “Tag in Range” pin of an RFID ID-12LA reader. • Ensure that the voltage across this pin is 0.0 ± 0.1 V. • Place a tag within range of the reader and immediately start a timer. • Confirm that the time needed for the voltage across the pin to reach 3.3 ± 0.1 V is no more than two seconds.

Indication Subsystem

The indication subsystem will quickly inform the user about whether all their desired items are in the bag. It will also quickly notify the user if the items in the compartment do not exactly match what was specified in the application. To these ends, a green 5 mm LED will be used to indicate to the user that no items have been forgotten. The LED will activate once all the items listed on the application have been placed in the backpack and in the specified compartments. It will turn off once all compartments have been closed, or once it has been continuously on for 30 seconds. One red 5 mm LED will be assigned to each compartment. The red LEDs will turn on if the items currently in the compartment do not exactly match what is on the application. They will turn off when their corresponding compartment has been closed, or after they have been continuously on for 30 seconds. To drive the LEDs, they will all be supplied with 3.3 V. Series resistors will ensure that the green LED operates at 2V, while the red LEDs operate at 2V. To guarantee that the LEDs will be activate only under the specified conditions, and that the LEDs turn on within ten seconds of these conditions being met, the Requirements and Verification table below will be used.

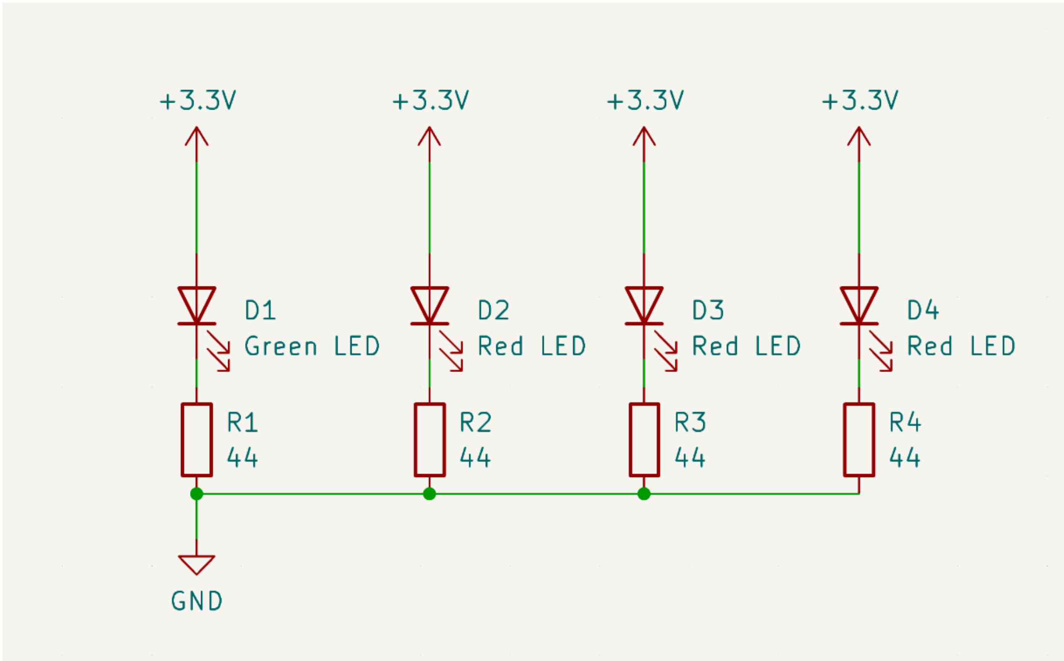

Figure 3: Indication Subsystem Schematic

Table 2: Indication Subsystem Requirements and Verification

Requirements	Verification
• The LEDs must be able to remain active continuously for 30 ± 5 seconds.	• Supply 3.3 ± 0.1 V to one of the LEDs. • Ensure that the LED turns on and immediately start a timer. • Confirm that the LED can remain continuously on for 30 ± 5 seconds. • Repeat these three steps for the remaining three LEDs.

User Interface Subsystem

The user interface subsystem will consist of a mobile application to allow the user to track the items in the backpack in real time. The application will also give the user the ability to change the items they wish to track. Furthermore, it will notify the user when an item is placed in the incorrect compartment. To carry out these functions, the application will enable the user to add and remove items from separate lists corresponding to each compartment. The user will have the option of choosing between adding an item that they have previously tracked or inserting a new one. The status of each item—present, missing, or misplaced—will be displayed adjacent to each item and will be updated in real time. Bluetooth (2.4 GHz) will allow the mobile application to interface and communicate with the microcontroller. The user interface subsystem must allow the users to create three lists corresponding to different compartments, each containing a maximum of at least five different items. The application must also be able to interface with the microcontroller from a maximum distance of at least two meters. The lists must be updated at least once every ten seconds to allow for proper real-time tracking. Moreover, the time at which missing items have been removed from the backpack must be displayed. To ensure that these prerequisites have been met, the following Requirements and Verification table will be used.

Table 3: User Interface Subsystem Requirements and Verification

Requirements	Verification
• Each item's status must be updated at least once every ten seconds if the user is at a maximum of at least 2 ±0.1 meters away from the backpack. • The time at which missing items were removed from the backpack should be displayed once their status changes from *present* to *missing*.	• Ensure that the mobile phone used to access the application is 2 ±0.1 meters away from the backpack. • Add a single item to any list on the application. Confirm that the item is shown as *missing* on the application. • Scan the RFID tag of the item listed on the application with the RFID reader of the corresponding compartment in the backpack. • Immediately start a timer and measure the time required for the *missing* status to change to *present* on the application. Confirm that this time is no more than ten seconds. • Scan the RFID tag with the same reader and note the hour and minute when the scan was complete. • Immediately start a timer to measure the time taken for the status of the item on the application to be changed from *present* to *missing*. Confirm that this time is no more than ten seconds. • Also confirm that the hour and minute appear once the status has changed to *missing*. Ensure that they are the same as what was noted earlier. • Immediately start a timer to measure the time taken for the status of the item on the application to be changed from *present* to *misplaced*.
• Users must be able to add and remove items from at least three different backpack compartments. Users must be able to add a maximum of at least five items to a given list.	• Ensure that the mobile phone used to access the application is no more than two meters away from the backpack. • Add five unique items to each of the three lists on the application. • Scan the RFID tag of each item with the RFID reader corresponding to the compartment it is assigned to in the application. • Confirm that the application shows that all 15 items are present. • Scan the RFID tag of one item from each compartment with the RFID reader corresponding to that compartment. Confirm that the application shows that they are missing, while the remaining

	items should remain displayed as present. Also confirm that the hour and minute displayed are the same as when the scan was complete. • Scan each of these items with a reader corresponding to a compartment that they were not assigned to. • Confirm that the application shows that those specific items are misplaced, while the remaining items remain present.
• Users must be able to add items and track items that have not been previously tracked.	• Ensure that the mobile phone used to access the application is no more than two meters away from the backpack. • Add a new item to any given list on the application. Confirm that it is shown as *missing* in the application. • Scan the RFID tag of that item with the RFID reader corresponding to the compartment it is assigned to. Confirm that the item is shown as *present* in the application. Also confirm that the hour and minute displayed are the same as when the scan was complete. • Scan the RFID tag of the item with the same RFID reader. Confirm that the item is shown as *missing* in the application. • Scan the RFID tag of the item with an RFID reader corresponding to a compartment that it was not assigned to. Confirm that the item is shown as *misplaced* on the application.

Power Subsystem

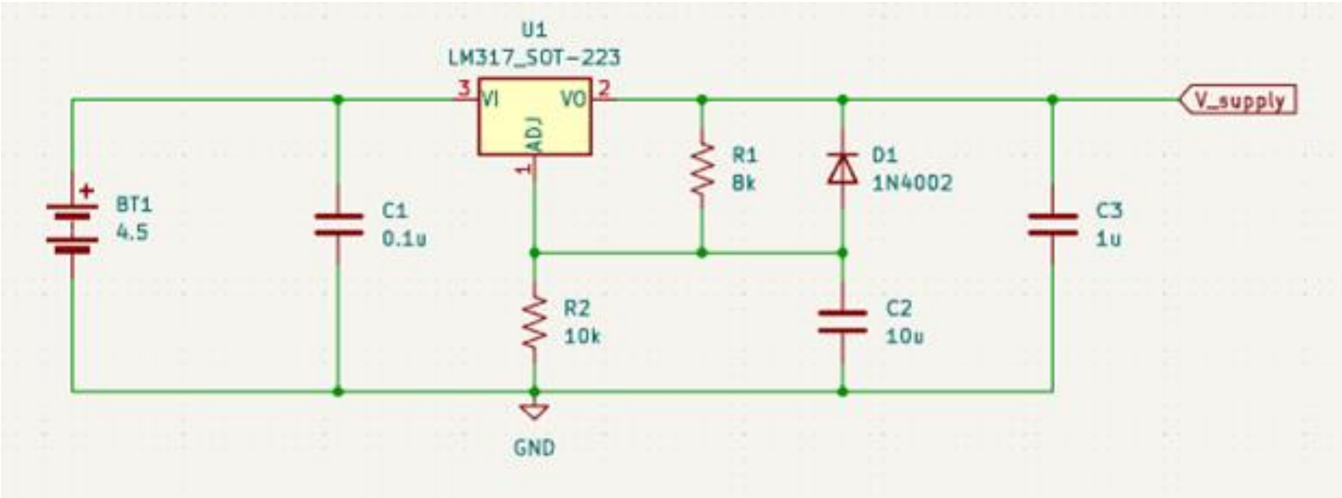

Figure 4: Power Subsystem Schematic

The power subsystem is responsible for delivering 3.3 V DC power to the rest of the subsystems. The power subsystem should supply up to 1000 mA of current. It consists of a battery and an LM317 voltage regulator. The voltage regulator used in this subsystem is a linear voltage regulator (low dropout regulator) with an output voltage of 3.3 V DC. A linear voltage regulator was used instead of a switching regulator because of its low noise output. This is important in this project because the noise might interfere with the sensors. Specifically, the output voltage ripple must be less than 3 mV peak-to-peak to allow the sensor subsystem to work properly. The LEDs in the indicator subsystem will receive power through the microcontroller subsystem, which is powered by the power subsystem. This allows the microcontroller to turn the LEDs on or off. To make certain that these conditions are met, the following Requirements and Verification table will be used.

Table 4: Power Subsystem Requirements and Verification

Requirements	Verification
• The power subsystem should output a constant voltage of 3.3V with less than 3 mV peak-to-peak noise at a maximum current of 1000 mA.	• Connect the power subsystem to a power supply set to 1000 mA on constant current mode. • Use an oscilloscope to measure the voltage waveform of the power subsystem. • Verify that the DC component is 3.3 ± 0.1 V. • Use the measure option on the oscilloscope to measure the peak-to-peak voltage. • Verify that the voltage ripple is less than 3 mV peak-to-peak. • Suddenly decrease the current of the power supply to 100 mA to simulate a change in the load. • Verify that the voltage ripple is less than 3 mV peak-to-peak. • Suddenly increase the current back to 1000 mA. • Verify that the voltage ripple is less than 3 mV peak-to-peak.

Control Subsystem

The control subsystem consists of ESP32-S3. It includes Bluetooth which is important for communication with the user interface subsystem. This subsystem will also consist of three RFID Qwiic readers, each connected to a separate RFID ID-12LA reader. The Qwiic readers will track scanned tags by marking and placing them on a stack, and they will relay this information to the microcontroller through I2C. The microcontroller will then transmit the results to the user interface subsystem through Bluetooth at 2.4 GHz. Moreover, the microcontroller will use the information it receives from the Qwiic readers and light sensors to send the appropriate signals to switches for activation or deactivation of the LEDs. To ensure the microcontroller subsystem can implement these functions, the following Requirements and Verification table will be used.

Table 5: Control Subsystem Requirements and Verification

Requirements	Verification
• The microcontroller should be able to read all three RFID readers' signals at the same time.	• Place a tag in one compartment. • Check if the microcontroller can read that tag ID. • Place three more tags, one in each compartment. • Check if the microcontroller can read all three tag IDs.
• RFID Qwiic readers must be able to store the data of at least five different RFID tags at a time.	• Place five 125 kHz RFID tags in the same compartment of the backpack. • Check if the first reader was able to read each tag by using an oscilloscope to measure the waveform of the SDA (the address & the data) and SCL (the clock) pins in the RFID Qwiic reader. • Confirm that all five RFID tags are present on the Qwiic reader stack using the necessary I2C commands.
• The microcontroller should store up to 15 RFID tag IDs along with their names and locations in the backpack	• Register 15 items in the microcontroller • Check if the microcontroller still has the 15 items' information stored in its flash memory.

• The microcontroller should compare the read RFID tag ID to the list of registered RFID tags IDs to determine if any item is missing. • The microcontroller should turn on the LEDs in the indication subsystem	• Register 15 items in the microcontroller. • Place 14 out of the 15 registered items in the backpack one by one. • The red LED signal for the compartment with an item missing should be HIGH. The other two red LED signals and the green LED signal should all be LOW. • Place the 15th tag in the backpack. • The red LED signal should all be LOW, and the green LED signal should be HIGH.
• The microcontroller should transmit 2.4 GHz Bluetooth signals to the user interface subsystem.	• Register one item in the microcontroller • Place the registered item in the backpack • Use a phone (or any other Bluetooth device) to read the Bluetooth signal. • The signal should specify the name and location of the tag.
• The signal to activate the green LED must be sent only when all the desired items are present and are in the correct compartments (as specified in the application). The green LED must not be active if there are items present in the backpack that have not been added to any list in the application, or if the backpack is closed. The green LED must take a maximum of ten seconds to activate and deactivate after the necessary conditions have been met.	• Ensure that the backpack is empty and that the mobile phone used to access the application is no more than two meters away from the backpack. • Add a single item to any list on the application. • Place the item listed on the application in the corresponding compartment in the backpack and ensure that its RFID tag was successfully scanned. • Immediately start a timer to measure the time taken for the green LED to light up. Confirm that this time is no more than ten seconds. • Remove the item from the list on the application and immediately start a time to measure the time taken for the green LED to light up. Confirm that this time is no more than ten seconds.
• A red LED must turn off only if all the items specified in the application are	• Ensure that the backpack is empty and that the mobile phone used to access

present in the corresponding compartment. If an item not specified in the application is placed in the compartment, the red will remain on, even if all the items listed in the application are present. • The red LEDs must take a maximum of ten seconds to activate and deactivate after the necessary conditions have been met.	the application is no more than two meters away from the backpack. • Place an RFID in an arbitrary compartment and ensure that it was successfully scanned. • Immediately start a timer and measure the time taken for the red LED corresponding to that compartment to light up. Confirm that this value is no more than ten seconds. • Add the item placed in the backpack to the list corresponding to the compartment in which it was placed in. • Immediately start a timer and measure the time taken for the red LED to turn off. Confirm that this time is no more than five seconds.

Software Design

Mobile Application and LED Real-Time Tracking

The core functionality of this project is its real-time tracking of items users place in the backpack. Tracking is done through a mobile application and a set of LEDs. The application explicitly provides the status of each item listed to be tracked, while the LEDs inform users of whether items are missing from each compartment, and the backpack as a whole, in a relatively quick manner. Therefore, it is essential that the microcontroller can identify what state the system is currently in and send the appropriate signals and data to the necessary components accordingly.

The system can be divided into three different states. To determine if it should remain in the same state, or if it should transition to another state, the microcontroller will take the following inputs from the mobile application, RFID Qwiic readers, RFID ID-12LA readers, and the light sensors.

- CLOSED: The microcontroller should send the necessary signals to ensure that all LEDs are off. Transitions into this state will occur when all backpack compartments have been closed. Once in this state, timers for each LED will be reset. As a result, after transitioning from this state to one requiring an LED to be on, the LED will activate regardless of whether it has been on continuously for 30 seconds before or not.

- OFF: The microcontroller should send the necessary signals to ensure that all LEDs are off. Transitions into this state will occur when the green LED has been on continuously for 30 seconds, or when each red LED has been on continuously for 30 seconds.

- ALL PRESENT: The microcontroller should send the necessary signals to the LEDs to ensure that the green LED activates, while the red LEDs are all off.

- MISSING/MISPLACED: The microcontroller should send the necessary signals to ensure that only the LEDs corresponding to the compartment with items missing will turn on. If an LED has been continuously on for 30 seconds, it will turn off regardless of whether there are items missing in the compartment it is allocated to.

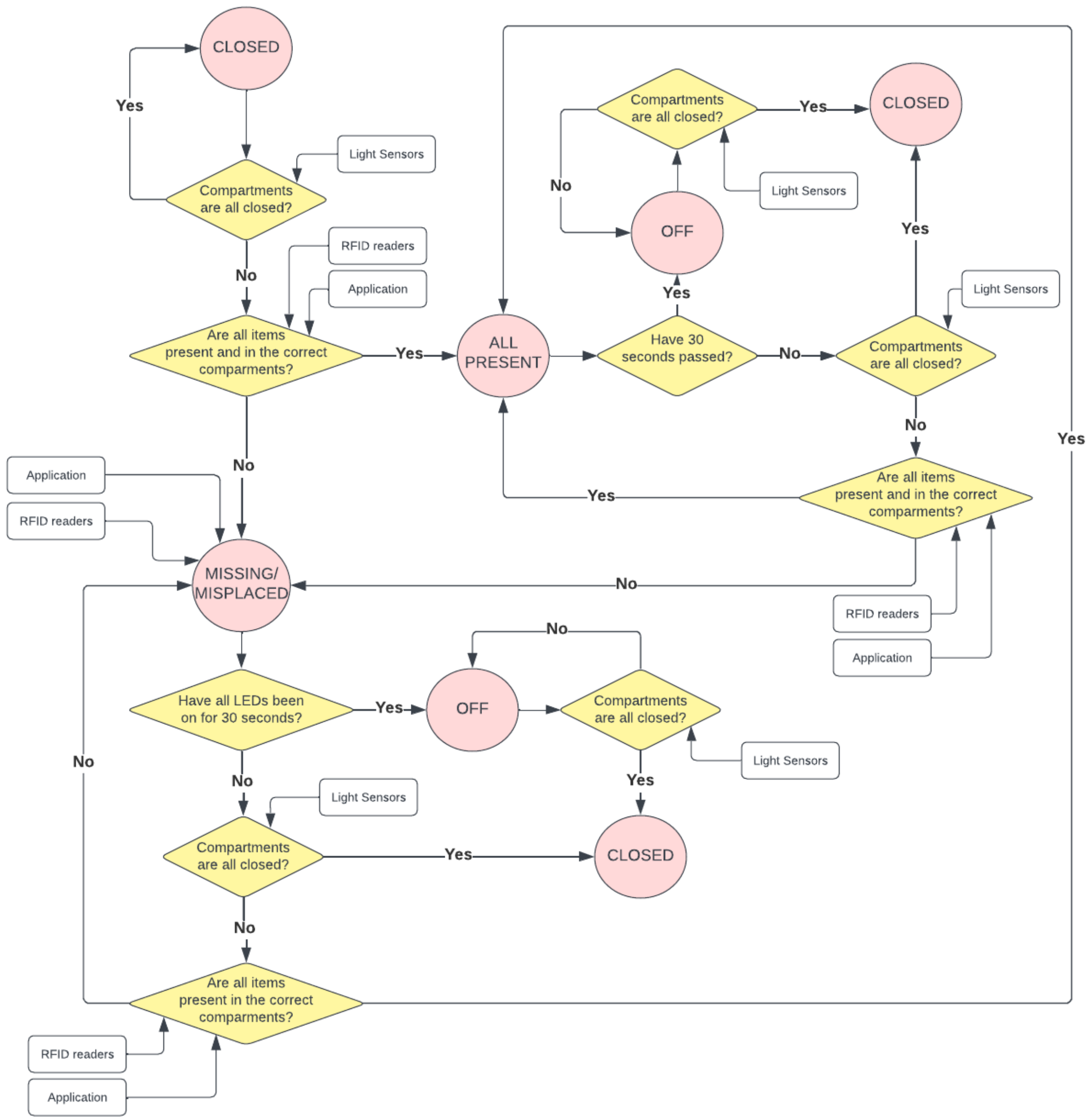

Figure 5: Real-time tracking flow chart

Tolerance Analysis

One possible risk with our design that would prevent the system from being able to successfully track the items placed in the backpack is interference between the RFID ID-12LA readers. Each ID-12LA reader will be attached to one of the two walls of the compartment they will be designated to. It is likely that two of the readers will be attached to adjacent walls, resulting in a minimum distance of approximately 2 cm between them. To ensure that interference does not occur, the penetration depth of the RFID signal must be significantly less than this value. The penetration depth of the RFID signal in a given material can be calculated using the following:

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

Here, f is the frequency of the RFID signal, which in this case will be 125 kHz. μ and σ are the permeability and conductivity of the material, respectively. Backpacks are typically made using nylon which has a permeability approximately equal to the permeability of free space $\mu_0 = 4\pi$E-7 H/m for signals at 125 kHz, and it has a conductivity of 3.8 E-3 S/cm [5]. The resulting penetration depth is as follows:

$$\delta = \frac{1}{\sqrt{\pi \times (125 \times 10^3\ Hz) \times \left(4\pi \times 10^{-7}\ \frac{H}{m}\right) \times \left(0.38\ \frac{S}{m}\right)}} = 2.309\ m$$

While this may indicate that interference is all but guaranteed, the addition of a few layers of aluminum in the unwanted direction can mitigate this effect. The permeability of aluminum is approximately equal to that of free space, but its conductivity is 3.538E+07 S/m [6]. The penetration depth of a 125 kHz RFID signal in aluminum is therefore as follows:

$$\delta = \frac{1}{\sqrt{\pi \times (125 \times 10^3\ Hz) \times \left(4\pi\ \times 10^{-7}\ \frac{H}{m}\right) \times \left(3.538 \times 10^7\ \frac{S}{m}\right)}} = 0.239\ mm$$

Such a small penetration depth means that a 125 kHz RFID signal can be easily blocked by using a few sheets of aluminum, preventing any interference.

Cost Analysis

Table 6: List of Components and Prices

Description	Part #	Manufacturer	Quantity	Extended Price	Link
RFID Reader ID-12LA (125 kHz)	SEN-11827	SparkFun Electronics	3	97.50	Link
SparkFun RFID Qwiic Reader	SEN-15191	SparkFun Electronics	3	64.50	Link
SparkFun Qwiic Mux Breakout	BOB-16784	SparkFun Electronics	1	12.95	Link
ISO RFID Tag (125 kHz)	RFID 125-ISO	Olimex LTD	15	8.25	Link
5 MM Green LED	SSI-LXH600GD-150	Lumex Opto/Components Inc.	1	1.32	Link
5 MM RED LED	SSI-LXH600ID-150	Lumex Opto/Components Inc.	3	3.75	Link
ESP32-S3 microcontroller	ESP32-S3-WROOM-1-N8	Espressif Systems	1	3.20	Link
LM317 Voltage Regulator	LM317DCYR	Texas Instruments	1	0.77	Link
AA Battery	815 BULKJ2	Energizer Battery Company	6	1.80	Link
Ambient Light Sensor	5591	Adafruit Industries LLC	3	13.50	Link
Total				207.54	

The total cost of the items in Table 6 is $207.54. The average hourly wage of an electrical engineer graduate from the University of Illinois Urbana-Champaign is approximately $50 [1]. The project will likely take 8 weeks to complete, and each member will spend an average of 20 hours per week working on it. The labor cost per person can be therefore calculated to be 2.5 x $50/hr x 160 hr = $20000. There are two members on our team, resulting in the total labor cost of the team being around $40000. Therefore, the total cost of the project is $40209.74.

Schedule

Table 7: Project Schedule/Timeline

Week	Task	Person
2/19 - 2/25	Finish design document	Everyone
	Make modifications to proposal and resubmit	Everyone
	Order parts	Abdullah
2/26 - 3/3	Finish first PCB design	Everyone
	Complete Design Review	Everyone
	Protype Microcontroller	Everyone
	Provide Machine Shop with necessary parts	Abdullah
	Protype Power Subsystem	Raef
3/4 - 3/10	Pass audit and order PCB	Everyone
	Protype RFID readers	Abdullah
	Start programming RFID Qwiic readers	
	Get Machine Shop updates	
	Start programming microcontroller	Raef
3/11 - 3/17	Assemble PCB and start testing	Everyone
	Make modifications to PCB design	
	Program RFID Qwiic Readers	Abdullah
	Test RFID readers	
	Order new parts if necessary	
	Finish programming microcontroller	Raef
3/18 - 3/24	Order second PCB	Everyone
	Start code for mobile application	Abdullah
	Get Machine Shop updates	
	Program and test light sensors	Raef
3/25 - 3/31	Assemble second PCB and test	Everyone
	Make final changes to PCB design	
	Continue working on mobile application	Abdullah
	Get Machine Shop Updates	
	Test indication subsystem	Raef
4/1 - 4/7	Make final PCB order	Everyone
	Finish mobile application design and code	Abdullah
	Test mobile application	Everyone
4/8 - 4/14	Assembly of final PCB	Everyone
	Assembly of entire system	
4/15 - 4/21	Debugging and final fixes	Everyone
4/22 - 4/28	Final demo	Everyone
4/29 - 5/1	Final Presentation and Final Paper	Everyone

Ethics and Safety

In designing and implementing our project, it is crucial that we adhere to the proper safety and ethical practices. To that end, the IEEE Code of Ethics adopted in June 2020 provides us with important guidelines to be followed. Several of the guidelines mentioned in this code are applicable to our project, addressing aspects of safety and ethics.

1. **Ensuring the safety of the users of this project [3]**

   It is likely that most of the users of this project will not be familiar with the technology implemented. The power subsystem in particular may cause harm to those who unknowingly tamper with it. Therefore, it is of the utmost importance that this subsystem, as well as any other subsystem, be sealed from users unless exposure is necessary. We plan on having both the microcontroller and power subsystems protected and not easily accessible to users. The connections between the subsystems must also be sealed off to prevent possible injuries from torn wires.

2. **Safeguarding the privacy of the users of this project [3]**

   One of the major components of this project is the mobile application, which would allow users to control which items they want to track. The application will therefore contain important information about the user, which can possibly be used against them maliciously. It is essential that this information is kept to the user and is not stored externally.

3. **Acknowledging faults and striving to receive feedback [3]**

   There are many nuances that we may have not yet considered in our initial design. We are approaching the implementation of the project with an open mind, aware that some modifications will be inevitable. We are also looking to take advantage of the guidance provided by the Teaching Assistants, Professors, and the Machine Shop to ensure that our project is successful.

4. **Treating teammates with respect and ensuring they uphold the ethical code [3]**

We are in daily contact with one another to ensure that we are both aware of our responsibilities to maintain the necessary progress on our project and meet deadlines. Through this constant contact, we have offered and received feedback from one another, and in the process, have come to understand the value each individual contributes to making the project successful. The communication we have established has allowed us to be fully conscious of each individual’s work to ensure that it is consistent with the ethical code.

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