ECE445 Project Proposal

Textbook Detection System with Radio-Frequency Identification

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1 Introduction

1.1 Objective

College Students are required to bring textbooks with them to attend classes. Sometimes students may forget to bring their books or lecture notes with them, especially for students with overload schedule. Failing to bring all the required books may affect students' studying efficiency. Most students use their memory as a traditional way to prepare for schedule.

Our goal is to track a list of textbooks to make sure that all the books needed for the student are in the backpack according to his/her daily schedule. In order to make a user friendly interface, we will develop a mobile application with our monitor system so that all the information related to the book will be transmitted remotely from the device to the student's phone. The basic technique we will use is RFID(radio-frequency identification) and each book will be equipped with a unique identification. We will use a microcontroller and a separate power circuit interact with our identification reader module and bluetooth module.

1.2 Background

Most applications related to a book reminder in the market are non-physical mobile applications. These apps are similar to a calendar and they lack physical devices to establish the connection between a the schedule and hardcopy textbooks. On the other hand, there are quite a lot applications about radio-frequency identification. However, most applications use RFID as anti-theft device such as credit card and ATM card[1]. Our design will combine the hardware RFID reader with an mobile application with bluetooth connection.

1.3 High-Level Requirements

- A common problem that may occur is the "Tag Collision", where two signals from different tags confuses the reader. Our system should be able to work with multiple textbooks without the influence of "Tag Collision"
- The power supply of our system should be able to provide enough power on a daily basis, such as 8 to 10 hours.

- We need to implement some protection circuit for the battery
- The RFID antenna should be large enough so tags can be detected easily

2 Design

2.1 Block Diagram

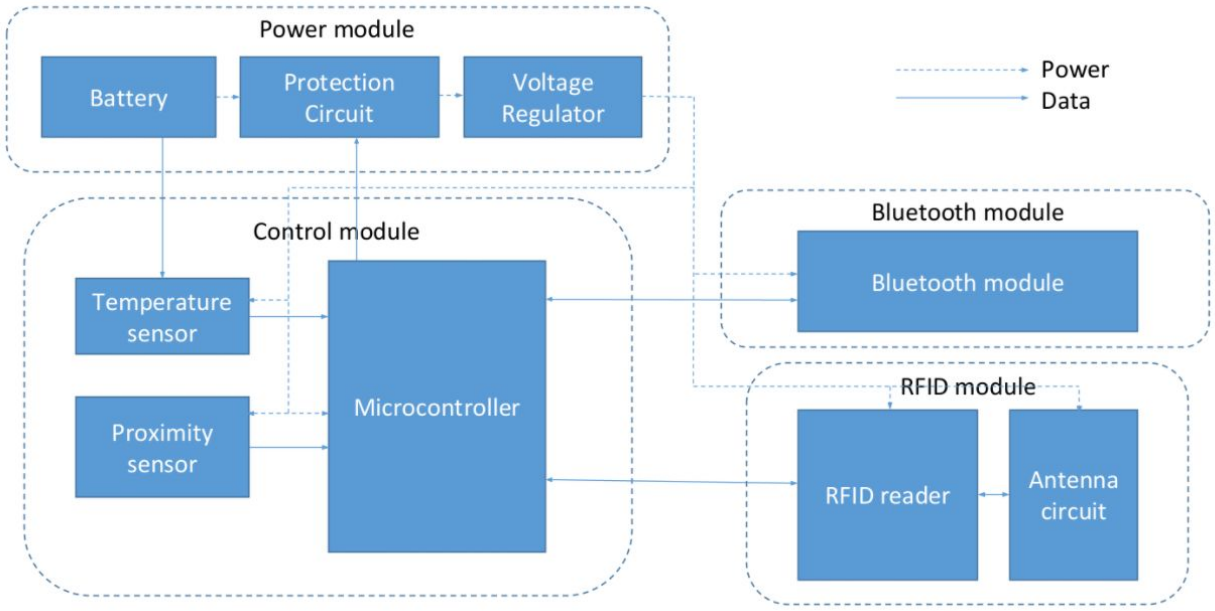

Figure 1. Block Diagram

Our system requires three sub-sections to operate: the power module, a control module, a bluetooth module and a RFID module. The dash line represents how power is delivered into different sections and the solid line represents how data flows between modules. The power module contains the battery, a protection circuit and a voltage regulator. The protection circuit will shut down power when battery voltage drops below 3.3V or above 4.2V. There is also a input from microcontroller that will shut down power when the battery is too hot. The voltage regulator is a low dropout regulator that will regulate battery voltage to 3.3V. The control modules consists of an ATmega328 microcontroller and two sensors to monitor the status of our system. The temperature sensor will be placed on battery to monitor battery temperature. If the

battery temperature is above 60 C°, microcontroller will alert user and if the temperature is above 70 C°, microcontroller will turn off power. There will be a proximity sensor near RFID antenna. If there is nothing in front of the antenna for a period of time, the microcontroller will turn off the RFID reader. In the RFID module, we will design an antenna circuit to improve the overall performance of our RFID reader. The reader will pass the information of the tag to the controller and it will then be transmitted wirelessly to a user device such as an android phone through our bluetooth module. We choose the bluefruit low energy bluetooth module, which has AT command interface and will be able to transfer data at 9600 baud[2].

2.2 Physical Design

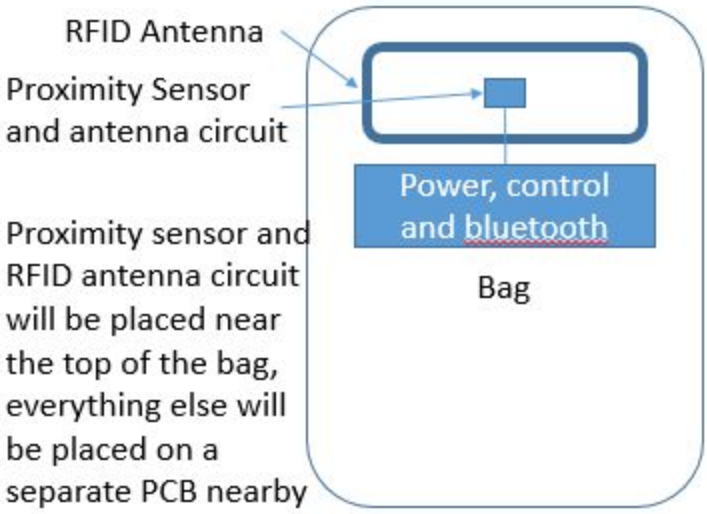

Figure 2. Physical Design

We plan on placing the RFID antenna and proximity sensor together near the top of the bag, everything else will be on a single PCB near the antenna. This will ensure that the tags will always pass the detection field but not staying in the field. The RFID antenna will be at least 15 cm wide and 3 cm high to achieve a relatively large detection area. The proximity sensor will be placed in the center of the antenna to detect movement. If there is no movement for a period of time, we will turn off RFID reader to save power.

3 Functional Overview

3.1 Power Module

3.1.1 Battery

For this project, since we need to ensure enough battery life for a day, we choose to use lithium ion battery. The battery capacity should be around 2000mAh, so it will be large enough for our application. For safety charging, we will use the charger designed for the battery and keep the charging current relatively low. In addition, we will add a 1A fuse to ensure output current stays below 1A.

3.1.2 Protection Circuit

There are a lot of potential safety problem with lithium ion battery, the most important one is the possibility of thermal runaway [4]. To prevent thermal runaway, we plan to implement a circuit that will shut down power when the battery voltage is below 3.3V or above 4.2V. Also, in case there is a thermal runaway on any of the cells, there will be a 1 pin interface with the microcontroller so it can shut down power when battery temperature is above 70 C°.

3.1.3 Voltage Regulator

Since the output voltage of lithium ion battery can range from 3V to 4.2V, we need a low dropout regulator to regulate battery voltage to 3.3V.

3.2 Control Module

3.2.1 ATmega328 Microcontroller

We choose an ATmega328 chip as our control unit. ATmega328 is a simple, low-powered, low-cost micro-controller[5]. We will use Arduino Uno as development platform for the application. The control unit should be able to ensure the correct data flow among different modules. Data from other modules includes identification sequence from RFID reader, communication with bluetooth module and data from proximity and thermal sensors.

3.2.2 Temperature Sensor

The temperature sensor is used to measure the temperature of the battery. We plan on using DS18B20 3 pin temperature sensor. The sensor will be placed on the battery and will have a 1 pin serial interface with the microcontroller.

3.2.3 Proximity Sensor

The proximity sensor is used to determine if there is anything moving in front of the RFID antenna. If there is no motion for a certain period of time, microcontroller will turn RFID reader off. The proximity sensor will only use 1 digital pin to communicate with the microcontroller.

3.3 Bluetooth Module

3.3.1 Adafruit Bluetooth LE UART

Since we want to have an user interface application, a bluetooth module will be able to transmit data wirelessly to a mobile device. The bluetooth board can be controlled using AT command set to query data or configure device address. The user can also manually update the firmware for new features.[2]. The bluetooth module will use a UART interface to communicate with the microcontroller.

3.4 RFID Module

3.4.1 RFID Reader

We plan on using PN532 chip as RFID reader [6]. It can be used as a 13.56MHz RFID reader chip. The reader will be used to interface with the antenna to communicate with the RFID tag and then pass the information to the microcontroller. The chip will use a SPI interface to communicate with the microcontroller and 5 pin interface with the antenna circuit. There will also be an additional pin connection to the microcontroller to power down the chip when needed.

3.4.2 RFID Antenna

We are going to design our own antenna for this project. We want a relatively big detection area so that tags will be detected easily. We want the antenna to be about 15 cm wide and 3 cm high. It will be placed near the top of the bag so the tags will always pass through the detection area. We will also design and tune the circuit so that the antenna can have a long detection distance. The antenna circuit will interface with RFID reader with 5 pins.

4 Block-Level Requirement

Block	Requirement
Battery	• Capacity should be around 2000mAh • Ensure current less than 1A
Protection Circuit	• Turn off power when battery voltage is below 3.3V or above 4.2V • Turn off power when microcontroller send a signal
Voltage Regulator	• Regulate voltage to 3.3V
Temperature Sensor	• Measure temperature from 0 C° to at least 80 C°
Microcontroller	• Two-direction data transmission between the Bluetooth module and RFID reader(data received from the reader and sent through the bluetooth) • Data transmission between sensors • Power down RFID module when not used for a period of time • Alert user when battery temperature is above 60 C° • Turn off power when battery temperature is above 70 C°
Proximity Sensor	• Detect movement of hand or book about 5 cm away
RFID Reader	• Two-direction communication between reader and microcontroller • Power down when needed
RFID Antenna	• About 15 cm wide and 3 cm high • Range should be at least 5 cm
Bluetooth Module	• Stable connection between the phone and the module to ensure data transmission

5 Risk Analysis

The microcontroller is the greatest risk to the successful completion of the project, because it controls all data transmission in order to operate the circuit correctly. Based on the limited number of pins on the microcontroller, we might adjust our design for each module accordingly. The two-direction communication can be tricky and we need to program the controller wisely.

On the other hand, the antenna and reader interface can also be a risk because it is the input of our design. The second risk is to make sure the antennas can differentiate all the IDs and generate the correct signal to the following modules. We can modify the antenna based on how the circuit performs. Finally, The achieve the wireless connection function of our design, we need to ensure the bluetooth module is correctly set up. This function is crucial because it involve the user interface and it provide information directly to the user the current status of our application.

6 Safety & Ethics

According to IEEE Ethics, #1: “to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.”[7], we, as future electrical engineers, are responsible for designing a safe and reliable application.

Since we will use Lithium-ion battery for this project, it is very important to keep the current and voltage within the limitation to prevent explosion[8]. In order to prevent potential hazards, we have a voltage regulator module and a protection circuit. The goal is the ensure that the overall circuit can operate with low current(below 1 A) and low voltage(about 3.3 V). On the other hand, users should not expose the power source to water or direct sunshine, which may cause safety issues on our battery. In addition, even if our final product may be able to automatically turn off the power by itself based on different conditions, it is also the user's’ responsibilities to check and turn off the power if this application is not in use.

Since the idea behind our project is to help students with their study, our application is also responsible for sending information for education purpose. According to IEEE Code of Ethics, #5:”to improve the understanding of technology; its appropriate application, and potential consequences; “[7]. We hope our project can provide students with basic knowledge in engineering design. It is also important that our design can influence other engineers in our

procession. We decided to make our code open source to “to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.”[7]

However, with the help of internet, it is easy to search for our project online. We hope people who are passionate about rebuilding or improving our project can respect our property and contribution, based on IEEE Code of Ethics #7:”to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others”[7]. If other project teams are going to use the design or code from our project, the techniques used in this application should be correctly cited

Reference

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