Desk Reservation System

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Design Document for ECE 445, Senior Design, Fall 2019

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3 October 2019

Project No. 20

Contents

1. Introduction

1.1 Objective

We live in a world with constant distractions. Sometimes we need personal space and time to think. What if there was a solution to reserve a seat in a library to facilitate this quiet time? This is necessary because not only is quiet time fundamentally important in today's society but also seats at our favorite library, Grainger, are hard to come by because of the first-come first-serve system.

The goal of this product is to accomplish the following type of workflow: The student reserves a particular seat in Grainger Library through their phone. The LCD on the desk then says the seat is reserved. The student arrives at the seat in a timeframe of 15 min and taps their RFID button on the compact device; this signifies check-in. The student uses the desk upto an hour; there is a proximity sensor verifying that the desk is being occupied. When it is time for the student to leave the desk, the student taps the RFID button on the compact device to signify check-out. The proximity sensor will confirm if the student left the desk. We would build 2-3 desk modules for our project. This will allow us to simulate a desk reservation system.

This reservation system has four unique components. First, it accepts desk reservations from a mobile phone. Second, it also allows you to reserve an open desk on the fly with your unique RFID button. Third, we enforce the time spent at a desk; there is a strict check-in, check-out process and a proximity sensor to verify if someone is occupying the desk. Fourth, if encroachment occurs, we will have a system to show the fees incurred for people overstaying their time.

1.2 Background

Our desk reservation system will be similar to the reservation systems that already exist in other industries. An example is the food industry. Currently, restaurants allow their customers to reserve tables in advance through their respective mobile application[1]. This helped restaurants eliminate the problem of overcrowding and it reduced wait times. Another use of reservation systems is in the airline industry. An example is the Computer Reservation System, which kept track of seats on airplanes and returned the availability of them[2].

There is also another system that parking garages use that tells their customers how many available car spots are present. They do this by placing a physical device over each parking stop to monitor how many stops are available. We plan on adapting this existing model to a desk reservation system for Grainger Library. This will streamline desk usage for students working at Grainger Library, allowing students to spend more time studying than searching for a desk. We plan to implement this system because all of us have experienced the problem no available seats in Grainger Library.

1.3 High Level Requirements

1. The desk module knows the status of each desk and if a reservation is made.

2. The desk module will verify if a user is present and alerts them if they exceed their reservation time.
3. We intend to build three desk modules; however, the system is modular and can support multiple desk modules.

2. Design

2.1 Block Diagram

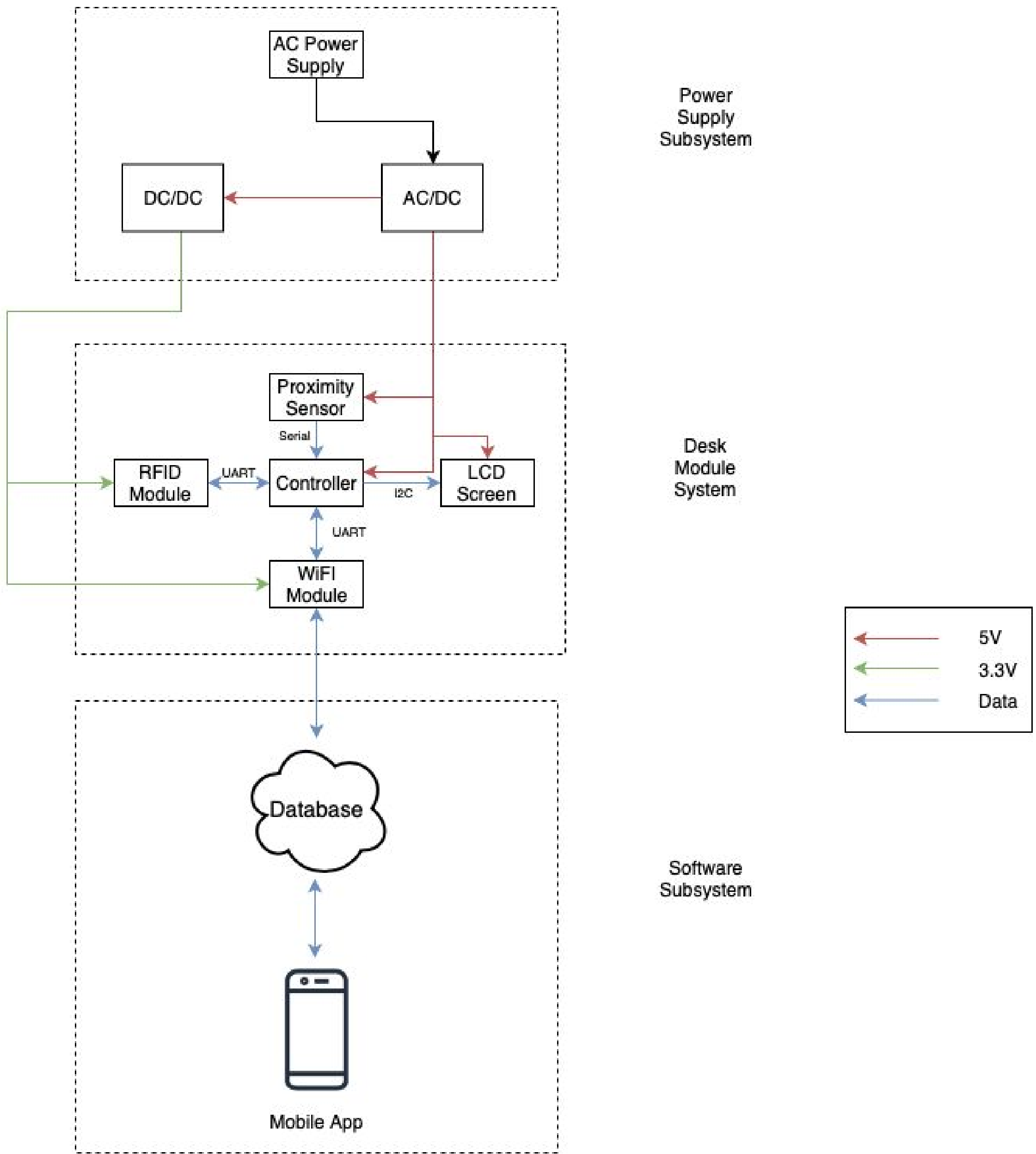

Figure 1: Block Diagram

2.2 Block Design

2.2.1 Power

This system requires two separate voltage conversions. The first voltage conversion is from the AC wall voltage to 5 V DC for the microcontroller and some other electronics. The second conversion is to a lower 3.3 V for the WiFi chip because it requires a lower voltage.

AC-DC Converter

This will change the voltage from the wall supply to 5V DC, which is needed for powering the electronics of the desk module.

Requirement	Verification
The AC-DC Converter should convert 120V(+/- 5%) AC to 5V(+/- 5%) DC voltage while under a resistive load (100Ω).	1. Measure output of 5V converter with a 100 Ω load connected with an oscilloscope to verify 5V(+/- 5%) DC voltage

DC-DC Converter

This will convert the 5V DC voltage to 3.3V DC because some of the components will require 3.3V DC.

Requirement	Verification
The DC-DC Converter can convert 5V DC to 3.3V (+/- 5%) with a 100 Ω load attached.	1. Use a voltage source to create a 5V DC input 2. Connect a 100 Ω load to it and measure output voltage with an oscilloscope and verify it is 3.3V (+/- 5%) DC

2.2.2 Desk Module

This subsystem contains the sensors and controllers for the desk module. The proximity sensor is an ultrasonic sensor and will be able to sense if the desk is occupied by a user. The RFID module will read an RFID button and send the ID to the microcontroller. The LCD display takes the status information and updates the display with the desks status. The WiFi Module interfaces between the database and the microcontroller to confirm the status of a reservation to an account.

Microcontroller

The brain of our system is a microcontroller, which will handle the communication between the WiFi module, RFID module, LCD display, and proximity sensor. The microcontroller will have analog and digital inputs and outputs. In addition, the microcontroller has to support serial communication protocols (UART, I2C, SPI)[3]. The advantage of using this microcontroller it is compatible with all Arduino libraries. The ATMEGA328-PU is a synchronic device which means it must operate on a clock cycle. We will use an oscillator to function as the clock.

Requirement	Verification
This microcontroller will need to send and receive data coming from other modules through UART with 1% failure rate.	1. Flash processor with Commands 2. Verify bits are flowing to the WiFi chip through the serial monitor 3. Have the WiFi chip send those bits back 4. Compare the values to see if they match
The resonator will oscillate at 16MHz (+/- 5%)	1. Turn on the multimeter and select the frequency function.

	2. Measure across the resonator and verify that the frequency is around 16MHz (+/- 5%)

RFID

We will use an RFID reader that will be paired with a 125kHz RFID button. The range of the RFID reader is 120 mm without interference. When scanned, the RFID module will output a serial string containing the unique ID of the button. The serial protocol between the controller and the RFID is UART. This is accomplished by connecting Pin 9 of RFID to a Digital Pin on the ATMEGA328-PU.

Requirement	Verification
The RFID reader can scan the RFID button within the range of 120 mm.	1. Scan the RFID reader with RFID button (Verify the button is within 120 mm of the reader) 2. Read the output of the RFID reader and display its value to the monitor 3. Repeat process to verify that the value remains the same when using the same button

Proximity Sensor

We will use the Ultrasonic Distance Sensor (HC-SR04) as a proximity sensor. This sensor will help us determine if someone has overstayed their time slot. The proximity sensor will communicate via serial communication. We chose this specific proximity sensor because we have familiarity with it from ECE 110, and its low cost will keep the desk module more affordable for production.

Requirement	Verification
Accurately detect whether an object is obstructing its view within the range of 0 to 2 meters (+/- 10 cm).	1. Place a 0.5^2 m box in front of the ultrasonic sensor to represent a person at the desk 2. Check to see if the ultrasonic sensor sends back a plausible measure 3. Use a measurement device (tape measure) to verify that the ultrasonic sensor's measurement is correct (+/- 10cm) 4. Change the orientation of the box and location and repeat

Display

The LCD screen will display the status of the reservation. The reservation will be represented by the color of the display and/or the message displayed on the screen. The LCD will be updated using the I2C protocol.

Requirement	Verification
Accurately display the reservation status on the LCD screen using I2C protocol to update the LCD.	1. Use the I2C protocol to write data to display 2. Change background color

WiFi

The WiFi chip interfaces with the microcontroller and the database. It eventually reads data from the RFID reader, proximity sensor and updates the database with relevant information. It also sends status updates regarding reservations to the LCD display. We picked the ESP866-01 because it has libraries[5] that interface well with databases. The ESP8266-01 also operates on 802.11 b/g/n which is the industry standard for wireless networks.

Requirement	Verification
The WiFi module can communicate with the backend with a 1% failure rate.	1. Blink(s) the LED on the WiFi chip then send the number of blinks to the database 2. Verify that the number of blinks on the WiFi chip is the number inputted into the database
The WiFi module can communicate with the microcontroller after 1 second of bootup time.	1. Wait 5 seconds after bootup 2. Pass commands from the database through the WiFi Module to the LCD 3. Verify it changes the text/color on the LCD
The WiFi module can receive data from the sensors on the desk module.	1. Print sensor data on the serial monitor then send the data to the database through the WiFi Module. 2. Verify that the data on the serial monitor is the same as the data inputted to the database.

2.2.3 Software

The software subsystem has two parts: database and mobile application. The database stores the data regarding reservations, desks and user profiles. It also sends data to and from the desk modules and the mobile application. The application is the user interface for the desk module. It allows our customers to select which desks they would like to reserve and displays their balance for late checkouts.

Requirement	Verification
Users can view open desks.	1. Verify opens desks presented in the mobile application are the same as the open desks in the database
Users can create reservations.	1. Query database to confirm new reservation was created
Scan RFID tag and see if it is in database.	1. Scan correct RFID and verify correct RFID is in database
Database verifies that user has checked into the correct reservation.	1. LCD displays message indicating that user is checked in
System alerts the user when they check into the wrong reservation.	1. Scan incorrect RFID tag and verify that LCD shows error message
System alerts the user when they overstay their reservation.	1. LCD displays message indicating that user is overstaying time

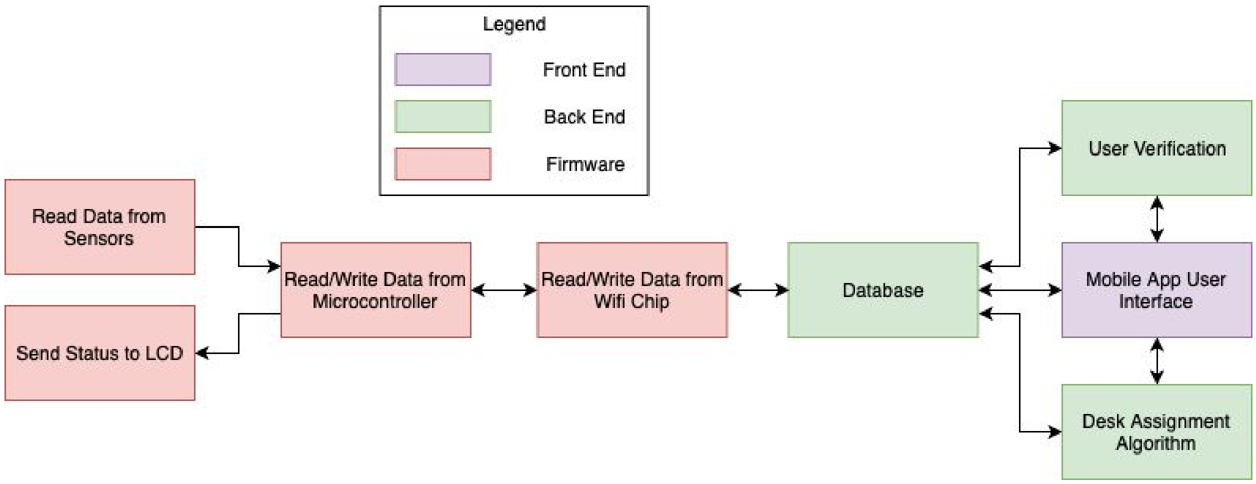

Figure 2: Software Flowchart

The microcontroller reads data from the RFID and Ultrasonic Sensor and sends it to the WiFi Chip. The data from the WiFi Chip is stored in a database. The mobile application will be the user interface of this project. It will communicate with the backend to allow users to reserve desks. Any new updates of information in this system will flow to the LCD display in the desk module.

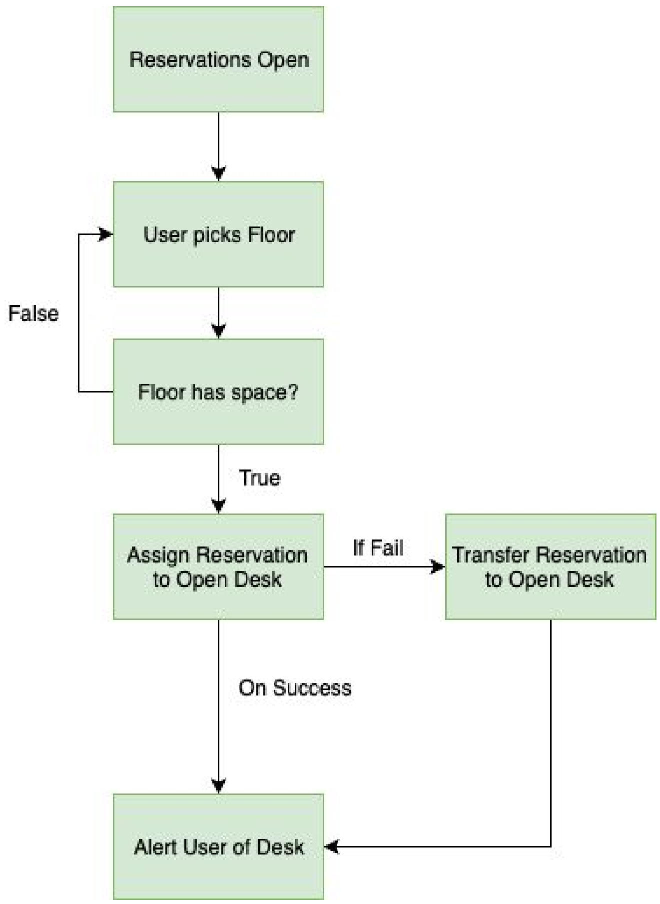

Figure 3: Desk Assignment Algorithm

Our users select which floor they would like to sit at Grainger Library. The user then selects what hour block they would like to reserve the desk. If there are errors in handling the reservation, we will assign our users an open desk. Users will be alerted of their reservation details up to one hour ahead of their reservation.

2.3 Physical Design

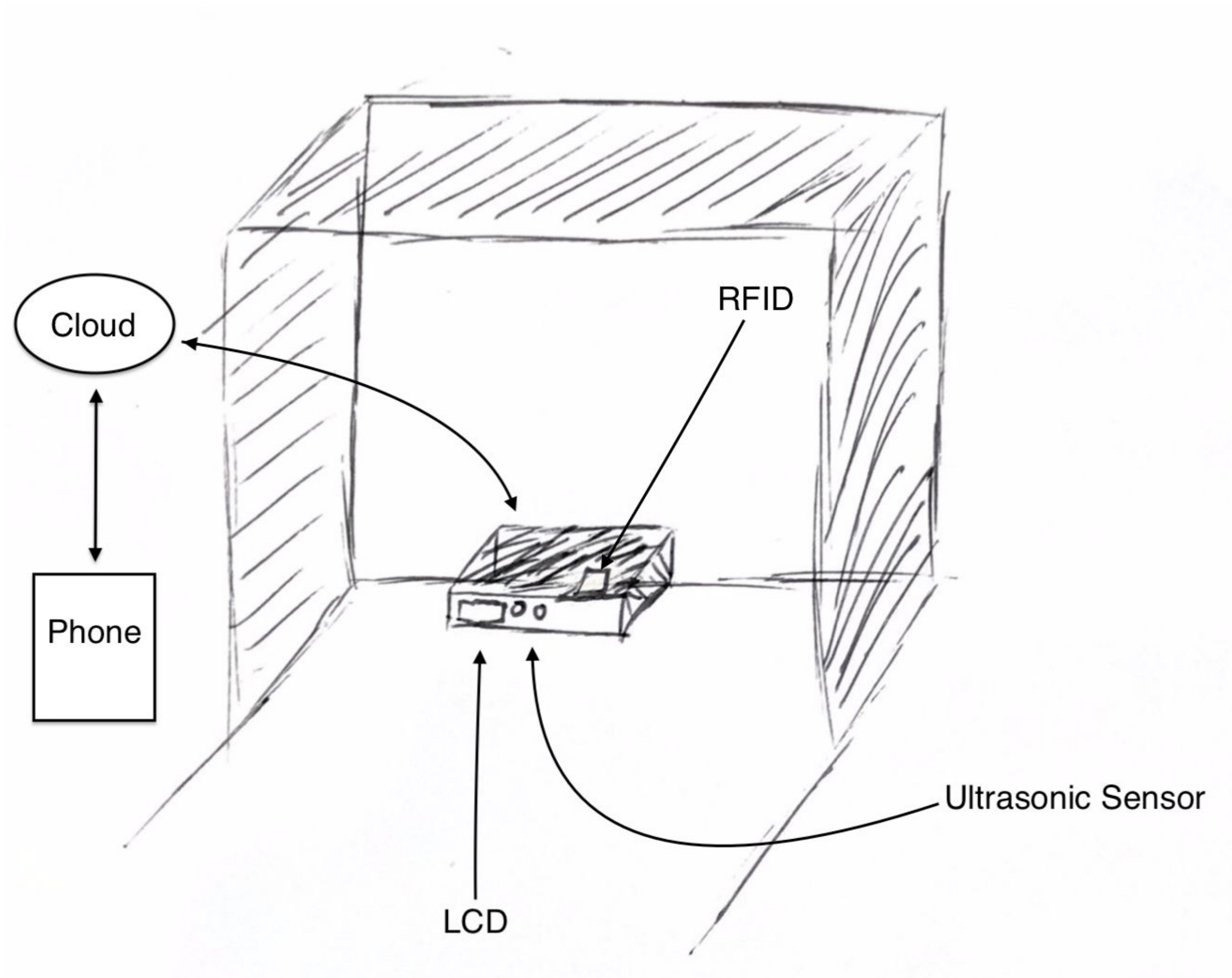

Figure 4: Physical Design

2.4 Schematic

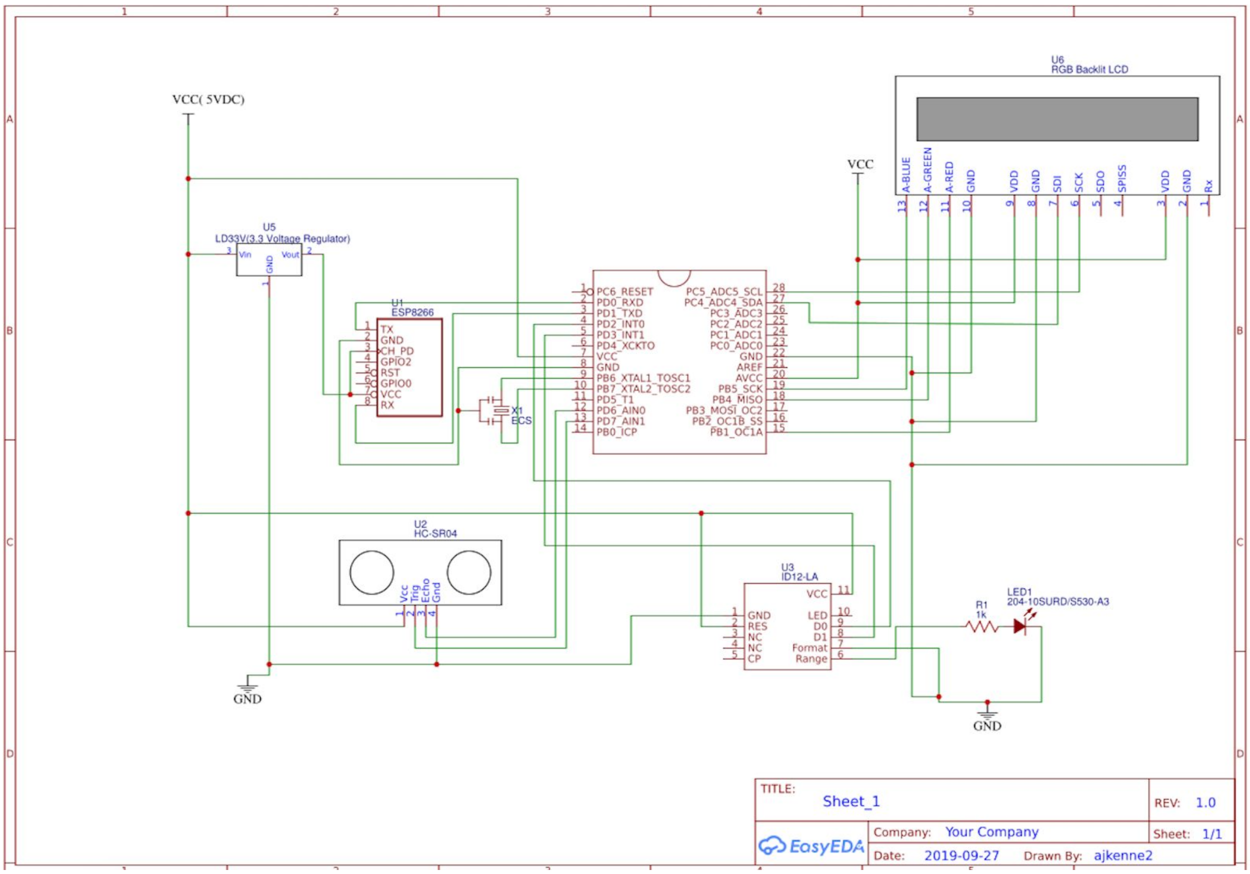

Figure 5: Circuit Schematic

2.5 Tolerance Analysis

2.5.1 Tolerance Analysis

The success of the Desk Reservation System depends on the accuracy of the ultrasonic sensor. It is necessary for it to be able to sense up to two meters for this project. After the trigger signal is toggled, the sensor outputs a 40kHz signal and waits for an echo. The time it takes for the signal to return is measured. The distance is calculated with the formula (1) below

$$\text{Distance(m)} = (\text{Time for Echo(s)})*(340\ (\text{m/s}))/2 \qquad (1)$$

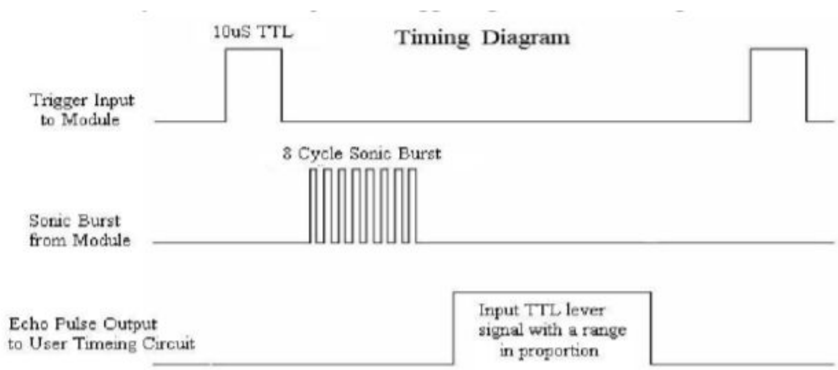

Figure 6: Timing Diagram [4]

The calculation is an average because the time is the forward and back travel of the echo to the sensor. The average does not include the difference in bouncing for a hard surface versus soft surface. We believe that there is no need for the accuracy of a few millimeters in the module which is what we would potentially lose due to not accounting for an object's absorbance factor, since an obstruction on a desk would be for a longer time and within a manageable distance. To ensure that we are getting proper readings, we will make the measurement cycle greater that 60ms.

2.5.2 Risk Analysis

The greatest risk for this project will be creating the desk module system. The module will be on a PCB holding the WiFi module, RFID module, proximity sensor, LCD screen, and microcontroller. The microcontroller will take the information from the sensors and transfer the data to the WiFi module and finally to the database. We will struggle with the PCB design because we have never made a PCB before. On the software side, communication between the microcontroller, WiFi module and the database will be challenging.

Each individual part in the desk module will have unique challenges because they will need to be individually configured and tested. The RFID module has to scan the RFID tag and the software has to link it to the right account with the reservation. The proximity sensor will need to be calibrated so that it can accurately detect the presence of a person working at the desk and not be impacted by nearby obstructions.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Our cost of labor was created by estimating our hourly rate to be $40/hr, working 12 hours a week, for 16 weeks, among three people. This results in a total cost of labor to be $57,600.00.

Table 1: Labor Cost

Name	**Hourly Rate**	**Hours (16 hours for 12 weeks)**	**Cost * 2.5**
Akeem Kennedy	$40.00	192 hours	$19,200.00
Mark Syrek	$40.00	192 hours	$19,200.00
Siddhant Jain	$40.00	192 hours	$19,200.00

3.1.2 Parts

Table 2: Parts List

Item	**Part Number**	**Manufacturer**	**Quantity**	**Price**	**Cost**
Wall Adapter Power Supply	TOL-12889	NLPOWER-CN	3	$5.95	$17.85
Voltage Regulator 3.3V	COM-00526 ROHS	STMicroelectronics	3	$1.95	$5.85
DC Barrel Power Jack/Connector (SMD)	PRT-12748 ROHS	Adam Technologies Inc.	3	$1.50	$4.50
WiFi Module - ESP8266	WRL-13678 ROHS	Ai-Thinker	3	$6.95	$20.85
16x2 Character	763-0216K3ZFS	NewHaven Display	3	$21.19	$63.57

LCD-RGB Backlight 5V	RGBFBWV				
Ultrasonic Distance Sensor HC-SR04	SEN-15569	Elec Freaks	3	$3.95	$11.85
RFID Button (125kHz)	SEN-09417	Sparkfun Electronics	3	$3.95	$11.85
RFID Reader ID-12LA (125kHz)	SEN-11827 ROHS	ID-innovations	3	$29.95	$89.85
Microcontroller	ATMEGA328-PU	Microchip Technologies Inc.	3	$1.90	$5.70
PCB	PCBWay	PCBWay	3	$0.00	$0.00
Assorted Capacitors and Resistors	Digikey	Digikey	3	$3.00	$9.00
Resonator	COM-09420 ROHS	ECS Inc. INternational	3	$0.95	$2.85

Total Cost for one module is $81.24
Total Cost for three modules is $243.72

3.2 Schedule

Table 3: Weekly Deadlines

Week	**Akeem**	**Mark**	**Siddhant**
09/29	Design Doc	Design Doc	Design Doc
10/06	Work On PCB	Acquire Parts/ test Power circuit	Serial Communication between Microcontroller and WiFi Chip
10/13	Work On PCB	Read Data from	Setup Database and

		RFID and Ultrasonic Sensors and Write Data to LCD Display	have write and read functionality between WiFi chip and database
10/20	Work with Siddhant on communication between WiFi Chip and Database	Acquire box for PCB to mount inside/	Develop the front end for the mobile app, finish sign-in process
10/27	Help Mark assemble PCB	Assemble Circuit onto PCB/Test Circuit	Develop the backend for the mobile app, allow for reservations to be made
11/03	Help Mark assemble PCB	Assemble Circuit onto PCB/Test circuit	Flashing the software on the PCB Test End to End Software
11/10	Fix PCB issues/make sure all components work Assembly of Box	Fix PCB issues/make sure all components work Assembly of Box	Focus on firmware/mobile app issues
11/17	Fix any remaining issues surrounding software	Prepare for demo	Fix any remaining issues
11/24 (Thanksgiving Break)	Prepare for final report	Final Report	Final Report
12/01	Presentation and Final Report	Presentation and Final Report	Presentation and Final Report

4. Safety and Ethics

4.1 Physical Safety

It is our obligation to uphold our standards of the IEEE Code of Ethics. We want to ensure that we follow Rule #1 and prioritize the “the safety, health, and welfare of the public, to strive to comply with ethical design [6]” for our project. Our system will be placed indoors so we do not have to account for weather. The desk module will be powered from the wall outlet and will be designed to prevent accidental electrocution. This enclosure will also be IP40 to protect against large objects from coming into contact with the electronics[7]. In addition, we will protect the desk module from abuse and prevent damage from drops.

4.2 Data Security

Respecting our customer’s privacy is the foundation of our product. We will follow the standards set in the ACM Code of Ethics. Customers are entrusting us with sensitive data. We plan to abide by Section 1.6 which states we “should only use personal information for legitimate ends and without violating the rights of individuals and group [8]”. Furthermore, this data is considered to be personally identifiable information. We will follow IEEE Code of Ethics[6] Rule #8 as our service will not discriminate on race, religion, and gender. Our database will be encrypted, and we trust that the database service will safeguard our customers’ data rigorously. After a certain period, we will also anonymize reservation data to follow the best industry practices. This follows ACM Code of Ethics Section 1.6: “prevent re-identification of anonymized data” [8].

We have highlighted the issues above that we think are fundamental to our product. We will also abide by the standards set by ACM, IEEE, and University of Illinois at Urbana-Champaign.

5. References

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