Intruder Detection System

ECE 445 Project Proposal - Fall 2018

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1 Introduction

1.1 Objective

Our objective is to create the standalone intruder detecting device. Its goal is to detect if any unwanted strangers are following the authorized personnel hence effectively blocking out the intruders from attempting to bypass the entrance security system that we see on campus. The team seeks to solve the issue in the lack of campus security by providing a direct method of enhancing it.

1.2 Background

The first measure of campus security within its buildings is the entrance, where the students are required to swipe their i-card before entering the building. This system, however, has proven to be faulty because strangers could bypass the security system by following the student without their consent. The rule of not allowing strangers in without confirming their identity or their respective access key has been loosely enforced and has failed to prevent crimes that happened on campus. Numerous theft incident that has and is occurring within the campus buildings[1] and even some of the more tragic incidents[2] that have occurred in the past stands as evidence for faults within the security system.

This device will activate once the input on the keypad is given from the authorized personnel on how many people are to go through the entrance. When input of number of people authorized to pass through is given this device will then detect the number people passing through the entrance and make sure that the count is respected. When the count is not respected it will raise alarm to the respective authorities notify them of any possible dangers within their building. This device is designed to minimize the authorized user’s interaction with strangers and enforce the rule mentioned above by adding it as a layer of required input before unlocking the entrance.

1.3 High-Level Requirements

1. Device must be able to detect people.
    a. People moving through specified region and their directions
    b. People moving in a cluster and be able to distinguish them individually.
2. Device must be able to raise alarm
    a. Notify the respective authorities by updating them with number of people entered and the number given in the input
    b. Notify the respective authorities by lighting the LED with specific colors signifying whether the count is respected or not.

2 Design

2.1 Block Diagram

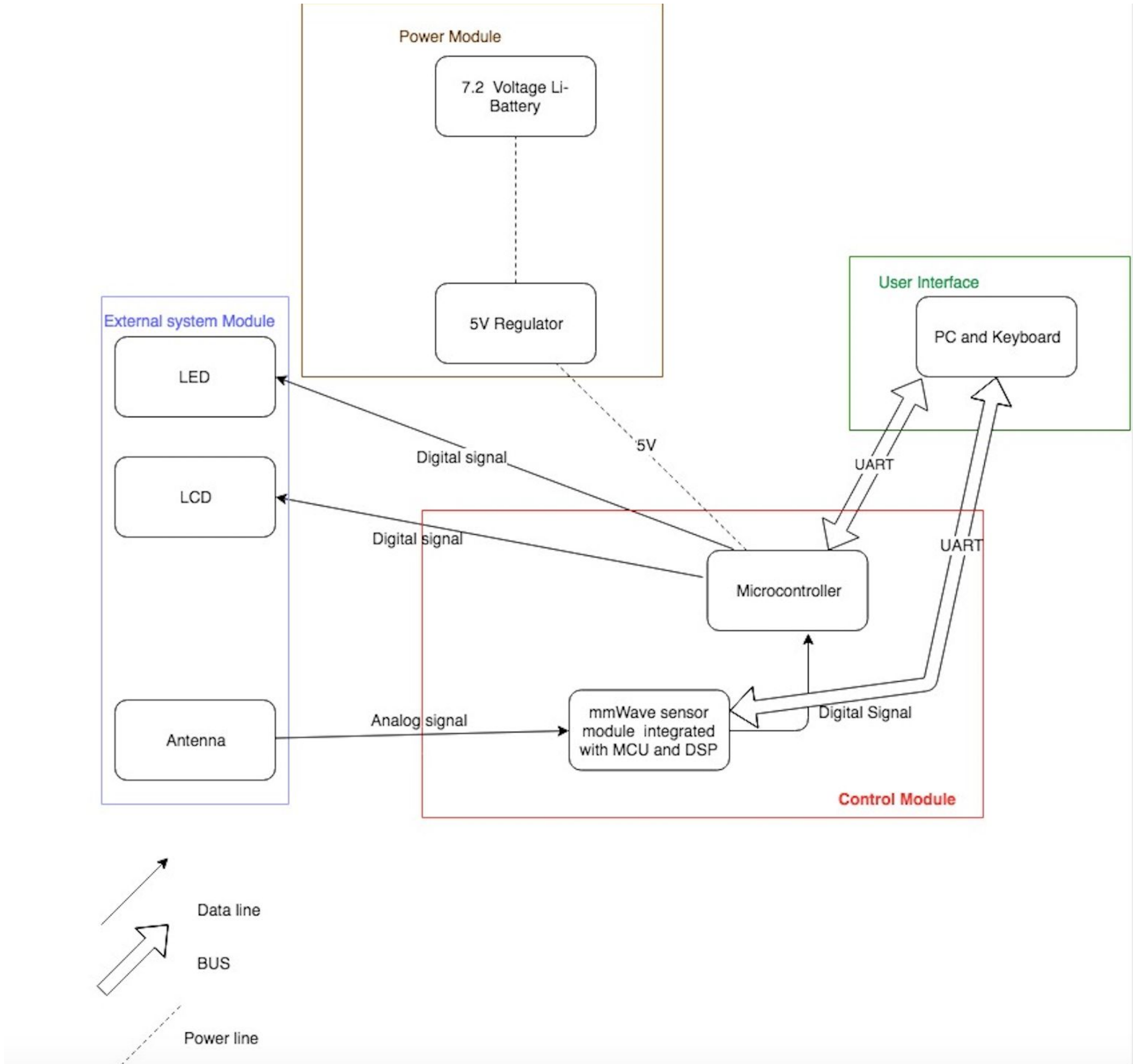

Figure 1: *Block Diagram For The Intruder Detecting Device*

The block diagram(Figure 1) shows the main components and how they link to each-other for our device. We use the Li-ion battery to power our PCB board, once our device is activated, the system will turn on, the mmWave sensor will send continuous frequency signal and will enable our software components to do signal processing coding to parse the data. Once the authorized personnel enters the number of people they want to bring in with them via keypad, it will send the generated data to the NAND gate to decide whether the number of people detected by the sensor matches the number they entered. If the number does not match it will light up the LED light accordingly to alert the respective personnel. The LCD chip will be used to tell how many people have been detected by the sensor. Lastly, we utilize the overvoltage and overcurrent protection circuit to protect our system.

2.2 Functional Overview

2.2.1 Power Module

Requirements	Verifications
Supply enough voltage (5V) to power the PCB board. Input voltage should be controlled.	Voltage output is to be measured via multimeter on the Li-ion batteries (~7.5V) as well on the system with the voltage regulator (output 5V).

We use 7.4V Li-on battery to power our PCB Board.However, since we only need 5V, we need use voltage regulator to control the voltage. Since mmwave sensor needs five different input voltage to make it work properly. we need four voltage regulators to control our input voltage: TPS54202H,LP87524B/J-Q1(PMIC), TPS7A8801RTJR, TPS7A8101QDRBRQ1. When 7.4V voltage comes into the PCB board, it will first, passing through TPS54202H, to get a 5V voltage. Then PMIC will divide this voltage to four small voltage as the inputs to mmwave sensor. Since we need 1.8V, 1.3V,1.2V and 3.3V voltage for mmwave sensor and PMIC can only provide 2.3V, 1.8V, 1.2V, 3.3V voltage, so we need another two regulator TPS7A8801RTJR and TPS7A8101QDRBRQ1.

Figure 2 is the schematic diagram for our power module. The first diagram includes battery, PMIC and TPS54202H regulator circuits. The other two are TPS7A8801RTJR and TPS7A8101QDRBRQ1 regulators.

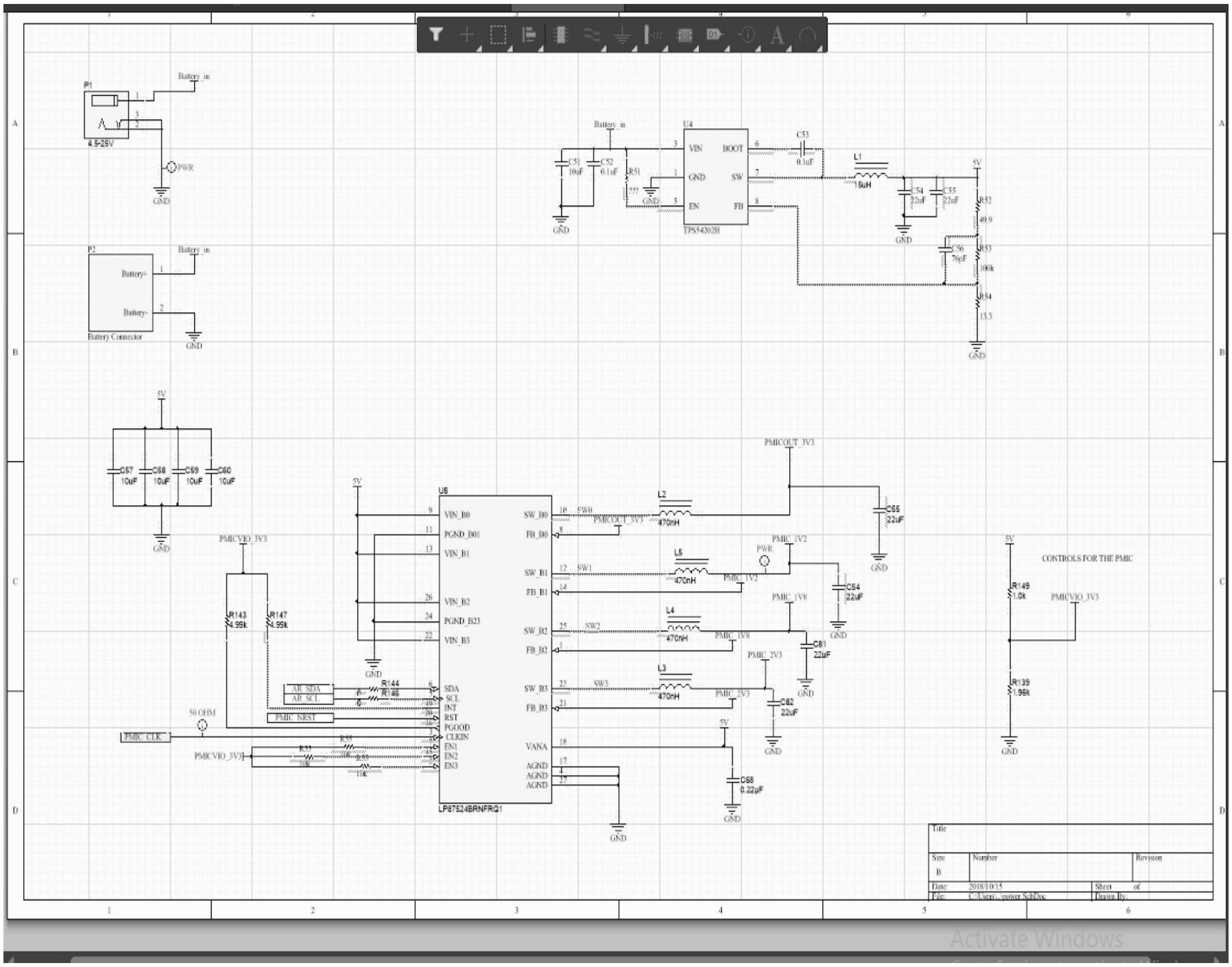

Figure 2: *Power module schematic*

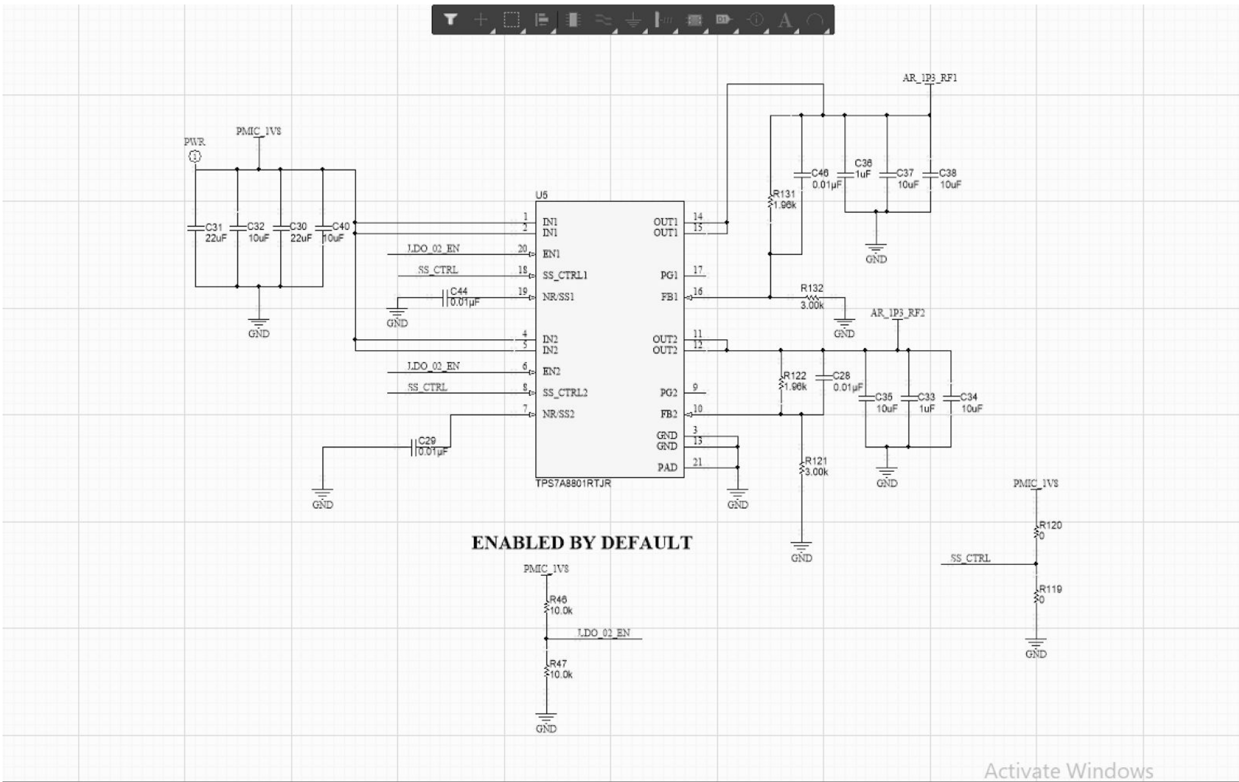

Figure 3: *LDO 1.3V schematic*

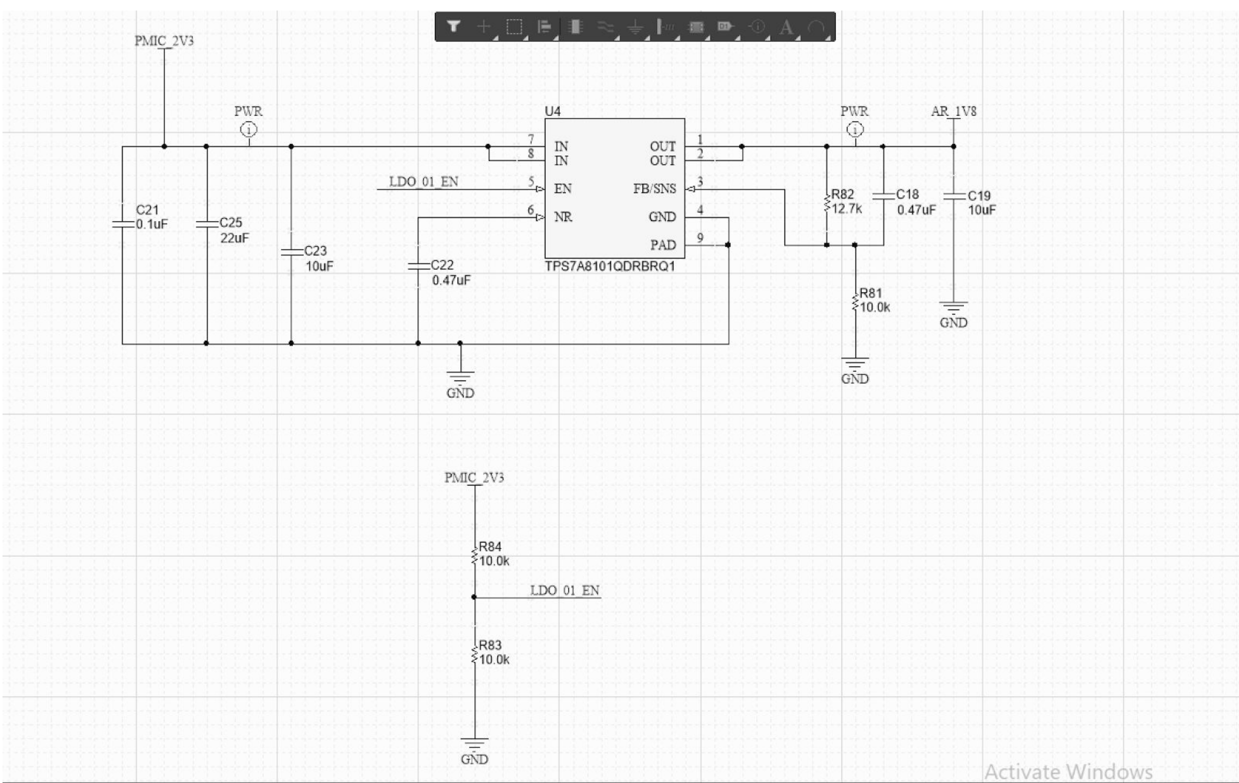

Figure 4: *LDO 1.4V schematic*

2.2.2 mmWave Sensor[3] Module （IW1642）

Figure 5: *IWR1642 mmWave chip picture*[6]

Type	Ball Number	Ball Name	Description
Power	L13		Connect to voltage regulator
Digital Ouput	J13	GPIO_1	Connect to MCU
Analog Input	M2		Connect to Receiver(Rx1)
Analog Output	B4		Connect to Transmitter(Tx1)
Analog Input	K2		Connect to Receiver(Rx2)
Analog Output	B6		Connect to Transmitter(Tx2)
Analog Input	H2		Connect to Receiver(Rx3)
Analog Input	F2		Connect to Receiver(Rx4)
Digital input	K3	GPIO_2	Connect to PC for coding
Ground	K7		Ground

Requirements	Verifications
Must be able to detect all objects, up to five objects within a clustered environment.	Test the component separately using the evaluation module and test kits to make sure it works as it should. Throw five random objects into the sensor detection range make sure they are all individually classified and data is accurate.

Following is the process of data collecting for the sensor: The RF will send continuous frequency wave to the objects(people we want to count) through Tx antenna. Rx antenna will receive the reflected wave from the object to the chip. After using ADC converter inside the chip, radar front end will then transmit the digital signal to DSP core. DSP is where we put the signal processing code of the input signal, So we need MCU to connect the sensor with PC through UART port. MCU and DPS are connected on the bus. Thus, we can transmit data between PC and sensor to complete the coding process.

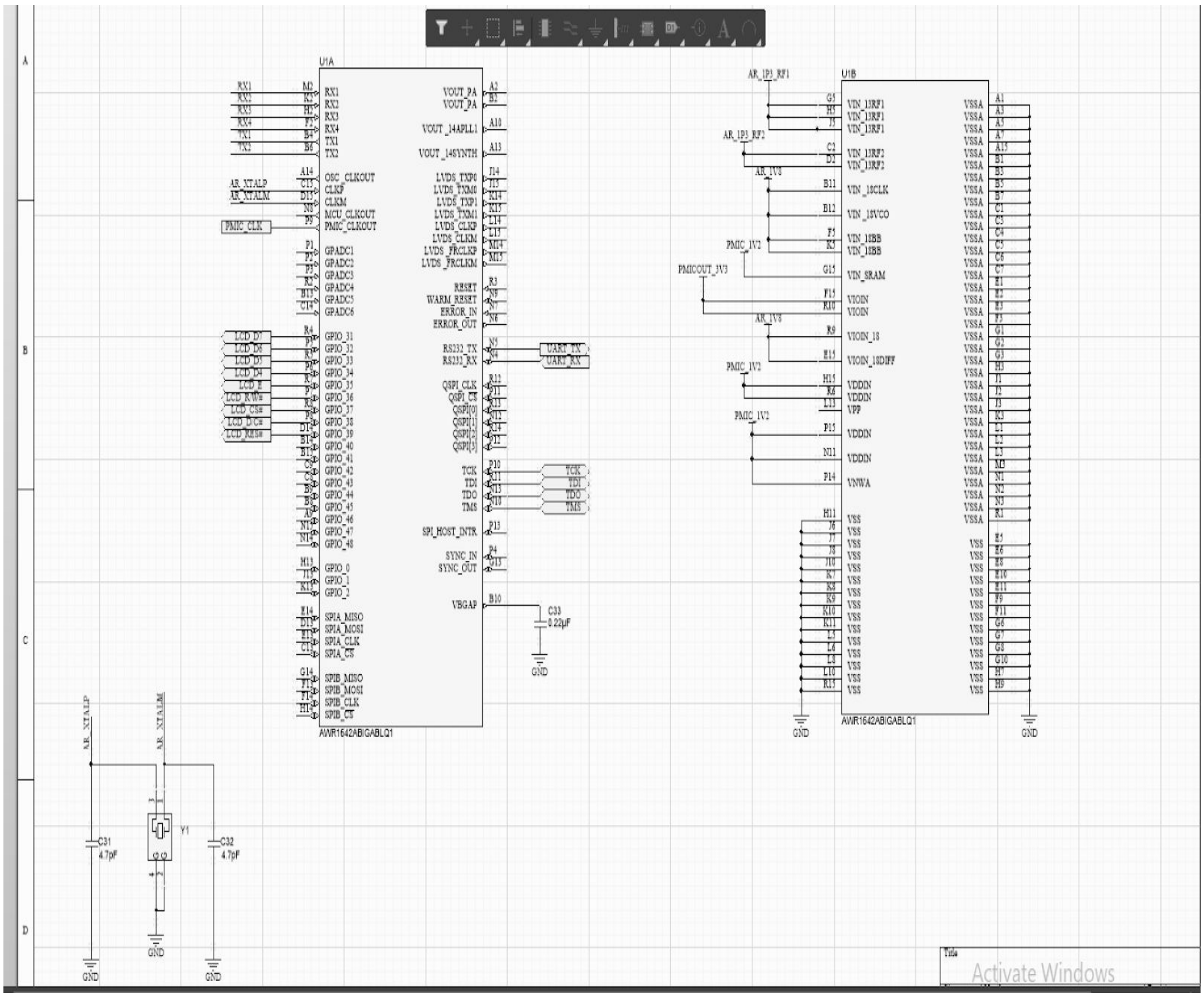

Figure 6: MMwave sensor schematic

2.2.3 LCD（VI-201-DP-RC-S）

Requirement	Verification
It is small enough to onboard onto the	Verify that pins are all fully connected

PCB and is able to show up to 2 digits ○ One digit from input ○ One digit from counting mechanism	with other parts of the system and send the test digital output to the LCD and check that the values update correctly for the two digital outputs.

LCD is used to show the number of people the sensor detected and the number of people that were inputted by the authorized personnel. Not only that it helps to detect the errors and provides safeguard against false positives it provides the respective authorities with the quality of life improvement to know exactly what is going on in their building.

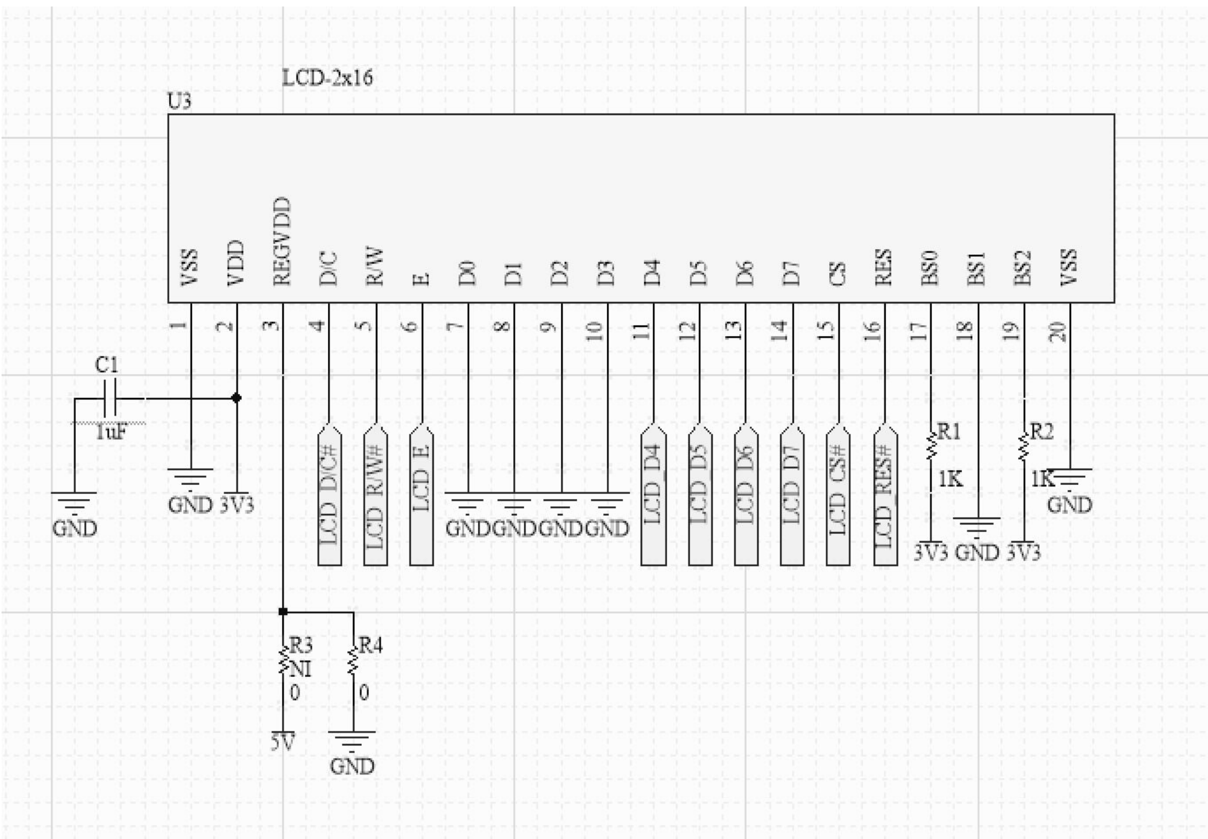

Figure 7: *LCD Schematic*

2.2.4 Control Unit

2.2.4.1 MCU（ATmega328PB）

Type	PIN Number	PIN Name	Description
Power Supply	4	Vcc	Power supply of MCU
GND	5	GND	Ground
Digital input	15	PB3	Connected to the PC output through UART
Digital input	31	PD1	Connected to the PIR sensor circuit output
Power Supply	18	Avcc	Connected to Voltage Regulator
Digital Output	32	PD2	Connected to digital input LED
Digitial Output	30	PD0	Connected to input LCD

Requirement	Verification
All components requiring digital input and output must be connected and is to react accordingly based on digital output from the software.	Load the test software to test each components individually, if the component is not something easily visible connect the digital output to the LED to check for the digital output. Load the test software for the digital input which will print on the screen the digital input it receives to verify their correctness.

MCU gets its input from the PC and then give the output to the tasks, LED can connect to MCU through the GPIO, and it also control the notification LED via IO, if IO is high, LED will not be red, if the IO is low, LED will be red. We also put the NAND Gate block into MCU, and use PC to compile the hex binary and save it to the MCU flash.

2.2.5 External system Module

2.2.5.1 TX/RX Antenna

Requirement	Verification
It must be able to tell the general direction of the object that is being detected by the mmWave sensor.	Needs to be done in parallel with the verification for the mmWave sensor. When testing random object detection make sure their position and direction can be distinguished when detected at

	two different ends of the detection range.

Tx will receive the radar signal and transmit to a continuous frequency wave to detect people. Rx will receive the reflected wave, this analog signal will then pass through the AD converter for further coding. This two sensors are soldering on the Board and connect directly to mmwave sensor chip.

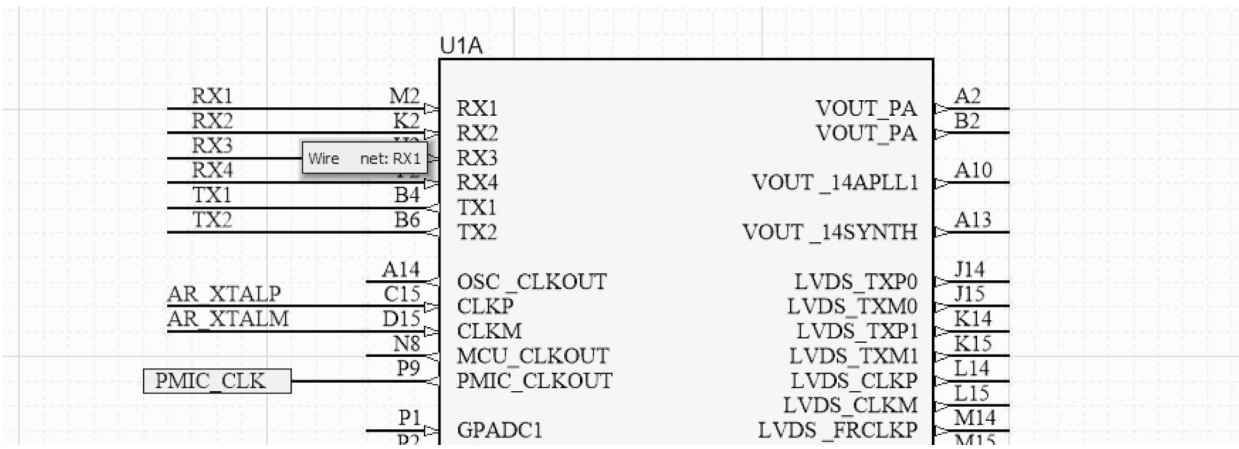

Figure 8: *Tx/Rx schematic*

2.2.5.2 LED(Luxeon 3535L)

Requirement	Verification
Be able to turn on or off based on the digital output that is given	Connect the one of the programmable digital output to the LED load the test software with fixed input to turn the LED on or off and verify that it works correctly.

LED will be red if the number of people the sensor detect is not equal to the input entered using the keyboard. LED is designed on the PCB board, controlled by MCU.The power also comes from voltage regulator.

2.2.5.3 User interface

We need MAX232 and JTAG chip to make connection with our PC and keyboard to PCB board. MAX232 is used to transfer UART port to RX232 to enable connection between PC and PCB. JTAG is used so that PC to code for our Board.

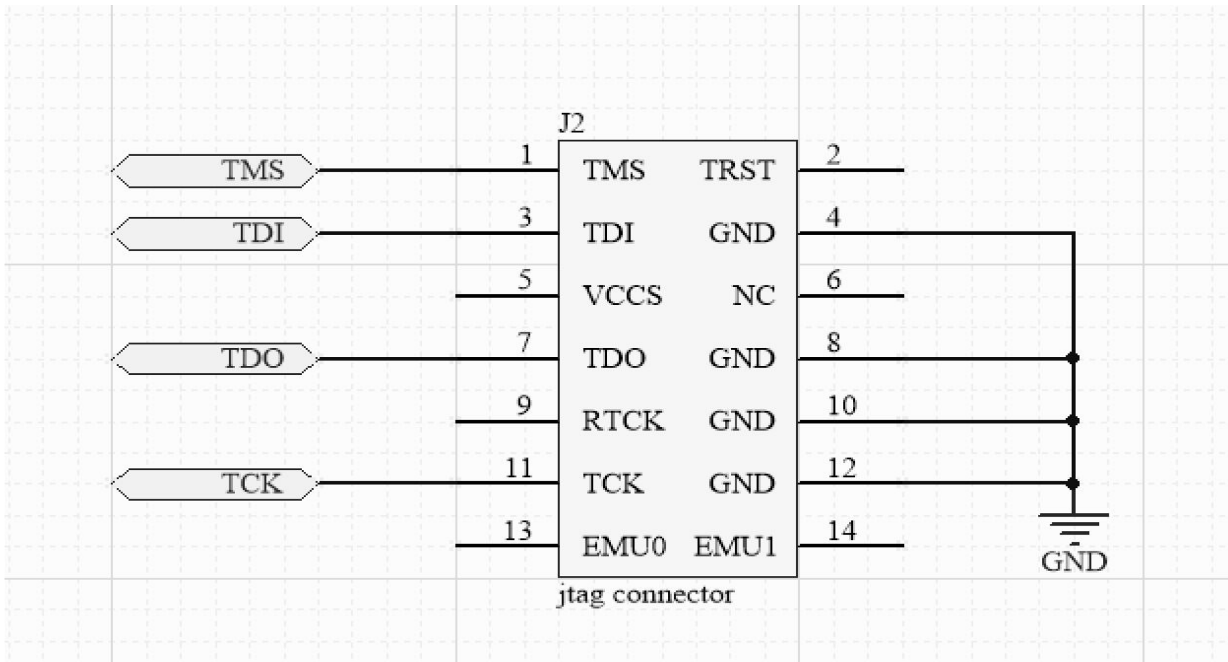

Figure 9: *JTAG schematic*

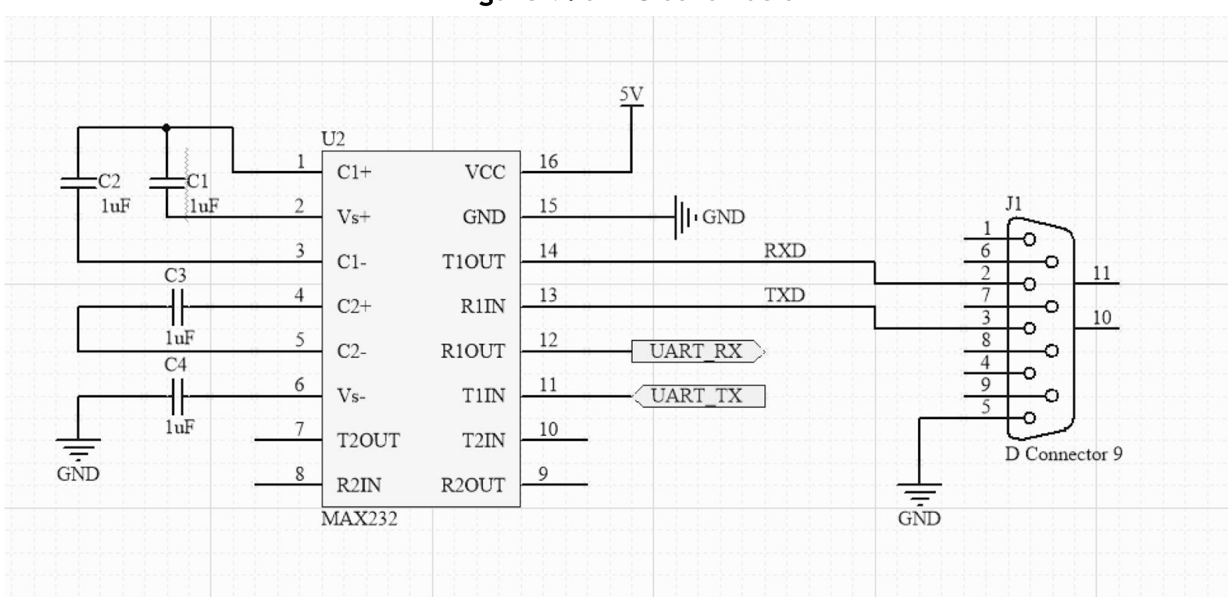

Figure 10: *MAX232 schematic*

2.2.6 Software Components

The purpose of the software component is to parse the data from the given input from the user and the activated mmWave system to output a digital signal that will be used on both LCD and LED to notify and alert if any intruder attempt is detected by the system. Figure 12 mentions human detection algorithm which will be the main component of the algorithm where once program have parsed the data of the object's velocity, position, and angle detected by the mmWave sensor. The program halt signal in terms of campus would be to making sure if the entrance door is closed or not, in a standalone case it would be manually generated. This implementation ensures that once the signal for the program to be halted is sent, there should not be a new human that is detected at least until the program is to be started again.

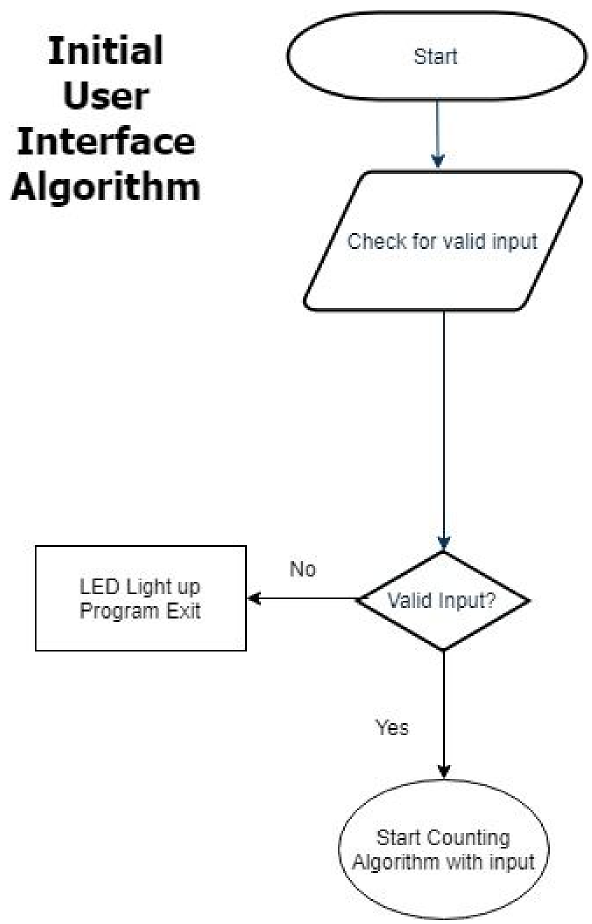

Figure 11: *Initial User Interface Algorithm*

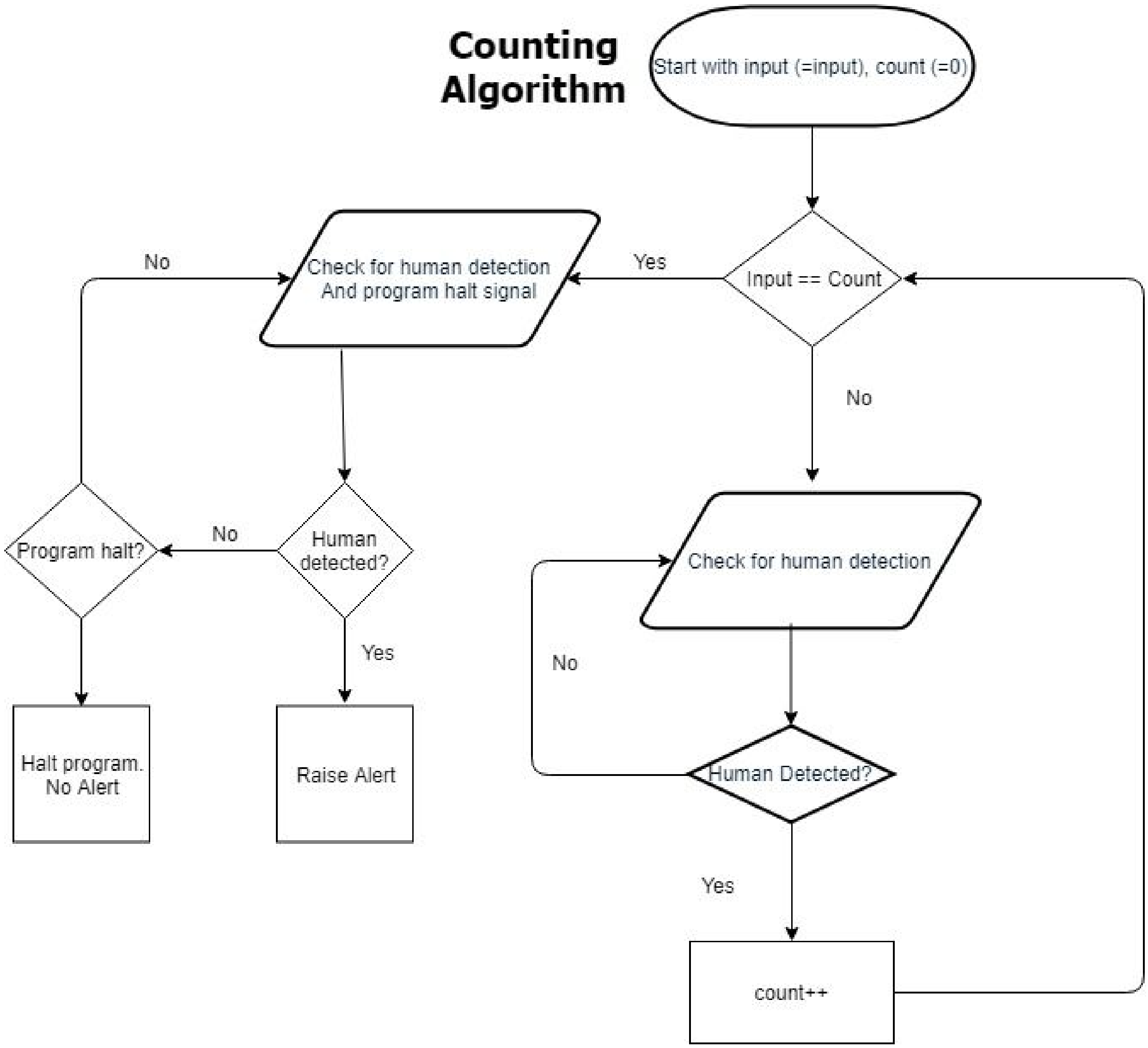

Figure 12: *Counting Algorithm*

2.3 Risk Analysis

The major components which possess the greatest threat to the success of our project is the sealing of the components of the PCB board as the pins are all very thin. The difficulty of soldering the chips and being able to parse the data (detected by mmWave via DSP chip) is our major concern, especially in a different environmental settings where it may be raining or lightning won't be as ideal. We stress the importance of parsing the data consumed, because our project deals heavily with security and relies on its ability to detect multitude of objects in an assumed clustered environment; the accuracy of the data is crucial to project's success.

Additional noticeable challenges that exist outside of the above mentioned major concerns are power efficiency and software false positives. In regards to power, since we will be running the entire system on Li-ion battery we want to make sure that the system runs as long as possible. Software aspects of the project involve around a lot of data handling and making sure that no false positives or loopholes exist within the system. We already noted how the accuracy is crucial to the success of this project and just from the feedback received regarding vibrating object we will have to be able to tell accurately if the object detected is a human, door, or none of the above.

2.4 Tolerance Analysis

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	$T_J = 25°C$	4.8	5	5.2	V
V_O	Output voltage	$I_O = 5$ mA to 1 A, $V_I = 8$ to 20 V	4.65	5	5.35	V
ΔV_O(1)	Line regulation	$V_I = 7$ to 25 V, $T_J = 25°C$		3	50	mV
		$V_I = 8$ to 12 V, $T_J = 25°C$		1	25	
ΔV_O(1)	Load regulation	$I_O = 5$ mA to 1.5 A, $T_J = 25°C$			100	mV
		$I_O = 250$ to 750 mA, $T_J = 25°C$			25	
I_d	Quiescent current	$T_J = 25°C$			6	mA
ΔI_d	Quiescent current change	$I_O = 5$ mA to 1 A			0.5	mA
		$V_I = 8$ to 25 V			0.8	
$\Delta V_O/\Delta T$	Output voltage drift	$I_O = 5$ mA		0.6		mV/°C
eN	Output noise voltage	B =10 Hz to 100 kHz, $T_J = 25°C$			40	$\mu V/V_O$
SVR	Supply voltage rejection	$V_I = 8$ to 18 V, f = 120 Hz	68			dB
V_d	Dropout voltage	$I_O = 1$ A, $T_J = 25°C$		2	2.5	V
R_O	Output resistance	f = 1 kHz		17		mΩ
I_{sc}	Short circuit current	$V_I = 35$ V, $T_J = 25°C$		0.75	1.2	A
I_{scp}	Short circuit peak current	$T_J = 25°C$	1.3	2.2	3.3	A

Figure 13: *Data sheet for the L7805*

Power component as with any other design is one of the most crucial part to the success of our project. Mainly as we have changed and updated our design we have ran a tolerance analysis on the voltage regulator and the battery. Initially we were using the 5V voltage regulator along with the two 3.6V Li-ion battery to power our System. Looking at the datasheet the maximum current output of 1A for the L7805 voltage regulator and its maximum drop out voltage in that situation is 2.5V dropout voltage.

Furthermore at the start of the project, we only used one voltage regulator, however, we then found out that because there are many different components inside mmwave sensor chip, for example, it has a digital power supply which has a limited voltage of 1.32V while I/O supply has a minimum voltage requirement of 3.15V. So we add four more voltage regulator including PMIC to control our voltage. If the voltage can't satisfy the limitation of each components inside the chip, it will not work correctly. However,as they can tolerant about 5% difference, the input voltage can not be exactly the same value as mentioned in datasheet. We also needed to consider the power consumption of other chips on our PCB board and the total power as well:

- LCD: Pmax = 5V * 0.135A = 0.675W
- LED: Pmax = 2.1V*0.125A = 0.2625W
- mmWave sensor = 2.14W
- Total power for PCB = 0.675 +0.2535+2.14=3.0775W

Therefore the upper boundary of total power is 3.0775W. We use 5V for LCD because the maximum input voltage is about 5V. LCD, in fact, can tolerate little higher energy as we have calculated. A change of ~3% will not influence the circuit behavior.

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

$50 (per hour salary) * 2.5 * 3 (# people) * 80 (hours per person) = $30,000

3.1.2 Parts

Parts	Manufacturer	Retail Cost ($)	Count
Li Battery	Panasonic	15.99	2
L7805 Voltage Regulator	STMicroelectronics	0.95	2
ATMEGA328P	Microchip Technology	2.2	1
PIR sensor	Panasonic Electric Works	12.62	1
Antenna	ProantAB	0.62	6
LED	Lumileds	1.34	1
LCD	Varitronix	4.32	1
IWR1642(mmWave)	TI	29.7	1
Total		87.78	

3.2 Schedule

Week	Jaeho	Beixi	Danni
9/24	Mock Design	Mock Design	Mock Design
10/01	Design Review	Design Review	Design Review
10/08	Finalize design, study mmWave SDK	Finalize design, order components	Finalize design and work on presentation
10/15	mmWave sensor initialization and create detecting API.	Collect the components and check,Start Design PCB	Measure each components after they arrive
10/22	Finish building the API with edge cases	Finish Design the PCB board	Finish Circuit design
10/29	Test the API with the individual component	Finish soldering PCB	Finish soldering
11/05	Test the software on the PCB board	Test the PCB board	Debug the PCB board
11/12	Test the project	Test the project	Test the project
11/19	Fall Break	Fall Break	Fall Break
11/26	Final touch wrap up	Final touch wrap up	Final touch wrap up
12/03	Mock Presentation	Mock Presentation	Mock Presentation
12/10	Presentation	Presentation	Presentation

4 Ethics and Safety

The most important ethics relative to our project is making sure that the our users feel secure and is able to trust our project. Our enhancement of security seeks to achieve one thing “To keep good people good” intrusion via following authorized personnel has proven to cause crimes that started from harmful intentions or from sudden impulse. We want to make sure that when making the security system better within the campus we want to have the design that works accurately to earn trust and does a simple job of keeping the door closed and locked for unauthorized personnel.

As we work on this project we uphold every aspect of IEEE code of ethics[5] in our implementation and especially the Article 5 and 6. We seek to improve the technology of campus security that has proven to be faulty with our technology. We only check for the vibration that comes from any objects within a specified region we can confidently say that we do not violate ethics because we do not identify the person we are detecting nor store any datas relative to them. The potential ethical problem may arise when this standalone project, its capability and data are misused by attached functionals, for example, campus could store the student i-card and number of people they have allowed into the campus dorm which could be a violation of privacy if it was to be stored and if the data was to be used against them without their previous acknowledgement.

The safety of our physical design itself is high as the sensors nor the possible overheating components do not directly interact with the users themselves. However, this does not mean that we will be lacking in trying to hold the highest standard when it comes to designing and implementing the hardware to prevent any possible accidents.

References

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