Intruder Detection System

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Abstract

The intruder detection system seeks to detect any intruder trailing the authorized personnel into the building they have no access to and alert the respective authorities. The overall design revolves around the usage of the mmWave sensor which requires four different variances of the voltage supplies and 160-pins soldered onto the board to function properly. In this report, we will discuss the design procedure, accomplishments, reasons behind the decisions that were made, and what the future holds for the project.

1 Introduction

1.1 Objective

Our objective is to create a standalone intruder detecting device. Its goal is to detect if any unwanted strangers are trailing the authorized personnel into the building. The system aims to effectively block out the intruders from attempting to bypass the entrance security system that we commonly see on the 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 intruders 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. Although human detection have already been built and commercialized in the past, there are none as of writing this report which utilizes mmWave sensor commercially for the purpose of human detection to enhance security and count them in clustered environment where this sensor excels the best at.

The core idea behind our project is to keep “good people good” by existing as an additional layer of warning. The intruder detection system will activate once the input on the keypad is given by the authorized personnel. This input will be the maximum number of people to go through the entrance once the access is granted. The system will then detect the number people passing through the entrance and make sure that the count is respected. When the number of people detected is higher than the input it will raise alarm to the respective authorities and notify them of suspicious activity within their building. Our team designed in such a way to minimize the user’s interaction with strangers.

2 Design

2.1 Component Overview

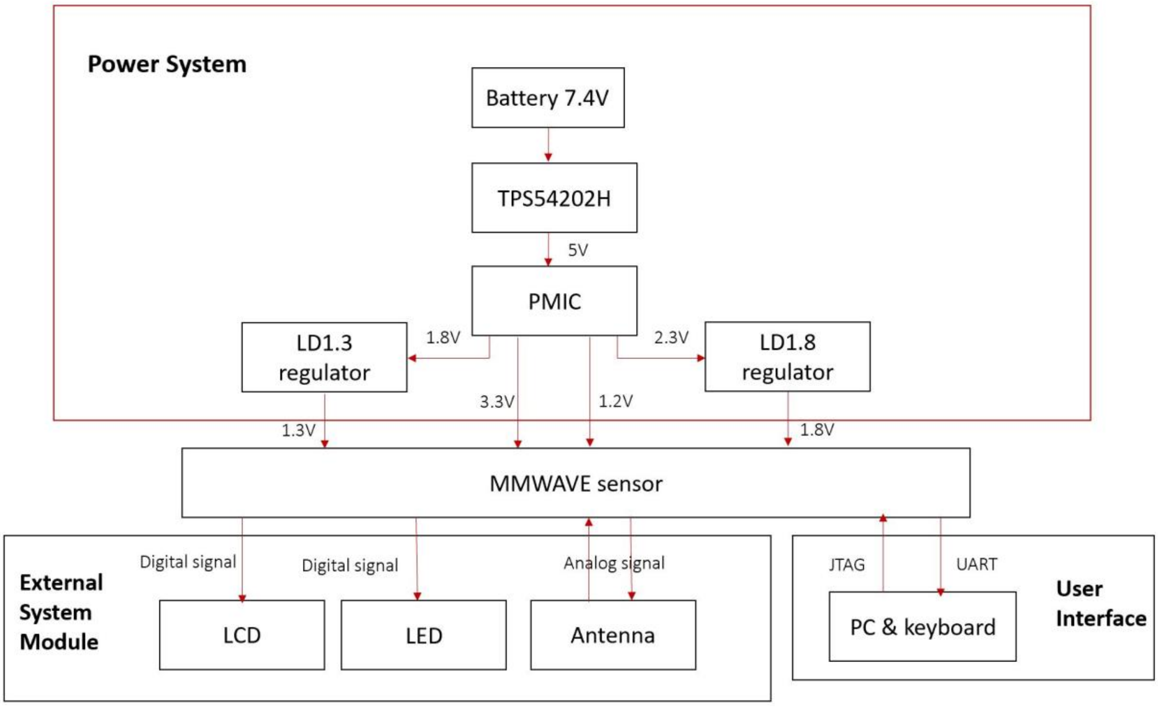


Figure 1: *Block Diagram For The Intruder Detecting Device*

As shown in Figure 1 the intruder detection system is made up of four main sub-system components: power system, mmWave sensor, external system, and user interface.

An input power from 7.4V Li-on battery is manipulated by three voltage regulators and power management integrated circuit (PMIC) to supply four different variances of voltages into the mmWave sensor for it to use all its functionalities as shown in Figure 2.1 and Figure 2.2 [3]. The sensor will be programmed via PC and receive input from the keyboard. The program loaded onto the mmWave sensor microcontroller (MCU) which will communicate with the LCD, LED, and its radar antenna to create input and output for the intruder detection system.

SUPPLY	DEVICE BLOCKS POWERED FROM THE SUPPLY
1.8 V	Synthesizer and APLL VCOs, crystal oscillator, IF Amplifier stages, ADC, LVDS
1.3 V (or 1 V in internal LDO bypass mode)	Power Amplifier, Low Noise Amplifier, Mixers and LO Distribution
3.3 V (or 1.8 V for 1.8 V I/O mode)	Digital I/Os
1.2 V	Core Digital and SRAMs

Figure 2.1: *mmWave required supply voltage for the device blocks [6]*

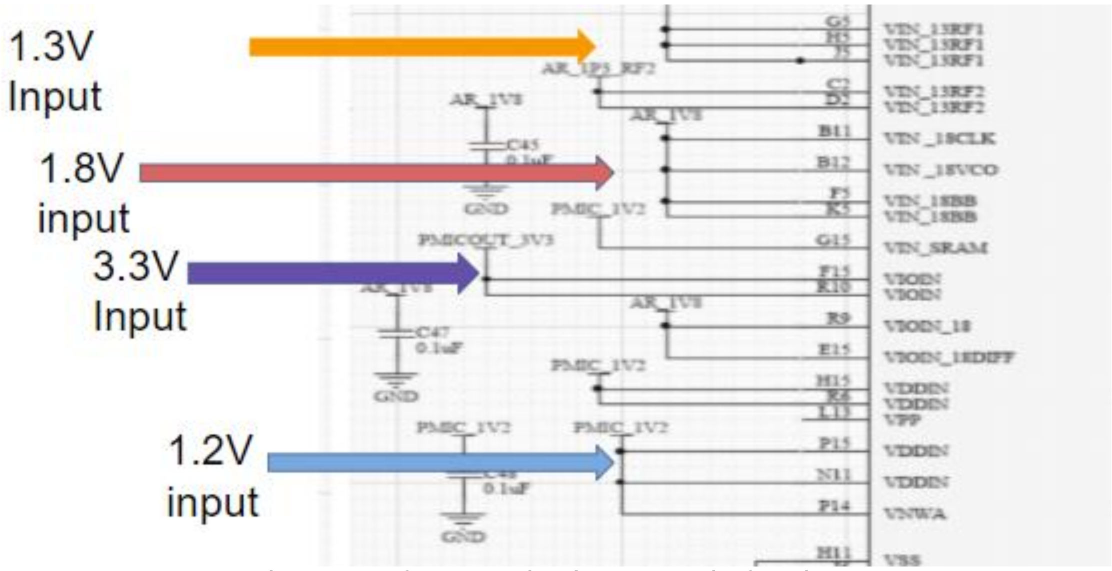


Figure 2.2: *pin schematic of required voltage supply for the mmWave sensor*

2.1.1 mmWave Sensor

The primary reason why we have employed the mmWave sensor for an object detection instead of choosing the more popular alternative for human detection such as passive infrared sensor (PIR) sensor [7] is because of mmWave's superior ability to discern multiple objects in clustered environment regardless of lighting or environmental condition. According to the specification listed by Texas Instruments (TI) [6], it is stated that within the range of 12 meters it is possible to detect multiple objects as long as they are ~3 cm apart from each other even in the dark, foggy, and or rainy conditions.

Therefore when we have decided to utilize the mmWave sensor, making sure that all 160 pins are soldered onto the printed circuit board (PCB) and making sure all parts shown in figure 3 are utilized was the biggest challenge for us. The antenna transmitters and receivers were to be used for were used for object detection, LCD and LED for port address programming and contacting to an external system, and join test action group (JTAG) and universal asynchronous receiver-transmitter (UART) for PC to communicate with the microcontroller of the mmWave sensor. The full pin schematic for all 160 pins soldered onto the board for the IWR 1642 mmWave sensor used in this project can be found on Appendix A.

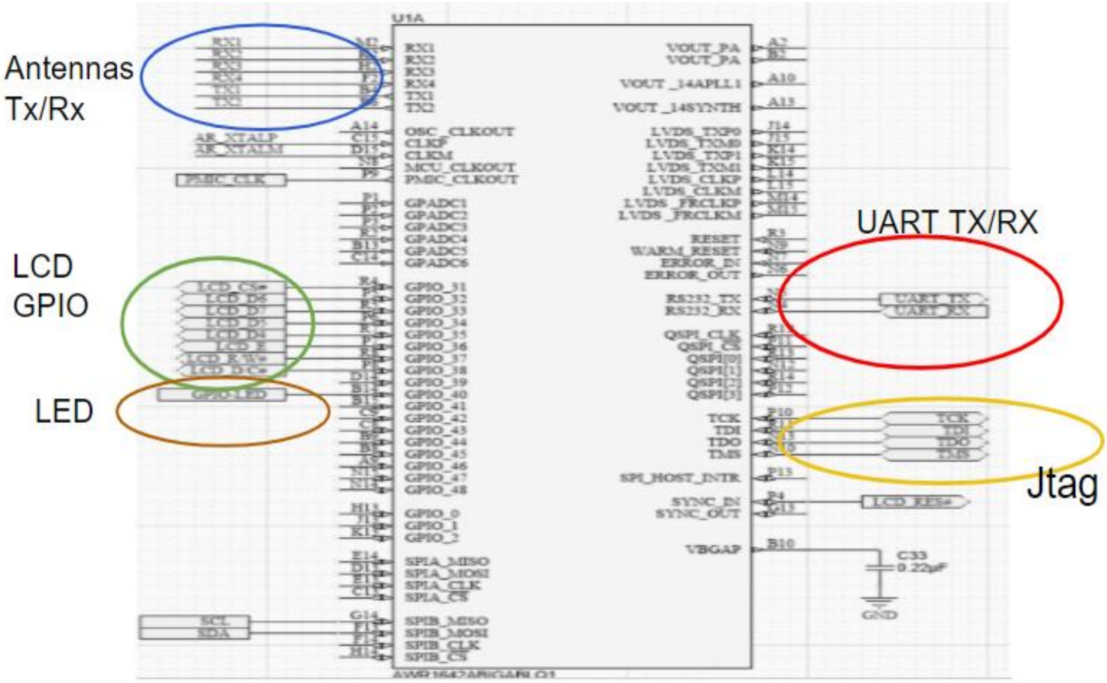


Figure 3: *pin schematic of mmWave sensor with each components labeled*

mmWave sensor utilizes the connected antenna and frequency modulated continuous wave algorithm, implemented by the TI, to keep constant track of object's position, size, angle, and velocity [4].

2.1.2 Power System

Due to the specification of the mmWave sensor our team was required to create an extensive power management integrated circuit (PMIC) along with four different voltage regulators to create the necessary input to the mmWave sensor.

For the stability of the power and to create the four variances of voltage inputs shown in Figure 2.1 the power system was separated into three different stages. Where in the first stage we would use the voltage regulator shown in Figure 1 in Appendix A to convert 7.4V battery output to 5V input for the PMIC. At second stage we would dive the 5V received by PMIC system into 1.2V and 3.3V for the mmWave sensor and 1.8V and 2.3V for the third stage as shown in Figure 2 in Appendix A. Lastly in the third stage two voltage regulators work with 1.8V and 2.3V input to output 1.3V and 1.8V respectively for the mmWave sensor which can be seen in Figure 3 and 4 in Appendix A.

2.1.3 External System and User Interface

As briefly mentioned during the explanation of mmWave sensor after having connected the all components of the mmWave sensor and implementing power system to supply necessary input voltages rest of the operation for the intruder system comes to uploading the software program logic to the microcontroller of the mmWave sensor to send data of the antenna via UART connection and raise alert on LCD and or LED components to alert the authorities that should be contacted in case intruder is detected.

One of the highlights of the design choice that were made when integrating the entire system together along with the external system and user interface is that we made the loop of forward connections with no backward compatibility as shown in Figure 4. This was done to be able to finish the project within the time frame of the semester given the complexity of the overall circuit and the challenges that exist.

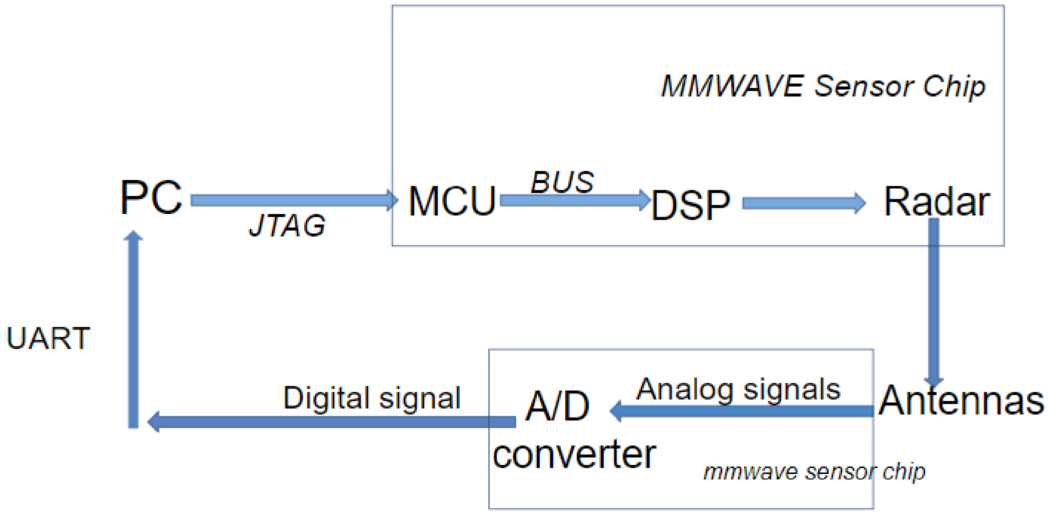


Figure 4: *Connection Loop Of All Sub Systems*

The antennas that are on-boarded onto the PCB and is connected to the mmWave sensor, as shown in Figure 6, detects any moving objects by detecting chirps, abnormality, from the continuous wave transmitted. According to the datasheet, this will perform best if it is above the object it is attempting to detect a point towards it at 45 degrees angle [4].

2.1.4 Software Components

The high-level flowchart software logic for the intruder detection can be seen in Appendix C. The code composer studio, an IDE tool provided by TI for programming their hardware, utilized the C programming language. When all hardware components are fully functional the mmWave works with the programmed configuration and the synchronous program structure between its MCU and digital signal processing core to make sense of the data coming in from the antenna and apply logic to it. It utilizes the inter-process communication and ping-pong buffer for synchronization and its ability to communicate back and forth with the subsystems that the chip contains as shown in Figure 5.

The design of the flowchart and program is intended to test the capabilities and to extend on top of it as time permits. The design choice was to make the software logic as simple as possible because implementing the PCB design and getting the data from the mmWave sensor was to be the main goal of this project.

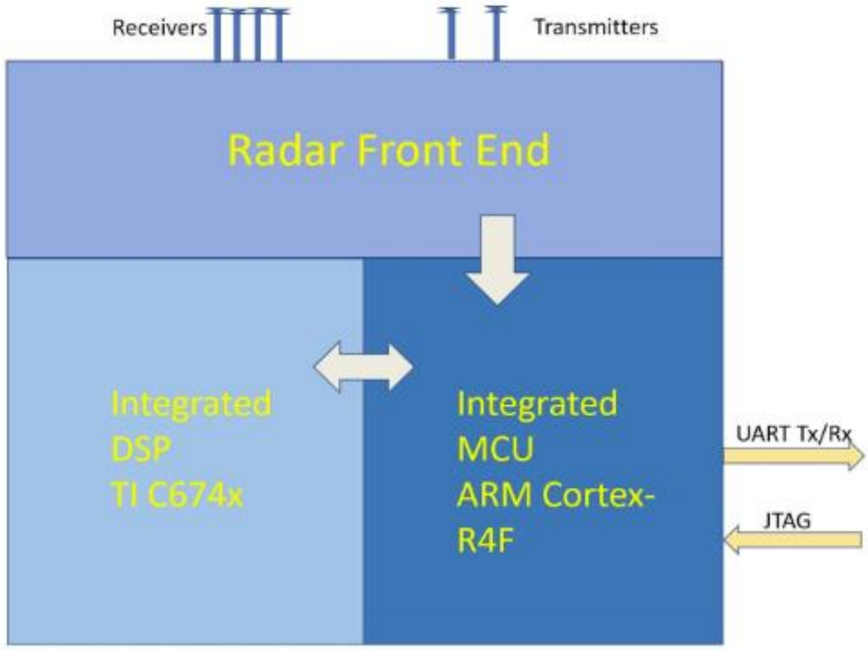


Figure 5: Internal interaction while programming running

2.2 Component Verification

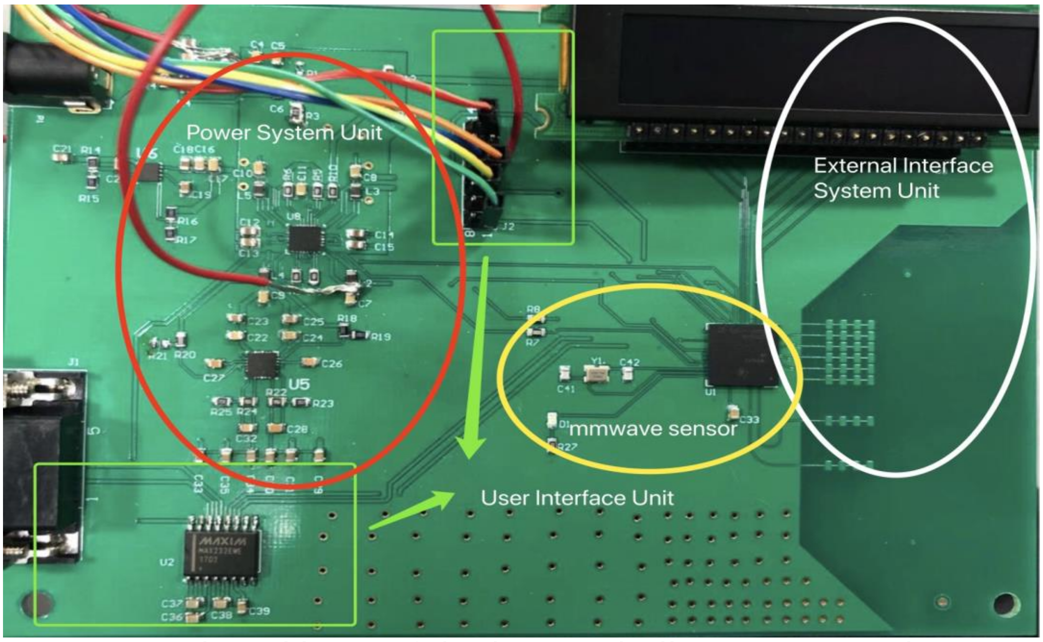


Figure 6: *Physical layout of the design with all components on the PCB*

After having completed the PCB board implementation our followed the verification table as shown in Appendix C and made sure all components were working as it should be.

2.2.1 mmWave sensor

We noticed the critical error in our system when we attempted to test the requirement and verification of the mmWave by loading the firmware provided by TI onto mmWave to test its functionality. However, when we attempted to connect to the mmWave sensor via a JTAG connection it would not respond. After series of debugging and seeing that there is no error in other components such as power system or PC software, we concluded that either JTAG connection is broken or we might have made unwanted connections while soldering 160-pins for the mmWave sensor.

Because of the way we have set up our connections as shown in Figure 4 not having JTAG connection means not being able to program nor configure the mmWave sensor. Which also results in our team in not being able to test Table 2-6 of our R&V table in Appendix C. Also because of the time constraint of the course we couldn't get the new mmWave chip or redesigned PCB in time after consulting Professor and TAs our team decided to finish out the other requirement and verification assuming that some kind of input existed that counts as human signal, replacing mmWave sensor's job by implementing external MCU and other signal sensors or digital input to test the other subsystems.

2.2.2 Power System

Although the JTAG connector didn't work we were still able to verify the successful completion of our power system and its requirements shown in the Appendix C Table 1 by testing the input and output of each respective voltage regulators and the PCB as mentioned in verification step. We were able to get all required voltage reading within the range we wanted, the output examples are shown in Appendix D Figure 1D - 4D.

2.2.3 External System and User interface

Failing to verify the requirement of the mmWave sensor has caused us to take the subsystems such as LCD, LED, and MCU to an external setup as shown in Figure 5D. We were able to verify the requirement as shown in Table 3,4,6 of our R&V by programming the digital input and output of the LCD and LED with an external MCU.

The high-level software logic were written in C for the purpose of loading onto the mmWave sensor's MCU, therefore we were also able to test the high-level software logic with the external MCU to provide minimum viable product as shown in Figure 7 as well.

```
Enter the number of people to enter upon succesful authorization: 23
Number entered needs to be less than 10
Enter the number of people to enter upon succesful authorization: 3
Number of people entered is 3
-----------------------------------------------------------
Authorization succesful, will start surveying the entrance
-----------------------------------------------------------
5617
Person entered
Person entered object id: 5617
1 people out of 3 people entered
7779
Person entered
Person entered object id: 7779
2 people out of 3 people entered
8531
Person entered
Person entered object id: 8531
3 people out of 3 people entered

-------------------------------------------------------------------
Will continue to survey for intruders unless halt signal is given (0)
-------------------------------------------------------------------
8884
Person entered
Person entered object id: 8884
Intruder detected raise signal to LCD
```

Figure 7: *Software Console Outputs*

3 Costs

Cost analysis has been performed to show the cost of every component and cost of potential labors that would've been taken to create this system, this is an example of final cost to produce one unit. Adding up the total costs of parts and labor the total cost came out to be $31145.20

3.1 Parts

The total part costs as well as individual parts are shown in Appendix D.

3.2 Labor

Based on recent work experience of team members we have averaged out the individual person's cost of labor to be $50 per hour.

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

4 Conclusion

4.1 Accomplishment

Overall, each sub-system are fully integrated onto the PCB and even though our team wasn't able to test the functionality of the mmWave chip due to the errors mentioned soldering and configuring the software for the mmWave chip which is being popularized in modern industry as a cutting-edge new technology it was a great learning experience. As of writing this final report device is functional as a minimum viable product to serve the purpose of "keeping the good people good" by sending alerts when intruders are detected and serves the high-level design that our team has originally intended without the usage of mmWave sensor's output.

4.2 Uncertainties

While we have a hypothesis as to why the connections with the mmWave don't work we don't have complete confidence without replacing each hardware out one by one. The uncertainty is that we aren't sure if it is the JTAG connection, soldering problem, or just a defective mmWave chip without having spare components to test it. The most likely cause is the most problematic solution since it would require our team to wait another week and a half for replacement mmWave chip or another hundreds of dollars for the new PCB board.

4.3 Ethical Considerations

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.

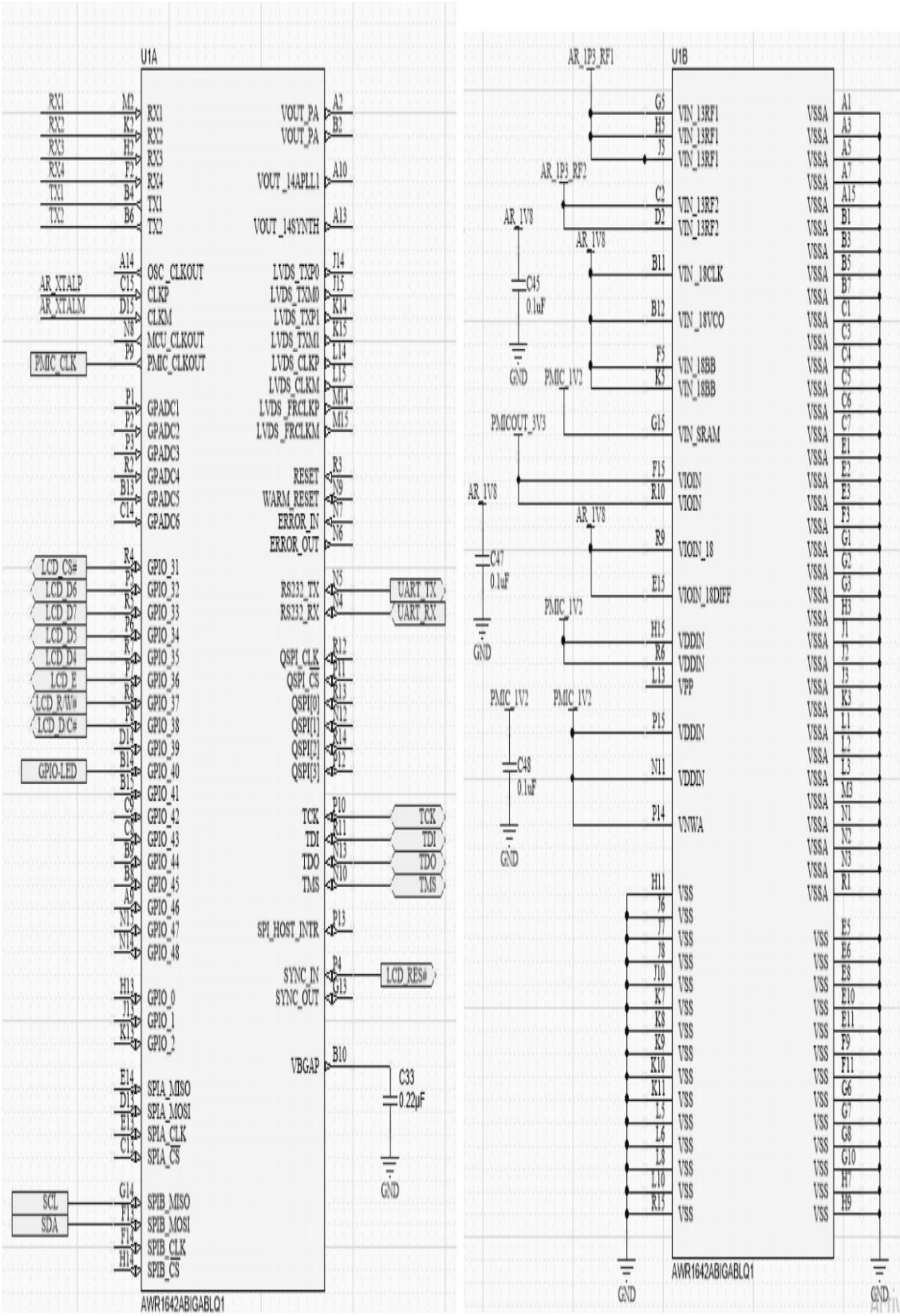
As we work on this project we uphold every aspect of IEEE code of ethics [5] in our implementation and especially the Article 5 and 6. We seek to improve the technology of campus security that has proven to be faulty with our technology. We only check for the disruption in wavelength that comes from any objects within a specified region and therefore we can confidently say that our project does not violate ethics because we do not identify the person we are detecting nor store any data relative to them. The potential ethical problem may arise when this standalone project, its capability and data are misused by attached device, 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

4.4 Future Work

The most of the error we had is due to the connection so one of the primary thing we wanted to do going forward is to design the JTAG to not rely on the jumpers, make the UART connection bi-directional so that even when JTAG connection doesn't work we can use the other connections to debug the chip. Lastly if we were to design this PCB we would change the layers from two layer design to four layer design to give us more room to solder for 160-pin mmWave sensor chip.

The software would have to expand upon as well to work with the mmWave SDK and its libraries to consume its signal and make sense of moving object datas to accurately detect humans

Appendix A: mmWave 160-Pin Schematic



Appendix B: Power System Pin Schematic

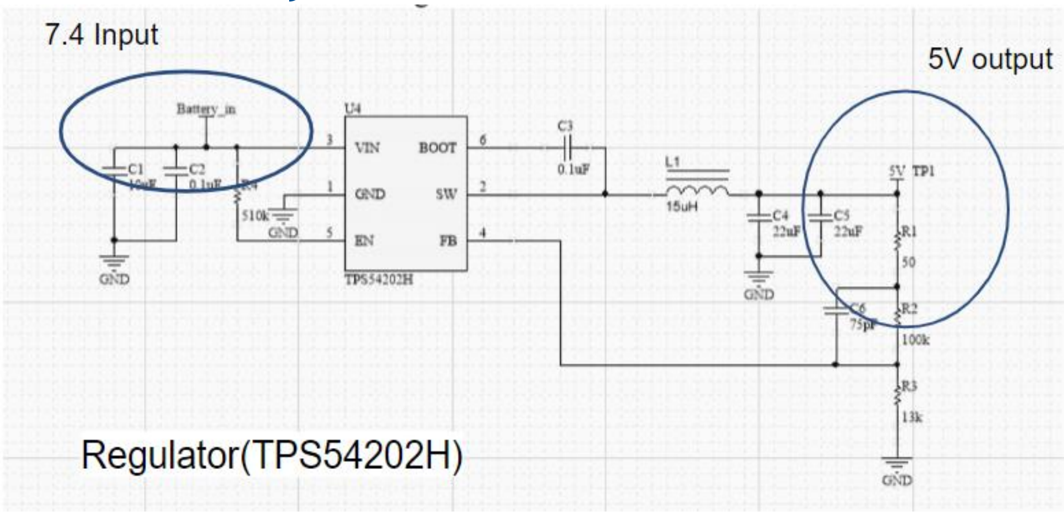


Figure 1: *Pin schematic for the voltage regulator (TPS54202H)*

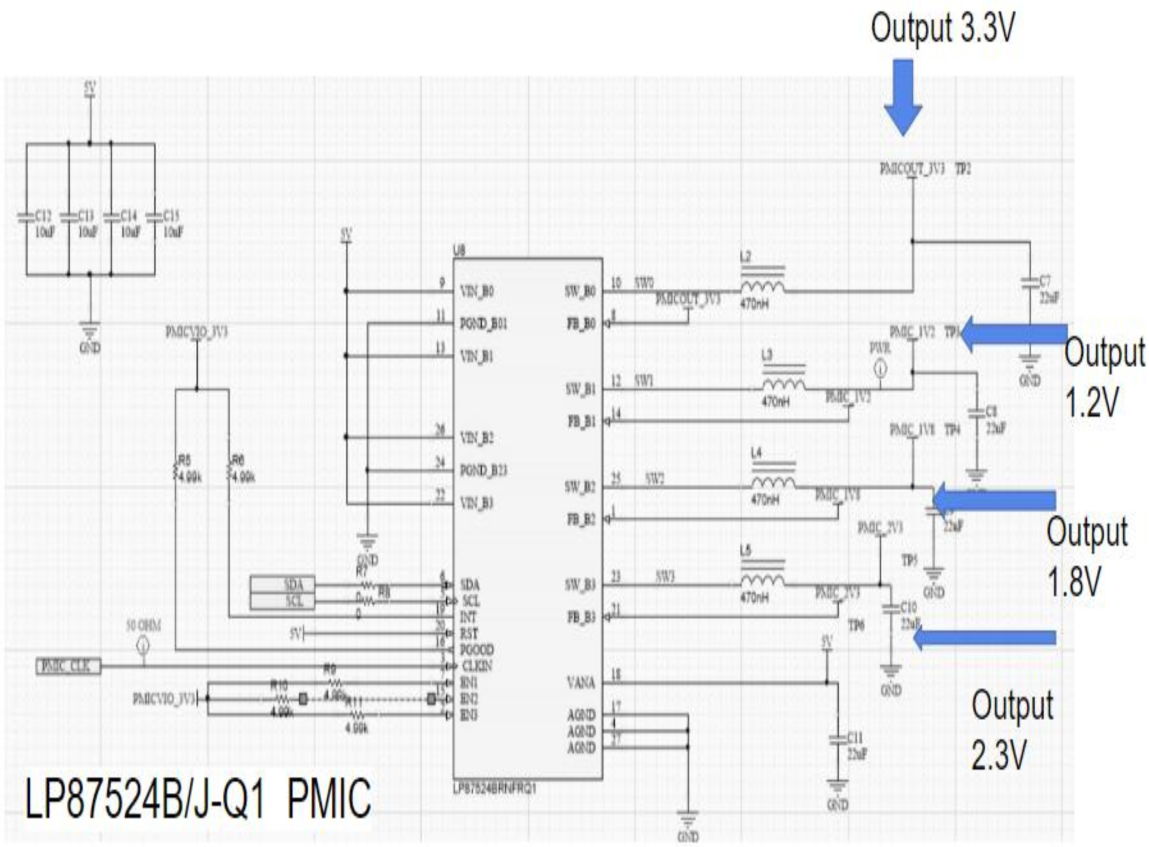


Figure 2: *Pin schematic for the PMIC and four outputs*

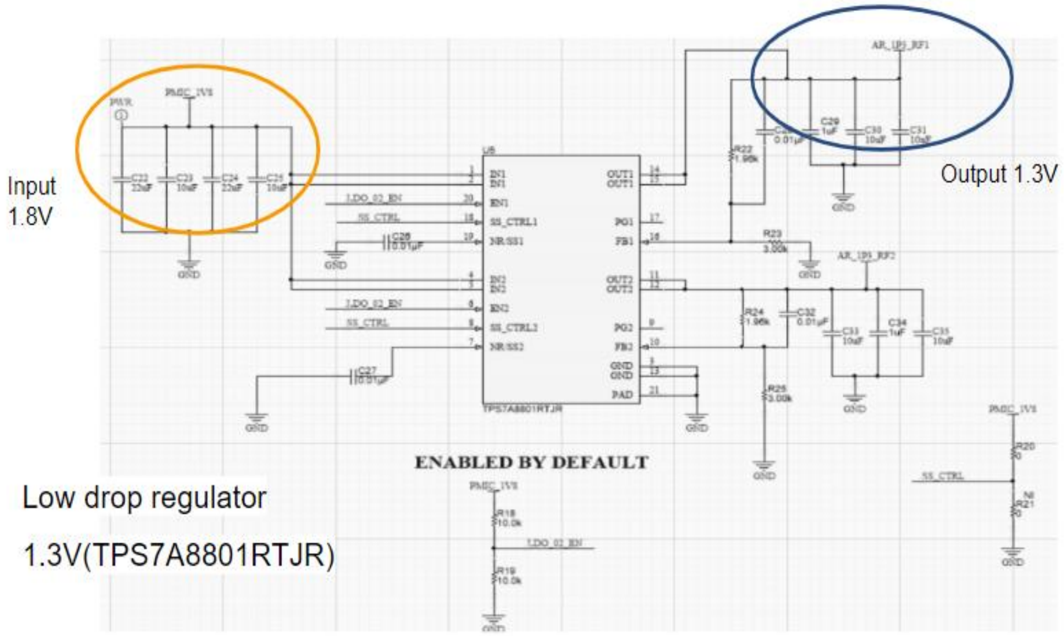


Figure 3: *Pin schematic for the LD voltage regulator1.3V output*

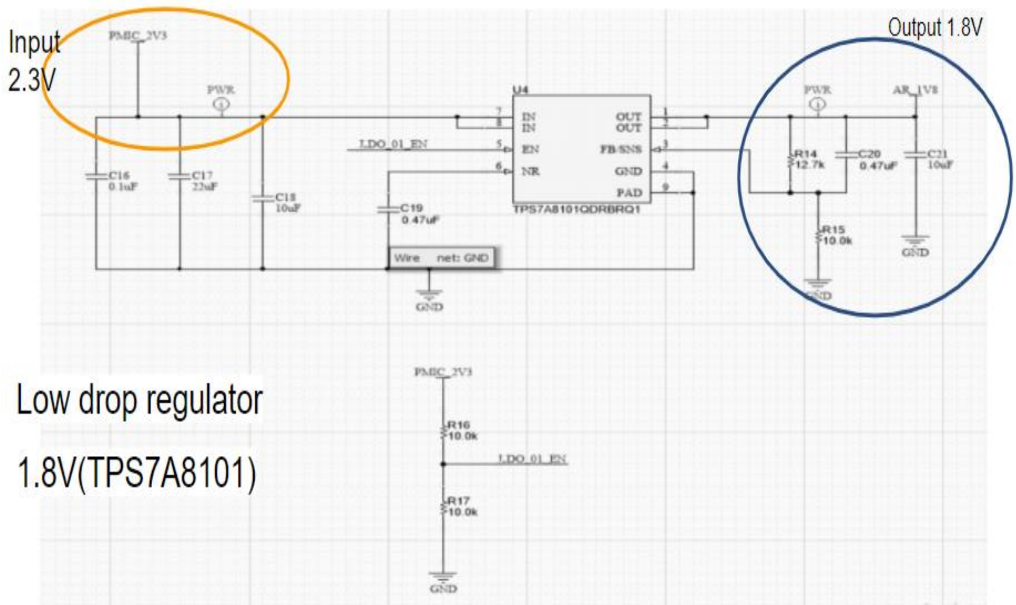


Figure 4: *Pin schematic for the LD voltage regulator 1.8V output*

Appendix C: Requirement and Verification (R&V)

Requirements	Verifications
Supply four variances of voltages given input voltage of 5V or greater for the mmWave sensor. Four variances of voltages should be: 1.2V, 1.3V, 1.8V, 3.3V	Test all voltage regulators and power management integrated circuit's input and output voltage using the multimeter after supplying 5V or more voltage to the system.

Table 1: *Power System R&V*

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.

Table 2: *mmWave Sensor R&V*

Requirement	Verification
It is small enough to onboard onto the PCB and is able to show up to 2 digits ○ One digit from input ○ One digit from counting mechanism	Verify that pins are all fully connected 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.

Table 3: *LCD R&V*

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.

Table 4: *MCU R&V*

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.

Table 5: *TX/RX Antenna R&V*

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.

Table 6: *LED R&V*

Appendix D: Hardware Results

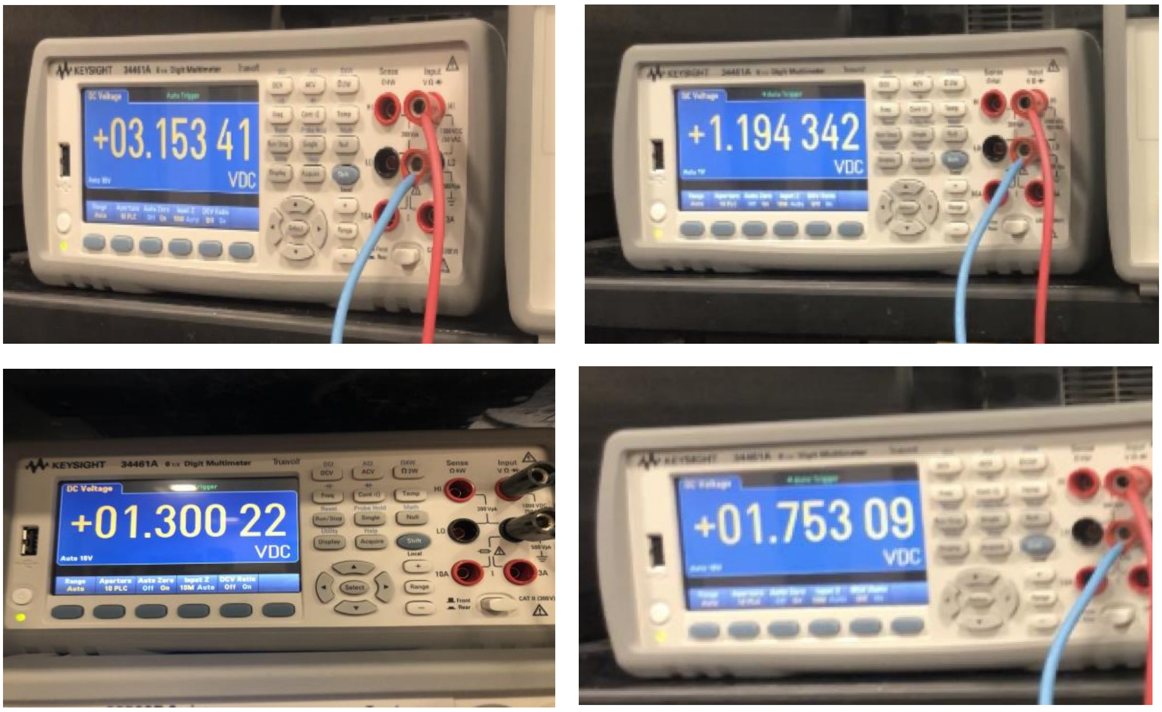


Figure 1D - 4D: *Four variances of voltage from the regulator*

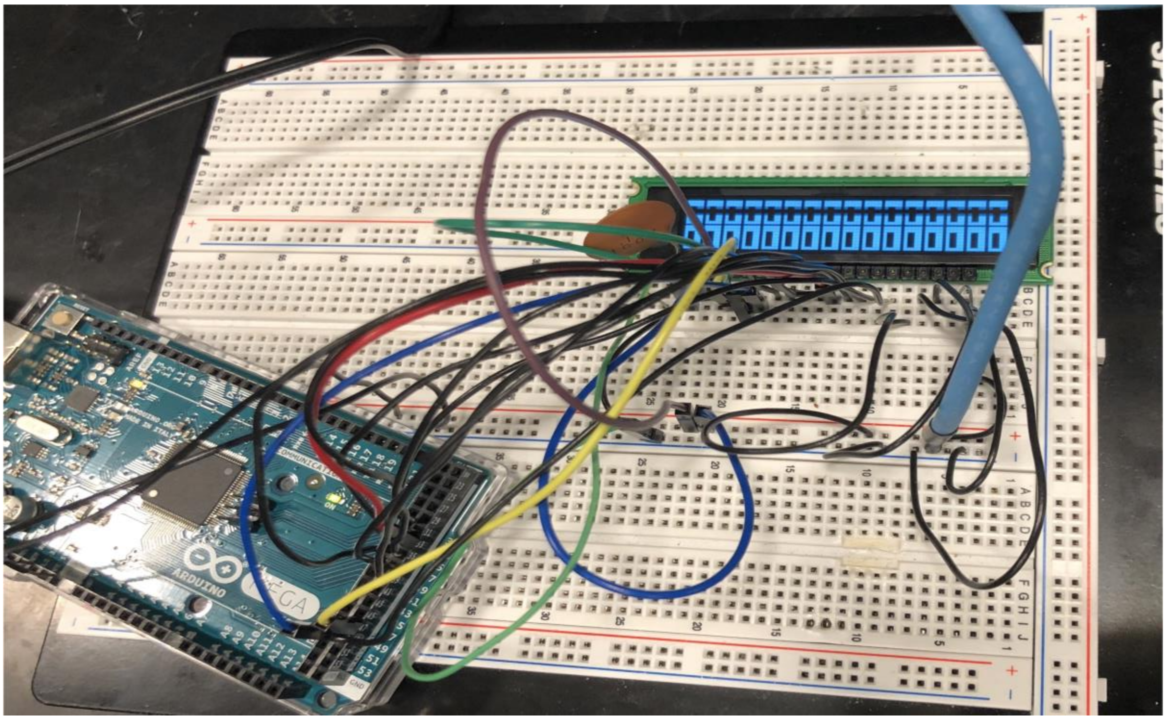


Figure 5D: *LCD with external MCU module*

Appendix E: Cost Table

Parts Name	Quantity	Cost
TPS7A8801RTJR	1	4.32
PS7A8101QDRBRQ1	1	2.83
LP87524JRNFRQ1	1	9.24
TPS54202HDDCR	1	8.55
LCD（NHD-0216CW）	2	53
XD10 Debug Probe	1	102.8
IWR1642	3	89.1
Atmega328	2	2.92
225-5419-ND	1	12.62
153-1003-ND	1	4.32
1416-1439-1	1	1.34
MCU	1	64
C1, C12, C13, C14, C15, C18, C21, C23, C25, C30, C31, C33, C35	13	503
C2, C3, C16, C43, C44, C45, C47, C48	8	
C4, C5, C7, C8, C9, C10, C11, C17, C22, C24	10	
C6	1	
C19, C20	2	
C26, C27, C28, C32	4	
C29, C34, C36, C37, C38, C39, C40	7	
C33	1	
C41, C42	2	
D1	1	
J1	1	
J2	1	
L1	1	
L2, L3, L4, L5	4	
P1	1	
R1	1	
R2	1	
R3	1	
R4	1	
R5, R6, R9, R10, R11	5	
R7, R8, R20, R30	4	
R12, R26, R27, R28	4	
R13, R22, R24	3	
R14	1	
R15, R16, R17, R18, R19	5	
R21, R29	2	
R23, R25	2	
U1	1	
U2	1	
U3	1	
U4	1	
U5	1	
U6	1	
U8	1	
Y1	1	
PCB	2	
Overall Shipping Fee		285.75
Tax		8.56
	Total	1145.2

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