Smart Dumpster

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Abstract
The primary goal of this project is to provide more convenient and secure usage of garbage dumpsters for the users. We have designed Smart Dumpster that is equipped with an automatic locking system to provide service only to the paid users, automatic lid opening system for comfort, fullness detection to prevent garbage mess inside and outside of the dumpster, and solar-powered battery that would make the dumpster self-sufficient. We hope that such a device would solve the common issues that come with using the dumpsters among the users. All further design considerations, verifications, procedures, and cost analysis are documented in the report.

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1 Introduction

Garbage dumpsters have enabled humans with a better life by allowing us to place trash outside of our houses. Due to their convenience, they have become an integral part of people's daily lives. However, despite the comfort that these big dumpsters have given, big issues associated with conventional use of these dumpsters still exist. Among many issues, the most common are the overflow of garbage from the dumpsters causing bad smell and often a big mess, illegal uses from people who did not pay for the service, and the inconvenience of lifting heavy lids to throw out trash.

In order to counter these main issues, we have designed Smart Dumpster that addresses all the common problems that come with the inconvenient uses of regular dumpsters. Our design consists of the following features. First, we have positioned the ultrasonic sensors that detect the fullness of a dumpster. The dumpster stays locked if the dumpster is full, and opens when it has some space. Second, we have installed the locking and unlocking mechanism of the dumpster which will give only the residents who paid for these services the access to the use of these dumpsters. Finally, we have placed the automatic lifting system using the linear actuator that opens the lid when the correct keycard is scanned from the RFID sensor.

The simple additions of automatic locking system, automatic lid opening system, and fullness detectors give tremendous benefits to its users. The fullness detectors using ultrasonic sensors would prevent the dumpster from garbage overflow that often causes mess and foul smell that exist in these sites. This will also eliminate the necessity of picking up the dumpster companies to not pick up the overflow of the garbage that is around the dumpsters, and easily clean them. The automatic locking system will prevent the unpaid users from throwing their garbage in the dumpsters, which would reduce the garbage in the dumpsters, thereby reducing the occurrence of the first common issue (garbage overflow). The automatic lid opening system would solve any issues with lifting heavy lids, thus enabling those with disabilities to easily dump their garbage. This is also true not only for the people with disabilities, but for the people who aren't tall enough, such as kids, and not strong enough, such as elderly people, to throw garbage with more ease. With such benefits, we expect this device to bring more convenient and secure use of dumpsters and enable a clean environment in the dumpster sites.

1.1 High Level Requirements

1. Smart dumpster is entirely solar powered by a combination of solar panels and battery. The solar panel will charge the battery at a rate of 6W and the 6600mAh capacity battery is able to supply power to the system for at least 20 hours at a output voltage of 5V.

2. The linear actuator and solenoid lock will use a input of 12V which is provided by a boost converter located on the PCB. The linear actuator will extend to 6 inches and will open the lid within 11 seconds. The lid will stay open for 5 seconds and close within 11 seconds as well. Both the linear actuator and the solenoid lock are controlled by the RFID module.

3. The overfill protection will be achieved by three ultrasonics sensors. The dumpster will be identified as “full” when there are less than 5 centimeters of space left in all height, width, and length directions. The dumpster will not open when it is full.

1.2 Block Diagram

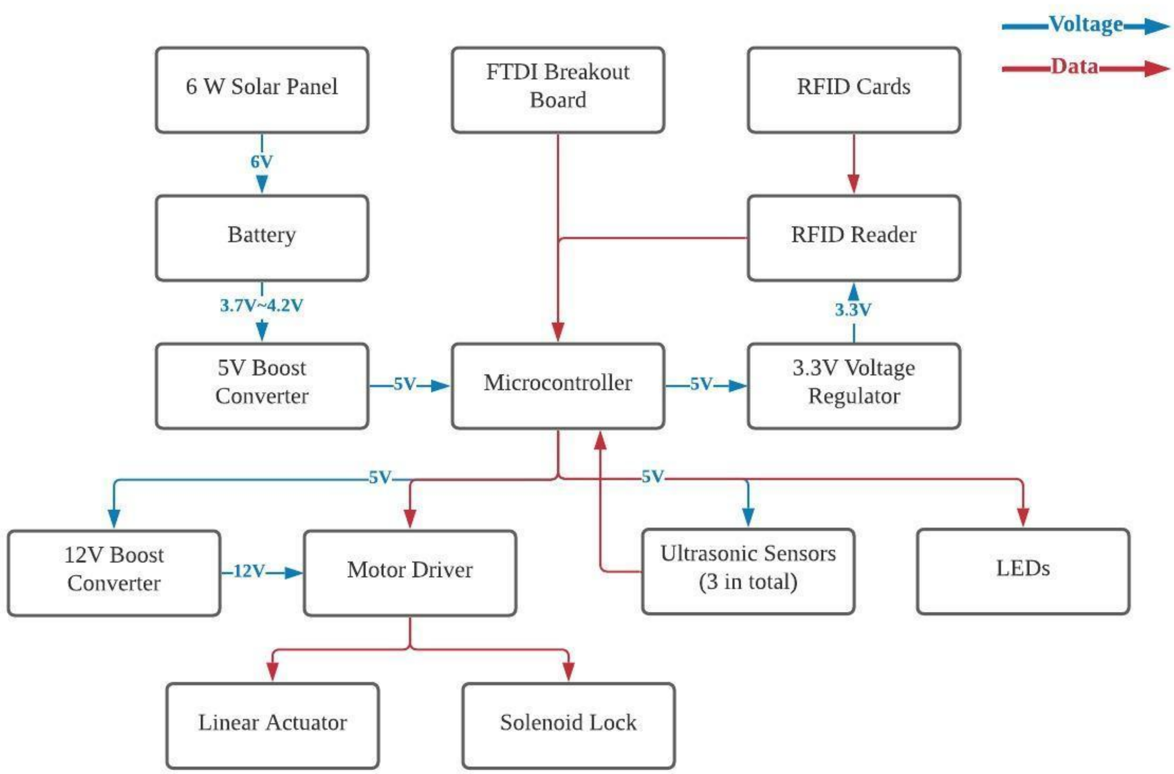


Figure 1. Block Diagram

Smart dumpster is divided into two main categories consisting of power group and control group. Fig. 1 shows the block diagram for the design. The power group consists of the solar panel, battery, a 5V boost converter, a 3.3V voltage regulator, and a 12V boost converter.In order to make the dumpster self-sufficient, we have installed 6 W solar panels that charge the battery, which has 20 hour battery life without any charging. The battery then will power the control group using voltage regulators and boost converters to supply the necessary voltages to different control group devices. The control group consists of the RFID reader, the microcontroller, the motor driver, and the three ultrasonic sensors. In the control group, the microcontroller will receive its inputs from the RFID reader, which tells whether the key is registered or not, and ultrasonic sensors that inputs the information on how full the dumpster is. Afterwards, it will send appropriate signals to solenoid lock and linear actuator, unlocking and opening the system if the correct key is scanned.

1.3 Physical Design

As shown in fig.2, Smart dumpster consists of solar panels, RFID reader, and LEDs on the outside. The solar panel receives sunlight to charge up the battery that powers the rest of the system. The RFID reader scans the key and inputs its information to the microcontroller. The LEDs signal the user whether the correct key is scanned or not.

As shown in fig, 3, inside the dumpster, it consists of the rest of the modules and components. It contains PCB that contains a microcontroller, boost converter and FTDI reprogrammable chip. The ultrasonic sensors are located on three sides of the dumpster to measure the height, depth, and length of the garbage. The linear actuator is installed on the side to automatically lift the lid when signaled, and the solenoid lock is in the front of the dumpster to prevent it from forcibly opening the dumpster. The battery is on the bottom, connected to the solar panels.

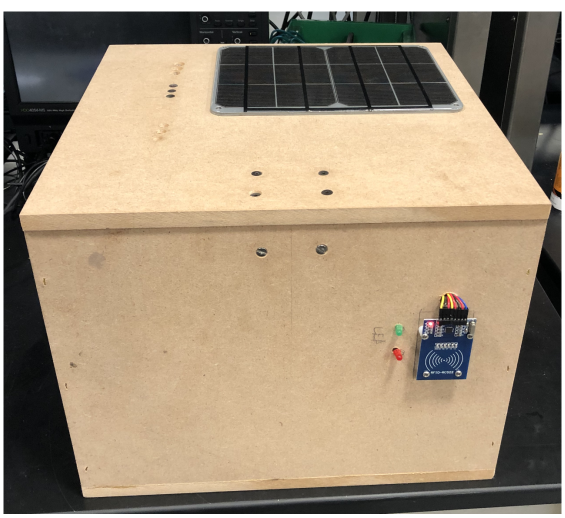


Figure 2. Dumpster outside

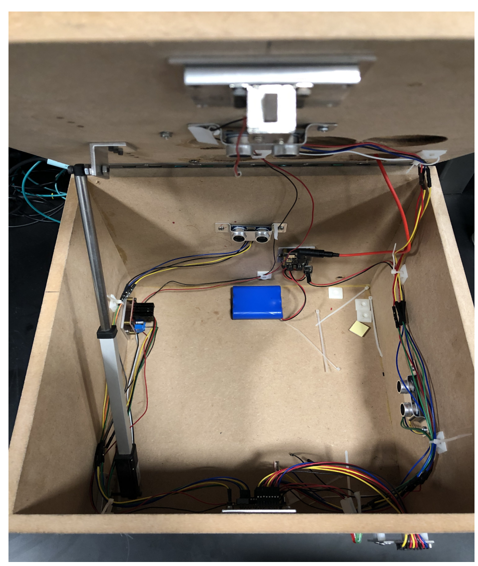


Figure 3. Dumpster Inside

2 Design

The power of the entire system is provided by a 6600mAh lithium ion battery pack charged by a 6W solar panel. The opening and closing mechanism of the dumpster is controlled by a 6 inch linear actuator and the locking mechanism is done by a solenoid lock. Both are controlled by the microcontroller and the RC522 RFID reader. The overfill protection function is achieved by three HC-SR04 ultrasonic sensors and the microcontroller used for this project is the ATmega328. The microcontroller can be programmed by a FT232RL FTDI module.

2.1 Power Group

The power group consists of 4 main components: a 6W solar panel with 6V voltage output, a charging circuit, a 6600mAh lithium ion battery pack, and a 5V voltage regulator. The solar panel and battery are specifically chosen to meet the power consumption of this project. This project uses approximately 1.5W of power(300mA at 5V) when idle, 2.88W of power(575mA at 5V) when opening the lid, and 2.0W of power(400mA at 5V) when closing the lid.

2.1.1 Solar Panel

This project uses a 6W 6V solar panel from Adafruit. Other solar panels that are on the market are viable as well. This specific one is chosen because of its high current output at 930mA at 6V. Since the system is constantly drawing 1.5W of power with it being idle, a solar panel like this with a higher power output is required to charge the battery in a reasonable amount of time. Other features that this solar panel has are waterproof, scratch resistant, and UV resistant. All of these are ideal for this project due to the nature of it will almost always be placed in an outdoor environment. It also has a length of 220mm, a width of 175mm, a thickness of 5mm with a weight of 225g which makes it better when compared to a typical 12V solar panel. Although a 12V solar panel offers more power at a higher voltage, its size and weight makes it a workable but less ideal option.

2.1.2 Charging circuit

The charging circuit used for this project is a Adafruit universal solar lithium ion charger. This is a bq24074-based charger with a 5V to 10V input voltage range which works well with the solar panel selection. The bq24074 chip that powers this charger is great for solar charging since it will automatically draw the most current possible from the panel in any light condition. It also offers a load output port which allows this charger to be connected to the battery and to power the PCB at the same time. It also has a max charge rate of 1000mA which is enough for the solar panel of choice. Other charging circuits with similar features should be valid alternatives to use for the design as long as it provides protection for the battery and has a max current rating more than 930mA. This charging circuit is chosen because of its efficiency and easy connections between the solar panel and the battery.

2.1.3 Lithium ion battery pack

The battery used for this project is a 3.7V 6600mAh lithium ion battery pack from adafruit. It is made of 3 balanced 2200mAh cells. This battery pack is chosen because it is a relatively small battery pack with a large capacity. It is also welded to a protection circuit that provides over-voltage, under-voltage and over-current protection. This battery pack can also provide a maximum 3.3A current output which is a good feature to have but not necessary for our design. It also has a recommended charge rate of less than 1A which works well with the solar panel we chose. Almost any lithium ion battery with a capacity larger than 5000mAh will work for this project. This battery pack is chosen because of its small size and large capacity. If this project is implemented into a real world design, then a combination of an even larger battery pack with a large 12V solar panel is definitely even better since it will be able to keep the dumpster running without the sunlight for a longer period of time.

2.1.4 Boost converters and voltage regulator

Two boost converters and one voltage regulator are used in this project. One of the boost converters and the voltage regulator are designed and built onto the PCB board while the other one is a purchased breakout board. The breakout board that is purchased is from a Adafruit MiniBoost 5V 1A board. While other boost converters or linear voltage regulators that provide a constant 5V output can also be used, this one is chosen because of its smaller sizes and the perfect input range of 2V to 5V when compared to others. The 1A current output limit also fits for our design since the system uses no larger than 1A of current throughout the process of operation. This boost converter is used to use the battery output as its input and output a constant 5V onto the PCB.

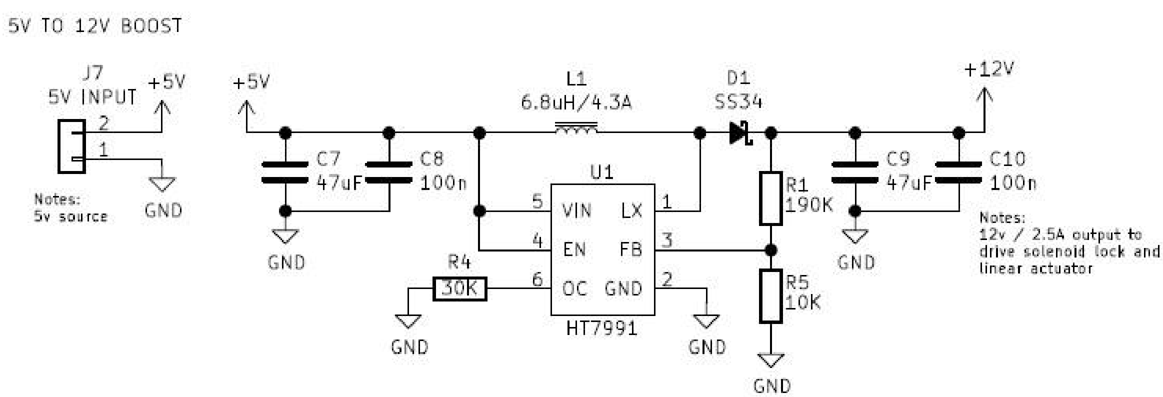


Figure 4. 5V to 12V boost converter circuit schematic

The other boost converter is a 5V to 12V boost converter. This boost converter circuit is designed for the linear actuator and the solenoid lock since both of these components require a 12V input. It utilizes the HT7991 chip which takes an input voltage of 2.6V to 5.5V and has an adjustable output voltage up to 12V. This boost converter circuit uses four fixed value capacitors, two resistors and an inductor for adjusting the output voltage, and another resistor for adjusting the current limit for the circuit.

Below are some equations that are used for calculating the specific components values for the circuit shown in fig. 4:

$$L = \left(\frac{Vin}{Vout}\right)^2 \times \frac{(Vout - Vin)}{Iripple \times fsw} \quad (1)$$

$$R2 = R1 / ((Vout/0.6V) - 1)\ (\Omega) \tag{2}$$

$$Iocp = 48000/Roc\ (A) \tag{3}$$

Equation (1) is used for calculating the inductor value. Equation (2) is used for calculating the resistors values for adjusting the voltage output of the circuits and equation (3) is used to adjust the current limit of the circuit. For our design, *Vin* is 5V and *Vout* is 12V, and we take *fsw* as 1MHz and *Iripple* to be 30% of the maximum load current. From equation (1), calculation will get that the inductance to use is 6.8µH. From equation (2), we get that *R2 = R1/19*. For our design, we choose *R1* to be 190Ω and R2 to be 10Ω. From equation (3), we choose the resistor, *R4,* which is also *Roc* in the equation to be 30kΩ so that the maximum current limit is set to 1.6A which is enough current for the linear actuator and the solenoid lock. Other values can be chosen for this resistor but all the other components values should remain unchanged for this boost converter to work properly. The capacitors C7, C8, C9, and C10 are all using the recommended values listed in the datasheet.

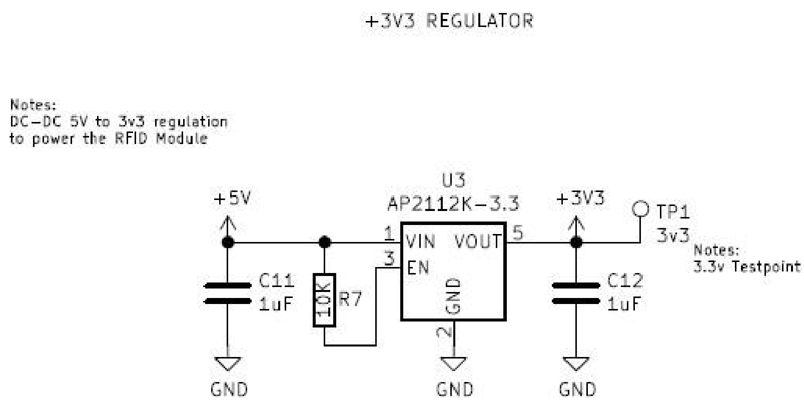


Figure 5. 5V to 3.3V regulator circuit schematic

Fig. 5 shows the circuit schematic for the voltage regulator circuit used in this project. This 5V to 3.3V voltage regulator circuit is designed for the RFID reader since it requires a 3.3V input. This 3.3V voltage regulator circuit uses the AP2112K-3.3 chip which is a CMOS process low dropout linear regulator with a fixed output voltage of 3.3V. It is a fairly common chip to use for voltage regulators and it fits the requirements for our design perfectly by having a recommended input range of 2.5V to 6.0V and the minimum output current of 600mA is sufficient for the RFID module. The values for capacitor C11 and C12 are both recommended values from the datasheet, and the resistor R7 is added between the ENABLE pin and the 5V input to set the enable signal to high for the chip so that this voltage regulator circuit is always enabled and functioning. The inputs for both the 5V to 12V boost converter and the 5V to 3.3V voltage regulator will come from the output of the first 5V boost converter.

2.2 Control Group

The control group consists of microcontroller, RFID cards, RFID reader, LEDs, ultrasonic sensors, linear actuator, and solenoid lock. The RFID reader scans the RFID cards, in which its signals, or input, go into the microcontroller and check whether the RFID card is registered or not. If the card is not registered, the LED flashes red and goes back to its initial state. If the card is registered, it triggers the ultrasonic sensors to measure the garbage distance and flash the green LED. The microcontroller then makes the decision on whether the dumpster is full or not, and if the dumpster is full, it does not trigger the linear actuator and solenoid lock. However, if it is not full, it triggers the solenoid lock to unlock and linear actuator to lift the lid.

The microcontroller receives its inputs from RFID reader and ultrasonic sensors, while it outputs the appropriate signals to linear actuator and solenoid lock accordingly depending on the inputs.

2.2.1 RFID cards

Each RFID reader will have a unique tag, or transponder, that will allow the RFID reader to know whether the user has access to the dumpster or not. It has an operating frequency of 13.56MHz, and has an operating distance up to 10cm.

The RFID card will be a simple card with a tag, or transponder, in the middle of the card. This is a passive component, which consists of an antenna and an electronic microchip. When it gets near the electromagnetic field of the RFID reader, the induction will cause the voltage to be generated in its antenna coil. This will serve as power for the microchip in the card. From the power it receives, it will send the message back to the RFID reader, which will read the data in the transponder and decide whether the card is valid or not.

2.2.1.1 Master Card

The master card is used to register different user key tags. There are three phases upon the scan of the master card from the RFID reader. The first phase is the register mode. Upon this mode, the LEDs will light both green and red until it gets scanned by the master card. In this mode, any user tag can be registered into the system. Upon another scan, the second phase is activated. The second phase is deregister mode, in which it deregisters any registered key tags. In this mode, only the red LED will flash until it goes to the next phase. The last phase, or the default phase, is the user mode, in which upon scanning the registered key tags, triggers the solenoid lock to unlock and the linear actuator to open when the dumpster is not yet full. In this phase, none of the LEDs will light up, as it is the default mode. If the master card gets scanned by the RFID reader for about 10 seconds, the system resets all the registered cards except the admin card and the master card.

The master card is intended for the use from the apartment owners who give access to the dumpster to its residents. By going into the first phase, or the register mode, they can conveniently register the key tags for their residents. Likewise for the second phase, or the deregister mode, they can deregister anyone leaving their property. If in the case where they lost the key, they can simply reset the system and register the key tags again.

2.2.1.2 Admin Card

The admin card is used to simply open and close the dumpster no matter how full the dumpster is. This card is intended to be used by the garbage collectors that clean the dumpster. Due to the limitation of the user keys being only able to open when the dumpster is not full, the garbage collectors would not be able to open the lid when they need to clean the dumpsters. The admin card will also not reset when the reset mode is activated by the master card.

2.2.1.3 User Key

The user keys are used to open and close the dumpster. These keys are intended to be used by the residents who pay for the apartment services. These user keys, after they get registered by the master card, triggers the dumpster to unlock the solenoid lock and open the lid. However, if the dumpster is full, it will not open.

2.2.2 RFID Reader

The RFID reader's range is 33mm, and it will use the VCC of the module with 3.3V. The pins will be connected with the microcontroller according to the schematic in Figure 6. The RFID reader will read the unique UID number when the card comes to the operating range, and can output the UID number to the microcontroller.

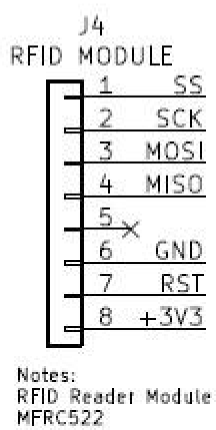


Figure 6: RFID Reader

Upon the reading from the RFID card, it sends the unique UID number to the microcontroller, in which the microcontroller checks whether the card is in the registered system or not.

2.2.3 Microcontroller

ATMega328 microcontroller first needs to burn the bootloader in order to program arduino code into the chip. After, it needs to be connected into a circuit according to Figure 7 in order to be then programmed into a working microcontroller. The crystal oscillator and capacitors will be wired in such a way in order to have the chip be at the same frequency as the arduino and a resistor to make the pin voltage to not trigger reset.

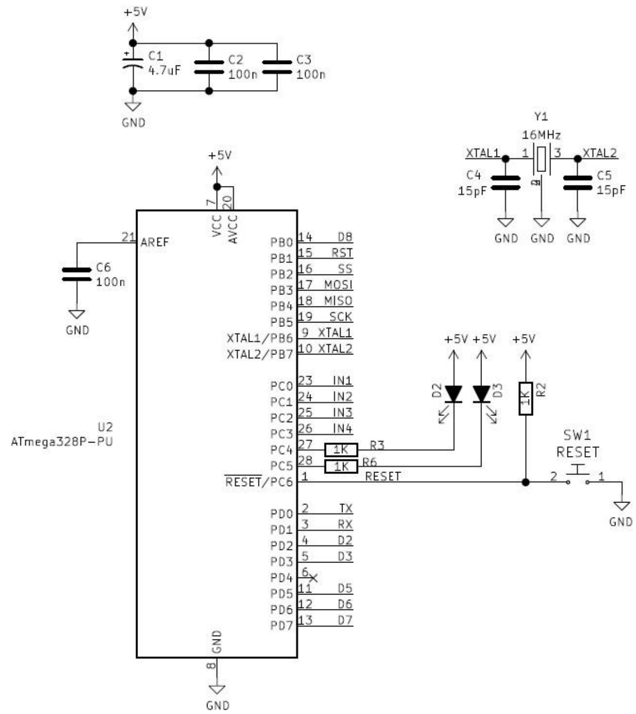


Figure 7: Microcontroller circuit

2.2.3.1 FTDI Chip

FTDI chip makes the direct reprogramming of the arduino code directly into the chip possible. The FTDI pin works around with the transmit and receive of the atmega328 chip to directly program the code into the chip. It flashes green LEDs in the middle during the transmission of the code, and upon its finish, it stops flashing, signaling that the code has been received by the chip. The FTDI chip must be wired like in Figure 8 in order to make the reprogramming possible.

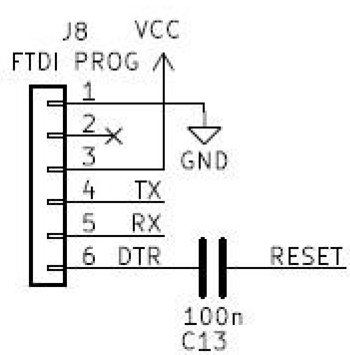


Figure 8: FTDI circuit

2.2.4 Software

In the software, we use two libraries for our code. The first library we use is SPI library, which is used to communicate with peripheral devices quickly. In this case, it is used to communicate with the RFID reader and the microcontroller. The second library we use is MFRC522 library. This library helps tremendously in reading and writing RFID cards. One such usage is to detect whether a new card is present. Unless the new card is present, the code does not need to run entire functions and states, as listed in Figure 9.

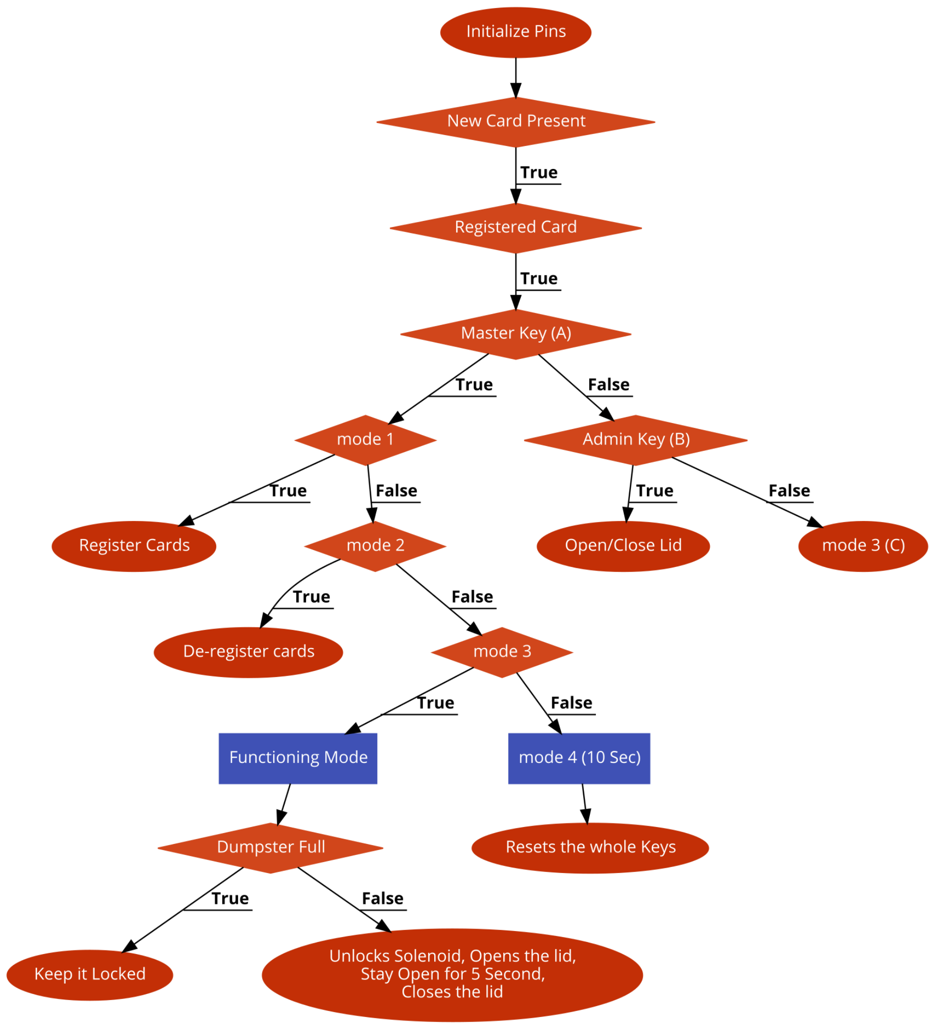


Fig 9: Pseudocode/High level overview

Figure 9 depicts the pseudo code of the software we developed. As it can be seen, the three states of the master key mentioned above are stated in the pseudo code, with the addition of reset, and there are in total three different types of keys.

Master card and Admin card are both pre-registered in the code, while the user key needs to be registered using the master card. This is because if the battery runs out in the case of an accident and reboots, it needs to be able to reprogram the user keys.

During the register process, the registered cards are stored in an array like format. The total number of cards that can be registered currently is 20, although this can be expanded with simple expansion of the array. When deregister happens, the array finds the element that stores the UID, and replaces it with zero, indicating that the spot is empty. In order to save the array memory, when the register mode scans another register card, it saves the UID of the card at the earliest element that's empty.

Upon the correct register in the default user state, and the dumpster is not full, the linear actuator and solenoid lock both get activated by the microcontroller. When the opening of the dumpster occurs, it initially triggers the solenoid lock to unlock first for about a second, and the linear actuator lifts off the lid for the next 11 seconds. The solenoid lock gets unlocked for only 4 seconds, and it goes back into lock mode during the lift off. Afterwards, it will stay open for another 5 seconds, and will close for the next 11 seconds. These timing are easy to program, and can be reprogrammed if the user thinks that 5 seconds of opening is too short of a time to dump the garbage.

2.2.5 Ultrasonic Sensors

Ultrasonic sensors are used to determine whether the garbage can is full or not through the principle of acoustic reflection. The trig pin, or the emitter, sends out a sound wave that gets reflected back to the echo pin, or the detector. The ultrasonic sensor sends the total time it took for the sound wave to come back to the detector in microseconds. However, because the sound wave is getting to the object and being reflected back, we need to divide the time by 2 in order to measure the time it took to get there. Also, since we know what the speed of sound is, we can write the following equation to measure the distance.

$$Velocity\ of\ sound\ =\ 340\ m/s\ =\ .034\ cm/\mu s \tag{4}$$

$$Time\ =\ Distance\ /\ Speed\ \ =>\ Distance\ =\ Speed\ *\ Time \tag{5}$$

$$D\ =\ .034\ cm/\mu\ *\ t\ /\ 2 \tag{6}$$

There are in total three ultrasonic sensors placed inside the dumpster. They are all attached inside, and placed in such a way to measure the height, depth, and length of the fullness of the dumpster. Upon the correct user key scan, it will always trigger the ultrasonic sensors to measure the distance from the garbage. The dumpster will only remain closed if the distances of the garbage for all three sensors are less than 5 cm.

2.2.6 Linear Actuator

Linear Actuator is attached to the inside of the box, and is primarily used to open the lid upon the signals from the microcontroller. The linear actuator requires 12 V to extend its body, and negative 12 V to retract it back to its original state. The current measurement of the linear actuator measures

10.4 inch when its retracted, and 15.9 inch when its extended, giving us about 6 inch extension. This extension is good enough for our prototype dumpster, as it gives enough space for the garbage with its extension. We also measured that in order to extend all the way, it needs about 11 seconds, leading us to code linear actuator to be inputted with the positive voltage of 12 V when extending and negative 12 V when retracting.

2.2.7 Solenoid lock

Solenoid lock is attached to the top and front of the box. There's a little metal cage that clicks on when it gets locked. The solenoid lock needs the input voltage of 12V, and has a default stage of being locked. When the lock is provided with voltage, the lock retracts, thereby unlocking the lock. It is made with iron material strong enough for the lock to be broken with brute force.

3 Design Verification

The specific requirements and verifications of each component that is used in this project can be found in table 1 in Appendix A. In this section, the more general requirements and verifications about the power group and the control group will be discussed, as well as the verification steps taken to verify the entire project when finished.

3.1 Power group verification

The single most important requirement for the power group is able to supply a constant 5V output to the PCB where it will get to the rest of the system. This verification is done by connecting the solar panel to the battery through the charging circuit, and then connecting the output of the charging circuit to the input of the PCB through the 5V boost converter. The output from the boost converter is measured to be 5V, which verified that the power supply to the entire system is working properly. The charging function of the solar panel is verified through looking at the two LEDs which are located on the charging circuit. The "good" LED suggests that a valid source is presented, in this case, the solar panel. The "charge" LED suggests that it is currently charging the battery. This function is further verified by measuring the voltage across the battery using a multimeter. Before charging the battery, the voltage across its terminals is 3.8V. After charging it using the solar panel for an extended amount of time, the voltage across its terminals increases to 4.1V, which implies that the charging function and the charging circuit is working as expected. The 5V to 12V boost converter and the 5V to 3.3V voltage regulator is verified the same way mentioned in table 1 in Appendix A.

3.2 Control group verification

The control group is verified by connecting both the RFID reader and the FTDI board to the microcontroller. The FTDI is verified by being able to write Arduino code into the ATmega328 chip. The RFID reader is verified by both looking at the serial monitor and the LEDs that are designed on the board. When a RFID card is placed close to the RFID reader, the serial monitor will display a unique UID number for different RFID cards. When a RFID card is placed near the RFID reader, the red LED will also flash, indicating that both the FTDI board and the RFID module is working properly. The ultrasonic sensors are tested and verified by using the serial monitor as well. When the system is running, the distances that each ultrasonic sensor is sensing will be displayed on the serial monitor. Looking at the distance data and observing the ultrasonic sensors' locations verified that the ultrasonic sensors are working properly.

3.3 Project verification

The entire project is verified after the two main groups listed in section 3.1 and section 3.2 are verified. When the master card was placed close to the RFID reader, both LEDs turned on. Placing any unregistered RFID card close to the RFID reader, both LEDs briefly flashed for a second. After placing the master keycard close to the RFID reader for two more times, both LEDs turned off. Then using the same RFID card, placing it close to the RFID reader turned on the green LED, indicating the card is registered, and the dumpster unlocked and opened itself. The dumpster lid stayed open for about 5 seconds on the top, then automatically closed and locked itself. Placing the master card close to the RFID reader two times after the lid was closed and the dumpster was locked only turned on the red LED. Placing the RFID card used previously close to the RFID reader, the red LED flashed. Using the master card to put the dumpster back into functioning mode, using the same RFID card did not open the dumpster. The red LED flashed, indicating that the RFID card had been deregistered and thus invalid.

The overfill protection function is also verified once the project is finished. After filling up the dumpster, using a registered RFID card did not open the dumpster up. The green LED flashes, indicating that the card is valid, but the lid did not open because the dumpster is full. Only using the admin card is able to open the dumpster. When using the admin card, both LEDs turn on and the dumpster lid unlocks and opens even though the dumpster is full. The dumpster lid also will not come back down unless the admin card is used again. At this point, all of the high level requirements of this project is verified and each individual component is also verified.

4 Costs

The cost of this project will be divided up into two parts: the labor cost and the parts cost. This section of the report shows all of the parts that are used for this project, their cost, and the total cost. The labor cost is calculated using the average salary of a graduate student at the University of Illinois at Urbana Champaign.

4.1 Parts

Part	**Manufacturer**	**Price**
6V 6W Solar Panel	adafruit	$13.98
3.7/4.2V 6600mAh Li-ion Battery	adafruit	$12.25
RFID Reader (RC522) + RFID Card	SunFounder	$6.99
Ultrasonic Distance Sensor (HC-SR04) × 3	ACEIRMC	$6.00
Charging Module (bq24074)	adafruit	$9.95
Microcontroller (ATmega328P-AU)	Digikey	$2.32
Motor Driver (L298N)	Qunqi	$4.85
Jumper Wires	SIM&NAT	$13.07
PCB	pcbway.com	$32.00
PCB surface mount components	Digikey + LCSC	$51.90
Linear Actuator	ECO LLC	$43.99
Solenoid Lock (Pomyaip2ucv8h14)	ATOPLEE	$6.79
Total		**$204.09**

4.2 Labor

The labor cost is calculated through looking up the average salary for Engineering graduates from Illinois which is $78,714 for electrical engineers and $96,996 for computer engineers for the year 2018-2019. Therefore, the average salary for a ECE graduate would be:

$$ECE\ Graduate\ Average\ Salary\ =\ \frac{\$78{,}714 + \$96{,}996}{2} = \$87,855/year$$

On average, a full-time employee works about 1,801 hours per year, thus

$$ECE\ Graduate\ Average\ Salary\ = \frac{\$87{,}855}{1{,}801 hours} \approx\ \$48.8/hour$$

Finally, the labor cost for this entire project is calculated using this average salary per hour with an estimate of 3 people working 10 hours/week with a total of 16 weeks for the whole semester:

$$Labor\ Cost\ =\ \$48.8/hour\ \times\ 10\ hours/week\ \times\ 16\ weeks\ =\ \$7808$$

5 Conclusion

5.1 Accomplishments

Our team is proud to have built a fully functioning smart dumpster despite the fact that our third member of the group dropped the class in the middle of the semester. Although we had to change the mobile app of the aspect for the project, we were able to mainly keep most of the important functionalities in the project and made them work. We were able to successfully implement the automatic locking system using the solenoid lock, automatic lid opening system using the linear actuator, fullness detection using the ultrasonic sensors, and all the components powered by the solar battery.

5.2 Uncertainties

The biggest uncertainty with our project came from ultrasonic sensors. Although the ultrasonic sensors we used were cheap and durable, these sensors are very weak in detecting the distance of the object with a soft surface. It is also very prone to deceptive readings when angled beyond zero degree. As it can be seen in figure 000, as soon as it gets away from plus/minus of 22.5 degrees, the accuracy starts to fall significantly.

We know that people throw garbage however they want it to be. Therefore, the garbage will definitely not be in the perfect, upright zero degree angled from the ultrasonic sensors. Therefore, we realized that the ultrasonic sensors will be prone to incorrect measurements in real life situations.

Also, the ultrasonic sensors are temperature sensitive, and the measurements can vary in accordance with varying temperatures. The dumpster is going to be placed outside, and the temperature will vary considerably according to different seasons. If the ultrasonic sensors are to be accurate, we would even need to install extra temperature sensors to add it into the distance calculating equation.

In the future, we will look for other, more reliable sensors to accurately measure the fullness of the garbage inside the dumpster.

5.3 Future work

In this semester, we have implemented the components with limited functionalities to accommodate with our limited budget. We know that we can improve the accuracy and functionalities by installing better components. Notably, the ultrasonic sensors must be replaced to get the correct measurements from the garbage, otherwise the fullness detection sensor will be useless functionality.

Another work that we can do is to protect the components that are installed on the dumpster. Currently all the components are open outside, and can easily be broken with enough power.

Dumpsters tend to be roughly treated, as people tend to throw the garbage into the dumpster. In order to present components from breaking, we would have to build protective equipment for the components, such as a shield for the RFID reader and thick tapes for the wires.

Finally, we believe that we would need to come up with functionality when the battery is low but the dumpster still needs to be used. We would need to add default open state when the battery is low, so that even with battery low, the residents can at least use the dumpster manually like the other, regular dumpsters.

5.4 Ethical Considerations

In accordance with the IEEE code of ethics, which calls "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment" [11], we have made valiant efforts to comply with the safety of our project.

In the case when the battery overcharges from the solar panel, we made sure to use the battery with overcharge protection. This would prevent the components from getting overcharge, and reduce any problems that might arise from overpowering other functional components that get powered by the battery. We have also made sure to make the solar panel to be waterproof, as these dumpsters will be outside and must be tolerant to any potential liquids.

Also, in accordance with "to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others" [11], we have made significant design changes after the design review from the professors. We have increased the number of our sensors from one to three, and also added a linear actuator instead of a regular motor. Even with such drastic changes and the finished project, we are still open to any criticisms and feedback to better our design. Additionally, we accept that our design is in accordance with IEEE that currently, the design is not marketable due to safety concerns, as it lacks protective equipment for the components. However, in the near future, we hope to fix these issues and come up with an improved work.

References

[1] 51yuansu.com. n.d. *WiFi 图标免抠素材免费下载_觅元素51yuansu.com*. [online] Available at: <http://www.51yuansu.com/sc/rsssxluwib.html> [Accessed 1 March 2021].

[2] Components101. 2019. *MG996R Servo Motor Datasheet, Wiring Diagram & Features*. [online] Available at: <https://components101.com/motors/mg996r-servo-motor-datasheet> [Accessed 1 March 2021].

[3] Elecrow.com. 2007. *MFRC522*. [online] Available at: <https://www.elecrow.com/download/MFRC522%20Datasheet.pdf> [Accessed 2 March 2021].

[4] Industries, A., n.d. *PowerBoost 1000 Charger - Rechargeable 5V Lipo USB Boost @ 1A*. [online] Adafruit.com. Available at: <https://www.adafruit.com/product/2465> [Accessed 5 March 2021].

[5] Jabbar, A., 2019. *Ultrasonic Sensor HC-SR04 with Arduino Tutorial*. [online] Arduino Project Hub. Available at: <https://create.arduino.cc/projecthub/abdularbi17/ultrasonic-sensor-hc-sr04-with-arduino-tutorial-327ff6> [Accessed 5 March 2021].

[6] K, A., 2016. *Measurement of ultrasonic distance sensor HC-SR04 and Arduino*. [online] Alexeyk.com. Available at: <http://www.alexeyk.com/en/text/review_HCSR04_arduino.html> [Accessed 5 March 2021].

[7] Last Minute Engineers. 2021. *How HC-SR04 Ultrasonic Sensor Works & How to Interface It With Arduino*. [online] Available at: <https://lastminuteengineers.com/arduino-sr04-ultrasonic-sensor-tutorial/> [Accessed 25 February 2021].

[8] Nedelkovski, D., 2021. *How RFID Works and How To Make an Arduino based RFID Door Lock - HowToMechatronics*. [online] HowToMechatronics. Available at: <https://howtomechatronics.com/tutorials/arduino/rfid-works-make-arduino-based-rfid-door-lock/> [Accessed 3 March 2021].

[9] Web.eece.maine.edu. 2013. *Product User's Manual – HCSR04 Ultrasonic Sensor*. [online] Available at: <http://web.eece.maine.edu/~zhu/book/lab/HC-SR04%20User%20Manual.pdf> [Accessed 27 February 2021].

[10] Workshop, D., 2018. *From Arduino to ATmega328 | DroneBot Workshop*. [online] DroneBot

Workshop. Available at: <https://dronebotworkshop.com/arduino-uno-atmega328/> [Accessed 2 March 2021].

[11] IEEE, ‘IEEE Code of Ethics’, IEEE, 2020 [Online]. Available:https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 17-March-2021]

Appendix A Requirement and Verification Table

Table 1. System requirements and verification

Requirement	Verification	Verification Status (Y or N)
- Solar panel outputs a maximum of 930-990mA at 6-7.7V in the sunlight	- Expose the solar panels under the sun - Measure the open-circuit voltage with a voltmeter, ensuring that it is below 7.7V - Place a large resistive load and measure the voltage drop to 6V - Using an ammeter to measure the current through the load is above 930A	Y
-Charging module outputs 930-990mA between 3.7-4.4V when solar panel is exposed in the sun	- Expose the solar panel under the sun - Measure the open-circuit voltage with a voltmeter, ensuring that it is below 4.4V and above 3.7V - Measure the operating current with a multimeter, ensuring that it is between 930-990mA	Y
Battery stores > 6600mAh of charge	- Using the already verified working solar panel and charging module, connect the battery pack to the charging module and expose the solar panel under the sun - Ensure the battery is getting charged through the solar panel by looking at the LED on the charging module - Expose the solar panel under the sun for about 7 hours, ensuring that the battery will get fully charged, can be verified by looking at the LED on the charging module - Connect the battery to a constant current test circuit and discharge the battery at 600mA for 11 hours - Use a voltmeter to ensure that the battery voltage remains above 3.7V	Y

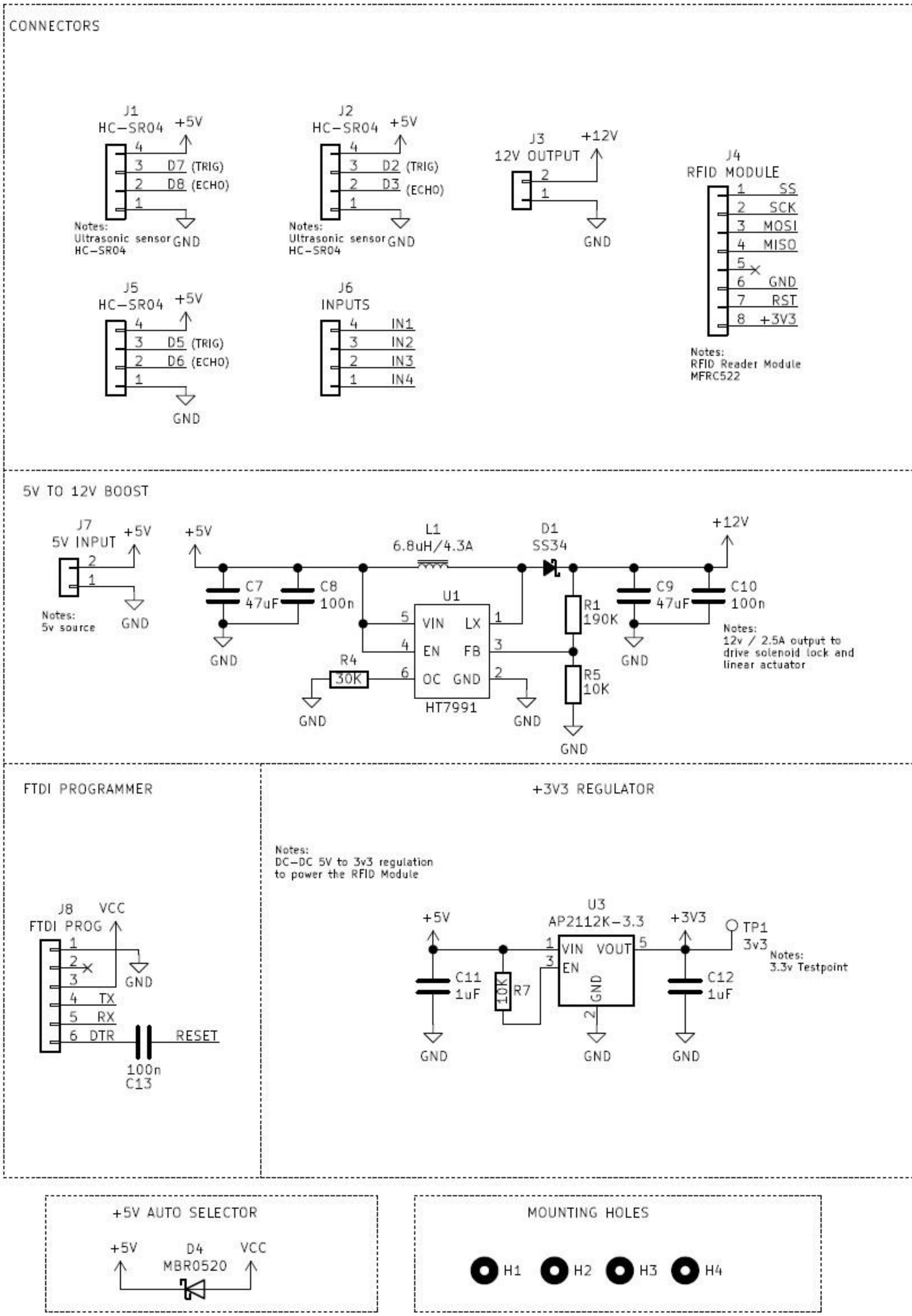
- 5V boost converter provides 5V +/- 5% from a 3.7-4.2V source - 5V to 3.3V voltage regulator provides 3.3V +/- 5% from a 5V source - 5V to 12V boost converter provides 12V +/- 5% from a 5V source	-Connect the input of the battery to the regulators - Measure the output voltage using a voltmeter or using an oscilloscope, ensuring that the output voltage stays within 5% of 5V - Provides a 5V to the PCB board - Measure the output voltage of the 3.3V regulator using a voltmeter or an oscilloscope, ensuring that the output voltage stays within 5% of 3.3V - Measure the output voltage of the 12V output of the PCB using a voltmeter or an oscilloscope, ensuring that the output voltage stays within 5% of 3.3V	Y
Each RFID card - Provides the operating frequency of 13.56MHz - Has a unique UID number - Has an operating distance up to 10cm	- Check whether the RFID card had been registered to the RFID reader - Place the RFID card nearby the RFID reader - Check whether the RFID reader responds with an appropriate response (Red for invalid access and Green for valid access)	Y
RFID reader - Provides the detection of 13.56MHz from the RFID card - Provides range up to 33mm - Able to output the unique UID number of RFID card it reads	1. Arduino Console Open - the MFRC522 library that outputs the detected UID can be seen 2. Arduino Console Not Open - Check whether the RFID card had been registered - Place the card on the RFID reader - Check whether the appropriate light flashes (Red for invalid and Green for valid)	Y
Microcontroller(ATmega328) - Provides 32Kb Flash Memory - 2Kb SRAM	- Place the registered RFID card on the RFID reader - Observe whether the LED light flashes green and triggers the unlocking	Y

- Pins that can serve as inputs and outputs - Compatible to coding in Arduino		
For locking/unlocking mechanism - Provides input voltage of 12V - Built with iron material that is strong enough to not break with human power - Matches the timing of the lock and unlock with the lid (30 secs) - Bar in the solenoid lock goes in when the voltage is supplied - Bar in the solenoid lock goes out when the voltage is not supplied	- Simply check whether the solenoid lock works by triggering the voltage on its input ● The bar goes in when the voltage is supplied ● The bar goes out when the voltage is not supplied	Y
- Linear actuator able to extend/retract	- Provides a positive 12V across the terminal of the linear actuator - The linear actuator should extend to 16 inch - Provides a negative 12V across the terminal of the linear actuator - The linear actuator should retract to 10.5 inch	Y
For all three ultrasonic sensors: - Measure Angle: 15°. - Ranging Distance: 2cm - 4m. - Accuracy can be up to 3mm.	- Connect the VCC pin to the 5V pin on the Arduino and connect the GND pin to the Ground pin on the Arduino. - In response, the sensor emits an eight-pulse sonic burst at 40 kHz, each pulse lasting at least 10 seconds. - To begin forming the echo-back signal, the Echo pin is set to HIGH. - If those pulses are not reflected back, the Echo signal will timeout and return low after 38 mS (38	Y

	milliseconds). - As a result, a 38 mS pulse means that there is no obstruction within the sensor's range. - Otherwise, It will produce a pulse with a width varying from 150 seconds to 25 milliseconds.	

Appendix B Circuit Schematic and PCB Design

Figure 10. Full Circuit Schematic



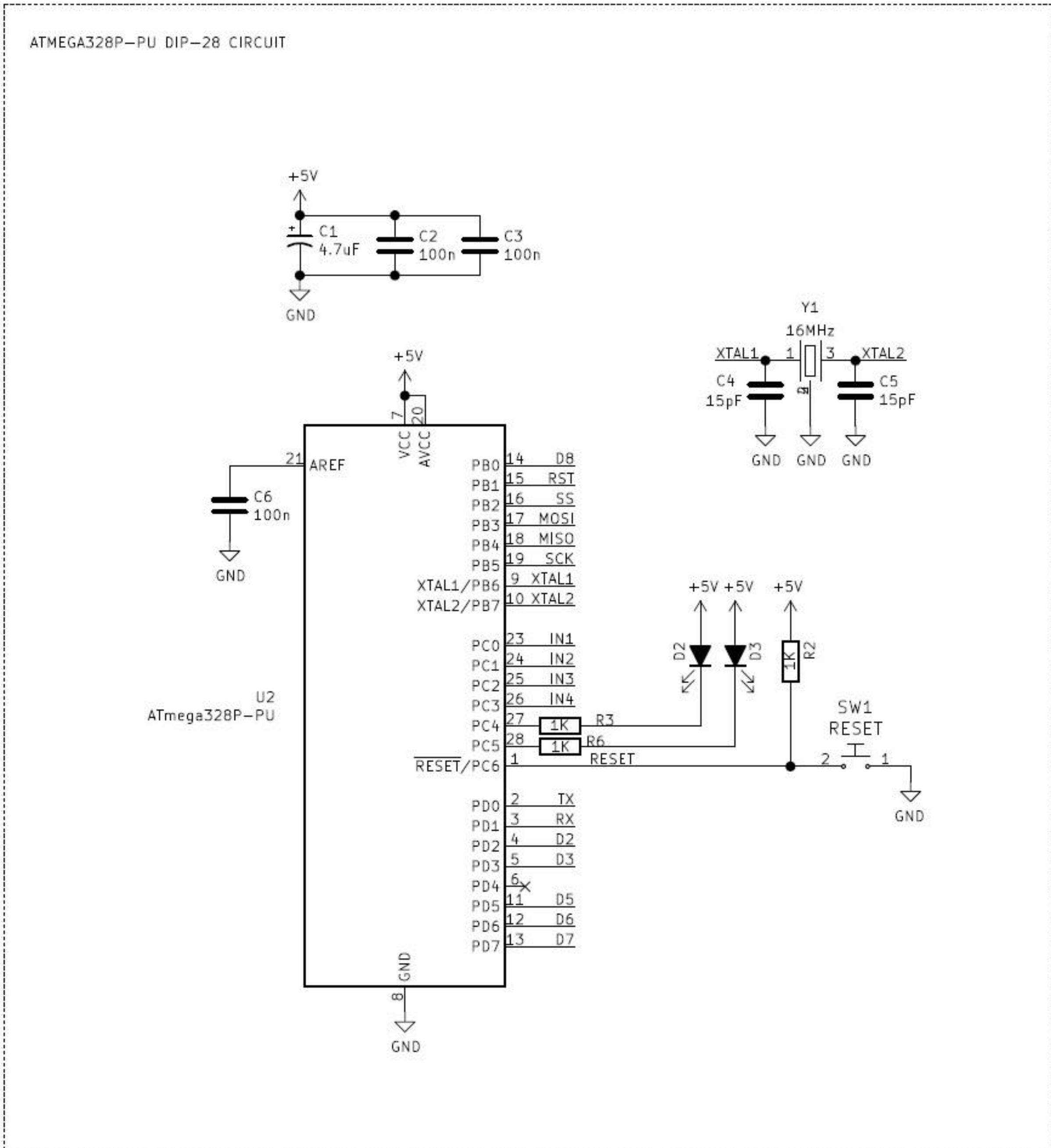

ATMEGA328P-PU DIP-28 CIRCUIT
+5V
C1
4.7uF
C2
100n
C3
100n
GND
Y1
16MHz
XTAL1
XTAL2
C4
15pF
C5
15pF
GND GND GND
+5V
VCC
AVCC
AREF
C6
100n
GND
PB0 14 D8
PB1 15 RST
PB2 16 SS
PB3 17 MOSI
PB4 18 MISO
PB5 19 SCK
XTAL1/PB6 9 XTAL1
XTAL2/PB7 10 XTAL2
PC0 23 IN1
PC1 24 IN2
PC2 25 IN3
PC3 26 IN4
PC4 27
PC5 28
RESET/PC6 1 RESET
+5V +5V +5V
D2 D3
1K R2
1K R3
1K R6
SW1
RESET
GND
U2
ATmega328P-PU
PD0 2 TX
PD1 3 RX
PD2 4 D2
PD3 5 D3
PD4 6
PD5 11 D5
PD6 12 D6
PD7 13 D7
GND
8
GND

Figure 11. PCB Design