TrashTalk

Group 15

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1. Introduction

Waste Management is an essential part of any strong developed society. Proper management can depict the cleanliness and level of comfort patrons can expect to have in their environment. Although trash and proper maintenance of trash may not be on the top of anyone's agenda, or even in the common discussion of current events, it is important. Big cities and big theme parks such as New York, Chicago, and Disneyworld respectively pay a lot of money on workers and equipment to keep a handle on trash. The way of doing so now in Theme Parks is simply having a person or more designated to a certain zone of the park and aimlessly walking around in that zone repeatedly waiting until the trashcans are close to full.

Emptying of trashcans in big city parks such as New York and Chicago are pretty similar to the Theme park method. In these big popular cities, trash maintenance is implemented with a relatively better system, yet still not adequate enough. Park and Recreation services in these cities routinely send workers out to empty trashcans throughout the Parks on a timed schedule constantly whether they're full or not. Garbage trucks are also used to help dispose of the trash which are being picked up from these areas.

This method of trash handling causes the unnecessary use of extra manpower, by having various different workers deployed to locations to visually determine whether or not trashcans need to be emptied. This method also wastes a large amount of gas from the garbage trucks which make a run around the city to pick up trash from the park locations no matter if it is a lot or not. A better method of trash handling would be Eco friendly by reducing the unnecessary driving of the gas Garbage trucks as well as labor effective by reducing the amount of unneeded workers. Ultimately, the improved method of managing trash in these big cities would be very beneficial to the city's budget by cutting cost.

1.1 Executive Summary

The design allows a network of trashcans to be self-sufficient and be able to communicate with each other on the status of their trash level. The trashcans form a huge network and are placed in various different locations deemed necessary. The network of trashcans communicates with one another every 30 sec to update their current status. The update time can be adjusted to any desired time interval. After updating, all of the trashcans then send their information to a home server to allow waste management workers to visually see the activity of the cans. After seeing the trashcans that need immediate attention, waste management workers can then pinpoint exactly which route would be most suitable for workers and garbage trucks to take to empty the trashcans.

The Trashcan's overall system consists of four subsystems. The four subsystems are the trash sensor detection system, the GPS location system, the user interface data collection system, and the self-sustaining power system. Each subsystem separately has their own strengths and list of various components, which helps complete the overall functionality of the trashcan. **Figure 1** gives a visual block diagram representation of the different subsystems that are merged together to create the overall Trash Talk design.

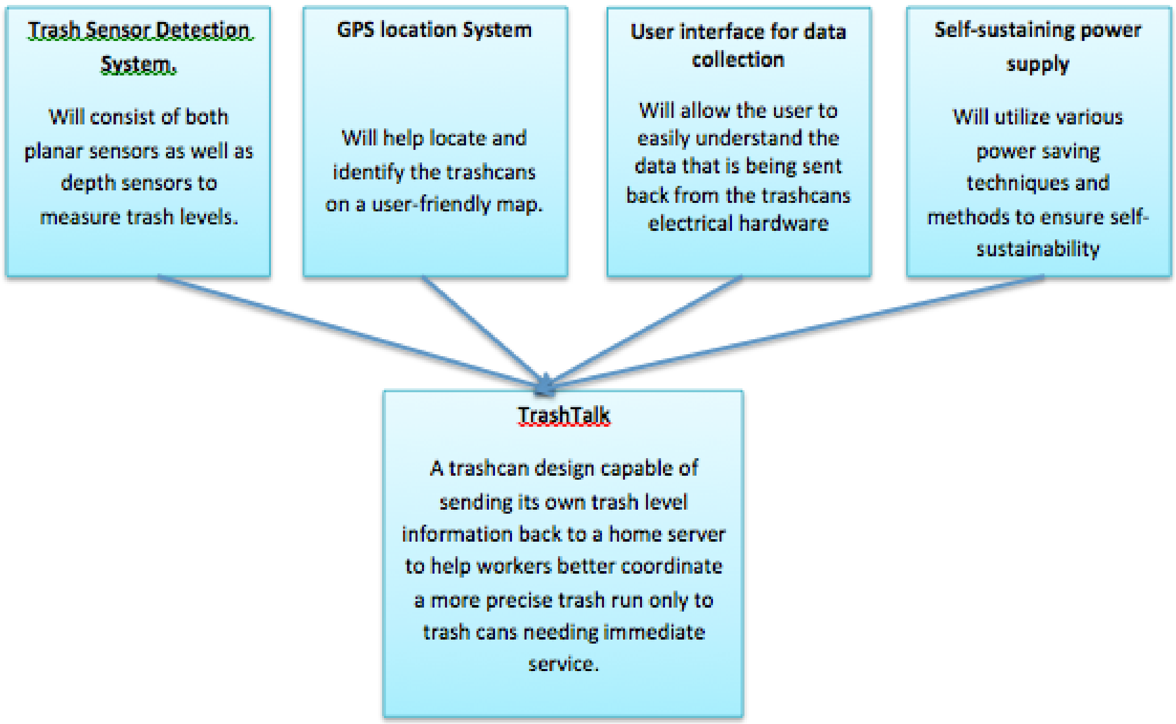


Figure 1: A block diagram of subsystems

Firstly, the user interface data collection system allows the user full access and visual representation of the information the trashcans send back to the home server. The interface will be viewed on a personal computer, which will serve as the home server. This capability allows any location to easily become the central location to view the data being sent. This is useful for workers on the move with electronics to view the home server. The user interface acts as the liaison for the human and the trashcans hardware, and allows easy interpretation of the data being collected. The system is user friendly by visually representing each trashcan as a node with a specific indication of whether or not the trashcans are full. **Figure 2** is a basic representation of how the trashcans communicate with one another and the various paths it can take to send data back to the home server. The diagram shows the majority of the possible pathways. **Figure 3** shows the nodes out of range from the home server with a red arrow. The Green arrows show a path that can be taken to reach the home server. If a trashcan is out of range to communicate with the home server, the trashcans then send its information to the closest trash can in a piggy back effect. Each trashcan node also has a specific identifier to help the user distinguish them from one another.

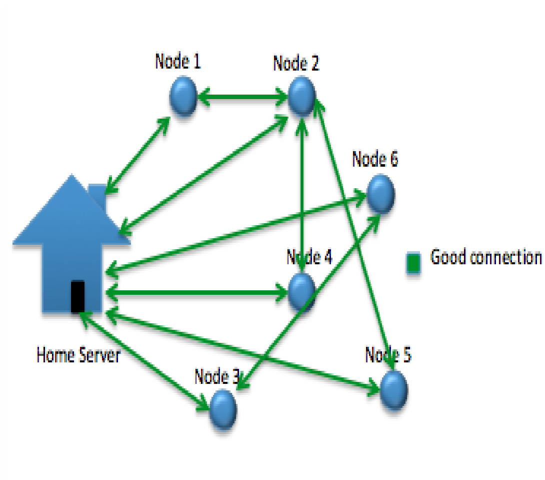


Figure 2: Home Network

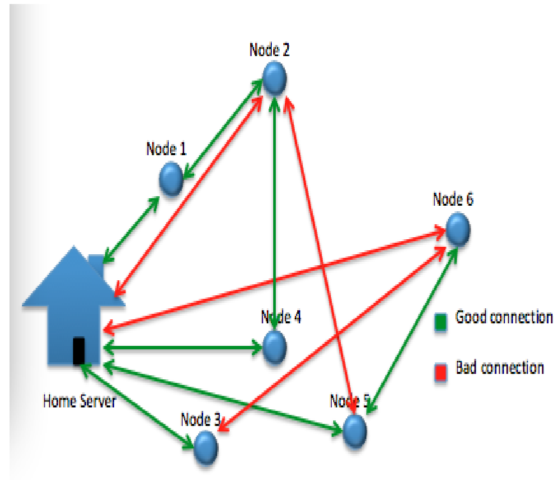


Figure 3: Nodes out of range

Next, the Trash sensor detection system utilizes planar sensors and a depth sensor. The planar sensors are located at the halfway mark of the trashcan as well as at the brim of the trashcan. Essentially, the planar sensor at the halfway mark indicates a half full trashcan when trash has breached this plane but has not yet reached the second sensor at the brim. This functionality indicates to the human looking at the user interface system that the trash level is less than 100% full but more than 50% full. The planar sensors at the brim of the trashcan once breeched along with the halfway mark sensors being breeched at the same time indicates that the trash level is 100% full. The depth sensor, is located at the top of the garbage structure looking down into the trash, and serves as the primary source of indication of the trash level. The planar sensors serve as the secondary source of indication of the trash level, and reassures or disapprove the accuracy of the primary reading from the depth sensor.

Also, the trashcans are self-sustaining and require minimum human interference by utilizing a capable onboard power system. The power system easily powers all of the electronics inside and uses both solar panels as well as rechargeable batteries to extend the trashcans lifespan enormously. The increased lifespan allows longer periods of operation while also lowering the amount of visits to trashcan for battery service maintenance. To contribute to the self-sustainability, the trashcan design uses energy efficient low powered sensors to continuously check for trash levels whenever the system is up and running. Another feature that helps with the trashcans self-sustainability for minimum human interaction is the sleep mode. Sleep mode essentially is the trashcan system in an almost dead like state with little to no power consumption. This can be adjusted by simply decreasing the frequency of trashcan status checks. Once the trashcans are needed for a new current data reading (roughly every thirty seconds) the system turns on from sleep mode do what is necessary to operate, send back compiled data to the home server, then return back to sleep mode.

Furthermore, in addition to the four unique subsystems, a self-healing network capability is implemented when trashcans are out of range from the home server. To communicate with the home server, out of range trashcans utilize other trashcans in close proximity and send its information back through them in a piggyback effect. Being able to monitor the location of only the trash cans which need attending to helps with saving gas and money by finding an effective route best suitable to reach each trashcan destination. As previously expressed, this network of garbage bins is essentially labor effective by allowing companies to better allocate manpower to the appropriate areas, instead of blindly sending workers out to each and every garbage location to be emptied every 20 - 30 minutes. Also by being able to visually see exactly which trashcans need emptying, companies can then create a more effective and efficient route to reach each trashcan. This both save garbage trucks gas consumption by having a more defined route to drive, and also save time for workers who are actually walking to and from each and every trashcan looking for trash levels. **Figure 4** illustrates the theory of operation of our project.

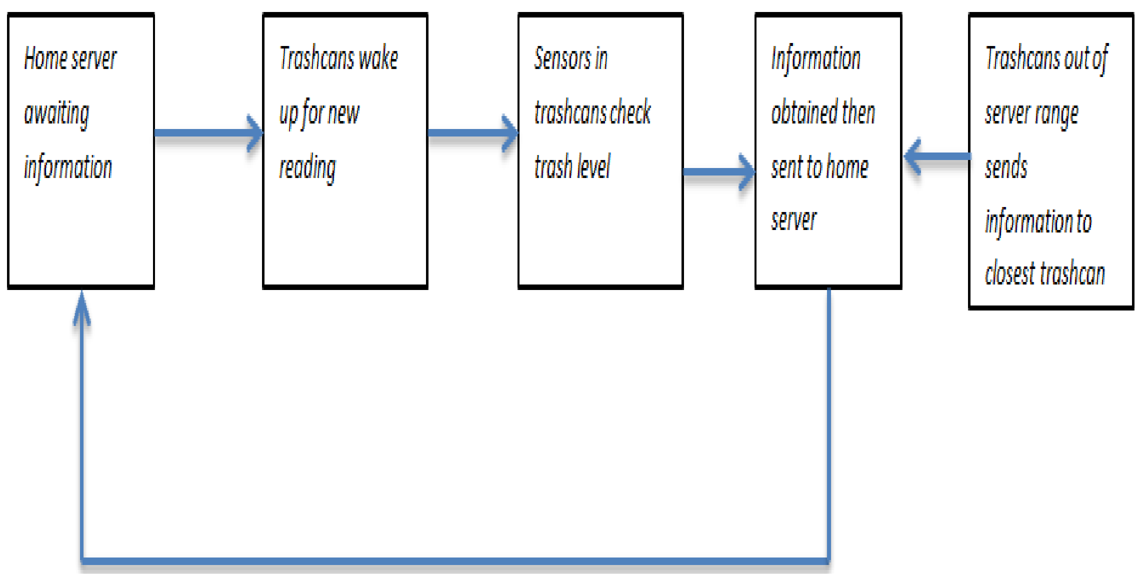


Figure 4: Theory of Operation

Going beyond the specification and details of the project design, the project is both resourceful and economical. All subsystems were scrutinized extensively to ensure that the design is logical and beneficial to society. The additional goal was to be financially conscious when building each subsystem for the project design, then incorporating them all as a whole. A strict selection method was employed to reassure that all of the appropriate materials components and materials were obtained. Additionally, through the selection process each material or part being considered had to be both of good quality as well as relatively affordable in order to even is considered for selection and addition into the total budget plan. The main and ultimate objective of the project was for it to be treated and executed as a real life corporation project in which the expectations are high and deadlines are not meant to be broken. Doing so ensured a top-notch project with a higher percentage of possible completion. Figure 5 shows a flowchart of the projects setup with arrows displaying what components are supplying others.

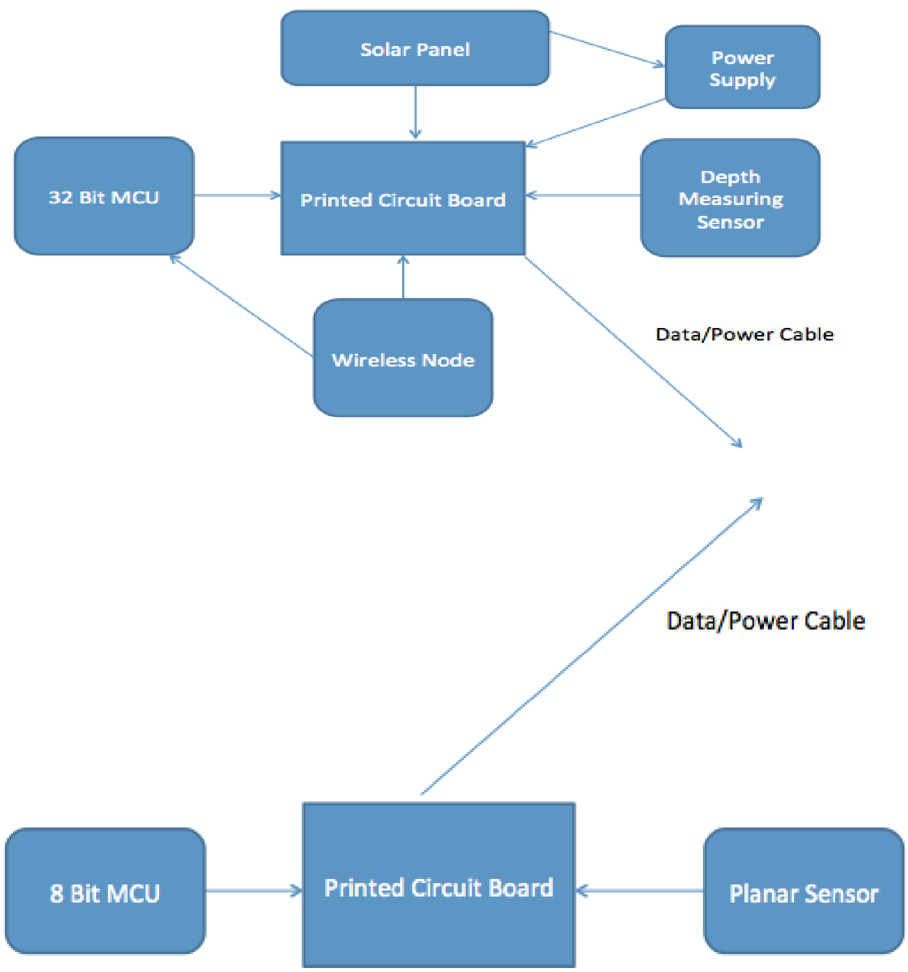


Figure 5: Flow chart of subsystems together

1.2 Project Specifications:

1.2.1 Specifications for Trashcan System:

The trashcan system is responsible for gathering information about the trashcan. The information gathered determines the status of the trashcan.The trashcan uses sustainable energy. Recharable batteries are used to power the trashcan system. Solar panels are used to recharge the batteries. The sensors return data to determine if the trashcan is full or not. Wireless communication is used to share data collected from the sensors.

- The system uses rechargable batteries as the main source of power.
- The system uses solar panels to recharge batteries.
- The system uses wireless communication to send and retrieve data.
- The system has two sensors to detect trash levels.
- The system communicates with the public users.

1.2.2 Specifications for User Interface:

The user interface is responsible to display the information of the trashcans. Information includes the location, the status, and the time last updated of each trashcan. It also gives the user additional information so that they know what different entities are represent on the map. The user interface gives the user the option to edit the system.

- The system is accessed via a website.
- The system displays three main components: a map, a map legend, and a status list.
- The system provides the ability to move the map to see locations not currently displayed on the map.
- The system provides the ability to zoom in on the map.
- The system provides the ability to zoom out of the map.
- The system displays the location of each trashcan with a marker.
- The system shows the status of each trashcan by color.
- The system shows what each colored marker on the map represents.
- The system lists each trashcan along with its identifer number, status, and the last time it was updated.
- The system provides the user the option to log into the system for more options.
- The system provides the user the option to look back at past history of trashcan statuses.

1.3 Tasks Assignment:

In Table 1, list the different components of Trash Talk and which team member is responsible for that section.

Component	Team Member
Trashcan	Rahn Lassiter
Power Supply	Jaquan Hodge
Microcontroller	Errol Bozel & Rahn Lassiter
Printed Circuit Board	Jaquan Hodge & Rahn Lassiter
LCD Display	Errol Bozel
Wireless Communication	Errol Bozel
Database	Paula Nguyen
User Interface	Paula Nguyen
Software Implementation	Paula Nguyen

Table 1: List of Components and Responsible Team Members

1.4 Milestone:

Goal	Date
Rough Draft of Paper	November 12, 2012
Final Paper	November 20, 2012
Begin Building	December 17, 2012
Test Phase	February 4, 2012
Finish Line!	April 1, 2012

Table 2: Milestones with Goal Dates

Table 2 is a list of milestones for this project. The Date shown on the table is the goal dates that the team had made early in the project. The research and design of the project took about three months. The implementation of the project took about four months. The new list of milestones is shown in Table 3.

	Start	Finish
Trash Talk	Sept 14, 2012	April 22, 2013
Senior Design 1 Paper	Sept 14, 2012	Dec 4, 2012
Power Supply Research	Sept 14, 2012	Nov 30, 2012
Trashcan and Sensor Research	Sept 14, 2012	Nov 30, 2012
Board Research	Sept 14, 2012	Nov 30, 2012
Software Research	Sept 14, 2012	Nov 30, 2012
Order Parts	Dec 17, 2012	Jan 21, 2013
Build Prototype	Jan 2, 2013	March 4, 2013
Software Development	Dec 17, 2012	March 18, 2013
Hardware Development	Dec 17, 2012	March 18, 2013
Testing	Feb 18, 2013	April 15, 2013
Presentation	April 22, 2013	April 30, 2013

Table 3: Milestone Table with Start and Finish Dates

1.5 Project Budget:

The final budget, which the group collectively put together, was created solely on the possibility that a sponsor would not have been obtained. It was agreed upon, that the project would be as economical as possible, as to ensure a low total amount paid for initial building of the prototype. The main objective was to approach the project from a resourceful and conservative perspective. The group wanted to approach the project as if it was a real life scenario at a corporation. If eventually produced in mass quantity to the public, the finished product should be able to stand out from future competition by being extremely unique as well as self efficient.

Realistically the budget was decreased as low as possible. It was agreed to make the lowest possible budget as well as choose the best quality products for the set price range. This was accomplished by treating both entities with the same priority. Making the budget too low would ultimately result in a poor made product that would not be marketable or competitive. To be competitive and relevant in a big market, the product was made to possess good qualities that did not become too expensive when it was implemented and created. The qualities, which were chosen, that affected the overall budget were, being economical, eco-friendly, self-sufficient, logical, and easily understandable to learn and use by anyone. All of these factors were consistently referenced when decisions were made to add particular parts and components to the budget. The initial component list was compiled and put into a table initially. Table 4 displays the initial list of components and items needed for the project with the estimated prices. The table displays the initial expected total amount the group expected to pay for completion of the project before extensive research and analyzing was done.

Once the basic component list was completed and all the necessary parts and prices were obtained, the list was than further analyzed for any possible lower costing part alternatives that would still be able to compliment the overall project. It was believed that by sticking to this selection process, the overall budget would continuously keep shrinking and become more economical. This selection processed proved itself very useful for the group. The selection process method helped make the group continuously look at the components on the list for any un-necessaries. Continuously monitoring both the component list and the expected overall total made the budget look more appealing and realistic and ultimately helped secure a sponsorship by Progress Energy.

The Selection process and vigorous screening the group adhered to helped cut back on unnecessary spending. The vigorous screening was in preparation for the worst-case scenario in which a sponsor was not obtained and the group members were personally responsible for the project financing. Fortunately a sponsorship was obtained. This selection process and vigorous screening method benefited the group by constantly lowering the projects total cost and improving the final budget. The selection process for the budget was also beneficial to the group twofold. First by giving the group members real life experience at managing and lowering the total budget to as low as possible. Secondly, the selection process indirectly forced the group members to learn more about the overall design of the project. The additional learning of the overall project design was made possible by forcing the group to analyze everything involved in the design to ensure everything was necessary. After looking at everything involved, the group then was able to make important decisions as to what parts or features could be eliminated without affecting the projects normal operation.

	Nomenclature	Part Number	Cost (ea)	Quantity	Total Cost
1	Distance Measuring Sensor	GP2D12	$25.00	2	$50.00
2	Analog to Digital Converter	ADS7841E	$20.00	4	$80.00
3	Planar Sensor	N/A	$25.00	3	$75.00
4	Commercial Grade Trash Can	N/A	$300.00	2	$600.00
5	Mounting Supplies	N/A	$60.00	3	$180.00
6	Enclosure	ML-58F*1508	$50.00	2	$100.00
7	Wires	278-1215	$10.00	5	$50.00
8	Microcontroller		$90.00	3	$270.00
9	Wireless Node		$90.00	3	$270.00
10	Solar Panels		$60.00	4	$240.00
11	GPS		$110.00	2	$220.00
12	Misc		$100.00	1	$100.00
13	Rechargeable Batteries(4 Pack)		$20.00	3	$60.00
14	Power regulator PCB Board		$90.00	3	$270.00
				TOTAL	$2,565.00

Table 4: Initial Budget Plan

1.5.1 Budget representation

After the selection process was complete, a new list of components and items was compiled. An overview of the budget plan is listed below in a spreadsheet form in Table 5. The final budget displayed is the most economical and logical option for the current time of completion. The budget list compilation process took into consideration the overall design quality the group wanted to obtain. Parts selected were economical but not subpar. The budget total is now set and have endured many changes and alterations and have ended at the following table. These various alterations and changes were made due to newfound alternatives, which were more economical for the overall project development.

	Nomenclature	Part Number	Cost (ea)	Quantity	Total Cost
1	Distance Measuring Sensor	GP2D12	$9.00	2	$18.00
2	Analog to Digital Converter	ADS7841E	$10.00	3	$30.00
3	Planar Sensor	N/A	$10.00	3	$30.00
4	Trash Can	N/A	$300.00	2	$600.00
5	Mounting Supplies	N/A	$10.00	2	$20.00
6	Enclosure	ML-58F*1508	$50.00	2	$100.00
7	Wire	278-1215	$10.00	3	$30.00
8	Microcontroller		$65.00	3	$195.00
9	Wireless Node		$85.00	2	$170.00
10	Solar Panels		$60.00	2	$120.00
11	GPS		$110.00	2	$220.00
12	Misc		$100.00	1	$100.00
13	Rechargeable Batteries(4 Pack)		$15.00	3	$45.00
14	Power regulator PCB Board		$45.00	2	$90.00
				TOTAL	$1,768.00

Table 5: Budget Plan

The two pie charts Figure 6 and Figure 7 show the initial projected budget for the project and the final improved budget after the selection process. The second and improved budget confirms the success of the selection process method. Both Budget Pie charts show a visual representation of how the project funds would be allocated to each subsystem as well as any remaining area of the project, which would need funding. The First pie chart Figure 6 was created with little to no research involved. The second pie chart Figure 7 is a visual representation of a redefined final budget list with extensive research and various alterations made. Figure 8 shows a bar chart representation of both the initial and Final Budget plan side by side. The bar chart shows the money saved from the cutbacks and alterations made to the major subsystems that required the most funds. The total projected savings was easily close to a thousand dollars.

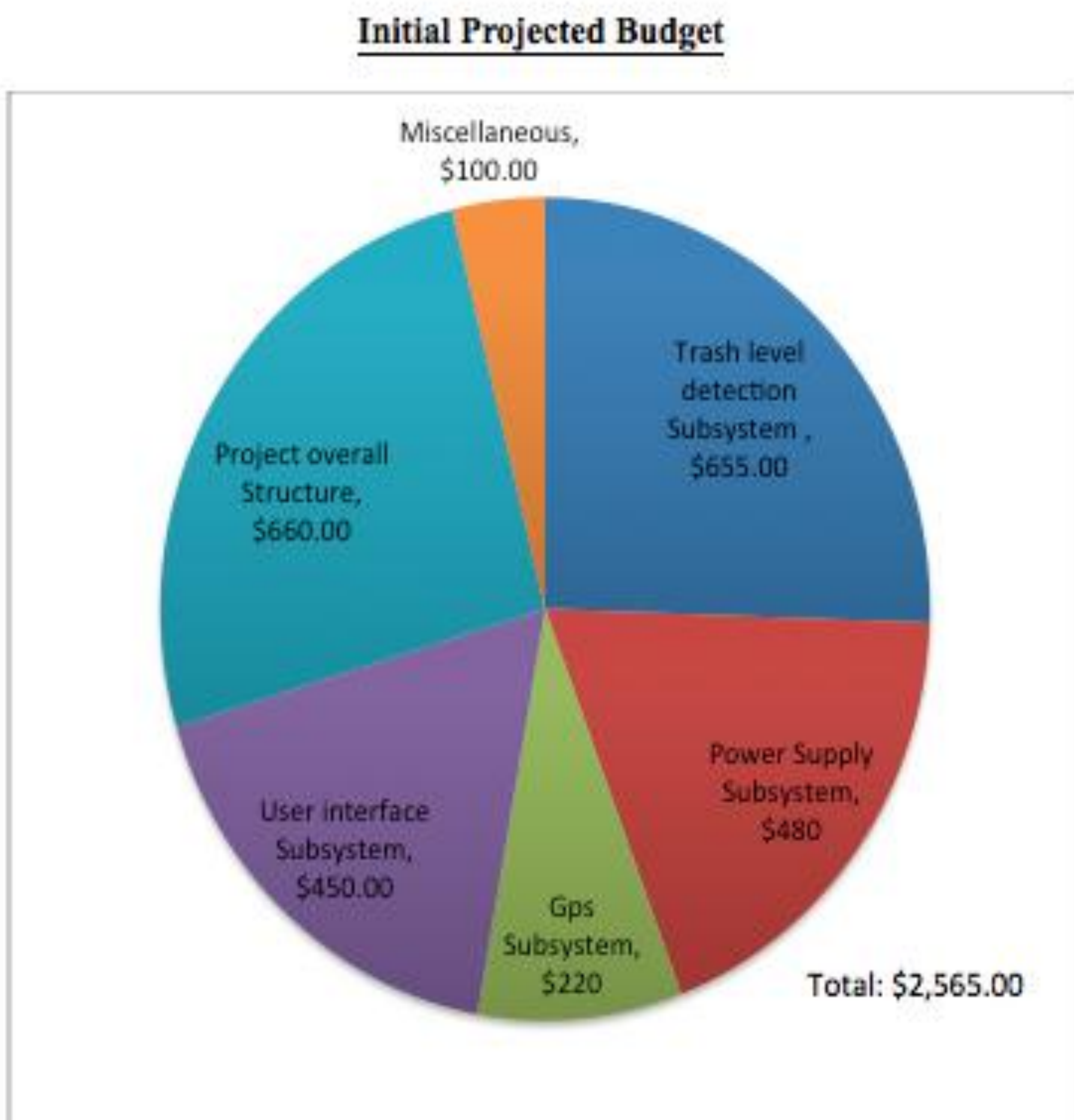


Figure 6: Initial projected budget pie chart

Final Budget

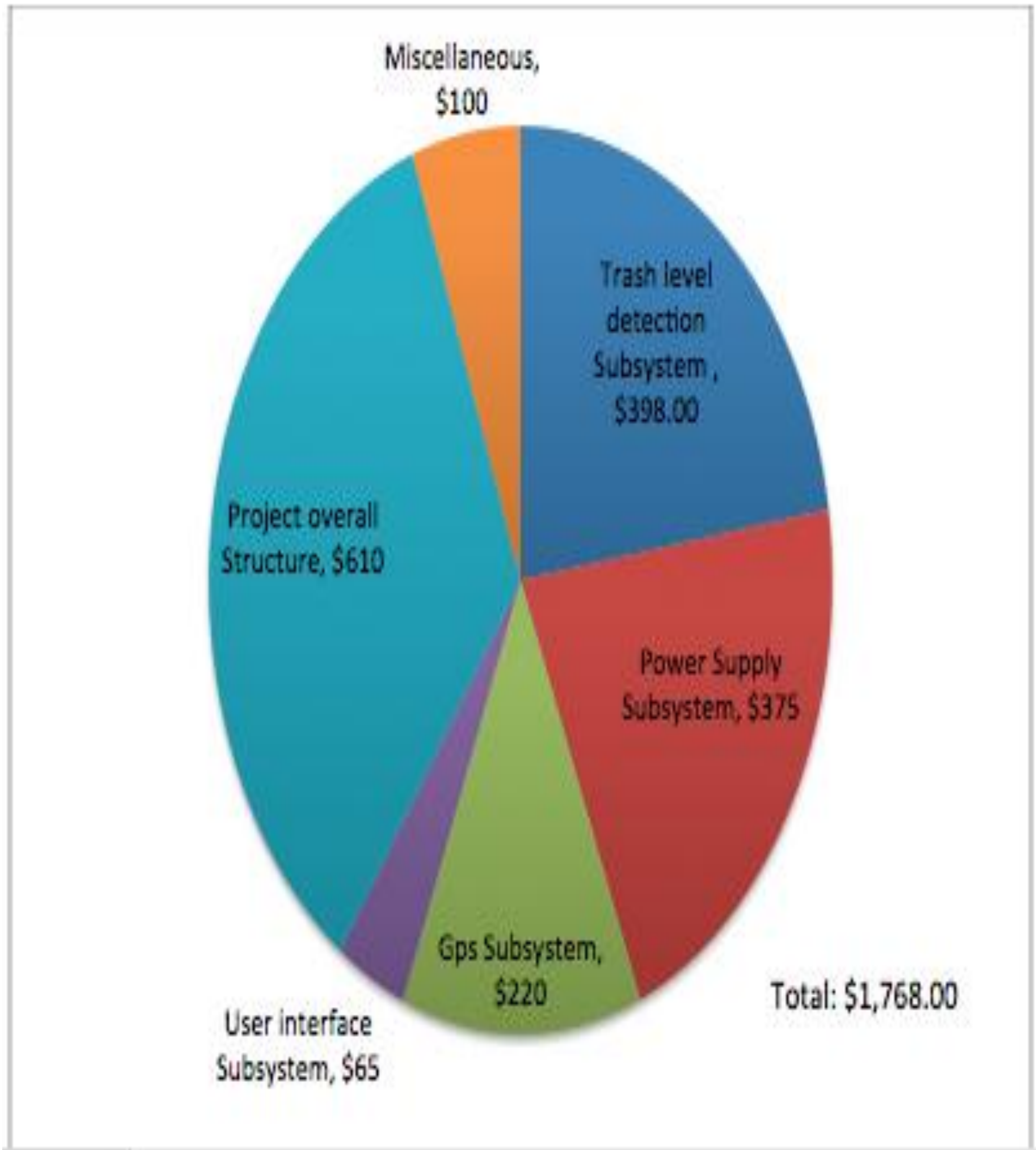


Figure 7: Final budget pie chart

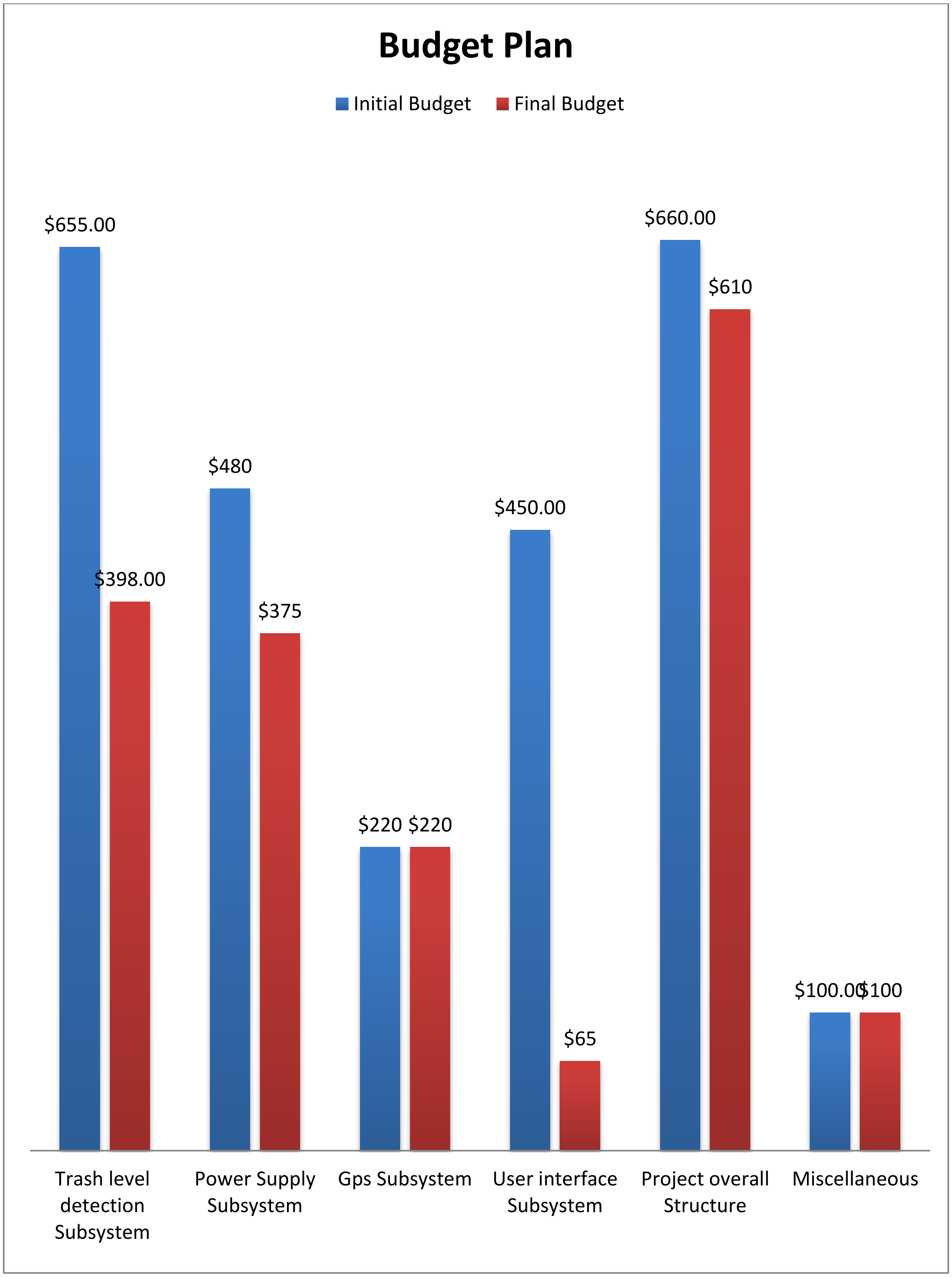


Figure 8: Initial vs. final bar graph

1.5.2 Financing:

Financing of the project ultimately consisted of sponsorship from Progress Energy, and some personal funding split evenly amongst the group members. Although Progress Energy was the Primary source of funding, each form of financing presented advantages as well as disadvantages, which influenced the group's overall productivity.

Financing of the project through sponsorship essentially was very appealing for the simple fact that it showed the advantage of providing little to no monetary contribution from the group members. Unfortunately, the group still endured the financial burden of the project until reimbursement was approved and dispersed back to the members. Another disadvantage of receiving funding from just sponsorship was the pressure and sense of urgency the group members felt to complete the project perfectly for the sake of the sponsor. The disadvantage just listed also was seen as an advantage or motivation from the perspective of the group members. Feeling the urgency to complete the project as fast and effective as possible helped make the project come together.

As said already, the sponsorship made the group feel a stronger urge to set more frequent and realistic goals. These goals were more easily obtainable with limited creativity in order to ensure completion. Setting the easily obtainable goals reduced the risk of failure, and ensured the ability to deliver for the sponsors in a timely manner. After the easy goals were completed and obtained, the group then decided to add more features. The group saw that it was wiser to being more realistic and less creative when someone else's money was being allocated to the project. It is understood that the sponsor expects a 100% achievement rate, with little to limited failure. Sponsorship was good a option for a disciplined group that knows what is expected of them and know they will get the job done. Another disadvantage that was made apparent about having the project funding solely from a sponsor was the cap on the money given. The group would have to work only with what was given. Fortunately, the money given for the project was enough to cover the project design, the group members then had to re-analyze their design and make changes to lower the allowed budget. This lowering of the budget also called for the elimination of some features of the design and the downgrade of some of the components being used. Overall, these changes resulted in a subpar product limited to the components that are affordable.

Financing of the project solely through the personal funds of the group members ultimately was the option picked that also presented some advantages and disadvantages. One advantage of personal funding from the group members was the increase in creativity, due to the fact that the members would understood that anything added was their responsibility to pay for. Knowing that one's own money is being allocated to a project reduces conservative thinking. Members were more willing to experiment with personal money with less expectation of achievement because no one would be disappointed other than themselves. The disadvantage of personal funding solely from the group was procrastination due to having to pay out of pocket. Group members may procrastinate and make longer deadlines because no one is counting on them and indirectly applying pressure. The group may also be too creative for their own means and think of a project that is not possibly feasible in the limited time given. The last disadvantage of personal funding could possibly be the situation in which the group is not financially capable of funding the project.

The last financing option that the group was interested, which was the actual one selected, was a combination of both sponsorship and personal funding. This funding option was mandatory since the sponsor did not release the funds in the beginning. In actuality this option was then most suitable for the group because it supplied the best of both options. The combination funding option would give the sense of urgency and applied pressure necessary to keep the group members focused. The fact that the members had to come up with the money initially before being refunded also helped the group be more conservative as to avoid paying too much out of pocket. The group members set more frequent and realistic goals to ensure success for the sake of the sponsor. The option allowed the members to be more creative and experimental to an extent since the project funding was partially the responsibility of the members. This option also allowed the members to ensure a good product with no budget cutting on any components or features by allowing more overall total funding. After analyzing and comparing the disadvantages and advantages, the combination option was used and most beneficial to the group.

1.6 Project Application:

Other than the large-scale Waste management application, another application for this system could be with a small company called Resident Services. They provide a variety of services, in particular, trash removal services for residents in apartment complexes. The current method for collecting trash from residents is to issue each member who has an account a roughly eight cubic feet box and the box is placed outside each member's apartment. Three days a week, someone will come by and pick up the trash bag(s) from each of the containers. The current system at one particular complex, Tradition at Alafaya, involves the person responsible for removal walking by each member's apartment to check the contents of the trash box. A map of the apartment is shown in Figure 9. Since the distribution of members of Residents Services is random, they essentially just walk past every apartment in the complex and check the boxes that they come across. The apartment complex is huge and spaced relatively far apart, as seen in the map below, and covers eleven buildings, which have three floors each and each floor has an average of five apartments.

This means that the Residents Services representative has to walk past roughly 165 apartments when in all actuality; approximately half of the residents are subscribers to the service. Also, since the amount of trash bags that they are able to carry is limited, they end up basically doubling the distance that they cover during any given visit. Utilizing the Trash Talk system, Resident Services could use either the planar sensor or depth measuring sensor to figure out if a resident has trash ready for pick up. They could also use the map or GPS portion of the system to schedule a more efficient route through the apartments, limiting their time and distance traveled, therefore saving the company money.

Figure 9: Map of residential area

1.7 Project Motivation

Motivation is an intangible natural desire that can lead to the production of magnificent things. An increase of motivation can also lead to the creativity that helps Engineers and Designers overcome obstacles and situations that were thought to be insolvable. This is why it was agreed that it was crucial to search and come up with a project interesting enough to greatly motivate the group on its on merit. Such interest would keep the group members passionately involved and intrigued.

Going beyond the general expectations of the group, motivation for the project came from the mutual interest that was shared. Along with the mutual interest, was the overwhelming eagerness to see the final design built. When initial research was conducted, the group wanted to explore the possibility of a project that would accommodate everyone’s collective mutual interest as well as individual interest.

The main interest of the group, which was incorporated into the projects final design and/or selection were the following; the project had to be something that either directly or indirectly improved the current living conditions of the people of society, had to be eco-friendly and not directly contribute to the pollution of the world, had to have a moderately difficult hardware component which would challenge the Electrical Engineers during the building stage, also had a moderately difficult programming component that would challenge the Computer Engineering student during the building stage.

In addition to the interest listed previously, the project had to be easily marketable and economical in the case that mass production becomes an option later on down the road. The project also had to be self-sustainable with minimum human interference. Lastly the project had to be user friendly and easy to maintain. The project was designed in a way in which, anyone can understand and use it. General maintenance does not require a specialist.

The list of shared interest from the group was constantly referenced during the brain storming and researching stage. It was understood that carefully selecting a good project idea would be beneficial to the group's productivity. A good sound idea that would incorporate all of the interest would allow the project design to be more unique and significant to the group.

1.8 Project Selection process

After much research and analysis, a previously done project seemed to identify and encompass everything that the group wanted. The previously done project was named Smartrash, and was completed by a group of engineering students from Boston University. The concept of the project was interesting because it addressed an inadequate procedure, which could easily be fixed. The students addressed the fact that big cities and big corporations such as theme parks did not manage their huge influx of trash as exceptionally well as possible.

The better method of management, which was presented by the project design, proved more beneficial than detrimental once implemented. Improving the trash management procedure into an easier and more exceptional method ultimately cut total cost allocated to it. The improved method also saved time while simultaneously increasing productivity. This was definitely a key reason that cities and theme parks would be interested in the design and see a practical use. Having practical use was a must. The group understood that it serves no purpose to create or design anything that cannot be seen being used in the real world.

Although at first glance, the project seemed like a right fit, further scrutinizing was necessary. A good or bad design/idea can drastically change a group of Engineers motivation and dedication towards its completion. To ensure that the project was a good choice, that would inspire the group members, it was compared to all of the group members' initial interest to see if it complimented them. The project idea would be selected only if it accommodated 80% or more of the expectations set forth.

The first interest comparison was whether or not Smartrash project design can directly or indirectly improve the living conditions of the people of society. If the project design were used in frequently visited areas such as public parks in New York City or Chicago, it would positively affect the living conditions of society. In places like public parks, park maintenance workers routinely walk around to various different trashcans constantly and empty them out whether or not they are completely full. All of this trash is then transported to an area for a garbage truck to pick them up and transport them to a landfill or recycling facility. Instead of having constant random truck runs. A better-managed trash system would essentially require the garbage trucks to arrive for pickup less time. This in essence would lower the fuel being burned, which contributes to the air pollution. Although minor, the small improvement that the project design would create would help the people breath less pollutants.

The second interest was whether or not the Smartrash project design was eco-friendly. The project design was self-sustainable by utilizing the capabilities of a solar panel and rechargeable batteries. The Smartrash idea was no different than a regular trash can. It did not require any building or interruption to the surrounding environment. The design also did not require any harsh chemicals or radioactive components, which could possibly be harmful to any surrounding organisms. By utilizing the capabilities of a solar panel, the design is able to use the sunrays to help power onboard components.

Also, the chosen project design had to be something, which was moderately difficult for both the Electrical Engineering students as well as the Computer Engineering student in the group. Interesting enough, the project design required much time and dedication to complete. The project had a number of electrical hardware components such as sensors, printed circuit board's and microcontrollers as well as computer-based components such as the user interface and location maps which all needed to be incorporated together. The project presented a few challenges, which were intentionally welcomed by the group.

The chosen project design had to be easily marketable as well as economically possible to produce on a mass scale if ever taken serious enough. The Smartrash design was both. The Smartrash design that we considered was easily marketable since it can possibly drastically save big cities and theme parks money. That alone shows that the design already has a targeted client list that would be interested if ever taken serious. The design is also economical since it does not require too many components to create.

Lastly, the possible chosen Smartrash design had to be relatively easy to learn and understand by anyone. It also had to be easy to maintain if necessary. The Smartrash design is not a very complex design. The fact that is has very few components helps with the easy maintenance of the overall system. Being easy to learn and maintain additionally cut down total cost by eliminating any "specialist" which would be necessary to troubleshoot the system.

After being stacked against the group's interest, the Smartrash project designed proved to be a good fit. Being a good fit and being able to accommodate the group's entire initial request, made the choice significant. Having the project incorporate all of the interest that was initially discussed helped stamp the design with the signature of the members. The quality and time invested into the project would help consumers meet the members through its design alone without having to physically see anyone if mass produced. Finding the right project fitting that criteria surely increased the interest level and dedication to complete it. The selection process deemed itself useful and was appropriate to get started with re-creation of the Smartrash project design from Boston University.

Figure 10: Free trash can

2. Trash Can

The trash can is, interestingly enough, one of the most important parts of the design of the Trash Talk system. Since the intent of the project is to develop a monitoring system that can be employed by areas such as parks, the idea is to use a trash can that is "typical" of one that you would find in a public area. From the research that was gathered on trashcansource.com, the prototype should be able to hold about 38 gallons and be about 36 in tall. The trash can pictured below was the priority choice for the prototype. The reason for this is the UCF LNR department donated the free trash cans to us.

2.1 Specifications

The minimum specifications of the trash can for the prototype are outlined in the Table 6.

Dimensions (inches)	30H x 18W x 18D (rectangular)
Dimensions (inches)	30H x 20D (circular)
Capacity (gallons)	38

Table 6: Trashcan specifications

Figure 11: Ideal Trash Can for Prototype

2.2 Type

The type of trash can that would be the most beneficial to use is a square, plastic trash can for mounting everything but due to a limited budget, the donated round receptacles have priority. The trash cans that were available from the LNR department are made out of steel. The trash can has a hinge on one side which provides a swinging door on the other. This allows for placement and removing of the rigid can liner. This also gives the capability to mount the planar sensors on one side more easily. The lid of the trash can for the prototype was not weather proofed due to funding. It is also made of steel but much thinner than the rest of the trash can. Flaps were not used to protect the laser from the elements but the sensor is positioned so that if the flaps swing outward, they don’t obstruct the sensor. We left the lid welded to the body and mounted the sensor inside of an enclosure. There were no conduits placed in the body of the trash can for wires. The ideal trash can is shown in Figure 11. It is made of plastic and is only missing flaps to protect the sensors from the elements. The exterior can be easily modified to accommodate any additions and it is inexpensive.

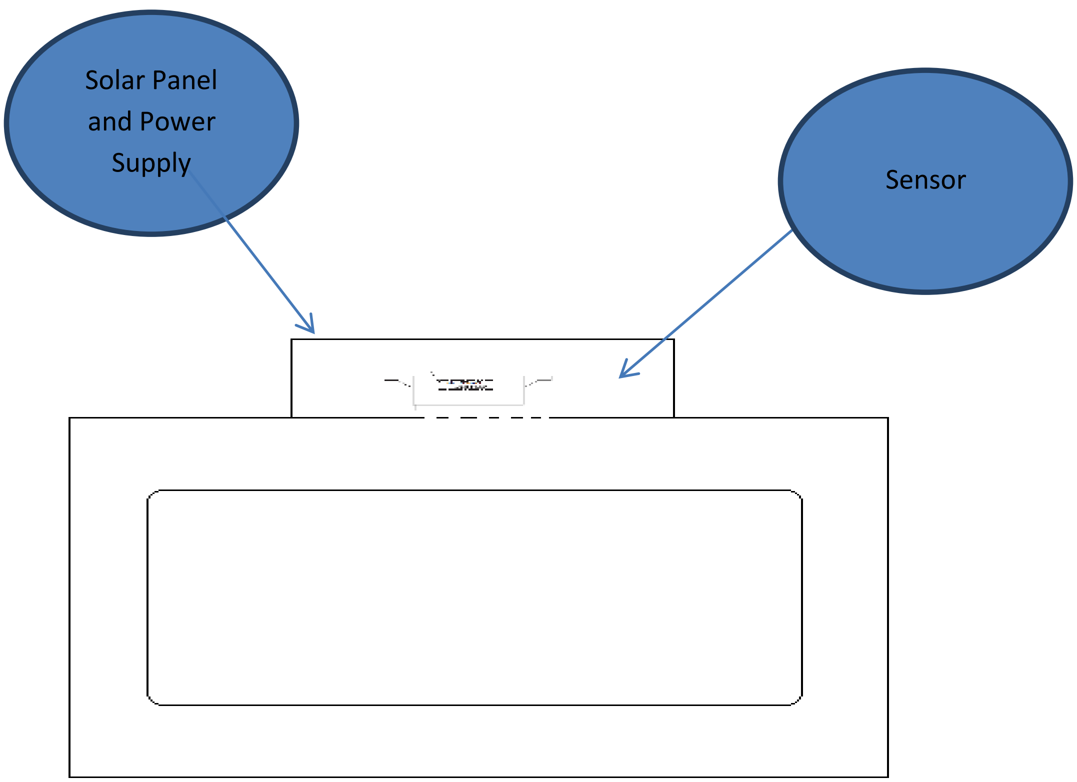


Figure 12: Lid Side View

2.3 Mounting

The positioning of all of the components of the trash can and the lid is pivotal. As stated earlier, the best approach is to have a lid connected to the body with a hinge but this would have required the use of a grinder to grind off a few welds connecting the lid to the body. The depth measuring sensor is mounted on the top, middle of the lid to achieve maximum accuracy. A hole was drilled into the center of the lid to route the sensor wires through. All of the supporting circuitry and power supply is mounted on the top side of the lid in an enclosure as pictured in Figure 12 and Figure 13.

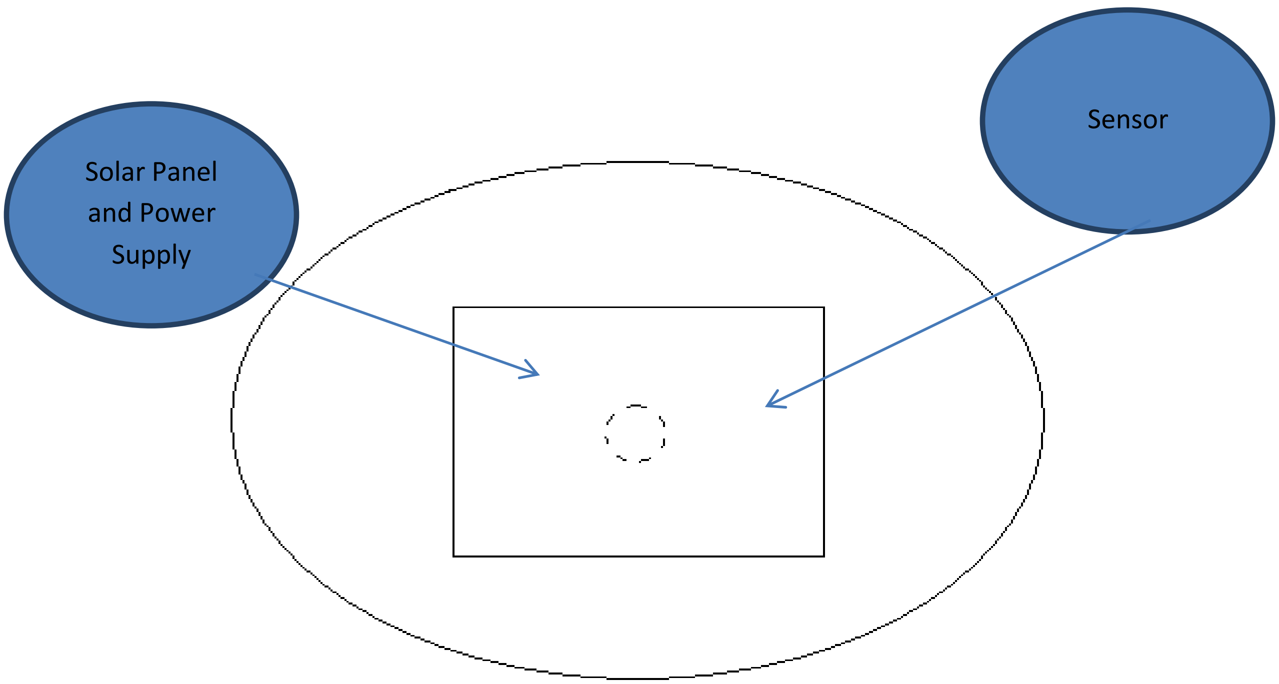


Figure 13: Lid Top View

The planar sensors are mounted on the inside of the barrel, spaced evenly at the middle and the top of the rigid can liner. The sensors and supporting circuitry is mounted on the inside of the rigid can liner with the sensor flush with the edge and on the side of the receptacle. This is shown in Figure 14.

Figure 14: Can liner and sensor Mounting

3. Power Supply Subsystem:

The self–sustaining power supply is important and unique because it powers the other subsystems. Having a capable power supply is essential to the completion of the project. The power supply subsystem is adequate enough to supply the necessary power to any and all components in the project design architecture. Going beyond being strong and capable, the power supply also utilizes some sort of sustainable energy method. The group agreed that a high priority when building the power subsystem was to ensure that the system did not contain any harmful entities. The Subsystem design was thus made efficient without any components or parts that is harmful to anyone coming across the prototype.

3.1 Power Supply overview:

Each trashcan structure uses the same power supply subsystem for its electrical hardware. The power supply subsystem supplies all components simultaneously. The entire power system is controlled by a printed circuit board (PCB), which was designed to regulate the voltage and accurately recharge the batteries onboard the system. The printed circuit board also ensures the proper voltage amount is being allocated to the Micro Controller Unit . The power supply system for each trashcan uses 6 rechargeable AA batteries. AA batteries were chosen because they are a moderate size, and supplied the necessary amount of current required for the components in the design. Figure 15 shows the visual representation of the battery shape and style, which was used in the power system design. To eliminate any possible problems due to too many battery types, the AA battery model is the only battery used for anything requiring power within the system.

Figure 15: A battery

The design uses at most 6 AA rechargeable batteries supplying an average of 1.5 volts and 2400mAh. The batteries are connected in series. The four consecutive batteries supply a total average voltage of 9V and a total average current of 14400mAh. The batteries are continuously being charged by a 12V solar panel supplying a total of 1000mA of current. Figure 16 shows a block diagram representation of the setup for the power system with a general idea of how it works. The solar panel supplies the necessary current to charge the 6 batteries connected in series. The printed circuit board accepts the current being applied and then automatically supplies it to the batteries only when they have depleted to a terminal voltage level below acceptable for the circuit to operate effectively. The specified setup of the Power system design, which utilizes the solar panels, extends the systems life cycle before battery replacement to about 8 months. The system life cycle time is only an estimate. After completion, the system can possibly exceed the time given by a lot more. The time allotted for the project was not sufficient enough to complete the testing of the actual life expectancy.

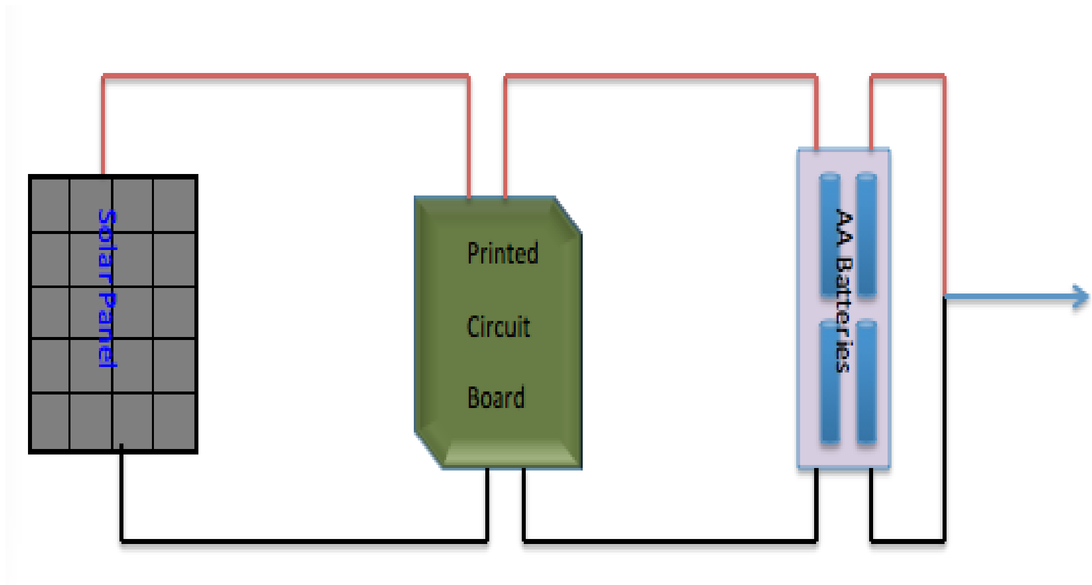


Figure 16: Block diagram of power subsystem

Initially, the power supply design was going to make use of just batteries alone. The group then agreed that using rechargeable batteries and having a way to recharge the batteries would lessen the amount of human interference by extending the batteries lifespan. A solar panel was than incorporated to make the battery life extension possible. Using the solar panel was easier to incorporate into the design instead of having to build a whole new charging component for the batteries. Having to possibly build a separate charging component would have required more time and research which would have consequently added an additional subsystem.

3.2 Battery description and selection:

The battery selection process was a relatively easy task to do. The most important objective was finding the appropriate battery that best accommodated the needs of the project. It was crucial to research the different batteries and compare their strengths and weaknesses. The battery must be able to last for a long period of time without easily losing its terminal voltage. The battery must not contain a poisonous or toxic component that can harm people and the surrounding environment. The battery must not supply above average voltage, which may be harmful to the sensitive electrical hardware involved in the project design. The average voltage maximum that will be used in the power system project design will be 1.5 volt. The batteries must be easily obtainable for any sudden problems, which may occur. Although rechargeable batteries are appealing and ideal for the project design, regular single use batteries will still be analyzed for possible use. The Single use batteries may provide some advantages not found in the rechargeable batteries. All of the different batteries will be researched then stacked against each other to see which one is most suitable for the project design. The compiled battery list will consist of the following battery types: Nickel-Metal Hydride (NiMH) rechargeable batteries, Nickel-Zinc (NiZn) rechargeable batteries, Nickel-Cadmium (NiCd) rechargeable batteries, Lithium-ion rechargeable batteries, Lithium single use batteries, and Alkaline single use batteries.

Nickel-Metal Hydride rechargeable batteries are steady voltage batteries, which supply a consistent voltage of 1.2V without a load. With a load the battery drops to about 1.1 volts. The NiMH battery has a recharge cycle of between 150-500 times. The battery discharges by itself at an average rate of 1% a day. On a monthly scale that self-discharge rate is roughly 40%. The self-discharge rate is the rate in which the battery discharges when not in use. The best and ideal use of the Nickel-Metal Hydride battery is its use in high drain devices that are constantly operating. The steady voltage rate supplied by the battery allows for consistent operation with little decline in performance. Ex: If used in a flashlight, the light will constantly shine bright instead of constantly dimming drastically as the battery depletes in energy. The battery is also capable of performing well in both cold and hot weather. Also the battery is recyclable and not harmful to the environment. As touched on briefly, the main disadvantage for the NiMH battery is its large self-discharge rate. The battery discharges drastically overtime when not in use. The project was designed in a way in which it will stay in a sleep mode as much as possible. The sleep mode essentially put the entire system into a nearly off state. This battery was chosen for the system. Although the battery is known to discharge drastically when not in use, the battery surprisingly held up well in the power system. The batteries terminal gradually discharged over time. If constantly discharging when not in use, the batteries would require more constant recharging which would decrease the total recharging cycles the battery has.

Nickel-Zinc (NiZn) rechargeable batteries have a high terminal voltage averaging around 1.6V. The terminal voltage for this battery can reach an astonishing 1.8 volts. 1.8 volts is relatively high when compared to the other batteries that have an average terminal voltage of about 1.3V. In the project design, a very high voltage was not necessary. Although the high voltage was not needed or necessary, having batteries with high terminal voltages could have been beneficial if the electrical hardware could withstand it. The good thing about the high terminal voltage was the ability to still supply an adequate amount of volts to the hardware when the terminal voltage drops. Ex: If a system is capable of utilizing voltage between 1.1-1.8V and still function correctly, the 1.6 average terminal volts NiZn battery would then have a larger window to operate effectively while depleting. The NiZn battery has a recharge cycle of between 400-1000. The battery has a large enough number of recharging cycles to expand the lifespans of the system. The battery is also environmentally friendly by not containing any elements that are harmful or difficult to recycle. The disadvantages that the battery presented were its low availability commercially. The Nickel-Zinc battery model is not as widespread and available as other commonly used batteries such as Alkaline. Its low availability would have presented a problem in a situation in which the batteries in the system suddenly malfunctioned. The batteries are hard to find which in turn would delay the projects operational time. Also the Nickel-Zinc batteries are relatively expensive when compared to easily accessible batteries.

Nickel-Cadmium rechargeable batteries have a steady state voltage of around 1.2V. The self-discharge rate is similar to NiMH batteries in which it loses roughly about 40% of its charge a month when not used. The estimated number of recharging cycles is around 1500. The large number of recharging cycles could have been beneficial to the project design in the long haul. The large number of recharging cycles enables the system to last longer by having a lot more possible opportunities to be charged. The Nickel-Cadmium battery is also durable and able to sustain some harsh conditioning. It is able to sustain various different weather changes in many locations. It is able to function properly in weather ranging from 10 degrees Celsius to 60 degrees Celsius. The Battery's durability allows it to be best suitable for high temperature electronics and high drain components. This type of battery is ideal for components such as tools, radios, and etc. The advantages that the Nickel-Cadmium battery presents are having a large recharging cycle number. Additionally, the battery's steady state voltage ability made it initially an appealing choice for the project design. The steady state voltage could have ensured that the projects components would have consistently received the same terminal voltage throughout the battery's lifespan. The Nickel-Cadmium battery has the most recharging cycles. This feature as previously mentioned was initially very appealing because it could have helped ensure the improvement and extended lifespan of the whole power system. This battery choice is also more easily accessible then other choices such as the NiZn battery option. The Nickel-Cadmium batteries are also more affordable then other batteries such as the NiZn option.

Lithium-ion rechargeable batteries provide an average terminal voltage of about 1.5V and provides between 1900-2900 mAh. The Lithium ion battery's best usage is for everyday electronics that are constantly being used; various electronics such as laptops, cameras, camcorders and etc. The Lithium-ion battery's recharging cycle capability is between 500 and 1000 times. The battery has a very low self-discharge rate. It was definitely one of the best batteries for having the lowest self-discharge rate. It's self-discharge is so small compared to other batteries that it is not necessary to take into consideration. Although the self-discharge rate is low, the batteries overall capabilities diminish as time goes on. The Lithium-ion battery is notoriously known for easily losing its overall lifespan due to many contributing factors. For long period of times in which the battery is not being used, the more the terminal voltage permanently decreases. Unlike other rechargeable batteries, which retain their terminal voltage after a recharging cycle, the lithium-ion batteries are not suited to retain its charge if left unused for too long. That is why the battery is used in everyday electronics that consistently are being used with little to no time of rest periods in between. The battery is most capable when constantly being utilized. The lithium-ion batteries are supposed to be the improvement to the lithium battery. Unlike the lithium battery ancestor, the lithium-ion battery has the advantage of being able to be recharged. The most prominent disadvantage of the lithium-ion battery, which made it not suitable for the project design, was its shortened lifespan when not constantly being used. Although the self-discharge rate is a sure plus, the fact that they can gradually lose their capabilities was a big enough reason not to use them. Also when compared to other options which were suitable for the project design, the lithium-ion batteries were more expensive.

Regular single use lithium batteries were the ideal batteries in the single use category. The lithium single use battery has the longest lifespan in comparison to other batteries in the single use category. The battery has a terminal voltage of 1.5 volts and a current of between 1900-2900 mAh. The batteries specifications are very similar to the lithium-ion batteries, which are the supposed new and improved option. The lithium battery is very versatile and durable. It is widely used for many electronics. The batteries best usage is also versatile. The lithium battery is best used for both high drain devices as well as low drain devices. Similar to it's replacement, the lithium battery has a very low discharge rate and can easily last between 10-15 years when not in use. The single use lithium battery had some apparent advantages over the lithium-ion battery, which is its supposed improved option. The apparent advantage was its lifespan ability when not in use. The lithium-ion battery diminishes overtime. Additionally, since the lithium batteries remain efficient when not in use, they would have been ideal to utilize in the project designs sleep mode method. Being able to keep its charge and terminal voltage when not in use would have surely extended the power system's overall lifespan. Also another plus for the lithium battery was its ability to perform effectively and consistently in both hot and cold weather. This ability to do so confirms how rugged and durable the batteries really are. The battery is capable of performing well easily in weather as low as 10 degrees Celsius as well as weather as high as 60 degrees Celsius. These temperature parameters are just the standard known range for which the batteries are known to work well. They easily are able to go beyond these parameters and still work well in more harsh conditions. The main disadvantage that was made apparent for the lithium battery is its inability to be recharged. Initially, all types of batteries were researched until it was agreed that a rechargeable component was the most beneficial to the project design. Lastly the batteries are relatively expensive in comparison to other easily accessible options. In the case of the design, the battery did not present enough advantages to be used in the project.

The single use alkaline batteries are the second option, which was researched from the single use battery category. The alkaline battery has a terminal voltage of 1.5volts and a possible current range of between 1800-2600 mAh. The alkaline battery is similar to the lithium singe use battery in which they have a very low self-discharge rate, which is not significant enough to take notice of. The battery can last between 5-7 years when not in use. The alkaline single use battery is also the most used battery in the single use category can are also the most easily accessible battery. Unlike the lithium battery, the alkaline battery is more affordable. The most prominent advantage of the alkaline battery was its commonness. Being common and accessible made it possible to obtain the batteries easily in the worst-case scenario in which the power system suddenly malfunctioned due to the batteries not working correctly. The disadvantages of the alkaline battery are its low non-use lifespan in comparison to the lithium single use battery. When compared to better-known single use options, the alkaline battery had no major advantages that would have greatly benefited the project design. Also the battery was not compatible with the automatic recharging component that is used in the project design.

Table 7 displays a quick general breakdown of each battery option, which was researched and analyzed for the project design. The advantages and disadvantages that directly affected the project design and may not include any additional factors that the batteries may possess over each other are also shown in Table 7.

After analyzing and stacking all of the batteries against each other, the agreed best option that was used in the project design was the Nickel-Metal Hydride (NiMH) rechargeable batteries. When the pros and cons of the battery were weighed in, the battery was the most suitable by being able to accommodate nearly the entire request set forth by the group in comparison to the other options. The battery is environmentally friendly because it does not use any harmful or toxic elements to function correctly. The battery has an adequate terminal voltage window, which can easily supply the electrical hardware with little concern of diminishing after a few uses. The Nickel-Metal Hydride battery also had an acceptable amount of rechargeable cycles which helped extend the power systems overall lifespan. Additionally the battery self-discharge rate was not a major problem in the project to work effectively. Lastly the battery is rechargeable which allows it to be compatible with the automatic recharging component.

Battery	Voltage (V)	Current (mAh)	Re-chargeable	Advantage	Dis-advantage
Alkaline	1.5	1800-2600	No	*Widely available *Affordable	*Non rechargeable
Nickel-Metal Hydride(NiMH)	1.25	800-2700	Yes	*Recyclable *Performs well in high drain devices	*High self-discharge rate *Does bad in hot weather
Nickel-Zinc(NiZn)	1.65	1500-1800	Yes	*Recyclable *large amount of charging cycles *Has a high output terminal voltage	*High self-discharge rate
Nickel-Cadmium(NiCd)	1.25	600-1000	Yes	*Relatively affordable *Very rugged in various weather conditions	*Highly toxic component *High self-discharge rate
Lithium-ion(Li-ion)	1.5	1900-2900	Yes	*Rechargeable option for the lithium battery *Very-low self-discharge rate	*Depletes greatly as time goes on *Expensive
Lithium	1.5	1900-2900	No	*Very-low self-discharge rate	*Non rechargeable

Table 7: Comparison of batteries

3.3 Solar panel selection

Finding an appropriate solar panel, which complemented the power system design, was easier than the battery selection. There were no main differences or variations for the small solar panel for electronics. The only differences for the solar panels were their voltage rating and possible output current. The best fit for the project design was a solar panel, which was capable of easily recharging the batteries being used. The batteries in the system are set up in series with a total voltage of 9 volts. The solar panel is rated at 12 volts and can successfully recharge the batteries when they are depleting. The 12-volt solar can easily reach an output voltage of 20 volts which rapidly recharges the rechargeable batteries. Another thing that was taken into consideration when the solar panel was selected was its physical shape and size. It was most beneficial to use a solar panel with an easily manageable size. The physical panel structure easily was incorporated into the structure of the trashcan. Having a small basic shape solar panel made it easy to mount and manipulate the solar panel to the top of the trashcan lid.

Along with finding the solar panel to supply the appropriate voltage, the solar panel also supplies the necessary amount of current to charge the batteries when they are depleting. To ensure that the batteries are not overcharged when being charged by the solar panel, an automatic battery charger circuit used in the system. In the case that the automatic charger component malfunctions, the trickle charging method is being used to minimize damage to the batteries. The trickle charging method charges batteries by only using 10% of their overall output current. Only using ten percent of the overall current would slow down the charging rate and ensure that the batteries are not charged too fast or charged with too much current. Example of this method being used on a 1.5 volt battery with output current of 2600mAh. To charge this battery using a solar panel utilizing the trickle charge method, the solar panel would be 1.5 volts or higher and have an output current of around 260mA. The solar Panel therefore outputs enough current to charge the batteries without the need of the regulation circuit. This method is unstable but charges the batteries accordingly. This method takes a very long time to complete.

Figure 17: A solar panel

To successfully use the trickle charge method, the battery setup was analyzed to calculate the total voltage along with the total output current. The design consisted of six AA batteries connected in series. The four batteries totaled collectively 9 volts with an output current of 14400mAh. This setup then required the single solar panel that can supply at minimum 6 volts and a constant output current of about 960mA. The current amount necessary was found by calculating ten percent of the total output current of the four batteries connected in series. The solar panel, which was used, was a best fit found to accommodate these specifications. The solar panel supplied the current to the six consecutive batteries that have a total maximum voltage of 9 volts with an output current of 14400mA. The 1000mA current is roughly ten percent of the initial 6 consecutive batteries output of 14400mA. Also beyond meeting the parameters needed for the six-battery design, the solar panel physical shape was great for the overall trashcan structure as well. The solar panel selected is a square shape and was easily incorporated into the top flat surface of the trashcan. In this location the solar panel is able to easily absorb the sun’s rays. The solar panel is the one shown in Figure 17. It shows the physical appearance of the solar panel to being. The shape of the solar panel is ideal to work with.

3.4 Automatic charger printed circuit board component:

The automatic charger printed circuited board has become a component that greatly benefits the projects overall design. The circuit board is essential because it extends the power systems overall lifespan by continuously monitoring the status of the batteries and then taking the necessary actions thereafter. The automatic battery charger circuit is able to determine if the batteries onboard need to be charged or if they should be left alone. More specifically, the automatic charger circuit continuously checks if the batteries are within a certain voltage range. If the batteries terminal voltage is above the set voltage range the circuit then stops the supply of current being distributed to them. If the batteries terminal voltage is below the set voltage range, the circuit then at that point allows the input current from the solar panel to supply them. The design idea for the circuit came from extensive research.

3.5 Circuit inspiration:

To ensure top performance at all times the batteries will always be at their peak state. Finding or even creating an appropriate circuit to successfully do so was then the task at hand. The initial inspiration for the appropriate circuit came from a basic battery charger. The simple battery charger charges the batteries when they are inserted into the allocated spaces provided. The down fall to this design was the fact that it continuously charged the batteries no matter what and the user would have to be the one to manually check whether or not the batteries were charged. The user would usually determine if the battery was charged by a series of light-emitting diodes (LED). There would be a red light, which would illuminate if the batteries voltage has depleted to a very low level and then a green light that would illuminate once the batteries have charged. Some of the simple battery chargers use a timer, which have a set amount of time to charge the batteries. After this time has passed, the green light then illuminates. Although the simple charger method deemed itself useful in our project design, it was not beneficial because it continuously overcharged the batteries which rapidly decays the batteries overall characteristics.

Continuing further research in battery chargers now being used today, an automatic battery charger was found. The automatic battery contained the same characteristics, which was wanted for the power supply subsystem design. As wanted, the automatic battery charger only turned on if the batteries inserted were below a certain voltage level for the specified battery type. The battery charger also turned off if the batteries terminal voltage levels were too high. This battery charger design in itself was self-efficient and capable of extending the batteries overall lifespan. Additionally the battery charger design did not require a physical overseer to monitor the batteries charging status. After analyzing the design and seeing that it would easily fit into the subsystems self-sustainability, It was agreed that the best automatic charging circuit should be similar to the one described.

After choosing the circuits overall design possibility, the system then had to be able to incorporate the solar panels that will be used. The automatic charger design now presently being used by people requires an A/C power supply and function by being physically plugged into the wall. In order to incorporate the solar panels, the circuit design would have to be altered to allow the current from the solar panels to be sufficient enough to charge the batteries with no problem. After searching, a design was found that incorporated the solar panels effectively. The design found was courtesy of electroschematics.com. The website supplied a host of various different circuit designs that could be incorporated into the project. The designs supplied gave a foundation to start from when creating the necessary personal circuit. Various circuits were of interest to be best suitable for recreation.

3.6 Circuit design Selection:

The first circuit design, which sparked an interest with the group, is an inverter battery charger, which utilizes input current from a solar panel. The design is courtesy of Electroschematics.com posted by P. Marian. Figure 18 displays the inverter battery charger with the ability to stop charging once the ideal terminal voltage is obtained. The schematic displayed shows a circuit capable of supplying a steady 16 volt supply with variable current ranging between 250mA to 300mA. The current can ultimately be altered and controlled by switching the resistor values of R1 and R3. When the solar panel is charged, the current then passes through diode D1 that become forward bias. In the forward bias mode, the current is then inputted into the regulator. The regulator can be adjusted to supply a specified amount of current. The current output from the regulator then passes through diode D2 and resistor R3. That same current then passes from diode R3 and enters zener diode ZD2 that conducts and then allows the current to begin charging the battery. In the case of the power subsystem design, the current would charge the batteries that would be connected in series.

The second circuit design, which sparked an interest with the project designers, was a design found that also utilizes a solar panel. The design is courtesy of Electroschematics.com posted by P. Marian. Figure 19 displays the solar panel automatic charger with current regulation and automatic cutoff. The schematic displayed as is with the component values listed is capable of charging a 6 Volt 4600mAh battery by using a 12 Volt solar panel and a variable voltage regulator to easily adjust the output voltage and current. The variable voltage regulator being used is an IC LM 317. The high voltage being supplied from the solar panel ensured that the system continuously charged the batteries with a sufficient amount of voltage and current. The voltage regulator is strategically placed between the adjust pin and ground to supply the output voltage to the battery. Resistor R3 restricts the charge current going to the battery while diode D2 prevents current from discharging from the battery once charged. Additionally transistor T1 and zener diode ZD act as a cutoff switch when the batteries reach maximum terminal voltage. As said also, the uniqueness of this design is its capability to cutoff automatically when the battery is fully charged. Also the design is unique because the user has the ability to adjust the current to the desired level suitable for specific batteries. This option allows the automatic charger to be nearly universal for all batteries since different batteries require different amounts of current to adequately charge.

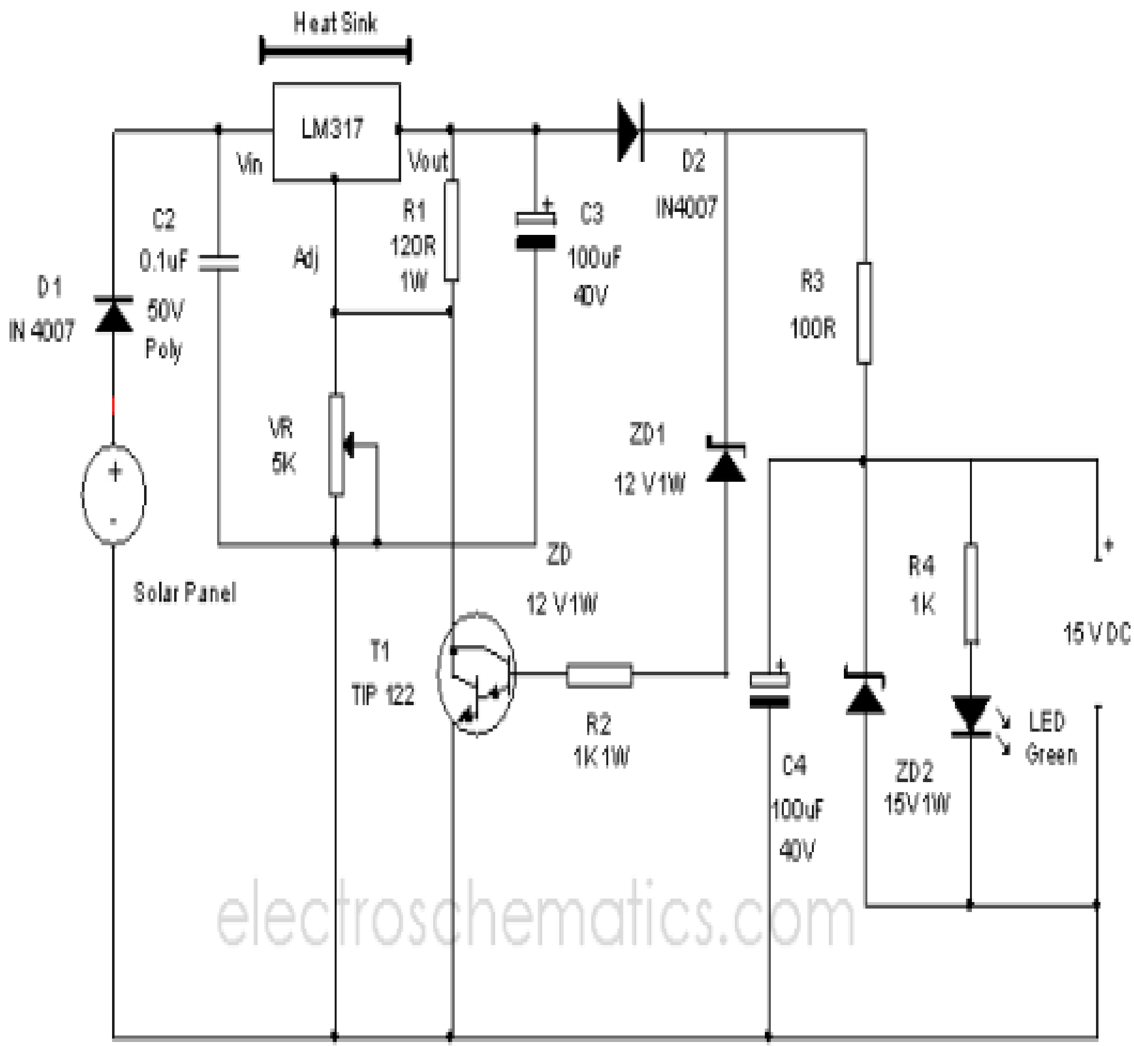


Figure 18: Inverter battery charger

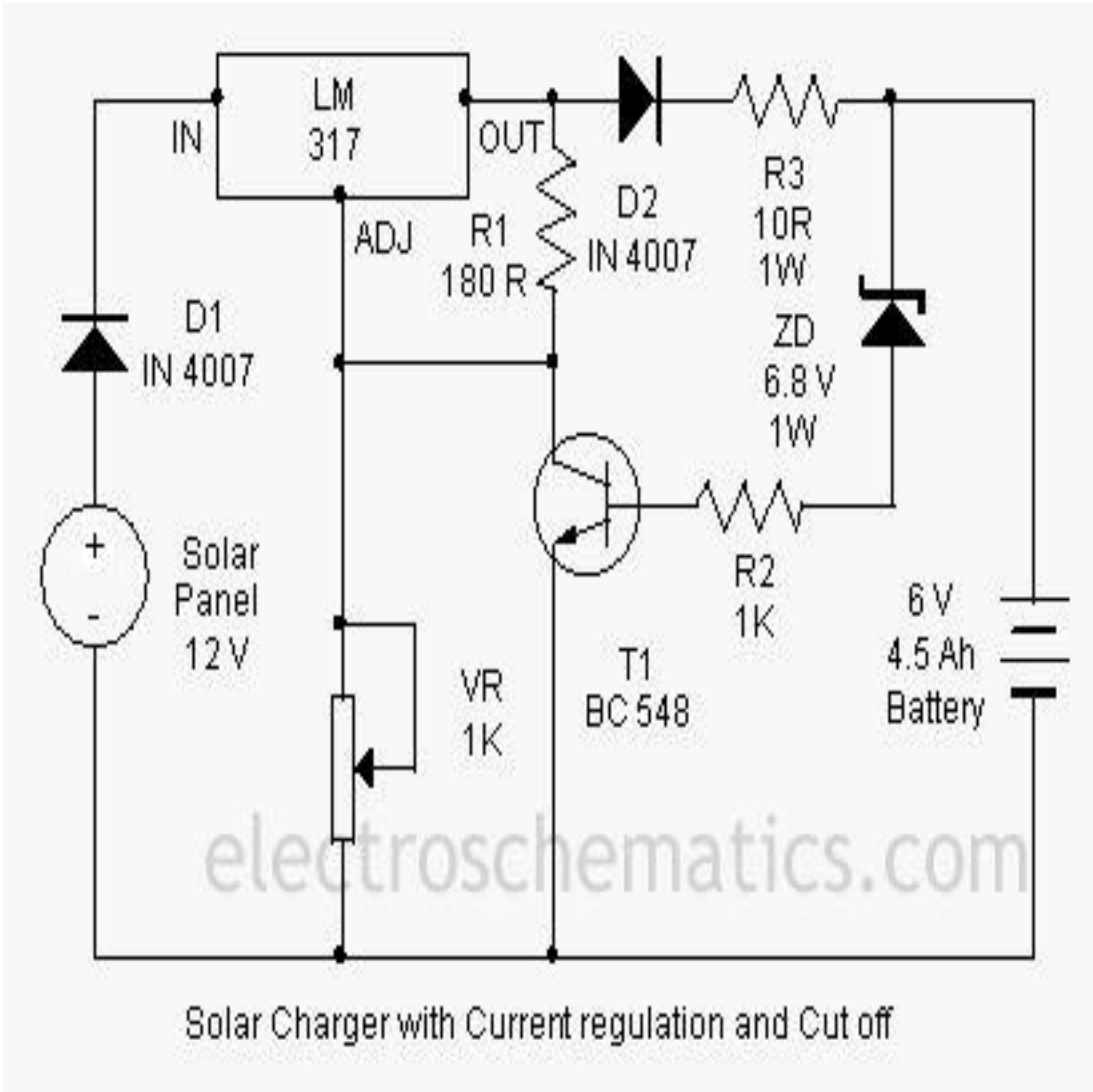


Figure 19: Solar charger

After analyzing both circuits displayed, the option that the group used in the prototype is option two. Option two is the solar panel automatic charger with current regulation and automatic cutoff capability. Although both circuits were very similar, the solar panel automatic is a better option because it accomplishes what is necessary while utilizing less overall components. Having a design that is less complicated to create saved a lot of unnecessary wasted time. A simpler design also reduced the time it took to troubleshoot in the case of premature failure.

4. Sensors

The main idea of this design is to provide a system that can detect when the trash can is full with a small focus on being able to identify the level of fullness. This was achieved by using a system of sensors. There is a depth measuring sensor and two planar sensors. The depth measuring sensor was placed in the lid, as identified in the trash can mounting system. The base specifications for the sensors are listed in Table 8.

Distance measuring range (meters)	0 to 1.5
Consumption current (Amps)	<1
Supply voltage (Volts)	<9
Operating temperature (Celsius)	< 49
Price (Dollars)	<50

Table 8: Base Specifications

4.1 Analog vs. Digital Sensor

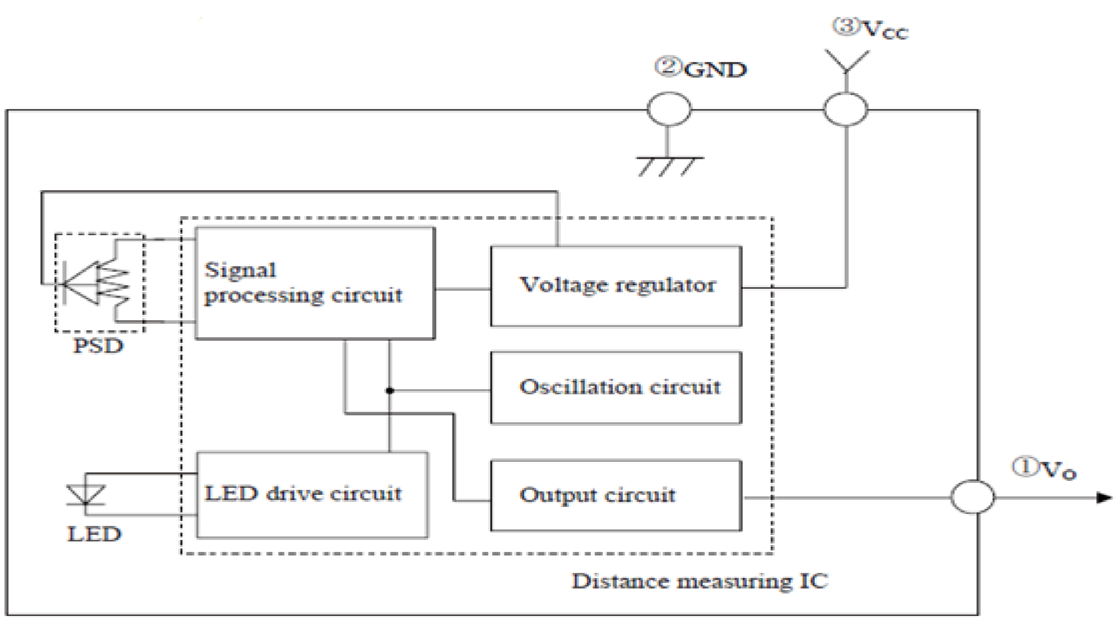


Figure 20: Block diagram of depth measuring sensor

It will use a system that emits a small voltage and identifies the current height of the object it is sensing based on the voltage returned. The block diagram shown in Figure 20 courtesy of www.sharpsma.com outlines the sensor operation.

The system is more sophisticated than undergraduate level of training so ordering a preexisting sensor may was more practical. Ideally, the prototype should use a digital sensor because digital has less error than analog. Also, with an analog sensor, there was a need for an analog to digital converter. Another important specification for the sensor is the maximum distance of the sensor. The Sharp GP2Y0A21YK Distance Measuring Sensor has a range of 0 – 130 cm and is digital and the Sharp GP2Y0A02YK0F Distance Measuring Sensor has a range of 20 -150 cm but is analog. This information was obtained from www.digikey.com. These are the only two sensors that have a range of over 100 cm which is necessary because the trash can minimum specifications have it at 76 cm tall. A list of side by side comparisons is shown in Table 9. The key factors in determining which of these sensors to use are the price and its feasibility. We chose the analog sensor which actually has a range of 80 cm.

Model (Sharp)	GP2Y0A02YK0F	GP2Y0D21YK
Distance measuring range	20 to 150 cm	0 to 130 cm
Type	Analog	Digital
Package size	29.5×13×21.6 mm	
Consumption current	33 mA	30mA
Supply voltage	4.5 to 5.5 V	4.5 V ~ 5.5 V
Operating temperature	-10 to +60	-10 to +60
Price	11.5	8.75

Table 9: Distance Measuring Sensor specifications

Figure 21: Image of sensor

As noted in Table 9, the biggest difference is the distance that the sensor measures. Our trash can have a depth of roughly 93 cm from lid to base which is covered by both sensors. The Sharp GP2Y0D21YK Digital sensor was the primary sensor that wanted to use because of the price and the older model was used in a previous, similar project and proved to be successful.

Another area of concern for the distance measuring system is the accuracy that can be obtained when using this in an open lid trash can. The reason for this is that in the data sheet, it is noted that “sources of high ambient light may affect measurement.” The way that the sensor operates is that the LED sends a signal down and it is reflected back to the light detector side. The sensor is displayed in Figure 21 and the operation of the sensor is shown in Figure 22.

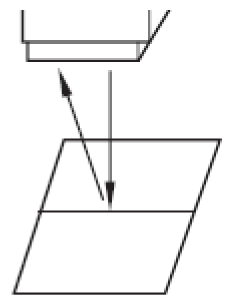


Figure 22: Operation of sensor

It appears that the angle of reflection of the sensor may be affected by the sun’s rays. As stated in the Trash Can section of this document, we thought about using flaps on the outside of the lid to block out the rays. An example of how the UV rays may enter and interfere with the trash can is shown in Figure 23.

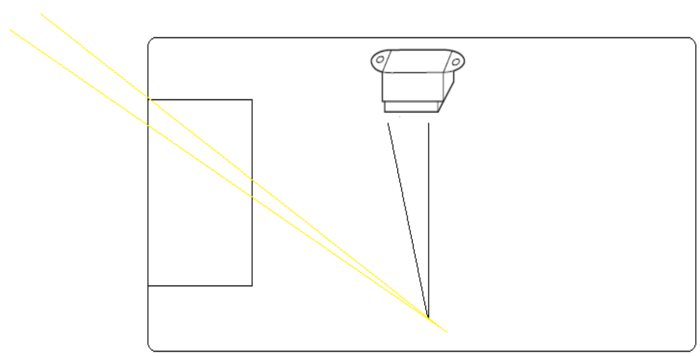


Figure 23: UV ray interference

As stated in the mounting section earlier, the depth measuring sensor and its associated components are mounted on the top, inside of the lid, inside an enclosure. The power that is applied to the sensor comes from the rechargeable batteries which get their power recharged via the solar panel. All of this is interfaced on a printed circuit board and vector board. According to www.junun.org, the digital depth sensor requires a 3 pin JST connector to mate the sensor with the circuit board. This is identified in Figure 24. The connector is not a mandatory item but is used to aid in providing power and connectivity between the sensor and the circuit board. The process by which the sensor is programmed and communicates the information received, is identified in the Node section of this document.

Figure 24: 3 Pin JST connector (www.junun.org)

4.2 Planar Sensor

The second type of sensor that we used for the Trash talk is the planar sensor. The purpose of the planar sensor is to provide a redundant system to verify that the trash can is filled to the level that the depth measuring sensor identifies. For example, if a long piece of cardboard is placed in the trash can but does not fill up the entire area, one of the sensors could identify the trash can as being full. There are plenty of ways to do this but there are a few approaches that we considered for accomplishing this task. They were the through beam sensing and distance measuring sensor.

4.2.1 Through Beam Sensor

The through beam system is a system that is employed in areas such as security sensors or garage door sensors. The way that it operates is by using a transmitter and a receiver. If the signal is not received from the transmitter, the system identifies that something has interrupted the signal; therefore something is in the way. The system is typically comprised of an emitting device, such as an LED, and a photoelectric receiver as the transmitter. If we had chosen to use this system, we would have built the circuit on a printed circuit board. The transmitters would be mounted on the outside of the trash barrel and the receivers would be one the opposite side and outside of the barrel. There would have to be two columns of transmitters and receivers in order to get a more accurate reading from the planar sensors. The beams will cross approximately in the middle to ensure that if there are long, skinny items placed in the trash can, they will be accounted for by at least one of the sensors. One of the disadvantages of using this system would be the amount of transmitters and receivers that would have to be built. We would have needed six of each to cover the amount of sensors that we need to make this prototype successful. This was one idea for implementing the planar sensor. Also, the rigid can liner that was used inside of the trashcan would have to have a smaller diameter to account for the enclosures that will be placed on the outside. Also, in a realistic environment, the through beam sensor is not ideal because of the buildup of dirt and trash residue on the sides of the trash can.

A more realistic idea for the implementation of the planar sensors would be to use two at the midpoint of the trash can to determine when the trash has reached the 50% mark and two sensors at the top to determine if the trash can has become full. This is illustrated in the Figure 25 and Figure 26.

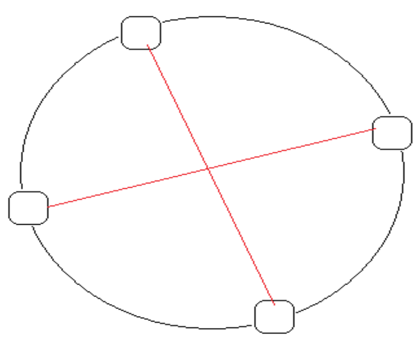


Figure 25: Top View of Planar Sensor

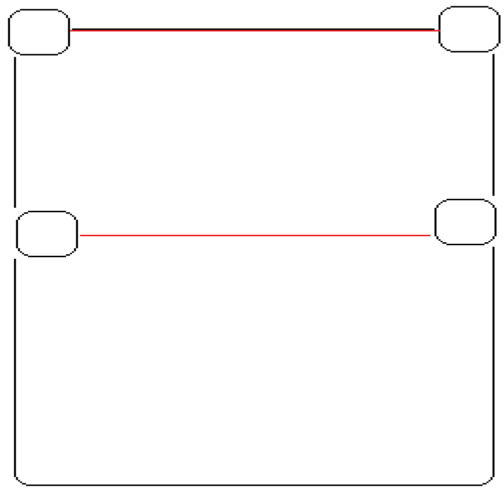


Figure 26: Side View of Planar Sensor layout

As you can see from the figures, we thought about using two sets of sensors on each level of the trash can. We decided to go with just one infrared sensor at each level. As stated before, this gives the system a redundancy at each level and with the depth measuring sensor. One type of sensor that was researched was from http://www.e-gizmo.com. The author of this sensor outlined a simple, cheap design for the through beam sensor system. The main components for the receiver are a voltage regulator, tone decoder and IRDA emitter-detector diode. The lists of components are identified in Table 10.

Parts ID	**Description**	**Quantity**
C1	10uF/16V Electrolytic Capacitor	1 pc.
C2	1uF/16V Electrolytic Capacitor	1 pc.
C3	223 Ceramic Capacitor	1 pc.
C4, C5	103 Ceramic Capacitor	2 pcs.
Ct	152	1 pc.
D1	LED red (3mm)	1 pc.
D2	LED green (3mm)	1 pc.
J1	Switch	
R1, R2	100 ohms Resistor	2 pcs.
R3	27 ohms Resistor	1 pc.
R4	10K Resistor	1 pc.
Rt	10K trimmer	1 pc.
U1	7805	1 pc.
U2	LM567	1 pc.
U3	IrDA	1 pc.

Table10: Component list for emitter

The components for the transmitter are essentially the same as the receiver except there is a timer instead of tone decoder. The list of components for the detector is shown in Table 11.

Parts ID	Description	Quantity
C1	10uF/16V Electrolytic Capacitor	1 pc.
C2	1uF/16V Electrolytic Capacitor	1 pc.
C3	103 Ceramic Capacitor	1 pc.
C4	681 Ceramic Capacitor	1 pc.
D1	LED green (3mm)	1 pc.
J1	Switch	
R1, R6	100 Ohms Resistor	2 pcs.
R2, R5	27 ohms Resistor	2 pcs.
R3	4.7K Resistor	1 pc.
R4	1.2K Resistor	1 pc.
U1	7805	1 pc.
U2	LM555	1 pc.
U3	IrDA	1 pc.

Table 11: Component list for detector

(Permission requested from http://www.e-gizmo.com)

The following schematics and associated printed circuit boards are shown in Figure 27, Figure 28, Figure 29, and Figure 30. As stated above, the schematics and printed circuit boards were obtained from http://www.e-gizmo.com. The authors were contacted via email but the supplied email address returned with a delivery error. Eventually, the contact information was found on a social media site and the authors verified that the designs are free for anyone to use.

These designs are not a definite inclusion in the prototype but give a system to base any number of sensors on. With the cost of various types of sensors being so high, the engineering decision would be to attempt to build a sensor for about a fourth of the cost of a prefabricated one. As you can see in these circuits, there is no microcontroller on the schematic and this component will need to be included somewhere in order to send the information received from the signal to the “brain” of the system.

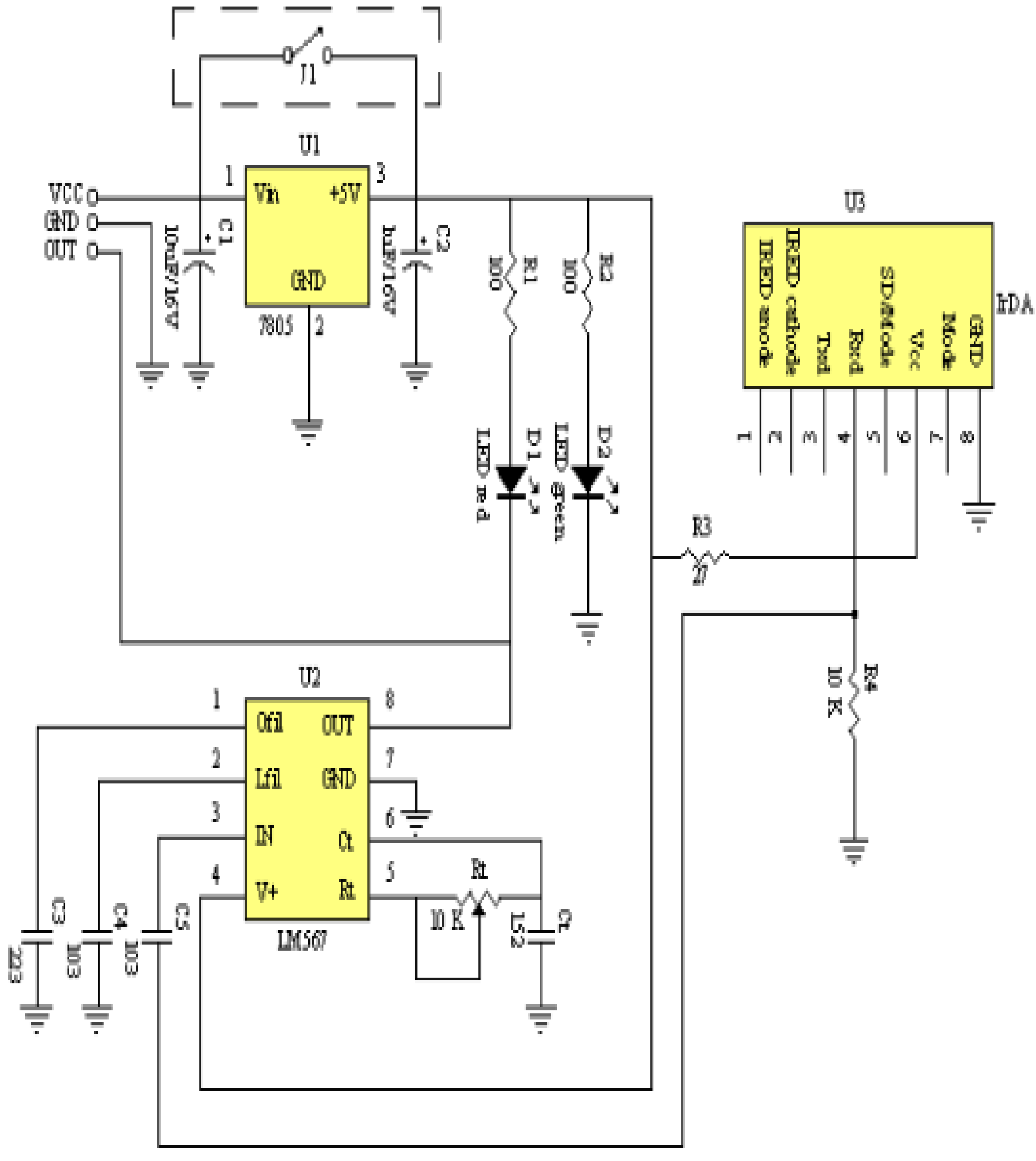


Figure 27: Receiver Schematic

(Permission requested from http://www.e-gizmo.com)

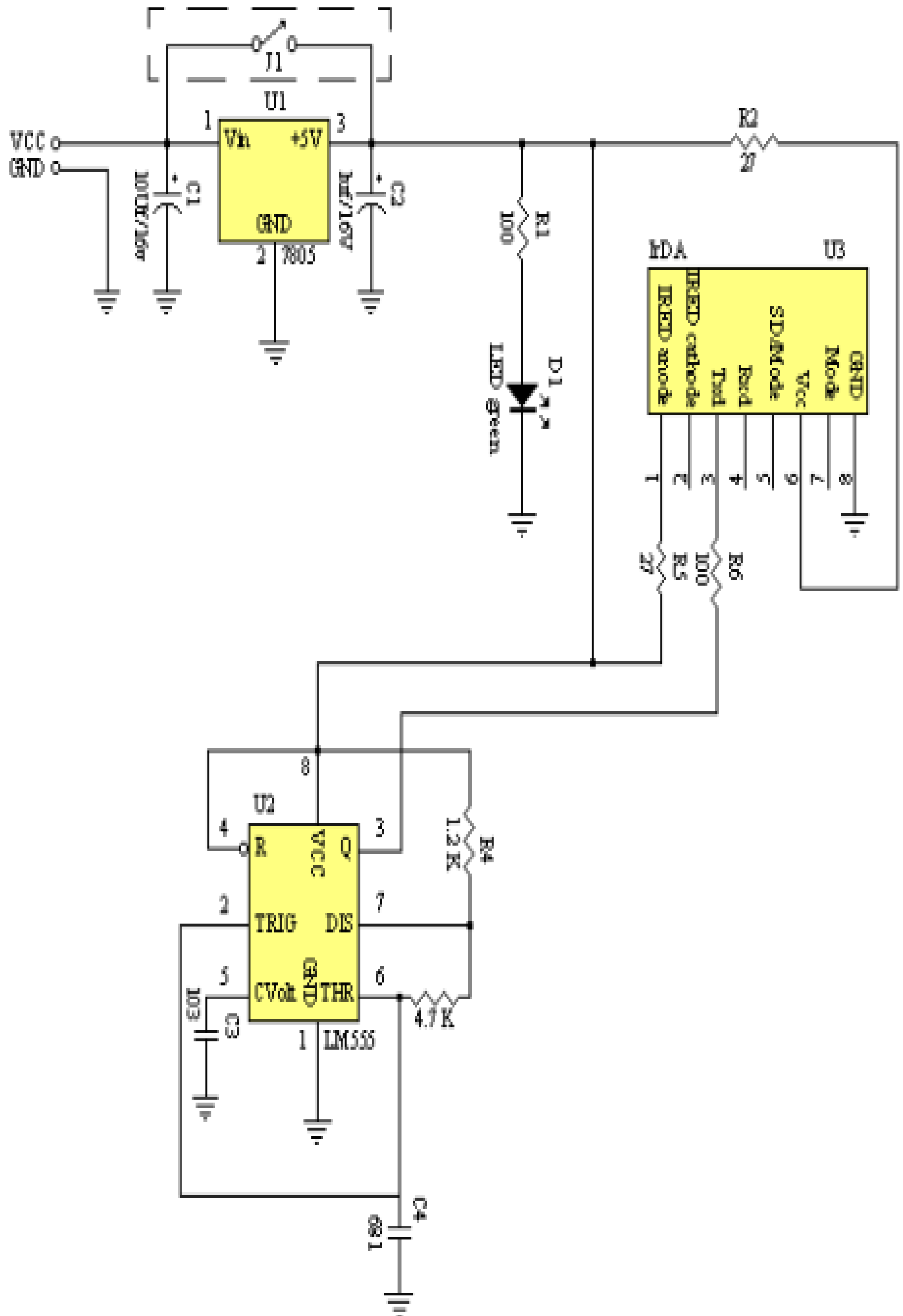


Figure 28: Transmitter Schematic

(Permission requested from http://www.e-gizmo.com)

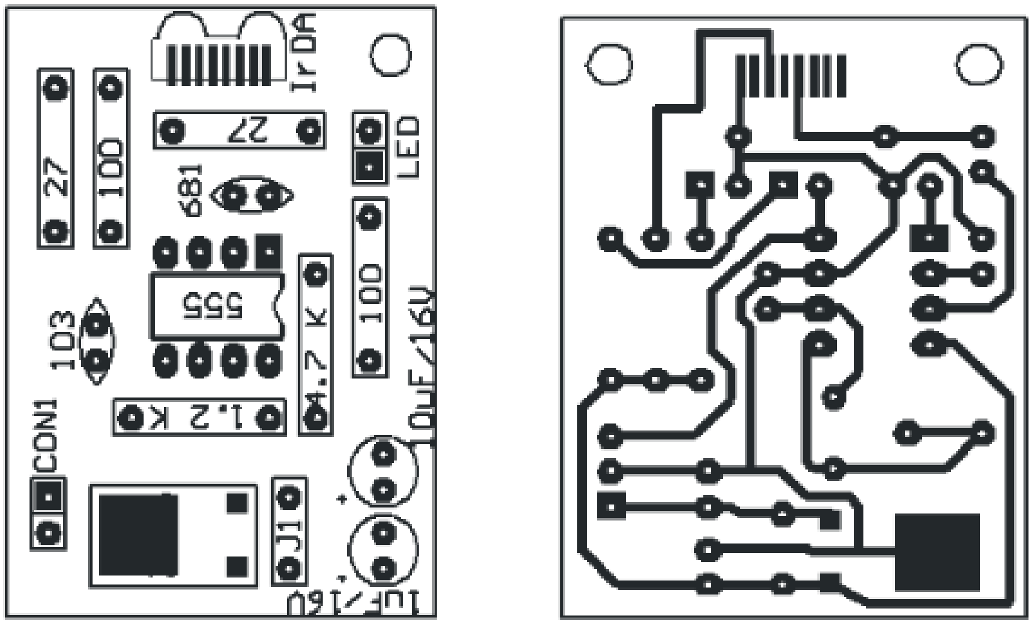


Figure 29: Transmitter PCB layout

(Permission requested from http://www.e-gizmo.com)

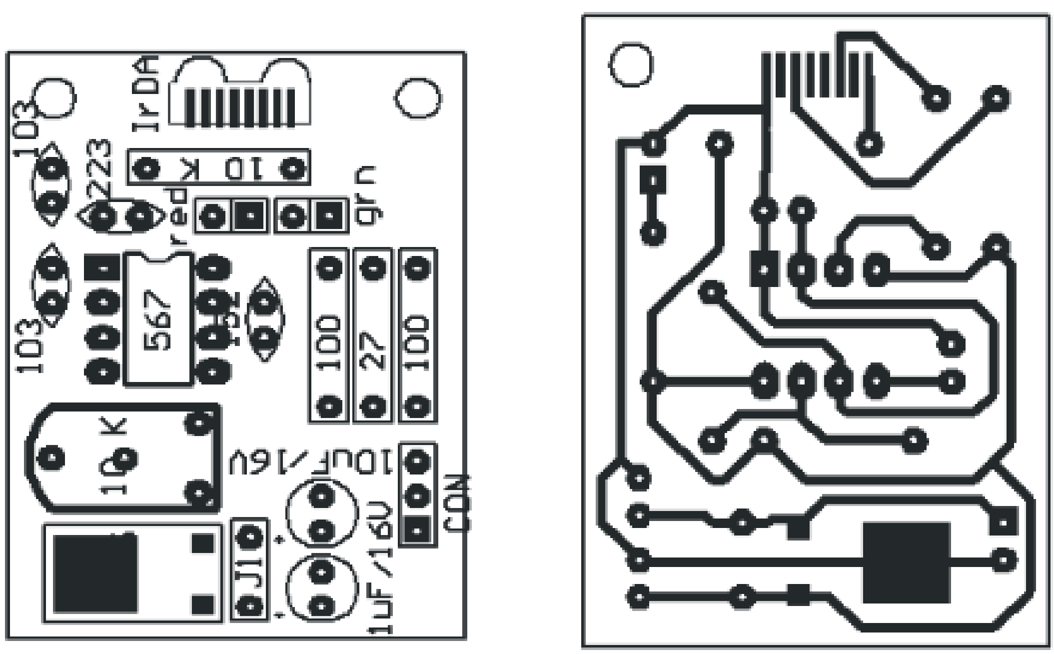


Figure 30: Receiver PCB layout

(Permission requested from http://www.e-gizmo.com)

Using the sensor design mentioned above would have proven very beneficial. Since it would have been on a printed circuit board, it might have been easier to integrate external devices. It can also be built using the resources at http://www.4pcb.com. This will reduce the cost of sensors by an estimated 33%. We did not end up choosing this type of sensor because of difficulty communicating with the designer.

4.2.2 Distance Measuring Sensor

Another type of sensor that can be used as a planar sensor is a distance measuring sensor. There are a variety of ways to use a distance measuring sensor. The authors of the previous circuit design have also designed a circuit that will perform the same functions. They call it a proximity-collision sensor. The theory of operation of this device involves the transmitter and receiver being on the same circuit board. The transmitter sends a signal and if the signal is not returned in a certain amount of time then no object is near. The lists of components for this circuit are displayed in Table 12.

Parts ID	**Description**	**Quantity**
C1	10uF/16V Electrolytic Capacitor	1 pc.
C2	1uF/16V Electrolytic Capacitor	1 pc.
C3	223 Ceramic Capacitor	1 pc.
C4, C5, C6	103 Ceramic Capacitor	3 pcs.
C7	681 Ceramic Capacitor	1 pc.
Ct	152	1 pc.
D1	LED red (3mm)	1 pc.
D2	LED green (3mm)	1 pc.
IC1	7805	1 pc.
IC2	LM567	1 pc.
IC3	LM555	1 pc.
IC4, IC5	IrDA	2 pcs.
J1	Switch	
R1, R2, R3	100 ohms Resistor	3 pcs.
R4	10 K Resistor	1 pc.
R5	4.7 K Resistor	1 pc.
R6	1.2 K Resistor	1 pc.
R7, R8	100 ohms Resistor	2 pcs.
Rt	10 K Trimmer	1 pc.

Table 12: Component list for circuit

(Permission requested from http://www.e-gizmo.com)

The following figures are the schematic and printed circuit board layout for the sensor.

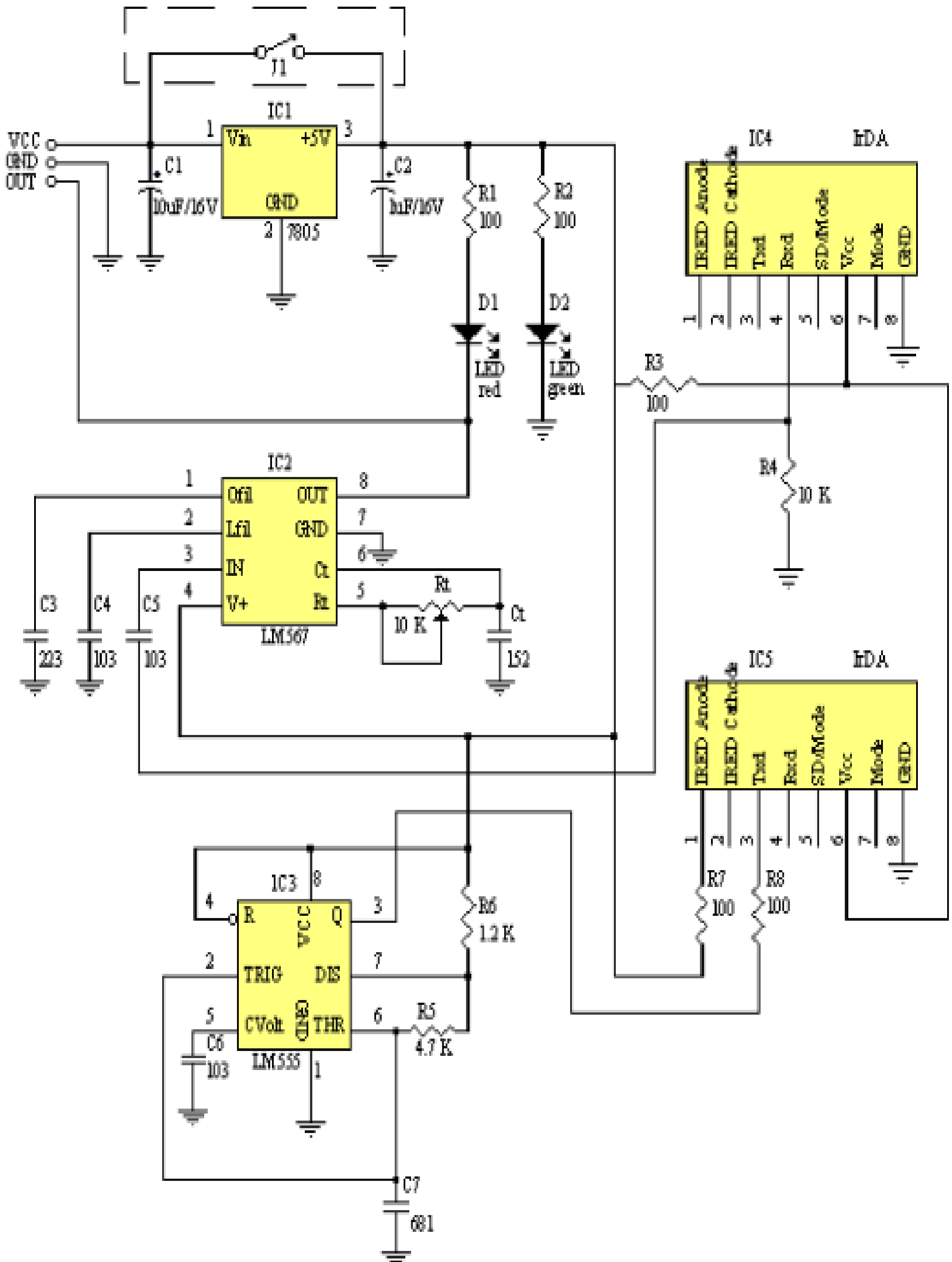


Figure30a: Proximity-Collision Sensor

(Permission requested from http://www.e-gizmo.com)

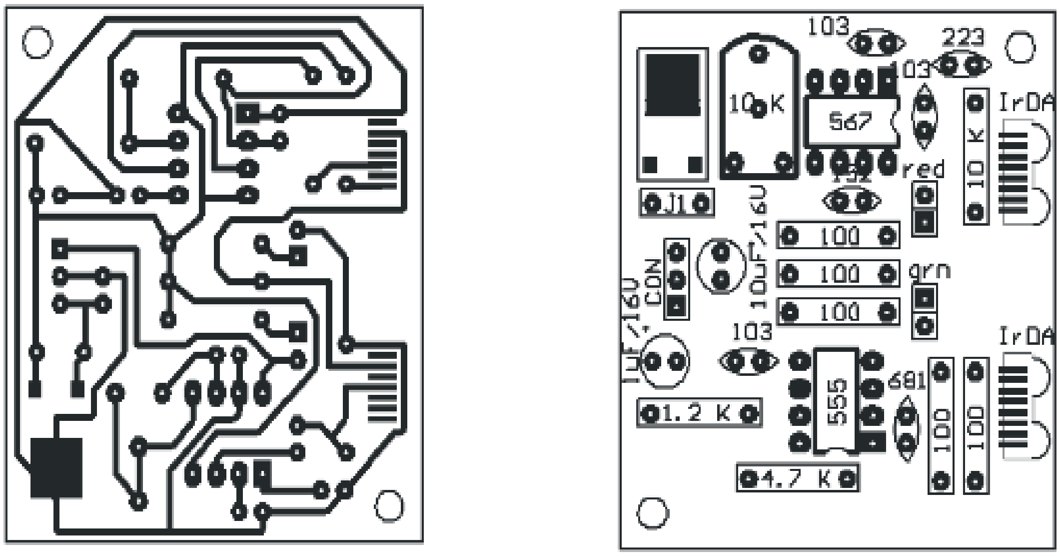


Figure 31b: Printed Circuit layout

(Permission requested from http://www.e-gizmo.com)

Another option for the planar sensor is to get a preassembled distance measuring sensor. The reasoning behind that is that the technology has a guarantee on it and will provide a higher quality service for the prototype. The general theory of operations for this is to have the sensor be set to measure a certain distance and if the value that is returned from the sensor is less than the value that is set for the sensor, there is something breaking the plane.

A good choice that could be used for both the depth measuring sensor and the planar sensor is an ultrasonic sensor. This is a safe choice for the depth measuring sensor for an open lid trash can because it is not affected by ultraviolet light unlike the infrared sensors. It can also be used as a planar sensor because the operation of the sensor is capable of sensing small distances as well as long. Some of the sensors that were researched are below.

4.3 Ultrasonic Sensors

4.3.1 Ping))) Sensor

The first ultrasonic sensor that was researched was the PING))) sensor. This sensor was discovered through an online search at http://www.parallax.com. It is a prefabricated sensor that has the capability to be used on a solder-less board or be soldered to a printed circuit board. The printed circuit board layout of the PING))) sensor is shown in Figure 32.

Figure 32: PING))) Sensor

The sensor was a good choice for this project because it is “low-cost and easy method of distance measurement.” This sensor is supposed to be a feasible replacement for infrared sensors and is good for either stationary or moving objects. It uses an ultrasonic pulse as the transmitter and calculates the distance by measuring how long it takes for the pulse to return. One especially notable benefit is that it is easy to interface this sensor with microcontrollers. The microcontrollers that are advertised are the BASIC stamp and Javelin Stamp. These microcontrollers will be explored more in the microcontroller section following the sensors. Some other notable features of this sensor are that it has simple pulse in/pulse out communication, indicator for in progress measurement and a 3-pin header for easy connection. It also has a variable width pulse which would possibly reduce the amount of sensors required for each level of the planar sensors. The side by side comparison of this sensor with the competition is displayed in Table 13. We chose this sensor because it was readily available at retail stores near us and because it was cheap.

4.3.2 Echo Sensor

Another ultrasonic sensor that could be useful is the ECHO sensor that was discovered on http://www.rhydolabz.com.

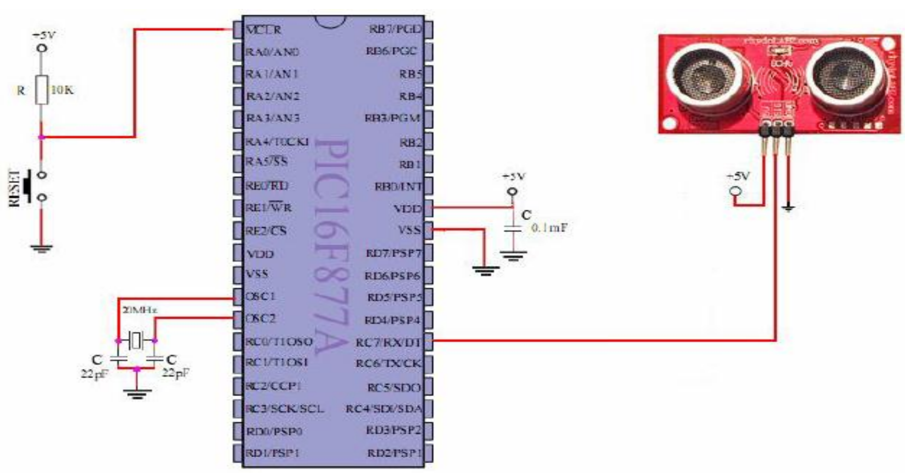


Figure 33: ECHO sensor with microcontroller

This sensor is similar to the PING))) sensor with slightly different capabilities. The most notable difference is the output. PING))) has a high/low voltage output but the ECHO uses an ASCII serial output. This means that it may require additional components to convert the output into a usable signal for the rest of the system to use. This sensors datasheet explicitly identifies that the air temperature affects the operation of the sensor. It is also a lot cheaper than the PING))) sensor but more expensive than the other sensors that have been researched. The accompanying microcontroller for the sensor is the PIC16F877A. This is what is shown in Figure 33. Some other features outlined on the site of the sensor are professional EMI/RFI compliant PCB layout for noise reduction, accurate and stable range data and auto triggered every 50 ms. Like the PING))), it also has an LED to identify in progress measurements and a 3 pin header for connections. The particular specifications that are important are listed in Table 13. We did not use this because of the accessibility of the PING))).

4.3.3 High Performance Ultrasonic Rangefinder

The next sensor that was researched was discovered on http://www.maxbotix.com. This site was more unique because they seemed to specialize in ultrasonic sensors. There are different series of sensors to choose from and the most applicable type was the High Performance Ultrasonic Rangefinder (HRLV). Out of this series, the MB1003 seemed to have the best specifications and features for the prototype.

Figure 34: MB1003 sensor

Out of all of the sensors in the series, it has the widest and most sensitive beam pattern and is an excellent choice for wide beam sensors. As stated before, this is ideal for the system because it limits the number of planar systems needed at each level. Some of the features of this sensor are:

- tolerates outside noise sources
- real-time automatic calibration
- optional external temperature compensation and internal temperature compensation
- Ability to read from all sensor outputs and firmware filtering for better noise tolerance and clutter rejection.

One of the disadvantages is that objects closer to 30 cm will always show at 30 cm. This could skew the data in a smaller model trash can. Also, this one is specifically designed for indoor operation; though it will be housed in an enclosure, it is still subject to the weather conditions. It appears to outperform the other ultrasonic sensors in the basic specifications but this comes with a higher price tag. There was also no mention of any accompanying microcontrollers. The ones that were mentioned earlier will be a good start for finding the right one to accompany this sensor. There are many different models from plenty of manufacturers but based on this research, many of them have very similar base specifications. The final decision depends on price and additional features. These sensors all have equal capability to be used in the planar system and in the depth measuring sensor portion of the trash can. The ultrasonic sensors also have a distinct advantage as far as the base specifications for the sensors. Table 13 is the final comparison of all of the ultrasonic sensors that were discussed.

Model	PING)))	ECHO	MB1003
Distance measuring range	2cm to 3m	2cm to 4m	30cm to 5m
Type	Ultrasound	Ultrasound	Ultrasound
Package size (mm)	22 x 46 x 16	51.54 x 25.73	19.9 x 22.1 x 15.5
Consumption current	20 mA	20 mA	3.1 mA
Supply voltage	5 VDC	5 VDC	2.5 to 5.5 VDC
Operating temperature C	0 to 70	0 to 70	-15 to 65
Price	29.99	18.24	37.95

Table 13: Ultrasonic sensor comparison

4.4 Additional components

Although we did not choose any of the schematics that were obtained from www.e-gizmo.com are to construct a sensor, there are a few additional components to consider if someone were to use them. They are the voltage regulator, tone decoder and timer. The devices recommended by the designers are the 7805 voltage regulator, the LM567 tone decoder and the LM555 timer. These are good devices to use but there could be others that might be more beneficial to the prototype than these.

4.4.1 Voltage Regulator

The 7805 is a member of the 78XX voltage regulator series. Its main purpose is to maintain a constant voltage. The 7805 is for 5 V outputs but in the event that a 12 or 15 volt output is required, the 7812 and 7815 are also available. Another regulator that was found that may be useful is the BEC Step-Down Voltage Regulator. It can take an input of up to 23 V and regulate it to five. Listed in Table 14 and Table 15 are other specifications found on www.pololu.com.

Minimum Operating Voltage	5 V
Maximum Operating Voltage	23 V
Continuous Output Current	3000 mA
Default Output Voltage	5 V
Maximum quiescent current	8 mA

Table 14: BEC Voltage Regulator Specifications

Another voltage regulator that was considered is from Texas Instruments. They have a model, LP2950 that is a fixed output voltage but has a wide range input also. The model doesn’t have an output higher than 5 V however but it is still a legitimate option. They do have a model, the LP2951 that also has a wide range input but has an adjustable output. Some of the specifications for this voltage regulator are below. This also provides an advantage because TI allows users to sample their components before purchasing them.

Minimum Input Voltage	1.6 V
Maximum Input Voltage	30 V
Maximum Output Current	100 mA
Minimum Output Voltage	1.2 V
Maximum Output Voltage	30 V

Table 15: TI Voltage Regulator

4.4.2 Tone Decoder

As stated above, the LM567 or LM567C Tone Decoder. According to www.ti.com, they are used to provide a saturated transistor switch to ground when an input signal is present within the pass band. Some of the features of this tone decoder are listed:

- 20 to 1 frequency range with an external resistor
- Logic compatible output with 100 mA current sinking capability
- Bandwidth adjustable for 0 to 14%
- Immunity to false signals

Another tone decoder available to use is the NTE832 and NTE832SM which has the same description as the LM567. These decoders contain the same features as the tone decoders above with one additional feature which is listed below:

- Center frequency adjustable from .01Hz to 500kHz

As you can see from these features, both tone decoders offer similar capabilities and can be used in the circuit.

4.4.3 Timer

The timer suggested is Texas Instruments LM555 and should suffice for doing the basic function of timing. The coupled microcontrollers may have timers installed in them and accomplish this task simultaneously with the other tasks. Some of the features of the LM555 found on www.ti.com are:

- Timing from microseconds through hours
- Adjustable duty cycle
- Normally on and normally off output

These are the applicable features to the Trash Talk prototype sensors.

4.5 Microcontroller for Sensor

The microcontroller for the sensors is one of the pivotal components of the circuit. It is what ties the whole circuit together by interpreting the signals from each type of sensor and delivers that information to the other parts of the trash can. The first microcontroller that was researched is the Stamp because it was paired with the PING))). Logic dictates that if these microcontrollers are used with one type of sensor, they should be able to be used with another.

4.5.1 Specifications for Sensor Microcontroller

The specifications for the microcontroller are somewhat arbitrary but are mostly based on research done on http://www.engineersgarage.com/microcontroller/. The site has a plethora of projects involving microcontrollers but a section dedicated to the 8051 family of microcontrollers. These seem to be the standard for beginner projects and seemed like an appropriate baseline for establishing the specifications for the microcontroller for this project. They are fabricated by Intel and the specifications are identified in Table 16 and were pulled from http://www.engineersgarage.com/8051-microcontroller.

Features	8051	8052	8031
RAM(bytes)	128	256	128
ROM	4K	8K	0K
Timers	2	3	2
Serial port	1	1	1
I/O pins	32	32	32
Interrupt sources	6	8	6

Table 16: Baseline Specifications for Microcontroller

These give a baseline for what type of capability that microcontroller should have and are not solid specifications. Since a lot of research was done with the intent of utilizing systems from parallax.com, some additional specifications were obtained from the site in conjunction with the Stamp and Javelin BASIC microcontrollers. They are identified in Table 17.

Features	Baseline
Operating Temperature (Celsius)	-20 to +70
Processor Speed	20 MHz
Voltage Requirements	2 to 15 V
Current Draw (@5V)	3 mA run/ 50 uA sleep

Table 17: Additional Specifications

4.5.2 BASIC Stamp and Javelin Stamp

The Stamp microcontrollers identified in the PING))) documentation are the BASIC and the Javelin. The BASIC comes in a variety of models that range from a basic 14 pin controller to an advanced 40 pin controller. The type of microcontroller that is needed for the sensors only needs to be able to handle basic functions such as switches, timers and sensors so anyone should suffice.

There is a detailed comparison of the BASIC controllers at http://www.parallax.com. The one that seems to have the basic functionality needed for this project is the BASIC Stamp 2 shown in Figure 35.

Figure 35: BASIC Stamp 2

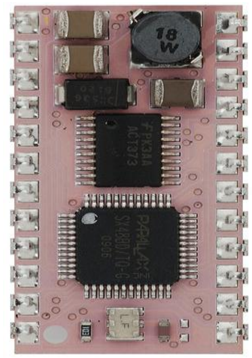


Figure 36: Javelin Stamp

According to the website, the BASIC 2 is capable of controlling and monitoring timers, keypads, motors, sensors, relays, lights and more. This is an expansive list of capabilities for a microcontroller. It is supposed to be relatively simple to program, utilizing a system called PBASIC for its programming. One of the drawbacks to this controller is that it may require additional components, such as starter kits, to get the full use out of the system. It is also on the more expensive side. The particular specifications are outlined in Table 18.

From the same company and website, the next microcontroller is the Javelin Stamp shown in Figure 36.

This one is also capable of controlling motors, sensors and lights but does not have all of the capabilities of the BASIC controller. Although it does not have the diverse capabilities of the BASIC, it still has the main capability of sensor operation which is the most important one. This one also requires a Stamp starter kit but is currently priced well below the BASIC. The specifications are in Table 18.

4.5.3 Microchip PIC16F877A

The next microcontroller is the PIC16F877A.

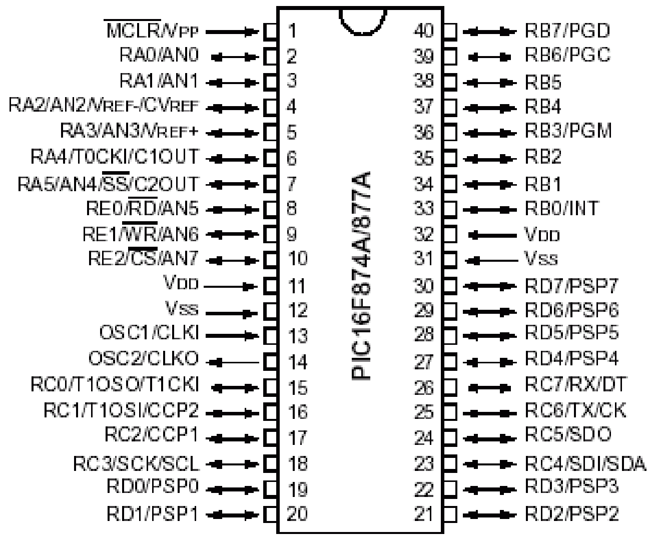


Figure 37: PIC16F877A

It is an 8-bit microcontroller manufactured by Microchip. Some of the special features of this controller include self-reprogrammable under software control, in-circuit serial programming, power-saving sleep mode and selectable oscillator options. It has basic functions as it is the most inexpensive controller researched thus far but it has the capability to control the ECHO sensor. The specifications for this are also listed in Table 18.

4.5.4 8051 Family Microcontroller (AT89C51)

As stated earlier, most of the baseline specifications for the sensor microcontroller were established based on the projects on www.engineersgarage.com. The project in particular had similar applications as it uses an infrared sensor that has an LCD output of the distance that is measured. This design spawned an additional idea to place some sort of LCD screen on the trash can in order to let users know that the trash can is full without having to open the lid. The microcontroller used by this design was the AT89C51 which is manufactured by Atmel. It is an 8-bit, 40-pin microcontroller with 4KB of flash programmable memory and 128 bytes RAM. The rest of the particular specifications are outlined in the microcontroller comparison table. A screenshot of the microcontroller with abbreviated outputs is shown in Figure 38.

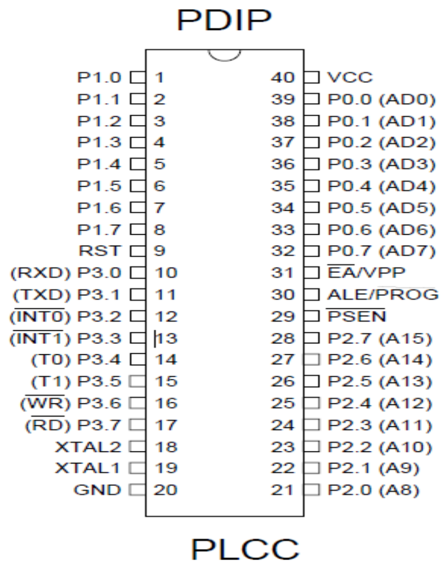


Figure 38: AT89C51 microcontroller

As you can see, there are plenty of microcontrollers that all have similar capabilities and could all fit into the schematic for the TrashTalk prototype. Below is the Microcontroller Comparison Table that compares the specifications of the baseline criteria identified earlier in this section.

Features	8051	BASIC Stamp	Javelin Stamp	PIC16F877A
RAM(bytes)	128	32	32	368
ROM	4K	2K	32K	256
Timers	2	1	1	3
Serial port	1	2	1	1
I/O pins	32	16	16	40
Interrupt sources	6	0	0	14
Operating Temp (Celsius)	0 to 70	-40 to +85	0 to 70	-40 to 125
Processor Speed (MHz)	20	20	25 (Turbo)	20
Voltage Requirements (VDC)	5	5	5	2 to 5.5
Current Draw (@5V) (mA)	15	3	80	20

Table 18: Microcontroller Comparison Table

4.5.5 Atmega328

The microcontroller that was ultimately chosen for TrashTalk was the Atmega328. This was chosen mostly because the system was prototyped using the Arduino developmental board and that is low cost, easy to program, and has a lot of online resources available were used to troubleshoot and solve a few of the problems that we encounter.

5. Board Type

5.1 Arduino board

Arduino board is very desirable for the design parameters of this project. This type of board is widely used around the world for small projects similar to this one. Downloadable kits make for relatively easy self-programming in a higher level language such as Java or C. As part of the design, the board would have to be programmed to produce specific output requirements given specific input parameters. For example, a signal with information about the level of trash will be sent to the master hub every twenty-five minutes or every five minutes based on the need and the demands of the application. This specific requirement will be dictated by the volume of trash collected on a given day in a particular area. This predetermined time is sent via the high level program. The system can be tailored to perform this task every five or every fifty minutes based on the needs of the city or location utilizing this technology. The flexibility of being able to program in a high level language as opposed to programming in a lower level (assembly language), makes this a very attractive option for this design. Debugging would be easier than assembly, code manipulation would be easier and faster, and this would alleviate many debugging and tracing issues that occur when programming in assembly language, which we know may be very problematic. If at some point an issue arises and further expertise is required, there are tons of resources and blog postings where users identify and clarify problems and potential solutions for a particular problem. This is a very popular board used for simple designs similar to the one that was designed in this project. This is one advantage of having a widely used board as part of the design. During the troubleshooting process, a lot will be learned about this board, its limitations and whether it surpassed our expectations. There are a few drawbacks with this type of board; it does require a considerable amount of power in comparison to many of the other boards to operate. Seven volts of potential difference is considerably a lot more than the amount required to operate other boards. Some require as little as one volt to operate. For this design, the board is battery powered, and a solar panel is used as a charging station for the rechargeable batteries that power the circuit board, in the event that the batteries aren’t able to power the board the solar panel will do so. Multiple double A batteries are required to provide seven volts to power the board. The solar panel is not very large, it is able to rapidly recharge the batteries as they are drained by the system using the Arduino board to monitor the trash levels and communicate with other trashcans.

Some Arduino models require anywhere from 3.3V to 12-15 volts in order to operate. This may cause the system of this design to be not as efficient as the design requirements. For this design, only the boards that required seven volts or less operating voltage were considered for this design. That way the system will still remain efficient and not be too intensive on the battery or solar panel systems. A closer look was taken into some of the boards that were being considered for this design. The Arduino based printed circuit board is the best choice for this project because of flexibility, how relatively easy it is to use the hardware and software. For this project, the Arduino based printed circuit board will be used to receive input from the sensors on the inside of the trashcan and relay that information to the main hub via the mesh network interconnecting the trashcans to each other and ultimately the main hub station. We exercised the option of purchasing the printed circuit board without any of the components pre-assembled. We ordered the components separately online from Digikey.com and soldered most of the components to the board ourselves. This was more difficult and more time consuming to have the board purchased preassembled, but this was the cheapest option for the group. This option costs a little bit more, and would have saved us a lot of time and energy. Given our budget constraints, self assembly made most logical sense, and the printed circuit board did not have too many components to be soldered to it.

Figure 39: Arduino board

The Arduino board shown in Figure 39 was very useful in testing the overall design to ensure that all the specific tasks required to be accomplish by the system are met. The use of this board for testing and verifying that everything does what is it supposed to do come from the ease of programming and use the Arduino to accomplish the required tasks of the system. The Arduino board was used in prototyping and was able to give clear and precise result of a required task. The Arduino board made trouble shooting the design more manageable and successful in the sense that the designer should be able to determine the direct location of potential problems due to configuration or the overall set up of the subcomponent or system as a whole.

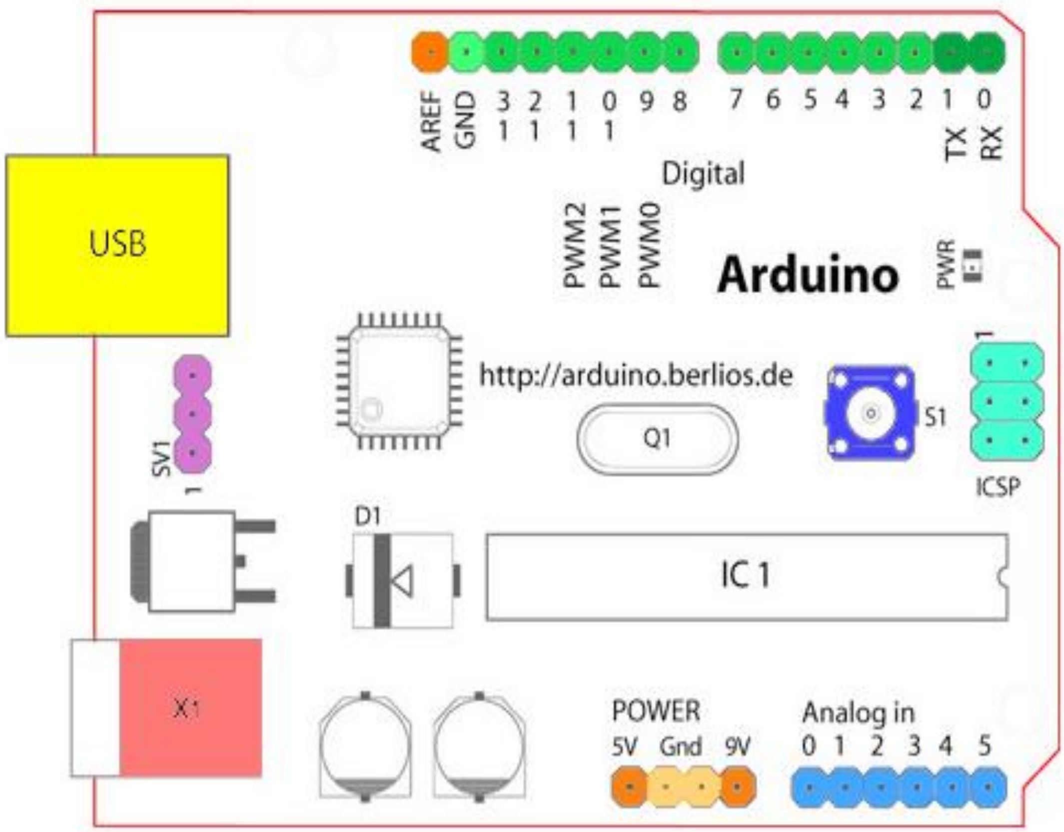


Figure 40: Top view of an Arduino board

The following components are shown in Figure 40. Starting clockwise from the top left:

- Analog Reference pin (orange)
- Digital Ground (light green)
- Digital Pins 2-13 (green)
- Digital Pin 0-1/Serial In/Out-TX/RX(dark green) –
- Reset Button – S1 (dark blue)
- In-circuit Serial Programmer (blue-green)
- Analog In Pins 0-5 (light blue)
- Power and Ground Pins (power: orange, ground: light orange)
- External Power Supply In (9-12 VDC) X1 (pink)
- Toggles External Power and USB Power – SV1 (purple)
- USB (yellow)

5.2 MSP430 on printed circuit board

Another option that was considered for this design was to utilize an MSP430 microcontroller assembled on a printed circuit board to achieve the goals and required tasks of this design as determined by the specifications. The MSP430 is a family of Texas Instruments microcontrollers are ultralow power and relatively easy to use. These microcontrollers would require very low power to operate.

This family of microcontrollers only requires a supplied voltage ranging from 1.8V to 3.6V. This is a very achievable outcome by simply utilizing two or three AA lithium ion rechargeable batteries which will be able to be fully sustained by a relative small three inch by three inch (3”x3”) square solar panel. They utilize very little power when on and far less when in standby mode. It only drains about 0.1 *10^ (-6) Amps. When in active mode, i.e. receiving data from the trashcan sensors or transmitting information to the other trashcans or main hub, it uses approximate 270 *10^ (-6) Amps at 1MHz and 2.2V. The MSP430 utilizes only .594 Watts of power when in active mode. This is a very low amount of power dissipation when in active mode and much less when in standby mode. It also has a very fast wakeup time when transitioning from standby mode to active mode. The MSP430 can “wakeup” in less than 1*10^ (-6) seconds. This means that there will not be virtually any delay when transitioning from sleep mode to transmit mode, making the data very reliable and almost current (within five seconds). It utilizes a 16-bit RISC architecture, and has two 16-bit built in timers. It also has a 10-bit AD converter and a data transfer controller (DTC) which should be sufficient for this design.

Figure 41: MSP430 microprocessor by Texas Instruments

Sixteen bits has more than enough capacity to accommodate the specifications of this project. The timers would have been utilized to put the system in sleep and active mode at their appropriate times and deemed necessary by the system manager or design requirements for a particular location, whether it be low, medium, or heavy trash traffic area. The 10-bit AD converter should be able to give readings precise and within a wide enough range so the system will be able to clearly distinguish whether or not the trashcan is full, half full, or empty based on the reading received.

Texas Instrument's ultra-low power MPS430 microcontroller shown in Figure 41 was one of a few top choices for the design of this project. The very little power required to operate this microcontroller made it a top option for the design of this project. The major benefits of its features to this design have been highlighted above as to why it was a top choice for this design.

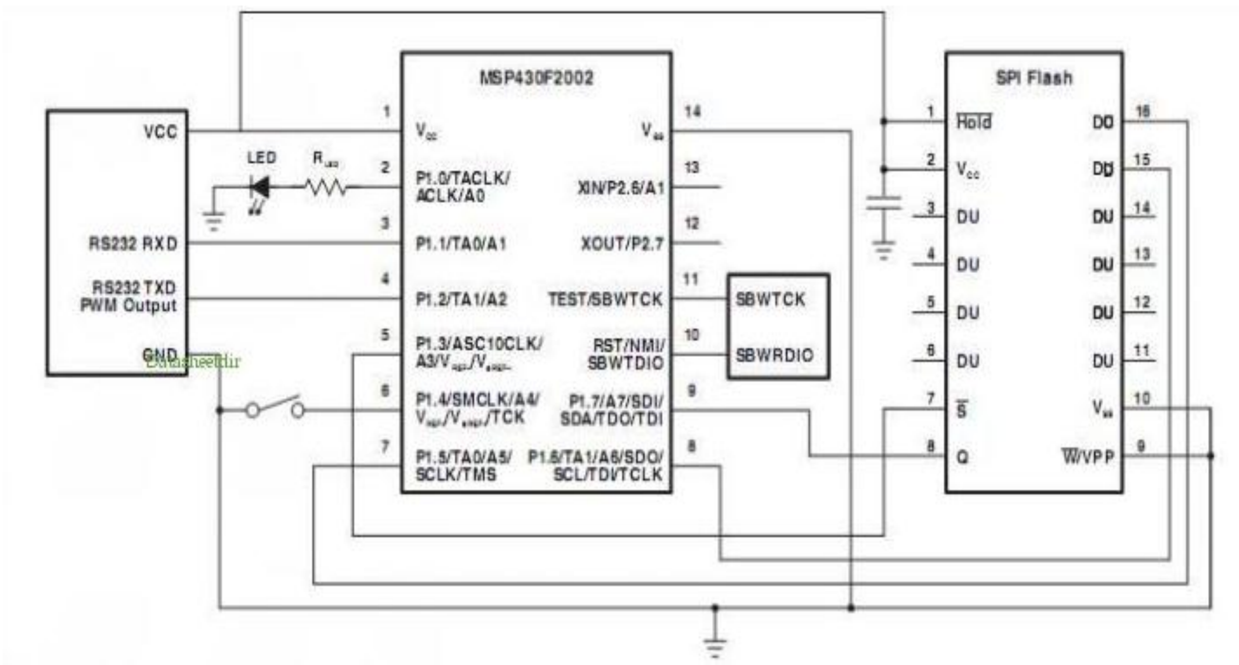


Figure 42: Schematic of TI's MSP430 Microcontroller design

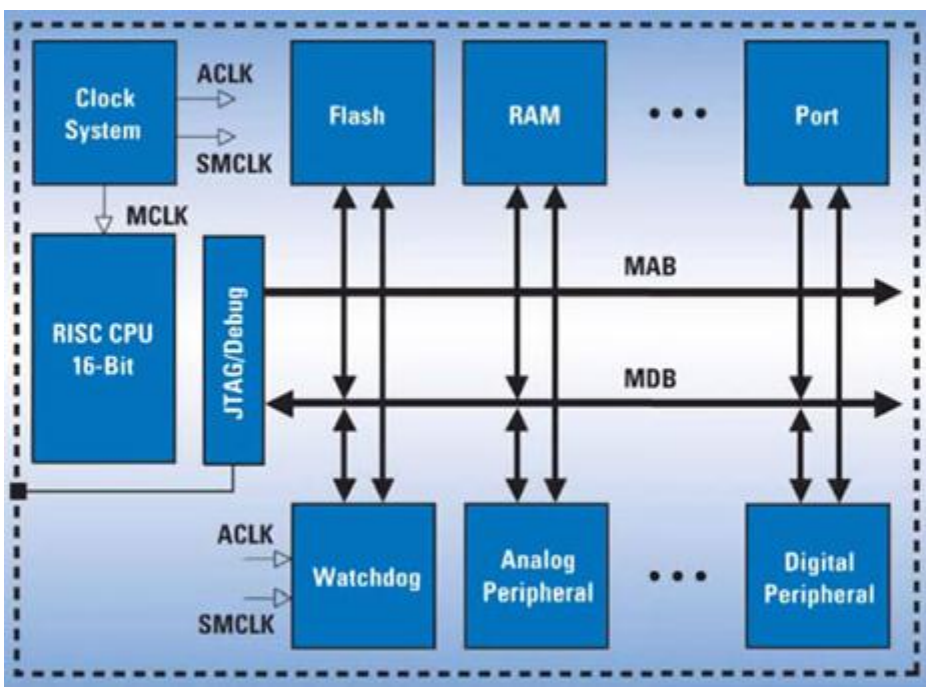


Figure 43: The MSP430 Architecture

The MSP430 architecture shows the specific components of its design that is useful and beneficial to this design. The auxiliary clock (ACLK) is sourced from the low frequency/ high frequency oscillator with a divider of 1, 2, 4, or 8. This is defaulted to 4 in its original state, this value can be changed to any of the other values given in order to better accommodate the function of the microcontroller in the design and use in the project. The auxiliary clock can be used as the clock signal for timers A and B. These timers could be used to set data transmission times and or a set time to talk to other microcontrollers in the network of trashcans. The master clock (MCLK) signal can also be sourced from low frequency/ high frequency oscillator or from the high frequency oscillator (if available) or from a built in digital controlled oscillator with a divider of 1, 2, 4, 8 as seen with the auxiliary clock. The master clock is used by the CPU and the system. This clock will be the one responsible for waking up and putting the CPU to sleep at set times to either collect data or transmit data. This gives the system the ability to be set and forgotten about without having to set the timer up for operation on a daily or monthly basis. This time could be modified to fit the design requirements as deemed necessary or required by the system administrator or system operator. This clock would not need to be modified or manipulated very frequently because of the ability of the microcontroller to manage itself and handle the required tasks without any interaction from an outside source, providing that the code it is running on does not have any errors and sufficient power is supplied to the microcontroller so that it can perform its required functions without any interruptions.

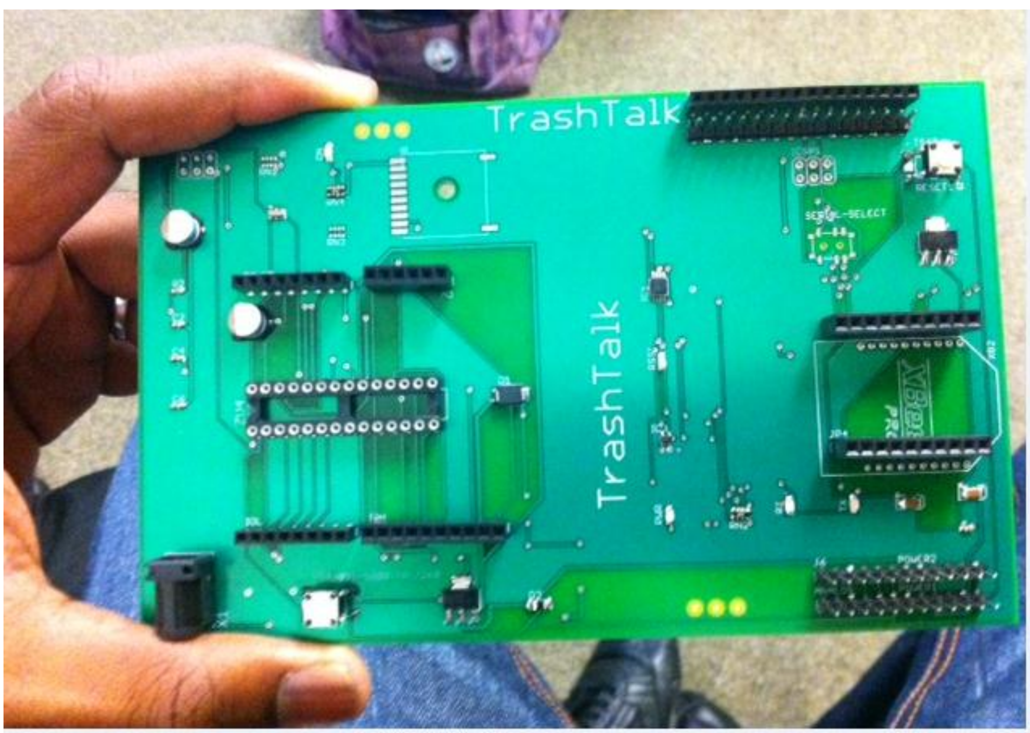


Figure 44: TrashTalk printed circuit board which utilizes the Atmega328 microcontroller

The implemented design is shown above. The board will incorporate the micro controller, receivers, transmitters, resistors, and capacitors required to complete the circuit and facilitate the design. Each trashcan will be equipped with a main control board which includes a microcontroller and the necessary components in order to complete the required tasks of the system, namely communicating to the other trashcans its current status and relaying information from the other trashcans to the main hub if the other trashcans are too far away from the main hub where the data is processed and analyzed and interpreted as useful information.

A MSP430 would have been very useful for the project design, the disadvantage of using this specific microcontroller for the design is that it requires too high of an input voltage. For this reason we chose the Atmega328 microprocessor. Twelve volts is quite a large amount of energy to be supplied by lithium batteries. Also, this would put an enormous amount of strain on the solar panel as well. Given the size of the system and where it will be used, twelve volts is too high of a potential difference required for the system to be self-sustaining, and self-sufficient.

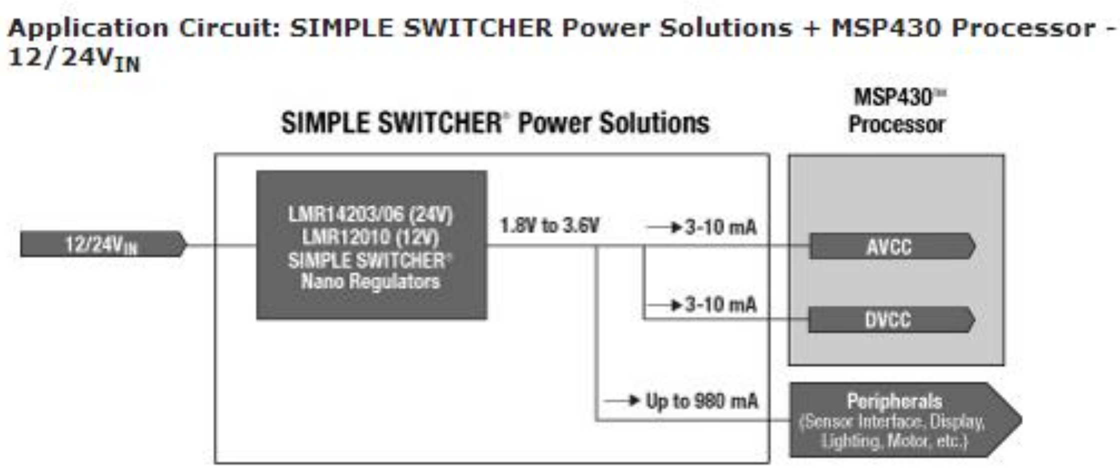


Figure 45: Circuit diagram of the MSP430 which utilizes 12-24 VDC

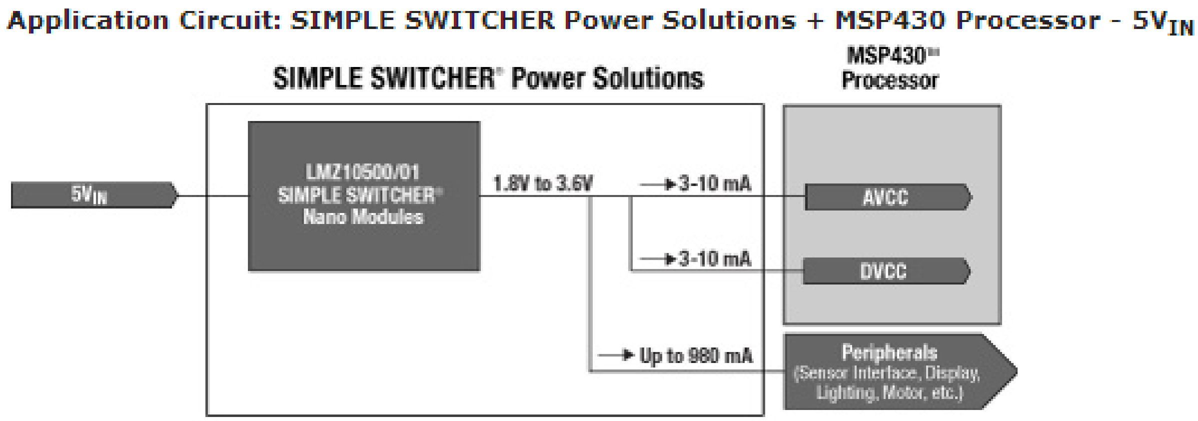


Figure 46: Circuit diagram of the MSP430 which utilizes 5 VDC

Above is a very similar design layout of the MSP430 which would have been much more suitable for the design in this project. Note the difference in operating voltage as compared to the previous MSP430 design which utilizes a lot more voltage on the input side compared to this one. Providing five volts from lithium batteries is an achievable task, this requirement would not put too much strain on the solar panels. A three inch by three inch solar panel should be more than enough to power the circuit or recharge the batteries when the power from the batteries are drained by the circuit. The five Volts required in this design fits right into our design at would be a major contributing factor to achieve a low cost, self-sustainable, energy efficient device.

5.3 BeagleBoard

This is a relatively low cost, low power consumption, open source, powerful single board single board computer developed by TI using their OMAP 3530 processor. The cost of this board makes it a possible choice for this design. It would give the design the flexibility to implement or expand the design further by creating room in the budget for such expansion. The low power consumption is another attractive feature of this type of board for the design. This would accommodate the use of the rechargeable batteries to power the board and contribute to the self-sustainable feature of the design as stated in the design requirements of the design.

The open source feature is another highlight of this type of board. This allows it to be modified to fit this design with a little bit of tweaking and modifying the program to accommodate the specific aspects of the design. The flexibility of this board allows it to be used in more ways than one for the design. It could be used to power the individual sensors inside of the trashcan or power the main board to communicate to other trashcans in the network.

Beagle Board measures around 3x3 inches and has all the functionality of a basic computer. This is a very powerful board occupying very little space which is exactly what this design requires in order to carry out its required functions. The Beagle board has numerous expansion ports for audio and video capability. Though attractive, these additional features are not required to implement the design requirements of this project. In this design, the implementation of a video feed will not be required; this may be used in future designs if a designer or design team would like to take this design a bit further. There is a possibility that the audio expansion port may be used to implement a microphone that listens for a distress signal. The appropriate authorities will then be notified.

The board includes SD/SDIO interface, USB 2.0. The board requires approximately 5 volts to operate and consumes up to 2 W of power in active mode, i.e. when receiving and transmitting data from one trashcan to the next. This is a very efficient microcontroller on this type of board, thus it doesn't get very hot by executing unnecessary steps or functions. It operates using an ARM A8 Cortex processor. The efficiency of this type of board does not require it to have any additional cooling done to it; hence it is able to occupy a very small surface area.

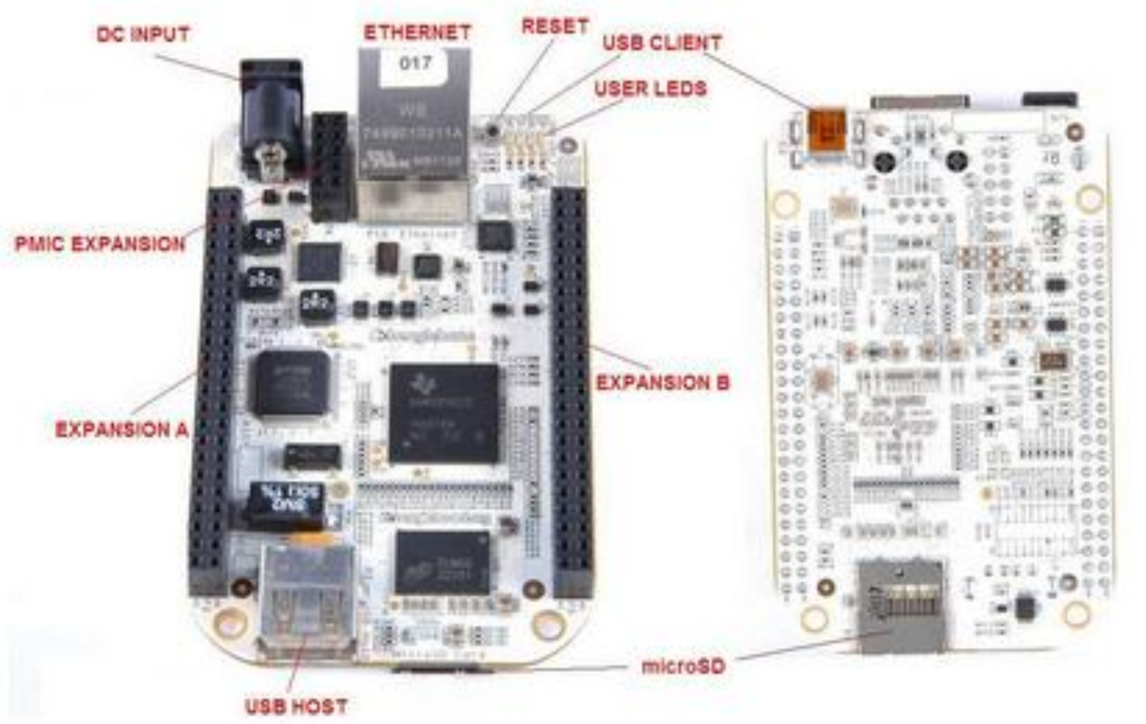


Figure 47: BeagleBoard layout

Some features of the BeagleBoard shown in Figure 47 are listed below:

- 600 MHz superscalar ARM Cortex A8 processor
- Over 1200 Dhrystone MIPS
- Up to 10 million polygons per second of graphic output
- HD video capable C64x – DSP core
- 256 MB LPDDR RAM
- 256 MB NAND Flash
- SD capabilities
- S-video output
- JTAG
- SD/MMC + socket
- USB 2.0
- 3.5mm stereo in/out
- RS- 232 serial

5.4 FPGA Board

Another option that was being considered for this design was to utilize an FPGA board. Field Programmable Gate Array (FPGA) is a manufactured board sent out by a manufacturer and can be programmed in the “field”, hence the name FPGA. This is an option for the design because of its flexibility and relative ease of use. Most, if not all FPGA boards are programmed using a hardware description language (HDL), the most commonly used HDL used to program this type of board in Verilog HDL, one of the main manufacturers of FPGA boards is Xilinx. Some of the newest technology from Xilinx features state of the art 28 nm HPL (High Performance and Low Power) process technologies. According to Xilinx, “the 7-Series all programmable FPGA family delivers breakout performance, capacity, and system integration while optimizing price/performance/watt.” Below is a table that highlights the deliverables for the all-new 7-series FPGA family of boards. FPGAs are made up of logic blocks that are wired together to form one circuit and implement to the required functions as required by the program. Zooming in to the design of an FPGA schematic will show logic gates and other devices primarily made up of logic gates performing logical functions and other operations. FPGA schematic is shown in Figure 48.

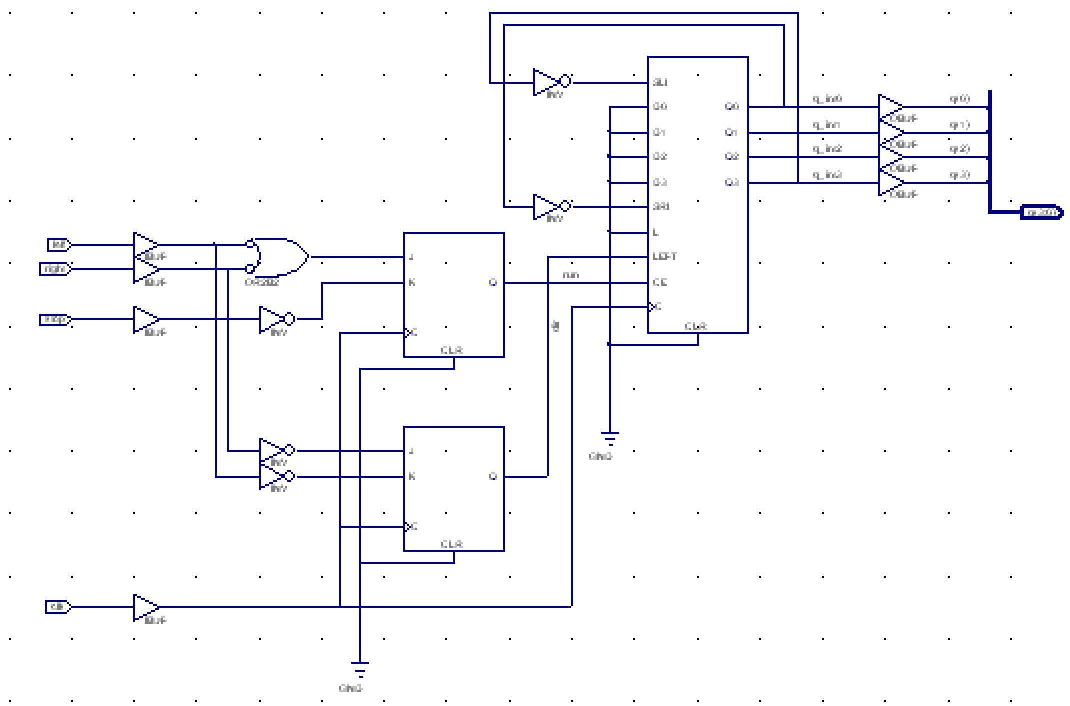


Figure 48: Schematic of an FPGA design

An FPGA design was taken into considered for the design of this project in order to implement logical expressions and functions as dictated by the program running the software.

Value	Deliverables
Programmable Systems Integration	· Integrate more system functions, focus on programmability
Increased System Performance	· Highest bandwidth and parallel processing leveraging programmable logic
BOM Cost Reduction	· Up to 50% — fewer components, simpler boards
Total Power Reduction	· Up to 70% — advanced process technology, integration and Tools
Accelerated Design Productivity	· TTM and TIM advantage through programmability, tools, IP and TDPs

Table 19: Highlights the improvements of current 7-Series FPGA family of boards

FPGA boards come in a wide range of capabilities and adaptability to each project's design. The Virtex-7 being the newest line of FPGAs produced by Xilinx has the most up to date and top of the line features. It may cost considerably more than say the less fast, less storage capable, less input/output pins on the Spartan-6. The cost of the Spartan-6 would be considerably less costly than the new top of the line Virtex-7 which utilizes some of the newest and best technologies available on an FPGA board powered by an ARM processor.

Some of the key features and distinguishable features are all highlighted in Table 20. None of the information was altered; it was copied in its direct form from the Xilinx website.

FPGA Comparison Table:

Features	Artix-7	Kintex-7	Virtex-7	Spartan-6	Virtex-6
Logic Cells	215,000	480,000	2,000,000	150,000	760,000
BlockRAM	13Mb	34Mb	68Mb	4.8Mb	38Mb
DSP Slices	740	1,920	3,600	180	2,016
DSP Performance (symmetric FIR)	930GMACs	2,845GMACs	5,335GMACs	140GMACs	2,419GMACs
Transceiver Count	16	32	96	8	72
Transceiver Speed	6.6Gb/s	12.5Gb/s	28.05Gb/s	3.2Gb/s	11.18Gb/s
Total Transceiver Bandwidth (full duplex)	211Gb/s	800Gb/s	2,784Gb/s	50Gb/s	536Gb/s
Memory Interface (DDR3)	1,066Mb/s	1,866Mb/s	1,866Mb/s	800Mb/s	1,066Mb/s
PCI Express® Interface	x4 Gen2	x8 Gen2	x8 Gen3	x1 Gen1	x8 Gen2
Agile Mixed Signal (AMS)/XADC	Yes	Yes	Yes		Yes
Configuration AES	Yes	Yes	Yes	Yes	Yes
I/O Pins	500	500	1,200	576	1,200
I/O Voltage	1.2V, 1.35V, 1.5V, 1.8V, 2.5V, 3.3V	1.2V, 1.35V, 1.5V, 1.8V, 2.5V, 3.3V	1.2V, 1.35V, 1.5V, 1.8V, 2.5V, 3.3V	1.2V, 1.5V, 1.8V, 2.5V, 3.3V	1.2V, 1.5V, 1.8V, 2.5V
EasyPath Cost Reduction Solution	-	Yes	Yes	-	Yes

Table 20: A FPGA comparison table

All of the FPGA boards that were being considered required very little voltage to operate. They all have over five hundred input and output pins. All of the FPGAs being considered have a built in transceiver with transmission rates ranging from 211 Gigabits per second to 800 Gigabits per second. The Vertex-7 has ninety-six (96) transceivers, while the Spartan-6 has little as six. Both would have been sufficient for the requirements of this design.

Each FPGA board has built in memory capability to store the code that controls its functions and data processed or received by board, which would then relay it to the other boards in the network and ultimately the main hub where the data is processed. The transceiver speed ranges from 3.2 Gigabits per second on the Spartan-6 to 28.05 Gigabits per second on the Vertex-7. This means that the data received or processed has the capability of being transmitted very quickly or not as quick if it not required being at its destination immediately.

The cost of the board and the need for the data to get there very quickly did ultimately determine the type of processor used. This does have a cost factor associated with it. The better and most up to date processor would cost more than one of the processors that have been in production for some time due to market exposure and the amount of time that has elapsed for a rival manufacturer to meet it current performance specifications and surpass them. On the other hand, the newest or most up to date design may be used for this design and it may be discovered that certain problems that the new processor encounter may adversely affect this design, and given the time it has been on the market very little troubleshooting tips may be available to the design group's disposal to use as an aid in completing the design successfully and meeting all the required specifications and completing all the necessary tasks as deemed in the testing portion of the design.

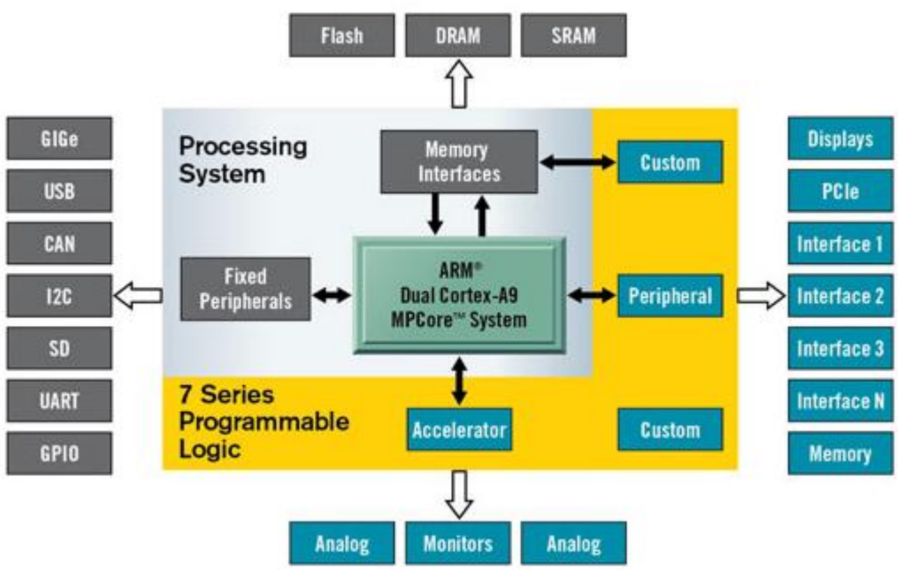


Figure 49: The architecture of the FPGA 7-Series

5.4.1 Cortex-A9 processor

As shown above, the FPGA 7-series has many user interface connections including a USB and displays. The display capability of this board type could have been very useful for this design, where an LCD could be used to display whether or not the trashcan is full. The dual-core ARM processor makes it very attractive to this design in that the information can be processed rather quickly and the execution time in order to display the required message on the LCD will be done with minimum delay. All of this is being accomplished with very little power being dissipated while in either active or standby mode.

5.5 TrashTalk PCB

The PCB design for TrashTalk was modeled after the Arduino Uno design. Elements of the original board that weren't being utilized were removed from the design, leaving behind only the essential components that are useful to the project. We eliminated the USB interface and all of its components and added to it the XBee shield which is used for wireless communication. A GPS module was added to the design to add flexibility and ingenuity to the project design. All of these features were added on keeping in mind that the design had to be operated by a maximum regulated 5V or less powered by the battery system or solar power system as necessary. Below the design of the PCB utilized in TrashTalk is shown below.

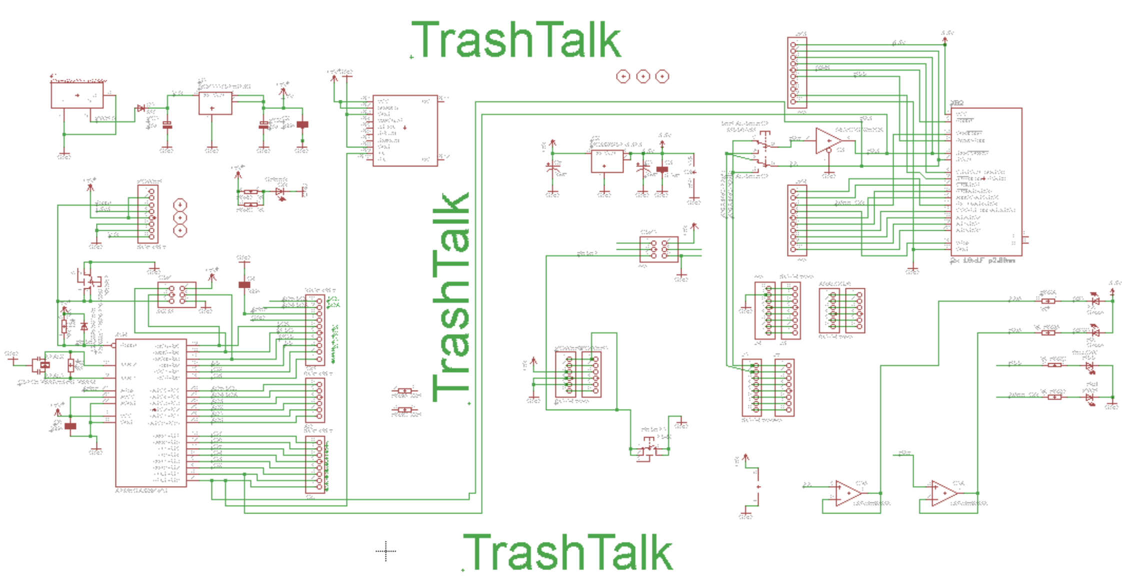


Figure A1: TrashTalk Schematic

The design uses a GPS for very precise up to the minute processing of the location of the unit. This would be very useful in a mobile application of TrashTalk, the user or system operator can pinpoint the exact location of each of the TrashTalk trash cans within a minute of getting a new location once the system refreshed and provides the new GPS coordinates to the microcontroller which then packages it up along with the sensor data and passes it to neighboring trash cans through the XBee wireless communicator. Some of the deliverables provided by the GPS device are listed below. We chose a Parallax 648 GPS system for the design because it gave desirable features along with cost flexibility and measures 1.25 X 1.25 X .35 in.

Figure: A2 Parallax 648 GPS

- Requires 3.3 – 5V at 65 mA
- Temperature Range: -4 to 158 degree F
- High Sensitivity
- 20 parallel satellite tracking channels for acquisition and reacquisition
- Built in rechargeable battery for memory and RTC backup
- Communicate via TTL or RS-232 asynchronous serial at 4800 bps
- Supports NMEA 0183 V2.2 data protocol

Below is the board layout with all of the components positioned in their respective location on the board. The board was strategically designed into two halves, the microcontroller side and the wireless communication side. This was strategically done to make trouble shooting and tracing inputs and output voltages and currents much easier. This made it much easier to identify a problem and pinpoint the potential problems and the source of the problem.

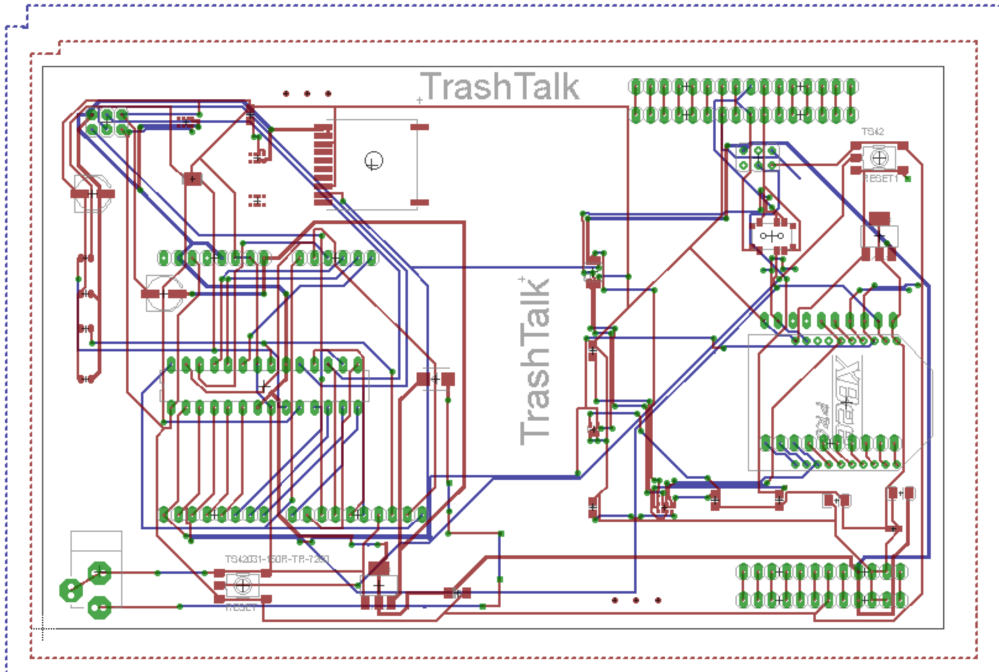


Figure A3: Board layout of TrashTalk

6. LCD Display

An LCD was being considered to be utilized in this design to alert the user whether the trash can is full or empty. This feature was replaced with a more useful feature, the GPS. The liquid crystal display (LCD) would have been attached to the exterior front of the trashcan and would display the text “FULL” when the trashcan is full and “NOT FULL” when it is not full. Our thought process behind the LCD screen for having an LCD’s is that if the trash can is going to be able to communicate, it should be able to communicate with people that will come up to deposit waste. One way to do this is to include a display panel on the side. It should be able to tell users if the trash can is full or not so that they do not waste time walking all the way there when there is no room. There are many available LCD displays available to choose from to be implemented in this design.

6.1 Segment LCD

A segment LCD is sometimes called an alphanumeric LCD is able to display Arabic letters and numbers represented by seven segments and fourteen segments respectively. Roman numerals can also be displayed of this type of liquid crystal displays. Plus and minus signs can also be displayed on the segmented liquid crystal display, measurement units and can also be displayed and each is treated as one segment. This could be a very useful tool in facilitating the message or image being displayed onto the screen of the LCD to the user. This choice of display would have given the group of designers the most flexibility in the design. This allows the system manager or user to display messages in languages other than English adding to the degree of flexibility the overall design has.

6.2 Dot Matrix LCD

Dot Matrix or Character LCD display can be used to display a number of lines of characters. The most commonly used dot matrix is able to display one to four lines of sixteen to forty (16 – 40) characters. Each character will be represented by a 5x8 dot. This type of display is able to represent Roman numeral characters as well as limited characters and symbols in other languages other than English. This LCD type adds the ability to represent a lot more than just a few words on the display, it has the ability to display a short message to the user containing anywhere from 16 – 40 characters. This LCD types takes away the added flexibility of communicating to the user in languages other than English.

6.3 Graphic LCD

A graphic LCD will provide the design team with the most flexibility in terms of the message being displayed to the person putting waste into the trashcan. This type of display is composed of pixels of rows and columns with each pixel being able to be accessed individually to display text, graphics, or combination of the two. This LCD type may be the most flexible, in terms of the message that can be displayed, but it is also the most difficult to design when implementing the circuitry to control the message being displayed.

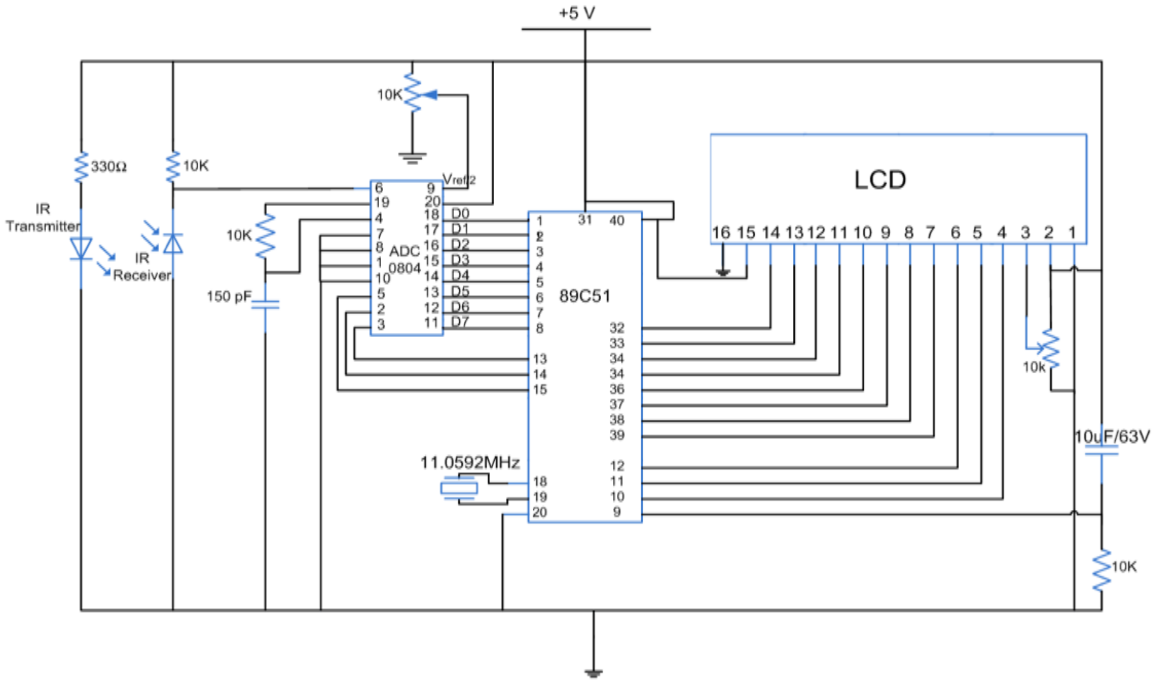


Figure 50: Sensor with LCD

7. Wired vs. Wireless

The most reliable way for the trashcans to communicate with each other would be through a hard wired system. This configuration would be a relatively low cost option way for the trash cans to communicate with each other and ultimately the main hub. Though reliable, a hard wired system could pose a lot of problems. The wires would have to somehow be concealed to reduce the chances of it getting damaged and for aesthetic reasons as well.

A hard wired system would restrict the trashcans to a fixed location, and moving them to say an area with heavier traffic to get better use out of the trashcan would mean removing, or unearthing the old wires and rewiring the system just as it was done before. This could be very labor intensive and time consuming. This would limit the flexibility of the system and could end up being more expensive than a wireless system once the cost required for manpower is factored into the cost equation. In a hard wired system, the wires may be exposed to the elements causing them to potentially be damaged due to exposure to the harsh conditions. Though reliable and cost effective, the hard wired option limits the flexibility of the system. If the wires connecting the trashcans to each other become damaged this could be problematic and time consuming to fix. Given its limitations, a hard wired system would have clearly not been a good option for this project.

Once that it was been decided that a wireless system would be more practical and reliable for this design, a closer look was taken into a few wireless systems. They were evaluated individually, and the most reliable, self-sustaining, cost effective one would have been chosen as the network system for this design.

7.1 Wireless Sensor Nodes

Wireless sensor nodes (wsn) are micro controller boards with communication devices permanently hooked up to them. The communication device is usually a radio, but it can also be an infra-red optical device or function with acoustics. This application is better suited for one system that sends information to some other location, and that's all it does. In our design, multiple devices will be communicating with the master node, therefore this system isn't suitable for the network. Another disadvantage of this type of network would be the ability for the hub to be in rage of every trash can. To increase the range of the system, every trashcan would need to have a very powerful communication system, which requires a lot of power for each board located in trash can. The design of this project requires multiple trash cans communicating with each other and ultimately the main hub station. Once the information arrives at the main hub, the information received is processed and translated into a status signal for the trash cans interfaced unto a map of the area where the trash cans are located. This is very similar to a star network shown below. This layout would consume a lot of power and would not meet our design requirements. It would also make things unnecessarily over complicated by having to create a central-hub station, meaning, the main hub needs to be centrally located in order to communicate with all the trash cans surrounding it. This topology is shown in the star network below.

7.2 Mesh Network

On the other hand, a mesh network or variation of a mesh network was be a much better fit for this design. The self-healing and self-organizing mesh makes it the ideal candidate for the network topology of this design. The multi hop routing protocol handles multi-protocol logic. It has the ability to allocate ids and retransmit packages if they get lost. It avoids package collision by listening on the channel before sending and including wait states if the channel is busy. This makes the system very reliable, in that, the package will continue to be resent until it is acknowledged by another node within the network.

The hub station will be able to communicate with the furthest trash can as long as it is within range of another one, which in turn is in range of another node, and so on. It detects all neighboring nodes in its range and establishes communication with the node which is nearest to the master node. If there is a break in the network, i.e. an acknowledgment signal was not received by one of the trash cans trying to talk to another one, this information is passed on to the main hub, which then lets the system manager or operator know that there is a break in communication to the specific hub it tried to communicate with. This lets the system manager or operator know exactly which node is posing communication problems, and allows for further investigation into the problem. This could pose a serious problem were the network topology of choice would have been a “line network” topology. Unless the furthest node is able to communicate to the main hub directly, this could pose a various communication problems if one communication link in the line is broken.

The design can be utilized in both indoor and outdoor situations; the network for a specific location may have eight trash cans or more. If the line topology is used and communication from trash can one ad two are good, but there isn’t any communication from trash cans three through eight, the system manager/ operator will have no idea of figuring out which node is having a communication problem. Every link from three through eight must then be physically inspected in order to figure out which node is posing the problem. This topology may be easier to implement than a mesh network, but it may be very inefficient and costly. Unlike the mesh network, there isn’t a backup communication system build in the design, unless the main hub can communicate with the furthest node. As mentioned before, this would consume a lot of power, hence more expensive. This design is not self-reliable, and potentially costly, making it an unwise choice to implement a self-sustaining, self-reliable system.

All communication issues could almost be entirely solved by implementing a fully connected network topology. Every node is connected with every other not in the network. If this design were implemented as the communication network for this design, this would make the system very reliable. It is so reliable that every trashcan knows what every other trash cans status is at all times. This gives rise to the option of having any node can be chosen as the main hub. This could be beneficial if the network covers a large area, say UCF campus for example. System manager A could be hooked up to a node at the north most point on campus, because he lives very close to the north side of campus. System operator B who lives thirty miles south of campus is system manager A’s relief. As opposed to driving an additional two miles across the diameter of campus, system operator B would connect to the southernmost node on campus and perform his duties there. He would save the two mile trip across campus at the beginning and at the end of his shift, saving time, money, and gas. Now, this communication topology may be the most reliable one discussed yet, but this reliability comes with a very high price tag. The amount of power consumed would be exuberant!

Like before, the amount of power consumed would be through the roof as well. In the example given above, the nodes need to be able to communicate across the entire diameter of the campus. The nodes need to be able to communicate directly with the furthest node away from it, as well as the node closest to it. The cost of such a system would be very high. The network would be very reliable; almost 100% reliable, this topology would have every node or trash can be a potential master hub. This design however may require a lot of power to operate. Unless an external source of power is available, this system would potentially require a very large size solar panel to operate. This design would be reliable yes, self-sustaining? No. Low cost? No. Answering these questions leads to a clear conclusion that this topology does not fit all of the design requirements of a reliable, self-sustaining, efficient, low cost system.

If a ring network topology were to be used for the design topology of this project, the benefits and drawback may be very similar to a line topology. The difference in the ring topology would give an advantage of communicating back to the central hub station in both directions. This gives each node two communication paths, clockwise and counter-clockwise. In the case of a broken link, communication to the main hub is still possible by communicating to the main hub in the reverse direction. This topology has many advantages in that each node does not require a lot of power because it will on be communicating over a relatively short distance to two of the nearest nodes in either direction. It is reliable in that there is a backup communication route built in to the network's design. It would be self-sustaining because it does not require a lot of power, hence and eternal source of power other than the batteries and the attached solar panel.

This design is a relatively low cost design like the mesh network. The only disadvantage the ring network has in comparison to the mesh network topology is that it is not as reliable as the mesh network. The ring network topology is similar in complexity and cost when compared to the mesh network, the fact that it is not as reliable as the mesh network will be the deciding factor between the two networks. For a negligible difference in price the mesh network is the outright winner as the network topology design of choice for this design.

The mesh topology does not require each unit to consume a lot of power, it is very reliable, it is self-sustaining, in that it would not require an external source other than the batteries that powers the system, and it would be a relatively low cost design. This network topology is the right fit for this design. It meets all the requirements of the design, i.e. self-reliable, self-sustaining, and low cost trash monitoring system.

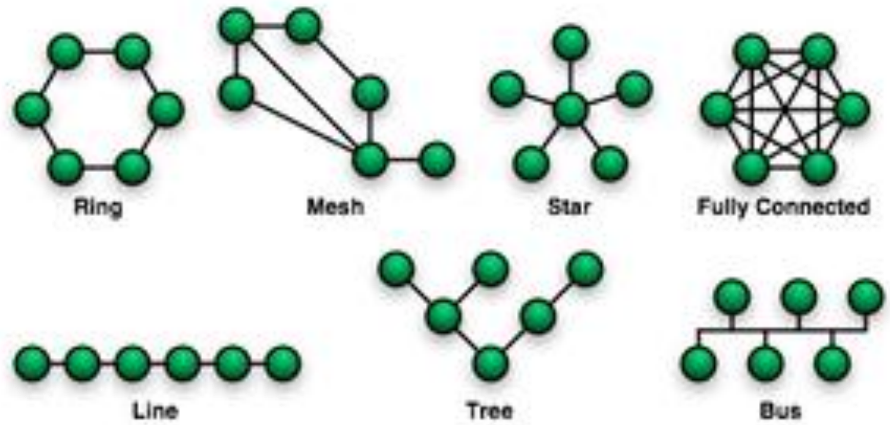


Figure 51: Network topologies

7.3 Infrared vs. radio frequency

We could have used and infrared led and an infrared receiver as a communication channel. Another option for communication channel was be radio frequency.

Infrared was the first choice for this design because it is relatively easy to setup and use. It is also one of least expensive ways to communicate wirelessly. This type of communication does require the transmitter of the infrared signal and the receiver of the signal to be in each other's line of sight. The infrared signal is swept out of a cone approximately thirty degrees. This may not pose of any major problems for our design because of the dimensions of the trashcan does not exceed fourteen inches in diameter or forty-eight inches in height. Making sure the infrared transmitter and receiver are within range and line of sight should be a relatively easy task to accomplish because of the trash can's size.

For transmittal of radio signal on the other hand requires the transmitter and the receiver to be only within range but not necessarily line of sight. As long as there isn't an impervious material separating the transmitter and the receiver, the signal should be received without any major issues. The transmitter could be on the inside of the trashcan and the receiver on the outside of the trashcan and still be able to communicate with each other without any distortion or altering of the signal. The same should happen if the transmitter were to be put on the outside of the trashcan and the receiver on the inside on the trashcan. One drawback of using radio communication is that if another device or system nearby is communicating on the same frequency, this may create interference with our communication system. This would reduce the reliability of our communication system, by giving false readings and wrong messages, hence confusing the system. As a result unnecessary trips may have to be made to empty a trash can that is reading full and really isn't. This would make the system less effective and cost efficient, hence defeating the purpose of designing a self-sustaining, self-reliable, trash monitoring system. This communication drawback may be avoidable if the communication system can be made secure, i.e. encrypted or by creating a specific way of communicating by sending and confirming or acknowledging every signal sent and received with a unique encoded message, That way the trash can knows to listen only to other trash cans and not random devices sending random signals. This type of communication would have to be set up as a “don’t talk to strangers” network. Then, and only then would the system meet the requirements of be a self-sustaining, self-reliable monitoring system.

7.4 WLAN

One option of the communication setup between the trashcans would be to use a WLAN network. There are a few factors to be considered when using WLAN, the device can either be manually set to a specific frequency, or be left to do so automatically. If the device is set up to automatically find the correct frequency, the device scans the frequency spectrum either to listen for an unused frequency or it can be set to listen for transmitted signals that have the same SSID (Service Set Identifier) as the one it is currently set to. Units with different SSID will not be able to communicate directly with each other, which would be detrimental for this design. The trashcans need to communicate with each other in order to get the information to the main hub station. Another factor to be considered when using radio frequency as the mode of transport to get the information from one trashcan to the next is the data rate. The data rate chosen affects access point (AP) coverage area, in that, the data rate is inversely proportional to the coverage area. In order for the devices to be able to communicate with each other, the data rate of each device has to be the same. The lower the data rate, the greater the AP coverage area and the higher data rates have less Access Point coverage in comparison to the lower rates of the system.

7.5 Wireless Communication

7.5.1 WiFi

When it comes to communication, the system used for this design must be fast, reliable, and operate over a considerable distance while utilizing very little power in transmission or standby mode. Once of the options being considered is **WiFi**. A WiFi network would be relatively easy to implement to accommodate this design. Each trashcan would just have to be fitted with the appropriate WiFi transmitter and a WiFi receiver. This would allow the trashcans to “talk” to each other via a signal transmitted at 2.4 Gigahertz. WiFi would allow the independent, self-sufficient trashcans to communicate wirelessly using radio waves over a computer network.

If a WiFi network is utilized in this design, the range of the system would be approximately twenty (20) meters or sixty-five (65) feet indoors and a significantly greater range outdoors due to ability for the signal to be transmitted without as many interruption partitions that are inside of a building as opposed to outside of a building, like walls or doors for example. To overcome this drawback, if the system were to be used indoors, multiple overlapping systems or access points may be the best solution for this problem. This would add to the overall cost of the system, hence taking away a degree of freedom for the overall design. This system is very similar to a hard wired Ethernet system; the major advantage of a WiFi network compared to a hard wired system is that it would be aesthetically pleasing.

Unlike its hard wired counterpart, there would not be wires running all over the place, making repositioning of any component in the system relatively easy as long as it is within range of the other network of trashcans. Another major advantage of using a WiFi connected network system would be that an additional component or components may be added to the system without having to be connected to an up and running personal computer in order to perform its required functions or tasks. This gives the network to be accessed remotely as long as internet can be accessed. This feature would add much needed flexibility to the system. Anyone will have access to the network independent of their current location, proving they have access to a somewhat reliable source of internet connectivity.

One disadvantage to a WiFi network is the security of the system. Breaches have been made relatively easy into the first security encryption system for WiFi networks. WEP (Wired Equivalent Privacy) encryption system has since been replaced by a less susceptible, much higher quality protocols WPA and WPA2. Although no sensitive data is being transmitted over the network, security may still be required for the system in order for it to remain reliable and the information being processed to be trusted as true and correct.

Adding a more secure network would make the data reliable, but there is a cost associated with encrypting the system. Unless the system is being utilized in military application or some sensitive or personal information is being transmitted through this system, a secured system may not be required. At least not one that is secure enough to increase the cost of the system significantly. WiFi connections may be disrupted or the speed of the system may be lowered because other devices within range of the system may connect to the system. This may cause added strain or load on the system. Most all 2.4GHz 802.11b and 802.11g are defaulted to the same channel at start up, this may create channel congestion of other devices are nearby and the default channels are not changed in advance to prevent this from occurring. If there are many WiFi networks within close proximity of each other, the signal to noise ratio (SNR) may be reduced by what is known as WiFi pollution.

Comparison of the security options available to the WiFi networks will be analyzed and implemented as deemed necessary by the user of the system, taking into consideration the cost, ease of use, security needs, power consumption required by the system, and proximity to other networks or devices operating on the same channel or devices that may interfere with or interrupt the transmission process of the system will be further analyzed and weighted accordingly by priority in determining the final specifications of the network.

7.5.2 Bluetooth

The other option that was being considered for this project for the network of trashcans to communicate with each other is by utilizing a Bluetooth network. Bluetooth networks are relatively easy to establish and is generally recommended for a point to point communication network. Bluetooth has been known to be very reliable in point to point communication networks, this would be ideal if we had one trashcan communicating with one other trashcan or one computer as the master station.

For this design, given the requirement that each trashcan must be able to establish a connection to the nearest node to the master station may be problematic using Bluetooth connectivity as a choice for the network of this design. While connecting two points to each other, hence the name, point to point, Bluetooth has been widely known to have very high data transmission rates and with an adequate antenna, this system could transmit for very long ranges. Some studies have reported an ideal Bluetooth connection may be able to transmit for more than one kilometer. This is a rather impressive feature, this would give our design added range, and this technology could take our design one step further.

Rather than being limited to the interior or a rather large building, or the confines of an apartment complex, this could be expanded throughout the limits of a small city, depending of the positioning of the trashcans to optimize transmission and reception. This would allow the system to be used in situations where a community dump is utilized and is collected at a predetermined frequency based on the assumed use by the surrounding residents.

Implementing this design to accommodate the needs of the municipal requirements could take the guessing out of how waste management officials determine whether or not a trashcan or dumpster in this case requires emptying. The improved accuracy would have the potential to eliminate the dumpster being overflowing with trash for two or more days, posing serious health risks and an eminent infestation by rodents and other animals looking for food.

Transmission power is very low for a network that utilizes Bluetooth technology. This is a very attractive feature of the type of network, as one of the specifications of this design requires the system to be self-sustainable and be operated with very little power dissipation in active or standby mode. In order for the entire system to be self-sufficient and operate on a few volts of energy, each component must also meet this requirement, this network type was being considered to be implemented in this design for the reasons listed above.

A network connected through Bluetooth provides a relatively secure connection. Each device talks to the other by establishing a trust agreement by a matching pin number; this creates a secure usage loop. However, Bluetooth is not the ideal network of choice when dealing with multiple nodes or trashcans in this design try communication with one other or multiple trashcans simultaneously. This drawback may cause the system to be considerably less reliable than the design specifications require.

The maximum rate that data can be transmitted using Bluetooth is reported to be roughly one megabyte (1MB) per second, while infrared is capable of transmitting up four megabytes per second (4MB), and WiFi is capable of much higher speeds. This may not pose a problem if the data being transmitted is relatively small, but expansion of the project may be limited to a certain degree if this was chosen for the network setup for this project. Realistically, a device connected through Bluetooth may only have a range of roughly fifteen (15) to thirty (30) feet of transmission, making it very impractical to utilize in this design for outdoor use.

7.5.3 ZigBee

A network that utilizes ZigBee protocol can also be operated on a 2.4GHz frequency band like WiFi and Bluetooth. It operates at much lower data rates than WiFi or Bluetooth. It is a high level communication protocol that uses small, low power digital radios to transmit data. Generally, ZigBee devices are used when establishing a mesh network, as this design plans to utilize. ZigBee utilizes intermediate or closer nodes in order to communicate to the ones further away from the system.

Any Zigbee device can be designated as the main or hub station within the system. This allows the network to be formed with no centralized control or any high power transmitter or receiver that is able to reach all of the other devices. The ZigBee network is best suited for designs that do not require a high data rate, long life of the battery, and secure networking. This is precisely the design criteria of this design.

The ZigBee protocol allows the system to be self-sustainable, self-reliant and very little power to operate in the transmission mode. The Zigbee network puts significantly less strain on the system in standby mode. ZigBee has a data transmission rate of 250 Kbits/s, this specification of the system is best suited for intermittent or periodic data transmission from a sensor or other input device. This is precisely the way the network is planning to utilize the ZigBee network, at a predetermined time set by the system administrator or system operator, the trash level will be checked and this information passed on the main hub where the data is processed which intern is used to update the webpage with the trashcans overlaid on the map of the area where the trashcans are located.

A few advantages that a network setup using ZigBee as opposed to WiFi or Bluetooth is that a ZigBee network has very low power consumption compared to WiFi or Bluetooth, Also it is a very robust network. A network established using Zigbee protocols tend to be very secure and resistant to interference from other devices from outside of the network. A ZigBee network can connect over 65,000 nodes! This is a lot more than this design requires, but this makes expansion of this project limitless in terms of the number of nodes available to be interconnected to each other within the same network.

There are a few drawbacks with the ZigBee network that have to be examined as to how they will affect this project. If needed, any possible remedies to fix or reduce its adverse effects of these drawbacks on the system would have to be tested and analyzed to ensure the system still meets its overall requirements of being low cost, self-reliable, and self-sufficient trash monitoring system. ZigBee networks have low data transmission rates. This may delay the information being transmitted from the trashcan to the main hub about its status and current condition.

Given the limited amount of data that the system will be using to communicate with the other trashcans in the network, the rate of transmission should be sufficient for the network of trashcans to communicate with each other effectively and with a limited delay from when the data is sent to when it is processed into useful information.

Another disadvantage of using a ZigBee network is that the devices are able to transmit over a shorter distance when compared to other wireless networks like WiFi or Bluetooth. The range able to be covered by the ZigBee protocol may depend on a number of factors. If the trashcans are positioned in a heavily wooded area the transmission range would be significantly less than if they were to be placed in an area where the trashcans have a direct line of sight. The specific situation in which the trashcan will be used will determine the communication system that will be implemented. For this design, the ZigBee protocol should suffice in allowing the design to meet all the specified requirements of the system as stated in the overall system requirement.

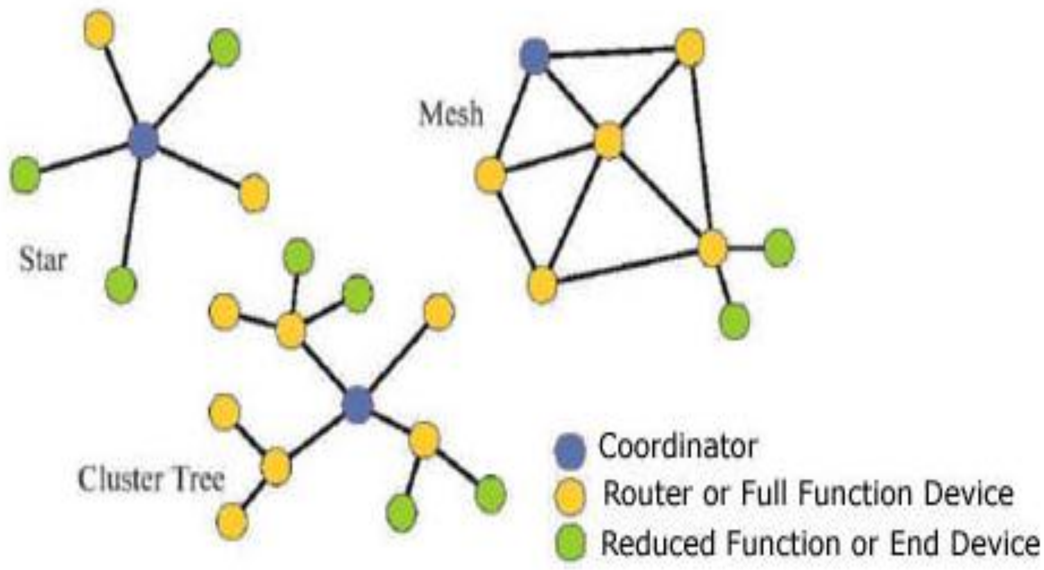


Figure 52A: Options available for implementing a wireless network utilizing ZigBee protocol as the method of communication between nodes.

The options available in the structure of the network, when using a ZigBee protocol, are shown in Figure 52A. The Star network will have the main hub centrally located to optimize communication to the other nodes. The Cluster Tree has the main hub not necessarily at the center of the network but within communication range of all the nodes within the network. The Mesh network does not need to be able to communicate with every node in the network directly, but can do so with the surrounding nodes by relaying the signal until it reaches its desired destination.

7.5.4 DigiMesh

DigiMesh is a type of mesh network just like ZigBee. TrashTalk network is created by a DigiMesh network. It allows all the wireless nodes in the network to be routers as shown in Figure 52C. It is a self-healing, self-forming network, so the routing of data packets is done by the wireless nodes themselves. This allows the network to be scalable and self-sufficient. DigiMesh was chosen over ZigBee because with the ZigBee network, the location of each trashcan determines if the trashcan needs to be either a router or end device. The ZigBee network will have to be configured similar to the one in Figure 52B. With the DigiMesh, a trashcan can be moved anywhere in the network without special configuration.

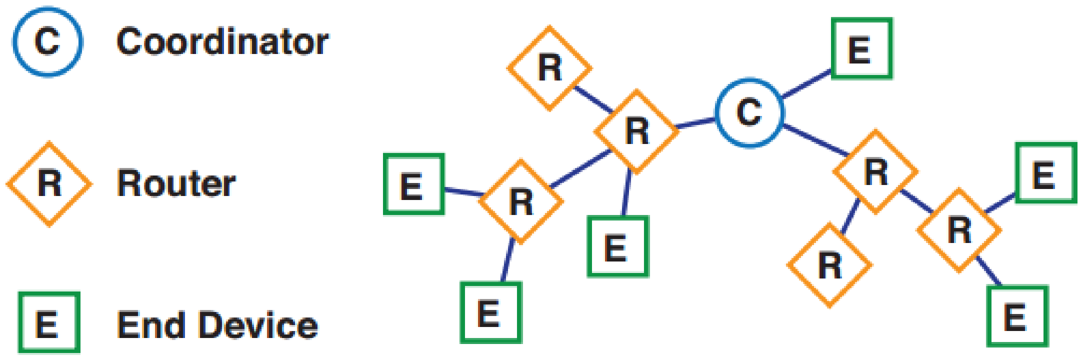


Figure 52B: Example of ZigBee Network

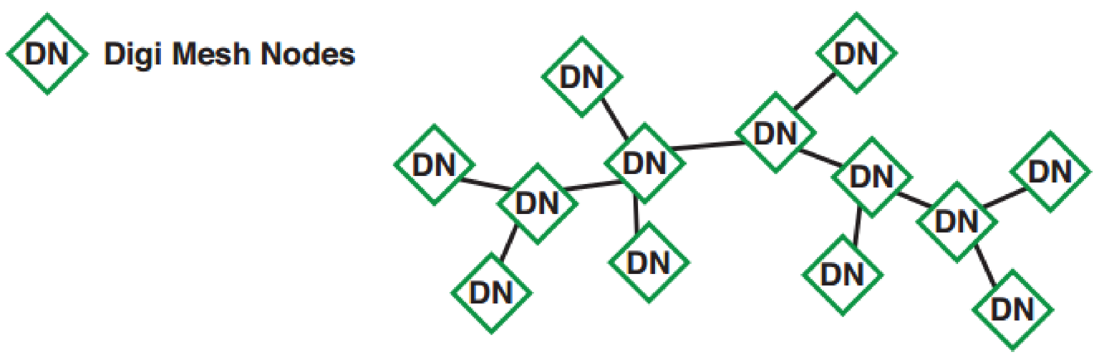


Figure 52C: Example of DigiMesh Network

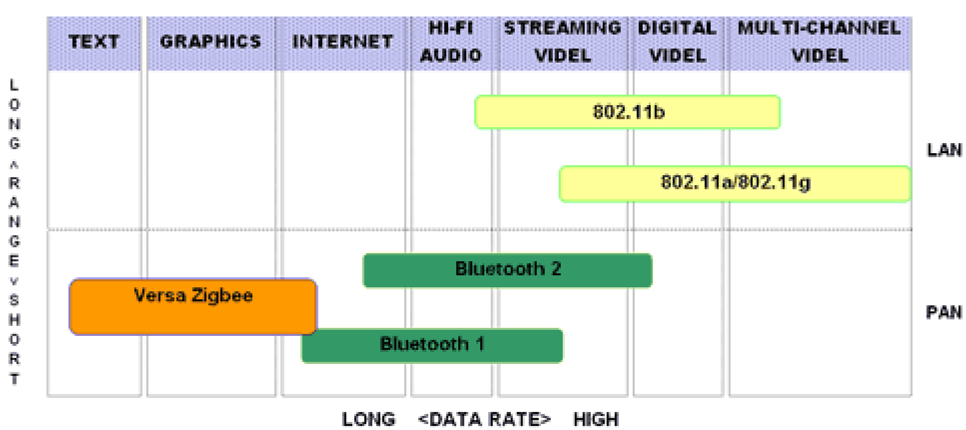


Figure 53: The use and capability of a ZigBee network in comparison to a Bluetooth network.

Figure 53 shows that WiFi has the longest range of communication compared to Bluetooth and ZigBee. ZigBee is suitable to transmit text and graphics given its low data transmission rate and is suitable for use in a personal area network (PAN).

As shown in the Table 20 the data transmission rate for the ZigBee communication system is 250 Kbits/second making it ideal for monitoring and control applications. Bluetooth is capable of transmitting data at a much faster rate of 1 Mbits/second. WiFi, which is best suited for email and video streaming applications, is capable of transmitting data at a much faster rate than both ZigBee and Bluetooth. WiFi is capable of transmitting data up to 54 Mbits/second. WiFi has the greatest range capability of the three wireless communication types; WiFi networks can communicate distances ranging from 50-100 meters. Bluetooth can transmit up to 10 meters between nodes; ZigBee protocol networks are able to transmit over distances ranging from 10-100 meters.

Compared to WiFi and Bluetooth, a network implementing ZigBee protocols is relatively easy to implement and of very little complexity. The network for this design will utilizes ZigBee protocol and will experience a rather slight delay in data transmission or roughly thirty milliseconds (30ms). This delay should not have an adverse effect on the overall operability of the entire project. This is a rather slight delay, and may not be noticed by the user at all. After comparing all the possibilities available to this design for a wireless network, it has been determined that Zigbee would be the best choice. Given its low cost, ease of implementation, transmission rates, and range, this would have been the best choice overall for this project design.

	ZigBee	Wi-Fi	Bluetooth
Application	Monitoring and Control	Email, Web, Video	Cable replacement
Physical/ MAC layers	IEEE 802.15.4	IEEE 802.11	IEEE 802.15.1
Data Rate	250 Kbits/s	11 & 54 Mbits/sec	1 Mbits/s
Range	10-100 meters	50-100 meters	10 meters
Networking Topology	Mesh	Point to hub	Ad-hoc, very small networks
Operating Frequency	2.4 GHz	2.4 and 5 GHz	2.4 GHz
Complexity (Device and application impact)	Low	High	High
Power Consumption	low	High	Medium
Number of devices for Network	64K	32 per access point	7
Network Latency New slave enumeration	30 ms	-	20 sec
Network Latency Sleeping slave changing to active	Devices can join an existing network in under 30ms	Device connection requires 3-5 seconds	Device connection requires up to 10 seconds
Typical Applications	Industrial control and monitoring, sensor networks, building automation, home control and automation, toys, games	Wireless LAN connectivity, broadband Internet access	Wireless connectivity between devices such as phones, PDA, laptops, headsets

Table 20: Comparison of ZigBee, WiFi, and Bluetooth

8. USER INTERFACE:

The home display for the user is user-friendly, simple, and easy to read. The user does not need any special or extensive training on the user controls. The system could have been offline implemented as a program running on an OS system, but it was implemented on a website.

The process behind the display analyzes and sorts the received data from the wireless networks and then displays the desired information to the user. The user interface can be used by multiple users and the home page does not require log in credentials. Adding a login to the home page would require more time spent by the user to remember their credentials and login. This also allows user at the location to be able to see all the locations of trashcans in the area. The home page was going to be made up of four components: the map, status list, the map legend, and the links to other pages. The status list was taken out from the home display. The map is the main focus of the home page. It is where the user looks to quickly and efficiently locate each trashcan and its status (trash level). The user can access two other page displays when logged in as an administrator. The two other web pages include access to edit the trashcan system and a table of trashcan history.

8.1 Process running on OS system:

If the display was presented by a process running directly off of the OS system alone, the user must know how to run the process. The user control could have been a stationary unit that includes the main wireless node that all the nodes send their information to and a computer system that has the program installed that would display the desired information on. A static map would have been needed with the program to run offline. The map would have limited the user to see only what is saved in a static map API on the system. To update the maps shown, a software programmer would have to go in and manually update the maps. All the received information would be stored into a database and then accessed by the process. The process on the OS system would not need to be connected to the internet, only to a wireless node.

8.2 Website:

The user interface was implemented as a website, although a process on the control system must be running at the same time. Running the user interface as a website gave more and easier options with running the map API. The process does not display any trashcan information to the user. It is used to read from the serial port that the wireless control system node is connected to, sort and save the received information of each trashcan, and updates the database with that information.

When the user enters the website address to their TrashTalk webpage, the user is shown the home page display. Each company/area that is being monitored, the website and software must be customized to that company's/area's settings. Google maps API was easy to implement on a website. Most map APIs that were available to use are widely created for implementation on a website or mobile app. The trashcans would have to be manually entered into the system by a software programmer or the user with valid login credentials. A GPS module was used to track the location of each trashcan on the map include of manually entering in the coordinates. The latitude and longitude coordinates is sent from each trashcan to the control system where the process stores the updated location in the database. The data being received from the network of trashcans is sorted and stored into the database. The website reads from the database to display the appropriate information of each trashcan being displayed on the map on the webpage.

The information of each trashcan would not be shown on the map appropriately if the user is not connected to the internet. The home display of the website can be accessed by any user of the internet, as long as they know or find the link to the website. Currently the website is running locally on a system with the database. If TrashTalk is deployed to a user, the website must be hosted on the internet. There are many hosts available for websites on the internet. The hardest thing is to find a free or inexpensive one that would not have an excessive amount of ads.

8.3 Hosts for website:

TrashTalk does not need to be hosted on the internet at the moment. If TrashTalk does need to be hosted one day, there are many options available. Eustis UCF server can be used by the faculty and the students. Although it is free for UCF students, the server has very strict permissions. Google Sites can also host a website for free. There are many free or inexpensive hosts for websites that can be chosen.

8.4 Map API

The map is the main element on the display, because it would show exactly where each trashcan is located. If the location of the trashcan is changed, it would be easier to see where the new location is rather than to just describe it or looking at latitude and longitude coordinates. The user is able to zoom in and out on the map displayed. The user also has the ability to move the map around to see other areas that were not currently displayed because of the limited map view.

8.4.1 Microsoft Bing Maps:

In addition to the road map, Microsoft Bing Maps can show the street view and bird's view of the location shown on the map. The usage of Bing Maps has a free offer of the usage of their maps. For educational and non-profit accounts, the street view is offered for free. There is an option for the user to zoom in and out. Multiple types of entities may be added to the map at a specified location. The location of the entity may be changed at any time even by the user. The map can be made to be interactive with the user; therefore it gives the user the option to move the location of the trashcan on their own without having a software developer manually entering it in.

Microsoft Bing Maps also offers the addition of a layer showing the traffic. Microsoft Bing Maps shows building, roads, and major walkways, but not sidewalks. The Bing Maps AJAX Control, Version 7.0 is the latest API from Bing Maps. I can be combined with other APIs to implement other features that are desired. It uses JavaScript to implement maps. The supported web browsers are listed in Table 21.

8.4.2 MapQuest API:

MapQuest is one of the first to provide maps on the internet. There is the option to either use a static or dynamic map. Bing Maps offers Licensed Data and Open Data to be implemented. Microsoft Bing Maps offers open JavaScript Maps API as Licensed Data or Open Data. The Open Data is free and could be edit the map to display the desired information. The Open Data portion can be powered by OpenStreetMap (OSM), which opens a range of options for Bing Maps.

OSM is a tool to help embed a map to a website using interactive GUIs. OSM allows easy editing with drag and drop entities. The user can simply change the location of the trashcan as needed. Customized icons could be used as an entity. Microsoft Bing Maps shows building, roads, and sidewalks marked by red dotted lines. Bing Maps can create an interactive map for a website. The user would have the option to zoom in and out on the map. Rotation of the map is also offered to the user. The supported web browsers are listed in Table 21.

There are a lot of external applications that would help the software developer implement Map APIs provided by difference services. OSM (OpenStreetMap) that was mentioned above is an open source worldwide map. Since it is created by users all around the world, the data that is provided could or could not be correct or validated.

8.4.3 Google Maps API:

Google Maps API is free to use for this project. If Google Maps API is used, the website must be publicly available without any charges. There is an option to remove the page from Google search so that it cannot be easily accessed by a random user. Street view and Google Earth view can be shown onto the website as well.

The static maps API has a maximum resolution of 640 x 640 and be scaled by 2x. The number of page loads for Google Maps API cannot exceed 25, 000 per day. The data is being updated every 30 minutes, so for 24 hours in a day the map would be updated and loaded at least 48 times a day. This is well under 25,000 map loads. The map can have the option to zoom in or out.

Markers can be added to the map to represent the trashcans that would be monitored. Customized markers can be used on the map as well. Markers can be added by longitude and latitude on the map and must be manually put on the map by a software developer. Google Maps offers a detailed map of the desired location, which includes sidewalks. To be able to map trashcans, it would be ideal to show where they are located on the sidewalk.

The three main APIs that Google offer is Google Maps JavaScript and Google Static Maps. The most currently updated version of Google Maps JavaScript API is Version 3 (V3). V3 gives the option to rotate that map. It also has the option to add layers to the map such as the traffic layer. V3 is supported by most of the widely used web browsers. The supported web browsers are listed in Table 21. The Google Static Maps would use URL parameters to request the map for the website. It would not need JavaScript to load and display the map on the website. The static map does not have any concern of what type of web browser the user is using.

	Microsoft Bing Maps	MapQuest API	Google Maps API
IE 7.0+ (Windows)	✓	✓	✓
Firefox 3.5+ (Windows)	✓	✓	✓
Firefox 3.5+ (Mac OS X)	✓	✓	✓
Safari 4 (Mac OS X)			✓
Safari 5 (Mac OS X)	✓	✓	✓
Chrome (Windows)	✓	✓	✓
Android	✓	✓	✓
Blackberry	✓		✓
Apple iOS	✓	✓	✓
Dolfin 2.0+ (Samsung Bada)			✓

Table 21: Compatible Web Browsers with Each Maps API

Google Maps JavaScript API V3 is the best option for this project. There were many different reasons why Google Maps API was chosen. One reason is that Google Maps API is supported on more web browsers than the Microsoft Bing Maps and MapQuest API. It gives the user more options to use the web browser they prefer. It provides more options to make the map user friendly and interactive than the Google Static Map API. The sidewalks are mapped as solid routes just like road ways, which would make it easier to locate outside trashcans. Google Maps offers more customization of the map view than the other map APIs mentioned above. There is an abundant amount of documentation on Google Maps API to make is easy to use as well.

On the Map, there are three different colored dots to represent the trashcans on the map shown. The red colored dot represents that the trashcan is full. The green colored dot represents that the trashcan is 50% full or less. The yellow colored dot represents that the trashcan needs maintenance. Maintenance includes corrupted data that was received, but is not limited to these events. The purpose of the legend is to reinsure that the user knows what each colored object on the map represents. The Google Maps JavaScript API provided markers that were customized to be different colors and have various interactions with the user.

The status list would have shown the trashcan identifier number, status number, and the time of the last data update. The list could be sorted by the status of the trashcan. The status list could be sorted by if the trashcan(s) that needs maintenance, then those that are full, and then the empty trashcans. The column for the time of “last updated” would provide the user when the data was received for each trashcan. The time of when the trashcan was last updated would be in 24 hour format. It would also show the date when it was last updated in month/day/year format. The status list was taken out of the home page. Instead, there is a page called “HISTORY” that can be accessed by an administrative user.

If user clicks on the “HOME” link and the user was already on the page, the page would just refresh. If not, the user would be taken to the home page described above. When the user clicks on “LOGIN”, the user would be taken to another page. The user is then asked to enter a username and password to access the administrative page. The user is asked only once to log in during a web session. A web session is closed out when the user closes the web browser. Once the user has logged in, the links on the top of the page changes.

8.5 History:

The history page allows the user to utilize the data collected. The page displays the trashcan ID number, status, latitude and longitude coordinates, and last updated time of each trashcan. This helps the user figure out which trashcans have been recently updated and if there were any issues with the wireless network or any of the trashcans. The history page is only accessible after logging in with valid credentials. It contains exactly what the status list would have contained if kept on the home page.

8.6 Edit Map:

The edit map page allows the user to add, remove, or change the location of a trashcan. When the user wants to add a trashcan, the user can click the “Add Trashcan” button. A popup would appear asking the user to enter an ID number for that trashcan. Once the user has entered a valid ID number and click “OK”, the brand new trashcan would be entered into the system. The trashcan would appear on the map once the updated status and location is received by the control system. A valid ID number would be a number that is not already given to a trashcan in the network. The flow chart for adding a brand new trashcan to the network is shown in Figure 54.

When the user wants to remove a trashcan, the user can click on the “Remove Trashcan” button. A prompt message would appear and ask for a trashcan ID number. If the trashcan ID number exists in the system, it would change the display parameter in the database to false. This parameter determines if a trashcan marker would be displayed on the map on the website. The event details are shown in Figure 55.

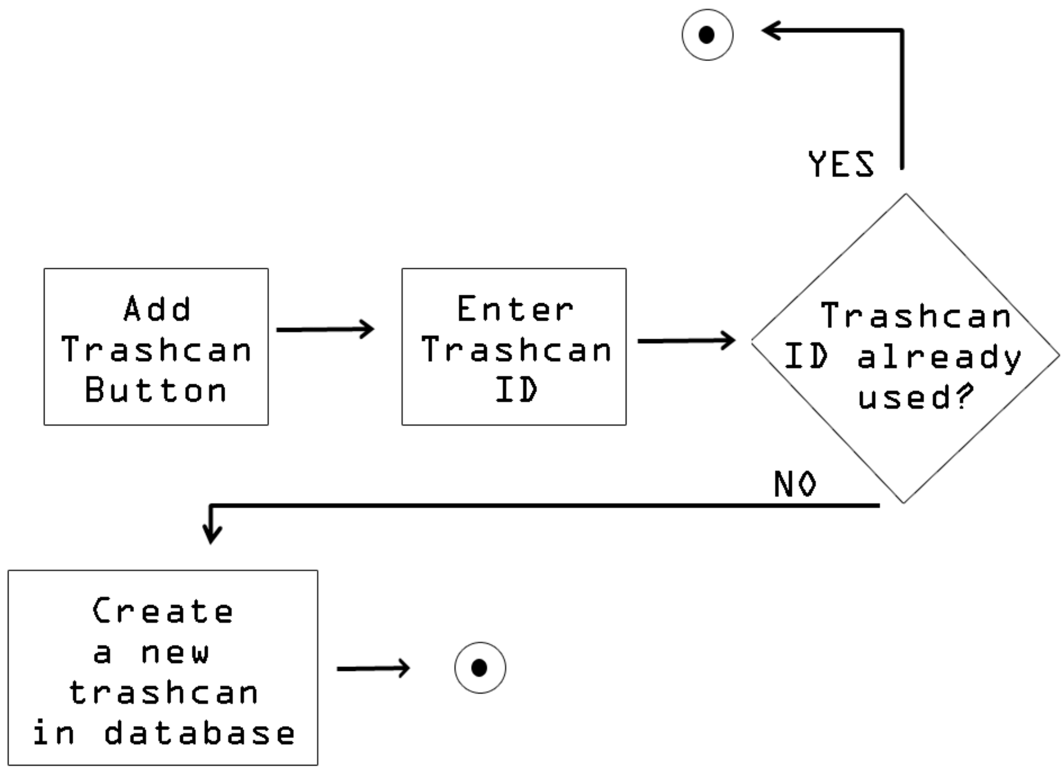


Figure 54: Flow Chart of Adding a new trashcan

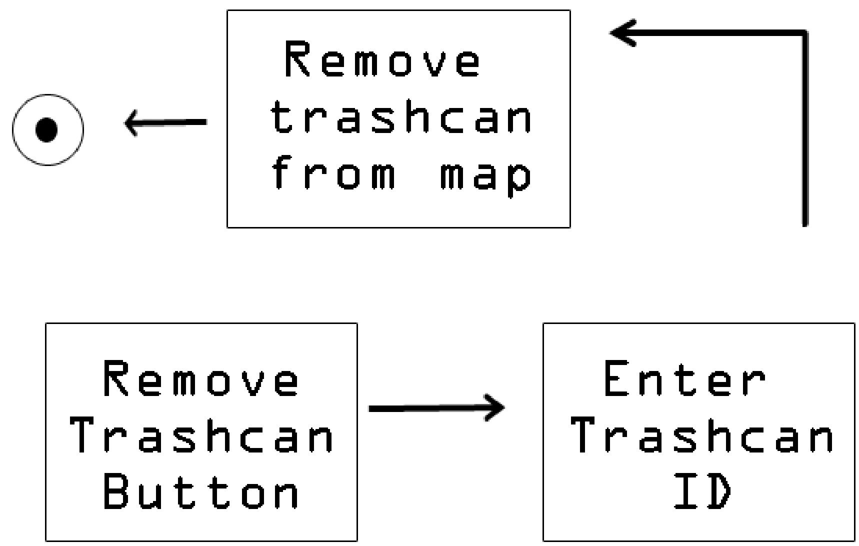


Figure 55: Flow Chart of removing a trashcan

The initial plan was to allow the user to manually change a trashcan's location. When the user clicks on the "Change Location" button, the user would be allowed to click on any trashcan marker on the map and drag it to the new location. Every time the user releases the mouse button click on the trashcan, a popup will appear. It would say "Are you sure the trashcan is in the location chosen?" The user would then have the option to say "YES, NO, or CANCEL". If the user clicks "YES", the new location would be saved in the database. If the user clicks on "NO", the user has the option to drag and drop the trashcan to a new location. If the user clicks on "CANCEL", the event will end. From the cancel event, the trashcan location on the map would have the last saved location. The event of changing a trashcan's location is shown in Figure 57. Since the GPS module was added to TrashTalk, the location is automatically determined by the GPS and the coordinates are sent to the control system. The control system would receive and update the markers' locations on the map.

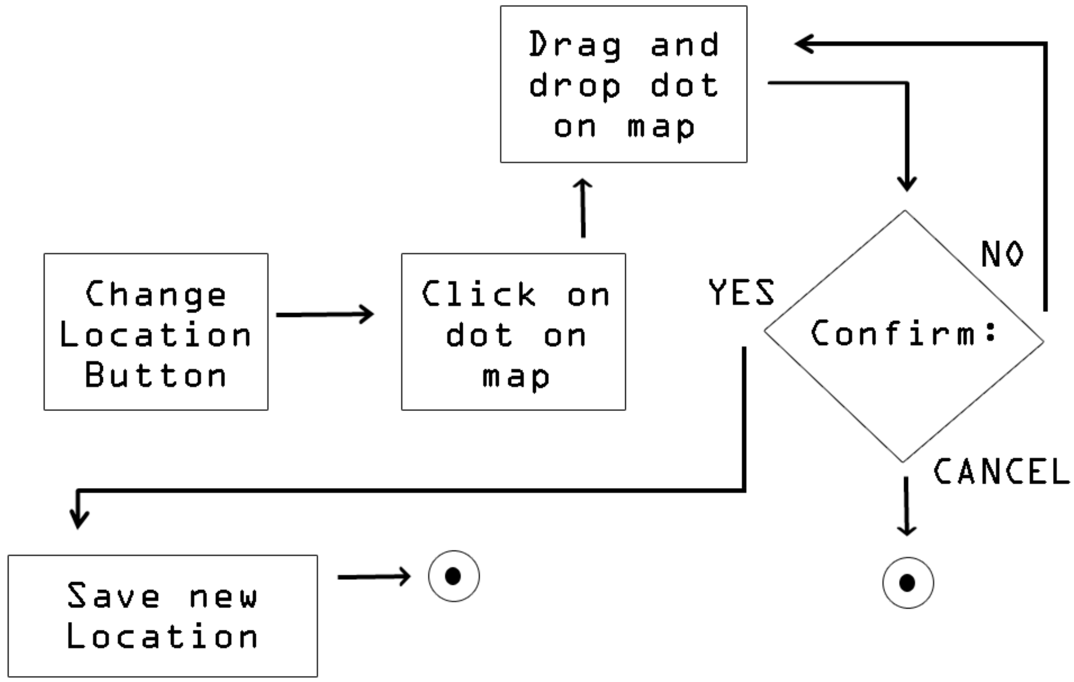


Figure 57: Flow Chart of changing the location of a trashcan

9. SOFTWARE:

9.1 Programming Languages:

9.1.1 JavaScript:

JavaScript (JS) is an object-oriented language commonly used as a scripting language. It is implemented on the client-side. The code can be inserted into HTML pages and runs on web browsers. JavaScript has a C-like syntax. JavaScript is used for the dynamically changing components on a webpage. The web browsers that support JavaScript are listed in Table 22 in comparison with the browsers that support AJAX.

9.1.2 PHP:

PHP stands for PHP: Hypertext Preprocessor. It is an open source scripting language and is implemented on the server side. PHP is used for the dynamically changing components on web pages. It generates HTML code that is sent to the client. PHP supports many databases which are listed (but not limited to) in Table 22. Since JavaScript and PHP are running on opposite sides of communication, they can be used together.

PHP	Supported Databases
	MySQL
	Informix
	Oracle
	Sybase
	Solid
	PostgreSQL
	Generic ODBC

Table 22: PHP supported databases

9.1.3 XML:

XML stands for Extensible Markup Language. Similar to HTML, but is not a replacement for HTML. It is used along-side with HTML to carry and store data for the web page. Tags are not predefined; therefore you make your own.

9.1.4 AJAX:

AJAX stands for Asynchronous JavaScript and XML. AJAX will run along-side with HTML on a web page. Asynchronous means that different components of the page can be loaded and ran at the same time. Since AJAX is able to complete functions of JavaScript and XML, it is ideal to use for the updating information on the GUI, event handling, and taking care of the data being transferred.

	JavaScript	AJAX
Internet Explorer 3 & 4	✓	
Internet Explorer 5+	✓	✓
Mozilla Firefox	✓	✓
Safari	✓	✓
Netscape Navigator 2+	✓	
Netscape 7.1+	✓	✓
Opera	✓	✓
Google Chrome	✓	
Konqueror		✓

Table 23: Supported web browsers by JavaScript and AJAX

9.1.5 Ruby - Ruby on Rails:

Ruby of Rails is a web framework that is written in Ruby. Ruby is an object-oriented program created by Yukihiro Matsumoto. It was influenced by the language Perl. Everything is an object in this language. Ruby and Ruby on Rails are two different things. Ruby on Rails is used for web development. The web developer with Ruby on Rails is able to gather information from a server and query a database. Ruby on Rails utilizes a significant amount of JavaScript libraries. Ruby on Rails can run under UNIX, DOS, WINDOWS95/98/NT/2000, Mac OSX, BeOS, Amiga, Acorn Risc OS, and OS/2 operating systems.

9.1.6 Python:

Python is an object-oriented programming language. Although it is a high level language, it is often used for scripting. It can run on Windows, UNIX, and Mac operating systems. Python has a large standard library with pre-implemented things such as internet protocols, operating system interfaces and quite a few other things. It offers help with web development and can access a number of databases. Python is also good for creating user interfaces.

The software should be able to interact with the web page and the database. A dynamic scripting language would be beneficial for the constantly updating information on the trashcans. The entire web page should not be loaded every time the trashcan information is updated. PHP is one of the most popular languages. It is widely and easy to use. It will interact with the transferred data and the database. It can also create the visuals on the website.

9.1.7 C:

The C programming language has been around since the 1970s and was created in parallel with UNIX operating systems. It was developed by a man named Dennis Ritchie between the late 1960s and early 1970s. This language led to the development of Java and C++. One of the disadvantages is that C is not an object-oriented programming language though. It is more difficult to maintain and debug C. Even though C is widely used by many programmers and applications, it has more limitations than other programming languages such as Java and C++. C may be used to code the microcontroller used for the sensors.

9.1.8 C++:

C++ programming language was influenced by C. It was developed by Bjarne Stroustrup who also took part in expanding C. C++ supports object-oriented programming like Java. C++ is basically C with added enhancements. It is backwards compatible and can compile and run C written programs. C++ has the ability to implement low level and high level features.

TrashTalk uses several different languages to accomplish its goals. Javascript, HTML, PHP, AJAX, and SQL were all used for the website. Javascript was used mainly for the Google Maps API and HTML was used for the structures for the webpage. PHP and AJAX was used mainly for the interaction from the webpage and the database. XML was used to retrieve each trashcan’s information from the database and saved into an XML file. The file was used to check for certain parameters and used as a reference to display each trashcan’s information on the webpage.

For the process that runs on the control system to read from the serial port, sort the received trashcan information, and stores the updated information to the database, C++ was used.

9.2 Programming for microcontrollers:

9.2.1 PBASIC:

PBASIC is a microcontroller based version of BASIC. BASIC is a family of languages used for high level programming. The original version of BASIC was designed by John Kemeny and Thomas Kurtz in 1964. Afterwards it was implemented by a group of Dartmouth students. PBASIC is used on STAMP microcontrollers. The code will be loaded into an EEPROM located on the microcontroller. It must be specified which version of BASIC will be used in the code.

9.2.2 Assembly:

Assembly language is a low level language used widely as firmware. It is one of the most basic programming languages for any processor. Each line of code corresponds to one machine code instruction. Even though Assembly is a simple language, it is more difficult to implement more advanced applications. The program will contain many lines that will make it harder to maintain and debug. Assembly language programs will perform faster than most other programs written in different languages. The programmer must have a clear understanding of Assembly language to efficiently write programs in it.

10. Databases

The database for the system is the aspect that holds all the data being sent and received. The database is hosted on the main computer used by the user. The database could be created and edited by a database management system (DBMS).Through the DBMS, tables are created with the attributes of the data being stored. The attributes will include the trashcan ID number; the status to the trashcan, the time the data was received at the host computer of each trashcan, and the current location of each trashcan. The original relational schema of the database in Figure 58 shows the breakdown of what the tables in the database would have been. Each trashcan is represented by the table “Trashcan”. The final schema included the trashcan ID number; the status, the time last updated, the latitude coordinate, and the longitude coordinate as “Trashcan”. The other tables shown in the original schema was not implemented.

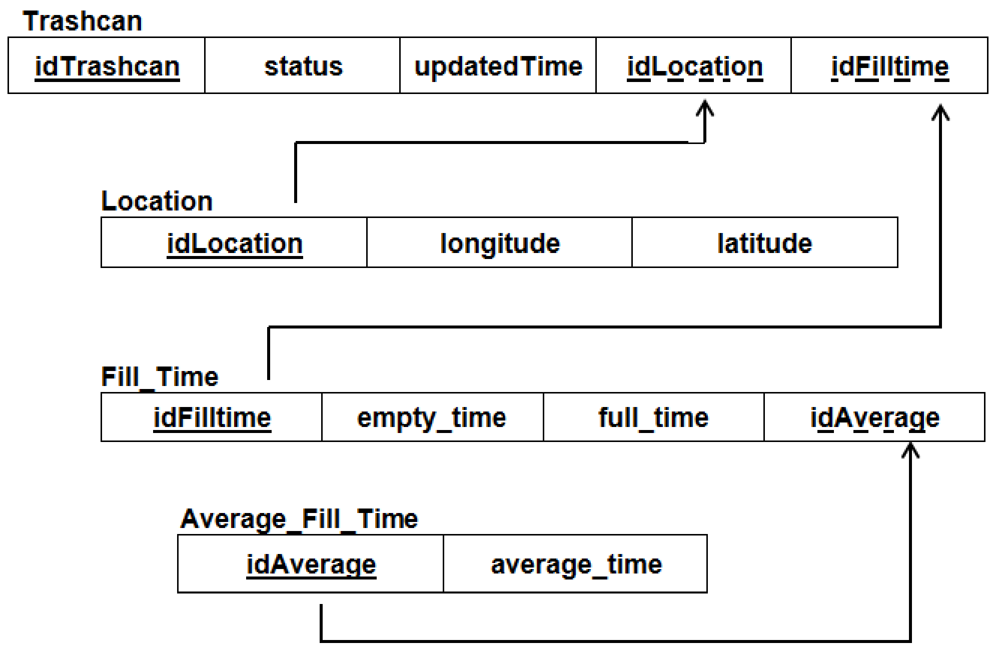


Figure 58: Relational Schema for the Database

10.1 MySQL:

MySQL is not an actual database, but a database management system (DBMS). It is also an open source DBMS. A database is a collection of data. To create a database, one must use a DBMS. MySQL is a relational DBMS, which means it uses tables to store the collection of data instead of putting all the data in one area. It provides organization and faster access time to the data. MySQL uses Standard Query Language (SQL). SQL is the most standardized language to work with databases. MySQL is supported by many operating systems. The list of supported operating systems is not limited to those listed in Table 24. In addition, MySQL has an application call MySQL Workbench that uses visuals and tables to help create SQL scripts. The SQL scripts can create a database, tables, edit tables, add data, and implement relationships between tables.

MySQL supported Operating Systems	Amiga
	Linux
	Mac OSX
	Novell Netware 6.0
	Solaris 2.5+
	Unix
	Windows

Table 24: Supported operating systems by MySQL

10.2 Oracle:

Oracle provides a database is a unit consisting of a collection of data. Oracle is mostly used for enterprise computing. It uses grid computing which provides lower cost, greater flexibility, and a greater level of service. Oracle runs SQL like MySQL and Microsoft SQL. It supports the higher level programming languages such as C, C++, Java, COBOL, and Visual Basic. To use Oracle, a fee is charged. However, the Oracle Database 11g Express Edition is the free to be used for development by students. This version can be installed on any host machine of any size and any number of CPUs. It will drain a lot of memory and slow the performance of the computer it is installed and is not as widely used as MySQL. Oracle Database 11g as an open source code does not have a lot of references available.

MySQL was chosen to be used for TrashTalk. There were more references and examples of how to use MySQL. It did not seem to take up as much machine resources as Oracle. Even though MySQL is now owned by Oracle, MySQL is significantly different from Oracle. MySQL is free to use and could easily implement a database. TrashTalk team has experience working with MySQL as well.

11. Software Design:

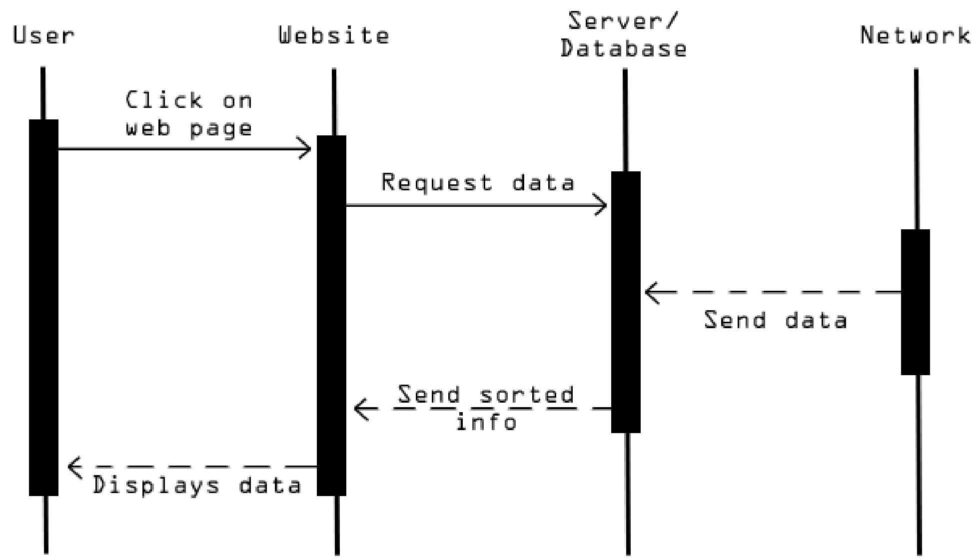


Figure 59: Sequence diagram for accessing the web page

The user has to access the web page before being able to see any information of the system. When the user loads the web page, the website then displays the trashcan information that is stored in the database. The sequence diagram in Figure 59 shows the sequences between the user, website, database, and network of trashcans. The data stored in the database comes from the network.

The wireless nodes to gather data from the sensors and the latitude and longitude coordinates. It then sends that data to the host computer. The host computer analyzes the data and does the necessary calculations needed to get significant information to store in the database. The process is shown in the flow chart in Figure 60.

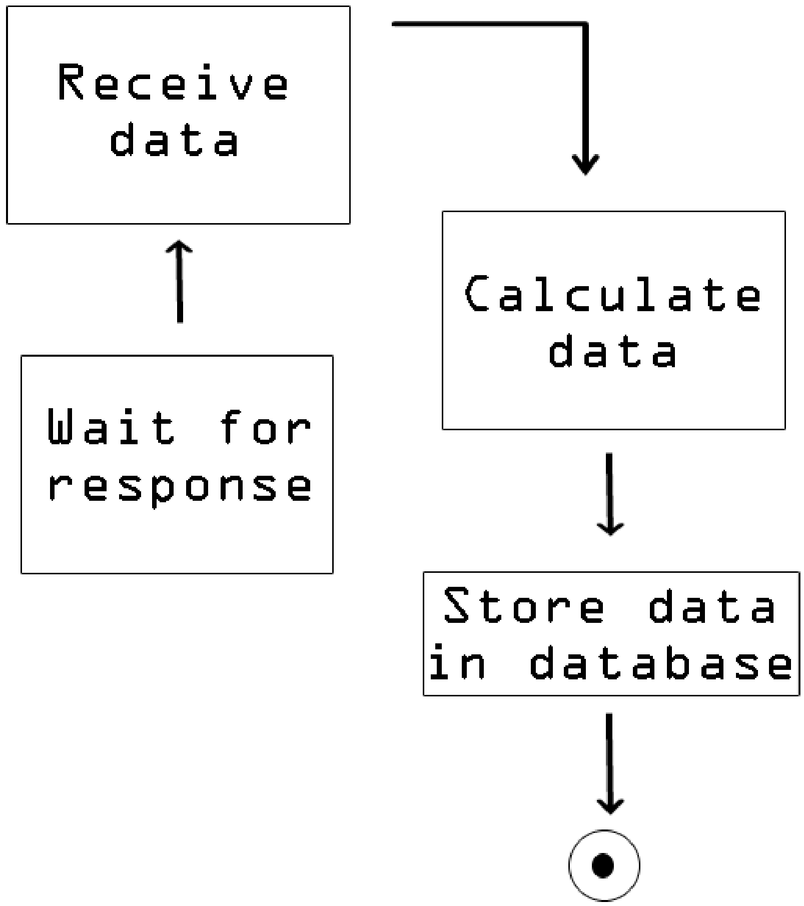


Figure 60: Flow chart of the getting data from the network

Once the user logs into the system as an administrator, the user has the options to add a trashcan to the system. When the user clicks on the “Add Trashcan” button, the website would search through the trashcan ID numbers in the database. It searches for any duplicates to the new trashcan ID number being requested. The result may be that the trashcan ID is not a duplicate and is inserted into the database through an XML file. The trashcan is added to the trashcan system. Once the trashcan sends its updated information, then the website displays the new trashcan on the map. If the result came back as a duplicate, the website notifies the user that the trashcan ID number was already used. The process is shown in the sequence diagram in Figure 61.

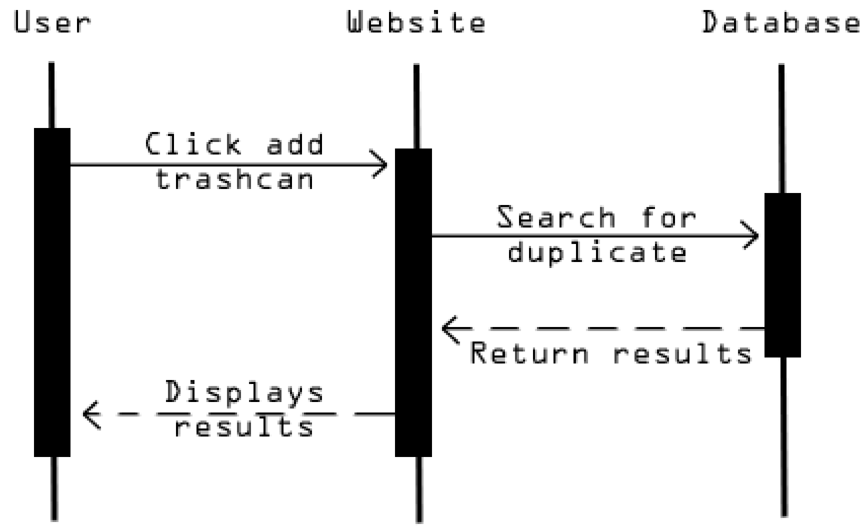


Figure 61: Sequence diagram for adding a trashcan to the system

As the user could add a trashcan, the user can remove a trashcan from the system as well. The user can click on the “Remove Trashcan” button and the website then searches the database for the trashcan. Once the trashcan is found, the display parameter is changed to false. Setting the display parameter to false prevents the trashcan marker from showing on the map. This process uses an xml file in the process of checking if the trashcan ID number is used on a trashcan in the network. If no errors occur, the website will remove the trashcan off of the map. The process of removing a trashcan from the system is shown in Figure 62.

In the initial design, the user could change the location of the trashcan. The user could click on a “Change Location” button. The website would search for the trashcan in the database and then access the location table. The location table would be updated with the new location requested. Once the query has been processed, the website would display the trashcan in the new location. The initial process of changing a trashcan’s location is shown in Figure 63.

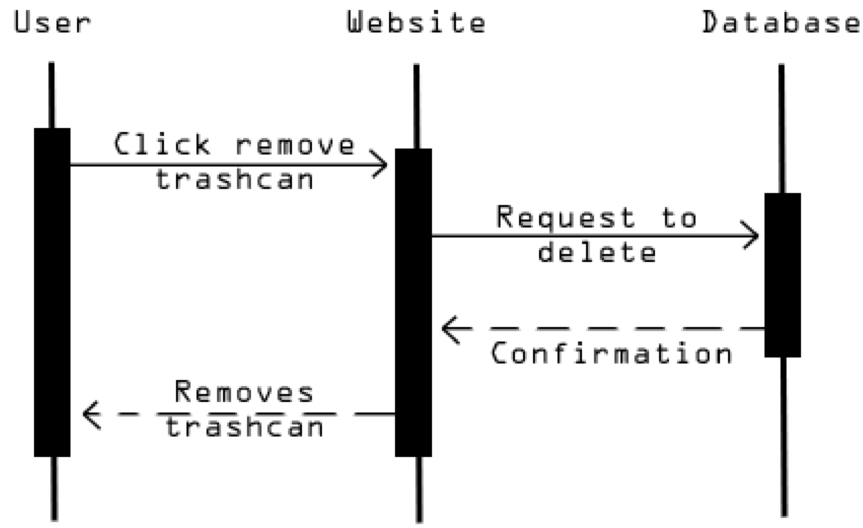


Figure 62: Sequence diagram for removing a trashcan from the system

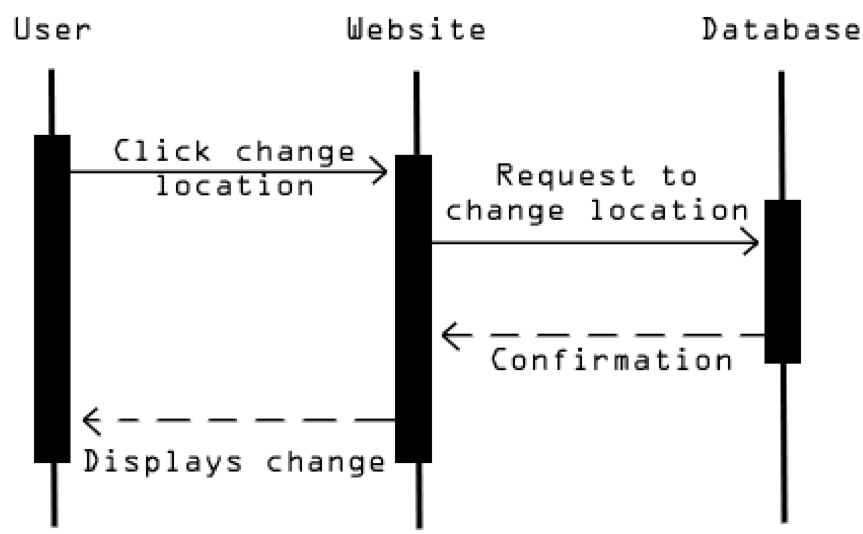


Figure 63: Sequence diagram for changing the location of a trashcan

12. Prototype

The following figure is the basic design composed of the components that will make up the major aspects of the prototype. The decision of these components was based on the research accomplished throughout this document.

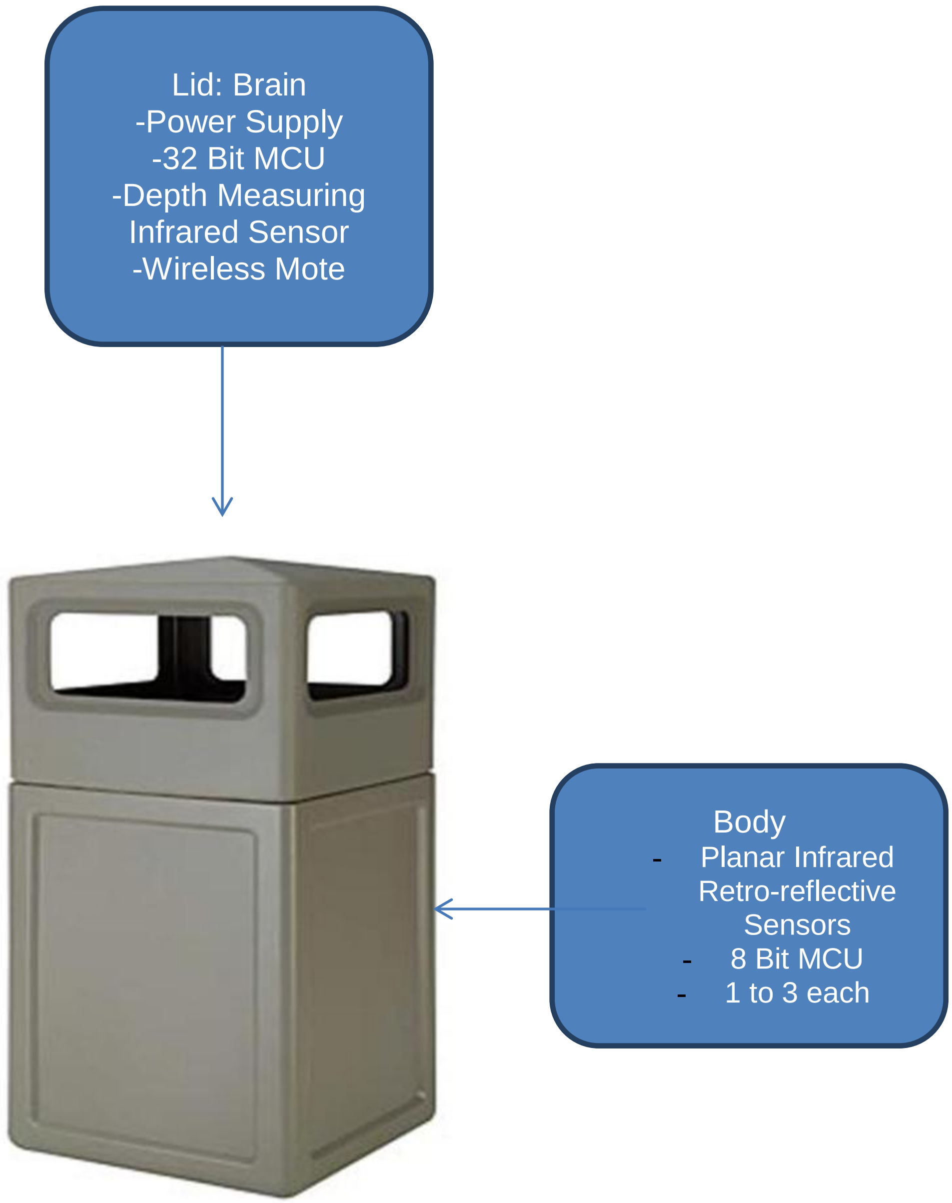


Figure 64: Trash Talk Prototype

	Type
Lid	
Solar Panel	9V Solar panel
Power Supply	Nickel-Metal Hydride (NiMH)
Depth Measuring Sensor	Ultrasonic
32 Bit Microcontroller	Atmega328
Wireless Network	DigiMesh
Body	
Planar Sensor	Infrared

Table 25: Component Breakdown

12.1 Interface Prototype

The home page of the website looks like the display shown in Figure 65. The home page has the map highlighted to be emphasized as the central component on the page. The box on the next to the map is the map legend.

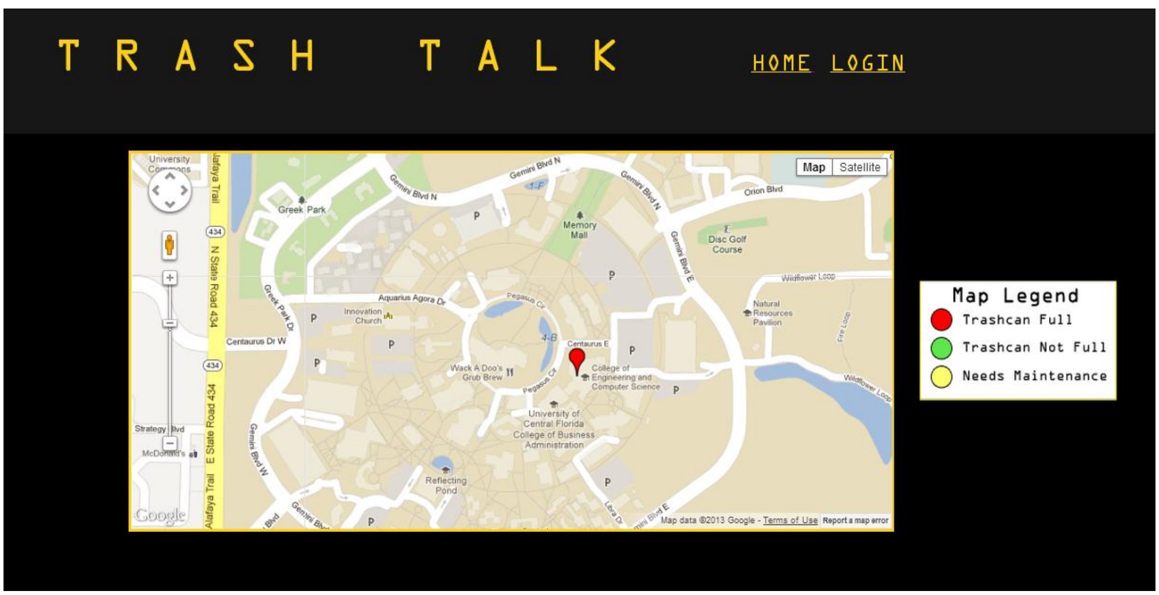


Figure 65: The Home Page view of the user interface

The map view is the most "pay attention to" component of the website. The user is able to click on the map and drag the view to different locations that were not currently shown on the map. On the map shown in Figure 66, the sidewalks are not clearly defined. Keeping that in mind, the user is able to zoom in on the map to enlarge the routes for easier reading. The user is also able to zoom out of the map.

Figure 66: User interface map view

The map legend is to simplify the webpage for the user. It lets the user know what each colored dot represents on the map. The red dot represents that the trashcan is full. The green dot represents that the trashcan is not full. The yellow dot represents that the trashcan needs maintenance. The map legend looks like the one shown in Figure 67.

Figure 67: User interface map legend

The status list that was going to be on the home page originally, would display more information of each trashcan that would not be known from looking at the map alone. The status list shown in Figure 68 is an example of what the list would have looked like. The status list would include the columns of the trashcan's ID number, the last saved status, and the time of when the data was last updated. If the list exceeds the list size vertically, a scroll bar would allow the user to scroll through the trashcans statuses.

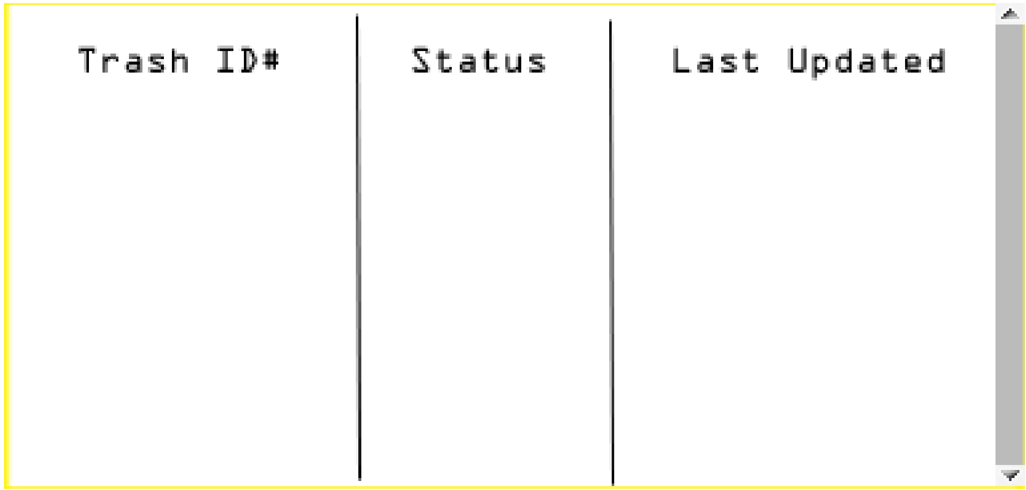


Figure 68: Status list of trashcans in the system

Figure 69: Available links from the Home Page

The links in Figure 69 is accessible from the home page and have the option to log in as an administrator. When the user clicks on the “Administrator” link, the user is shown the page displayed in Figure 70. This page requests that the user enters a username and password to gain access as an administrative user. The user can enter text in both the username and password blocks and then click the “OK” button. If the user does not enter a valid combination of a username and password, the user will be informed and asked to enter a valid one.

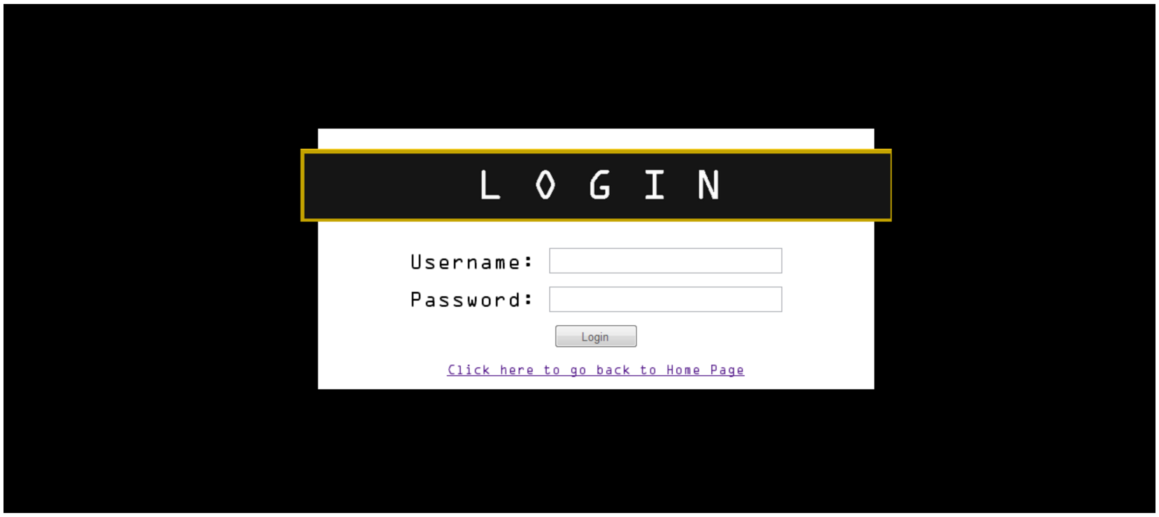


Figure 70: The LOGIN view of the user interface on a website

Figure 71: Available links for an administrative user

The display of the “HISTORY” page looks like the display in Figure 72. The “HISTORY” page lists the trashcan ID number, status, latitude coordinates, longitude coordinates, and the time of last updated of each trashcan in the system. This page allows the administrative user to see the list of trashcans in a larger and more detailed view.

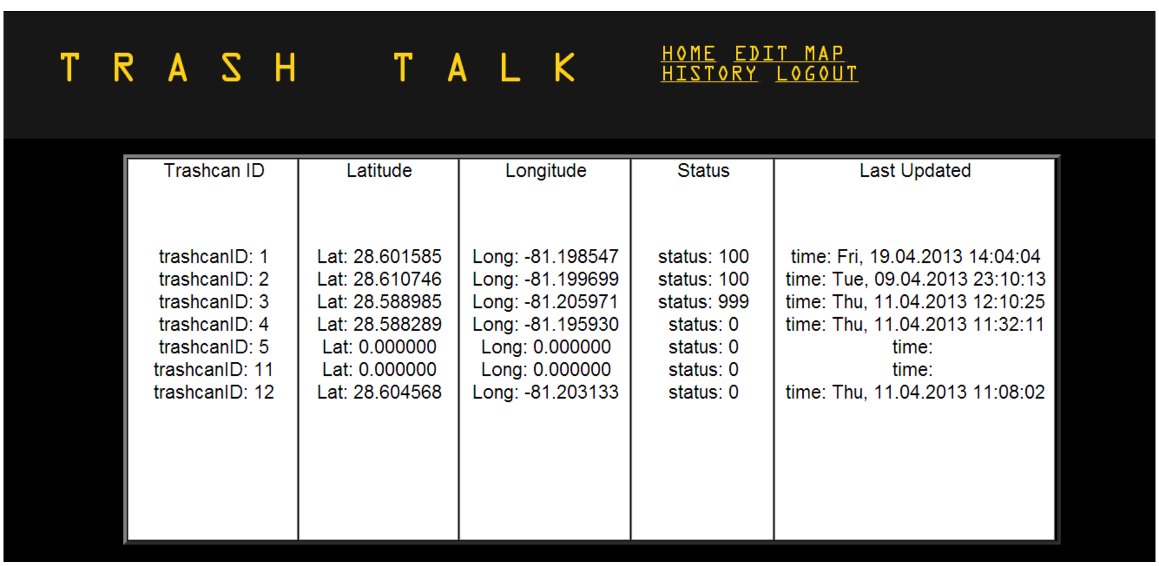


Figure 72: The HISTORY page view of the user interface on a website

Once the user has logged in, the links at the top of the page will change. The links will change from removing “LOGIN” and adding “EDIT MAP”, “HISTORY”, and “LOGOUT”. The links at the top of the page looks like Figure 71. The first page that is shown after logging in is the “EDIT MAP” page. The “EDIT MAP” page looks like the display in Figure 73. On this display, there is a view of a map, two edit options, and a map legend. The map is the same map that is shown on the home page. The only difference is the interaction with it when the user decides to edit the system. The map legend lets the user know what each of the colored dot represents. It is the same map legend on the home page.

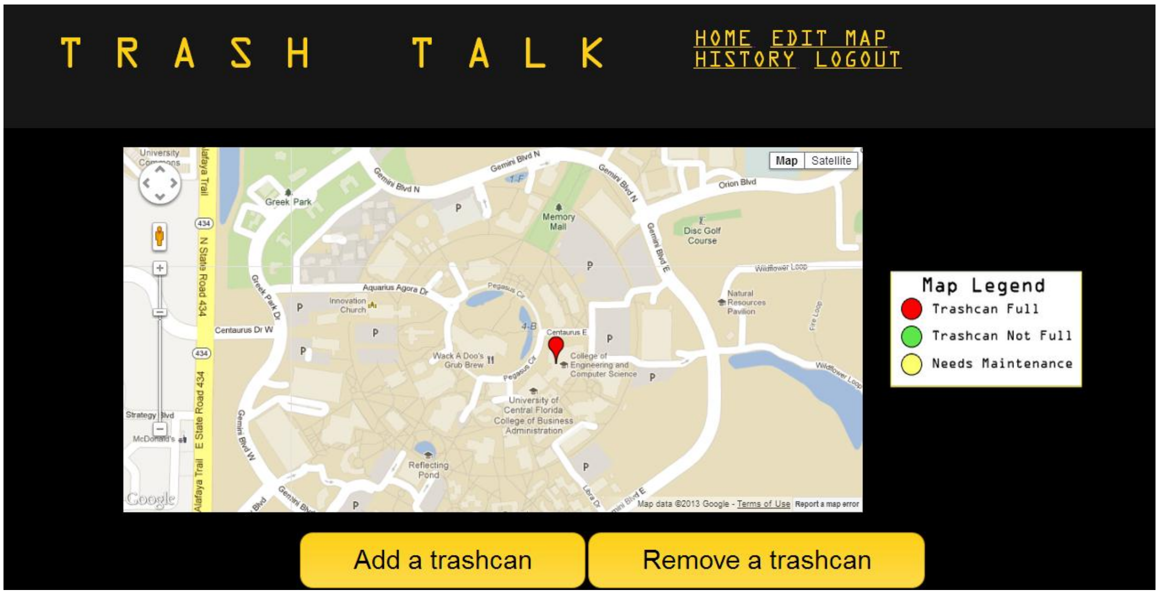


Figure 73: The EDIT MAP page view

The user can click on the button labeled “Add a trashcan”. A message box will appear asking the user to enter a trashcan ID number. The message box is shown in Figure 74. A trashcan is added to the database with the trashcan ID number entered. The user is notified if the addition was successful or not. The successful message says “Trashcan was added to the system”. If the trashcan is already exists in the system, the message either says “TrashcanID already exists, but is not shown on map. Would you like to display that trashcan on the map?” or “TrashcanID already exists and is displayed on the map”.

The user can click on the button labeled “Remove a trashcan”. It gives the user the ability enters a trashcan ID number to delete it from the map. After the user enters a trashcan ID number, a message box appears. If the trashcan ID number does not exist in the system or is not displayed on the map, the message box shown in Figure 75 appears. If the removing of a trashcan off of the map is successful, then a pop up appears notifying the user.

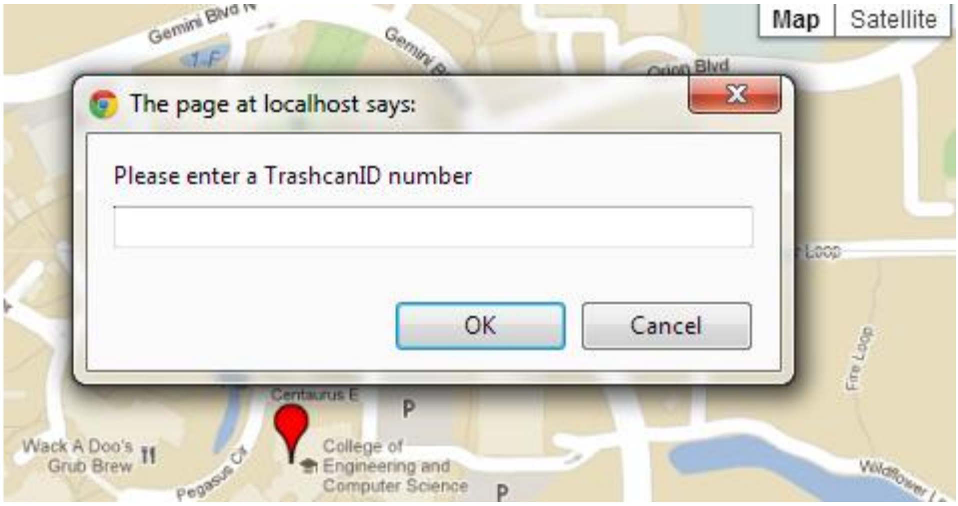


Figure 74: Pop up window to enter trashcan ID

The user can click on the “Change Location” button. It will allow the user to click on a trashcan on the map and drag it to a new location. After dragging it to a new location, a message will appear asking “Are you sure you want to move the trashcan to this location?” The message box is very similar to the one used with removing the trashcan from the system. The options will be to confirm or cancel the location change.

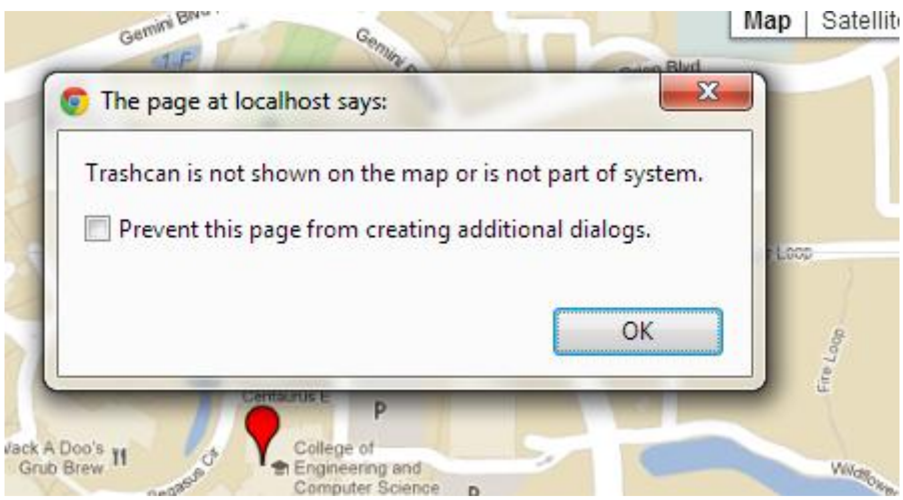


Figure 75: Pop up window from removing a trashcan

13. Project Testing:

Testing of the projects design consisted of subsystem testing for each subsystem as well as a full system testing when everything was incorporated together. Various different test cases were conducted to find out the capabilities and limitations of both the subsystem and full system. The testing scenarios consisted of a host of complexity levels ranging from relatively easy to moderately difficult. Having a broad range of cases with different difficulty levels will ensure that the design would stand up to the specifications set forth, whether it may be something as simple as a dead battery all the way to something as difficult as the solar panel not correctly utilizing the sunrays and completing its intended mission. If the subsystem or full system does not behave as expected, adjustments will be made to meet the specifications initially set forth. Also, extensively testing the subsystem and full system will make apparent whether or not all features that will be added to the design are actually feasible.

13.1 Overview of testing:

First, the sensor subsystem will be tested by seeing which cases would negatively affect the sensors proper reading. It is important that the sensors in the trash cans properly sense the trash levels. The sensor design will consist of a halfway mark planar sensor, a full way mark planar sensor located at the brim of the trashcan, and a depth sensor located at the top of the trashcan aiming down into the trash to reassure the planar sensors readings. The test conducted will be compared to the initial test control case. The control case will simply involve the trashcan design properly reading the trash level when the trash is filled to the halfway mark and the full way mark. The Trash level will then be compared to the depth sensor to reassure its accuracy. After comparing the planar sensor readings and depth sensor reading in the control case, it will then be determined if the sensors are properly calibrated for further testing. After the control case has been set and the group has something to compare test cases too, the test cases would then involve various different scenarios, which may cause a problem if encountered in a real life-operating situation. The cases will include but not be limited to introducing items into the design such as a mirror, a dense item, a glass bottle and more.

Secondly, the user-interface subsystem for data collection will be tested in the same manner as the other subsystems. A control test case would first be set up in which everything works accordingly. To do so, the trashcans will all be emptied to ensure that an accurate reading is being sent back to the user. The control test would then be repeated for halfway trash levels as well as full trash levels. After the control test cases have been completed, various different scenarios, which could possibly negatively interrupt the user interface, will be inducted. Such cases would involve but not be limited to invalid user input, data collection immediately after loss network connection, Invalid data collection from trashcan readings, receiving data from trashcans moved out of range of the home server, and etc.

Thirdly, the self-sustaining power supply subsystem will be also be tested in the same manner as the other systems. The power supply subsystem test will consist of testing the reliability of the power sources, which would supply the whole design. The system will be self-sustaining by utilizing both solar panels and rechargeable batteries. The system would furthermore be self-sustaining by using a sleep mode method, which would put the entire system into a low state nearly off phase. The control test case for the power subsystem will initially be tested when the system is working effectively at peek performance. This would be done so with the power printed circuit board component working properly with the batteries being fully charged and the solar panels efficiently supplying the right current amount at the right time. The control test case would then be analyzed to ensure that it would fulfill the initial specifications listed. After the test are conducted in the nearly perfect control test case, the results and data obtained would then be referenced for the various additional test cases to be implemented. The various different cases that will be implemented will involve actual things that may occur in a real life situation. The test to be conducted will include but not be limited to removing the printed circuit board connection to the batteries to see how long the system will last on a single charge. This test would also be the same if the solar panel were disconnected since it supplies the current that goes through the printed circuit board that in turn charges the batteries. Other test cases may also consist of but not be limited to having the power system operate in cold temperatures as well as hot temperatures, the sleep mode disabled with constant continuous usage and etc.

Lastly, the system as a whole will be tested as well. The testing will be conducted and handled in the same manner as the subsystems. First the control test case will be conducted with all subsystems synced together working as one whole design. The control test case will consist of having the whole system work flawlessly from start to finish with no outside variables affecting it. To do so, the normal operation will be the user going to the computer and inputting the appropriate information necessary to log in and access the home server. The User can then wait for the system to automatically refresh the trashcans status or manually press the refresh button. The trashcans would then wake up from sleep mode and then sense the trash level. At this point the batteries in the system should be fully charged due to the solar panel and printed circuit board working properly. Everything should be performing appropriately. The results and data received from this operation will then be stored and referenced for the other test cases. The various other test cases that will be implemented then compared to the control system will consist of but not limited to testing the system in a heavily wooded area, in a controlled refrigerated unit, in a wide-open area with no surrounding elements to possibly affect it, and etc. The trashcan testing can then revisit various test cases used for the individual subsystems. It is important to make sure that the system as a whole still acts accordingly in those situations.

13.2 Power supply subsystem testing:

The following test cases were completed to test the limitations of the power subsystem.

Disabling PCB from battery

This test case examined how fast the battery actually discharged by itself when it is not connected to the automatic charging circuit

- Access the battery compartment with the wires connected to the printed circuit board
- Disconnect the wires connected to the automatic printed circuit board
- Analyze how rapidly the battery discharges when not being replenished by the solar panel and printed circuit board
- Take readings of the batteries output voltage and current every 4 hours with a multi-meter
- Record the output voltage and current and collect in a table for easy comparison

Cold weather

This test case examined the limitation of the trashcans' power subsystem components under different controlled cold weather

- Find a useable refrigerated area; can be a completely emptied home refrigerator, a commercial grade refrigerator or something similar
- Initially set the controlled refrigerated area to 10 degrees Celsius
- Keep the whole trashcan system within the controlled area at constant temperature for 5 hours at a time
- Measure the terminal voltage and current output from the batteries using a multi-meter
- Record the data collected into a table for easy comparison
- Repeat the steps over while decreasing the temperature by two Celsius each time

Hot weather

This test case examined the limitation the trashcans' power subsystem components under different controlled hot weather

- Find a useable hot area where the temperature can be easily altered and controlled. Possible areas can be a sauna or a car with ample amount of room
- Initially set the controlled heated area to 35 degrees Celsius
- Keep the whole trashcan system in the controlled area at constant temperature for 5 hours at a time
- Measure the terminal voltage and current output from the batteries using a multi-meter
- Record the data collected into a table for easy comparison
- Repeat the steps over while increasing the temperature by five Celsius each time

13.3 Sensor Testing

The following section is designed to outline certain criteria to test each of the sensors. Each sensor must pass applicable parts of the Sensor Tests to be integrated in the circuit

Weather Test:

Wind Test

- Connect the sensor to the printed circuit board
- Place object a specified distance in front of sensor
- Use an object that generates air flow (fan or leaf blower) to blow on sensor
- Ensure that output of distance matches your specified distance

Ping

Distance(cm)	Sensor Output (cm)
10	10
20	20
30	30
40	40
50	50
60	60
70	70
80	80
90	90
100	100

Cold Test

- Connect the sensor to the printed circuit board
- Place the circuit board in a freezer for ten minutes
- Remove the sensor from the freezer
- Place object a specified distance in front of sensor
- Ensure that output of distance matches your specified distance
- Repeat this procedure but place sensor in regulated refrigeration unit and set temperature to 45 degrees F
- Leave sensor in this environment for six hours
- Remove sensor from refrigerator
- Place object a specified distance in front of sensor

- Ensure that output of distance matches your specified distance

Ping

Distance (cm)	Sensor Output (cm)
10	10
20	20
30	30
40	40
50	50
60	60
70	70
80	80
90	90
100	100

IR

Distance (cm)	Sensor Output (cm)
10	-3
15	13
20	23
25	29
30	33
35	36
40	39
45	42
50	44

Heat Test

- Connect the sensor to the printed circuit board
- Place the circuit in an sealed container in an outdoor environment that is at least 90 degrees F
- Leave the circuit outside for at least two hours
- Place object a specified distance in front of sensor
- Ensure that output of distance matches your specified distance
- Repeat this procedure but leave the circuit outside for eight hours
- Place object the same specified distance in front of sensor
- Ensure that output of distance matches your specified distance

Ping

Distance (cm)	Sensor Output (cm)
10	10
20	20
30	30
40	40
50	50
60	60
70	70
80	80
90	90
100	100

IR

Distance (cm)	Sensor Output (cm)
10	-3
15	13
20	23
25	29
30	33
35	36
40	39
45	42
50	44

This concludes the weather portion of the test. These tests were designed to test the sensor and the circuit in relatively extreme weather conditions to ensure maximum performance. The next section will test the ability of the sensor to accurately measure distances.

Distance Test

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object 10 cm in front of the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

Ping

Distance (cm)	Sensor Output (cm)
10	10
20	20
30	30
40	40
50	50
60	60
70	70
80	80
90	90
100	100

IR

Distance (cm)	Sensor Output (cm)
10	-3
15	13
20	23
25	29
30	33
35	36
40	39
45	42
50	44

Angle Distance

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object approximately 15 degrees above the center line of the sensor and 10 cm in front of the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)
- Replace the object approximately 15 degrees below the center line of the sensor and 10 cm in front of the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

Ping

Left

Distance (cm)	Sensor Output (cm)
10	13
20	20
30	31
40	41
50	51
60	62
70	72
80	80
90	91
100	102

Right

Distance (cm)	Sensor Output (cm)
10	11
20	21
30	30
40	40
50	51
60	61
70	71
80	81
90	92
100	102

Additional Angle Test

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object 10 cm in front of the sensor for a baseline measurement.
- Move the object 10 degrees laterally, perpendicular with the plane of the sensor
- Observe the output and verify using the Pythagorean theorem
- Repeat until the object is out of the range of the sensor
- Repeat the steps above moving laterally in the opposite direction
- Compute the percentage error based on the specifications identified in the datasheet

Ping					
Left			Right		
Angle	Distance (cm)	Sensor Output (cm)	Angle	Distance (cm)	Sensor Output (cm)
0	10	10	0	10	10
10	10	10	10	10	10
20	10	12	20	10	11
30	10	N/A	30	10	N/A

This concludes the distance and angle measuring tests for the sensors. Since the datasheets should outline the minimum and maximum distances and angles that the sensor is able to identify, this will aid in accomplishing the goals for the prototype outlined in the beginning of this document. The next section involves testing the sensor when it is exposed to different elements such as rain, sunlight or dust. This will be the Elements test section.

Elements Test

Lights

The reason light, specifically sunlight, is included as a test in this section is because certain types of sensors are adversely affected by the UV rays. The following tests should identify which types of sensors perform well under these conditions.

Sunlight

- Connect the sensor to the printed circuit board
- Position the sensor outside in a non-shaded area
- Place a solid, non-reflective object 10 cm in front of the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

IR

Distance (cm)	Sensor Output (cm)
10	-21
15	-7
20	14
25	22
30	34
35	40
40	42
45	46
50	51

Artificial Light

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object 10 cm in front of the sensor
- Place the beam of a light bulb within six inches from the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

IR

Distance (cm)	Sensor Output (cm)
10	-4
15	14
20	24
25	30
30	34
35	37
40	39
45	42
50	44

Dust

Dust will be a common problem encountered for a sensor placed in a trash can outside. In order to simulate dust, common baby powder can be used as it has the same appearance as dust.

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object 10 cm in front of the sensor
- Squeeze the powder container until a noticeable cloud appears in front of the sensor.
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

IR

Distance (cm)	Sensor Output (cm)
10	-3
15	13
20	23
25	29
30	33
35	36
40	39
45	42
50	44

Rain

Rain is another element that needs to be accounted for by testing. This can be simulated by using a hose attachment from a sink.

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object 10 cm in front of the sensor
- Position the water hose in front of the sensor so that the water does not splash the sensor
- Get a steady flow of water and observe the output then calculate the percent error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

IR

Distance (cm)	Sensor Output (cm)
10	-3
15	13
20	23
25	29
30	33
35	36
40	39
45	42
50	44

Darkness

Another factor to consider is the aspect of darkness. All of the other tests are assumed to be in an ordinarily lit room although in a trash can there will be reduced visibility.

- Connect the sensor to the printed circuit board
- Place a solid, non-reflective object 10 cm in front of the sensor
- Turn off lights and limit the amount of sunlight exposure
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

IR

Distance (cm)	Sensor Output (cm)
10	-3
15	15
20	24
25	30
30	34
35	37
40	40
45	42
50	44

The tests above should be adequate to test the sensors in the various elements faced for outdoor equipment. Up until this point, the tests have been designed to measure objects that are solid as well as non-reflective. In the real world, there is a large variety of substances and materials that are placed in a trash can and the sensors must be able to accurately measure all of these. The following section is the Real World Trash test.

Real World Trash

Transparent Material

For transparent material, use a piece of one inch thick clear glass or plastic, preferably 12” x 12” so that whatever is used to secure the item does not interfere with the sensing.

- Connect the sensor to the printed circuit board
- Place the block 10 cm in front of the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

Ping

Distance (cm)	Sensor Output (cm)
10	10
20	20
30	30
40	40
50	50
60	60
70	70
80	80
90	90
100	100

IR

Distance (cm)	Sensor Output (cm)
10	-17
15	-4
20	17
25	38
30	38
35	40
40	42
45	46
50	45

Reflective Material

The sensors must be tested against reflective material to ensure that the readings are not adversely affected. The use of a mirror or aluminum foil is acceptable for this section.

- Connect the sensor to the printed circuit board
- Place the reflective object 10 cm in front of the sensor
- Observe the output and calculate the percentage error
- Increase the distance by 10 cm
- Observe the output and calculate the percentage error
- Repeat the above procedures until the distance is 1 m (100cm)

IR

Distance (cm)	Sensor Output (cm)
10	0
15	1
20	25
25	31
30	34
35	38
40	40
45	43
50	44

After accomplishing all of these tests, the PING))) and Sharp sensors proved acceptable for the prototype.

13.4 Web interface testing:

To test the web interface, it is very important to pay attention to the compatibility to operating systems and compatibility to web browsers. The GUI is the most important aspect. It is the main interaction with the user. The ✓ represents that the test on the system was successful.

The web page interface is the most important interaction with the user. It must be tested thoroughly to avoid dissatisfying or confusing users. Once the user loads the web page, the following procedures will be done to test the web interface component:

- ✓ Click zoom in button on the map.
- ✓ Click zoom out button on the map.
- ✓ Click on map and drag map to change location view.
- ✓ Click on the "LOGIN" link at the top of the page.

On the Login Page:

- ✓ Click "Login" without entering any text in the username or password text boxes.
- ✓ Enter text into the username text box and the password text box.
- ✓ Click "Login" with wrong username or password entered. (Shown in Figure 76)
- ✓ Click "Login" with correct username and password entered.

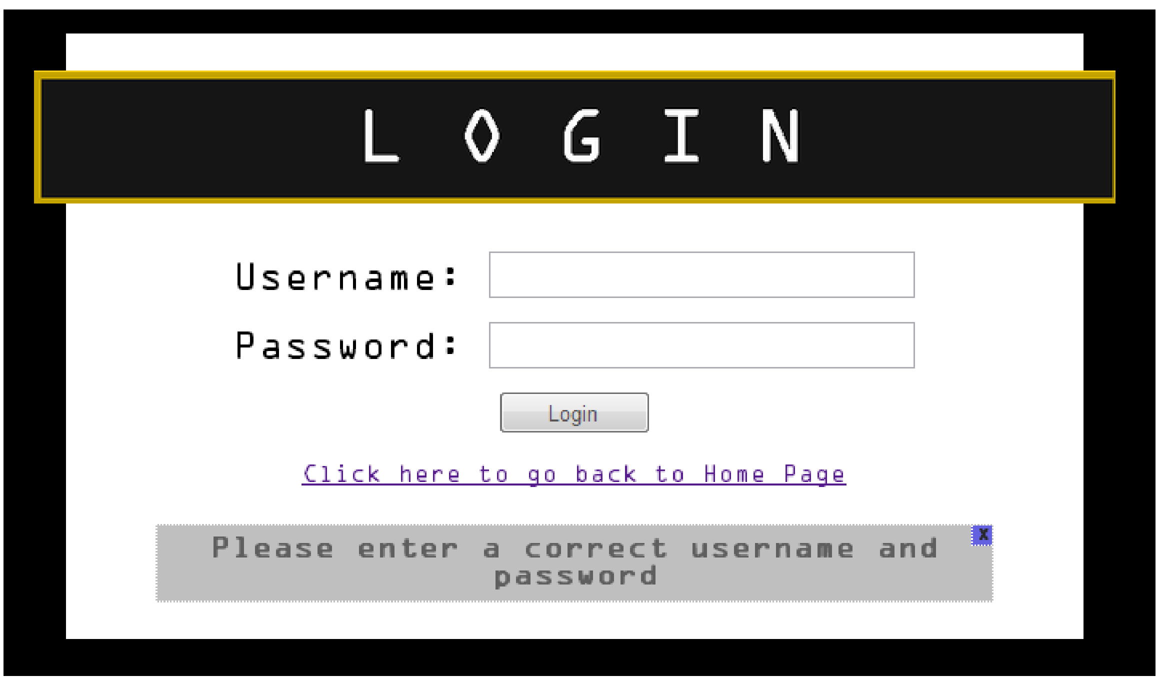


Figure 76: Entered wrong username and password

On the Edit Map:

- ✓ Click on the “Add Trashcan” button.
- ✓ Enter an already used Trashcan ID number to add and click “OK”.
- ✓ Enter a not used Trashcan ID number and click “OK”.
- ✓ Click on the “Remove Trashcan” button.
- ✓ Enter a Trashcan ID number to remove and click “OK”.
- ✓ Click the “Logout” button.

13.5 Database testing:

To ensure that the data is being received and stored in the correct place, database testing is necessary. It was tested that the queries used returned the correct data. Any time there is data received, the database has to be updated. It must be validated that every primary key must be unique and the table has the correct constraints for each attribute. With all the calculations and handling done on the data, the database must not make mistakes. The database is a very crucial part of Trash Talk.

- ✓ Add a trashcan.
- ✓ Set status.
- ✓ Change status.
- ✓ Remove a trashcan.
- ✓ Change the location of the trashcan.
- ✓ Change data on time last updated.
- ✓ Get information for every trashcan on the map.
- ✓ Get all past information of status for every trashcan.

12.6 Code Testing:

To test the code, unit tests will be created. The unit test will be added to the software to test that the software is handling the inputs and outputs correctly. The data manually added to the unit tests should be created in mind to try to fail the test. It will show if the software can handle the range of different inputs and outputs. The main sections of software are listed below:

- ✓ Sensor data received.
- ✓ Sensor data displayed.
- ✓ Map display.
- ✓ Trashcan location display.
- ✓ Login.
- ✓ Get time of updated trashcan information.
- ✓ Calculate status of trashcan.
- ✓ Get status of trashcan from database.
- ✓ Get changed location of trashcan.
- ✓ Add trashcan information to database.
- ✓ Remove trashcan.
- ✓ Add trashcan.
- ✓ Logout.

14 Project Operations

14.1 Sensors

The sensors that have been used in the Trash Talk prototype are the Parallax PING))) ultrasonic sensor and the Sharp GP2Y0A02YK0F analog sensor. These sensors are connected in series with the PING))) sensor closest to the power supply. They all require a 5 V DC supply and their own individual signal input into the microcontroller. The PING))) sensor is the depth measuring sensor so the code is setup to allow it to measure the actual distance that the trash is from the top of the trash can. The Sharp sensors are the redundancy for the PING))) sensor and are programmed to detect if a value is returned that is less than the normal operating value. The code is setup to return just a status which includes the level of trash, the trash can ID and the GPS location.

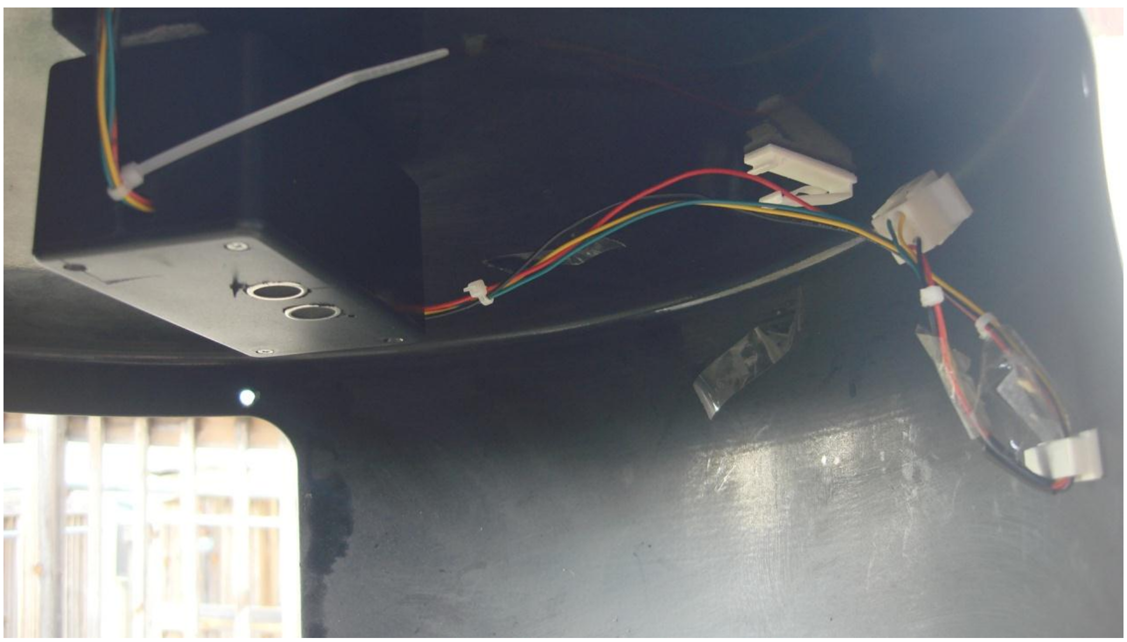


Figure 77: PING))) Sensor with IR sensor wire input

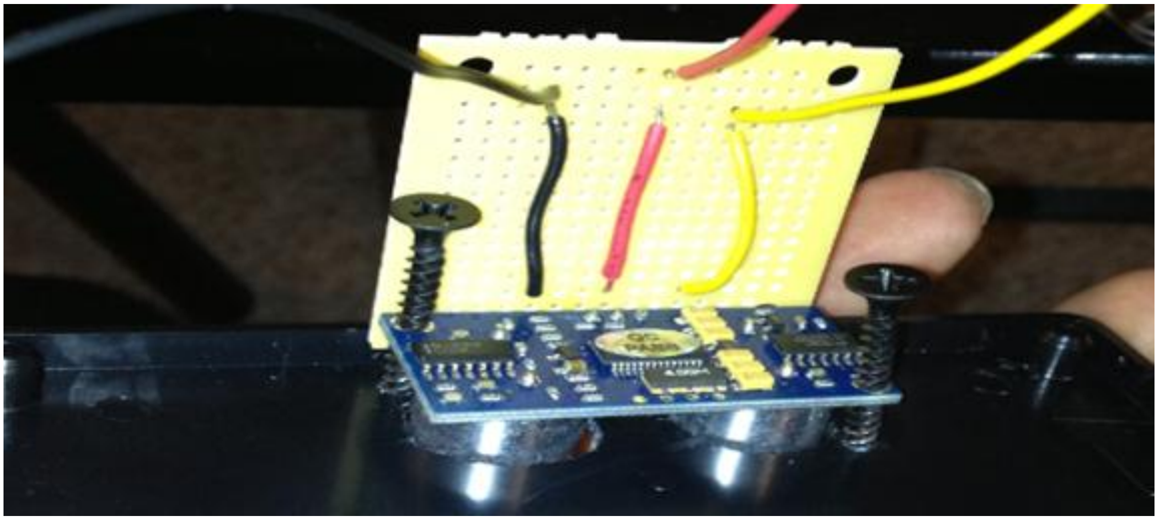


Figure 78: Interior View of PING)))

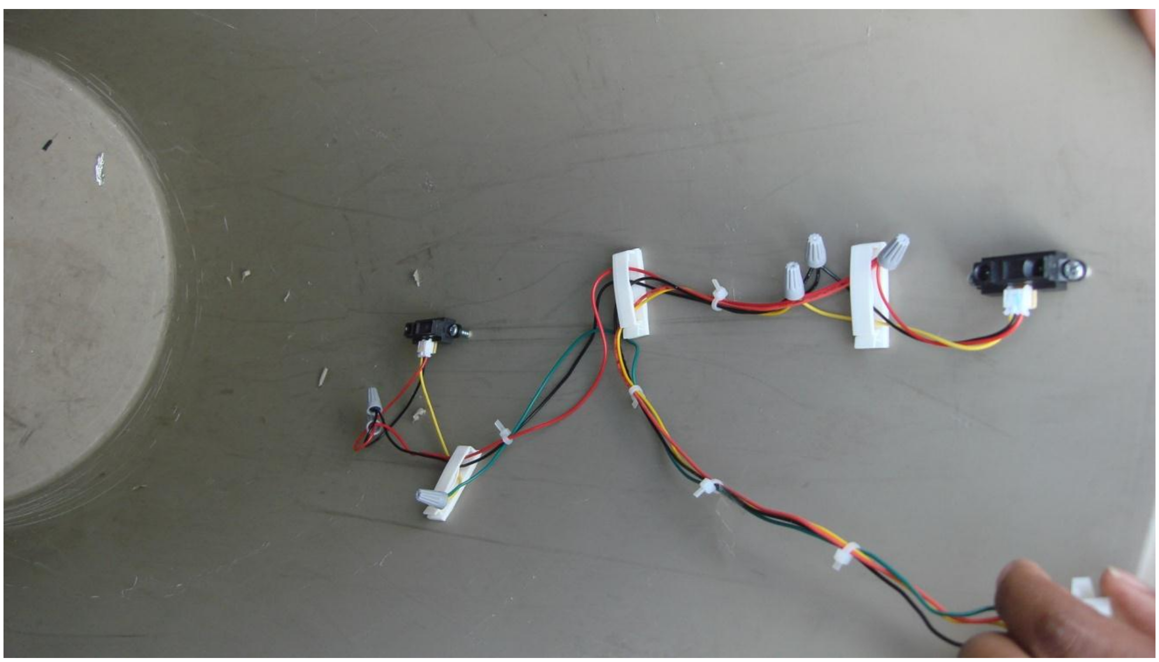


Figure 79: IR sensors in trash can liner

Troubleshooting Sensors

If the sensors are not operating correctly, use the sensor only code.

- If the values returned from the IR sensors are the same, check to make sure that the ground and voltage supply wires are secure.
- If one of the sensors is reading zero, check to make sure the voltage supply wire is secure.
- If the output of the IR sensor is greater than the normal operating output, ensure that the signal wire is secure.
- If the PING))) sensor is reading zero, check the all the wires connecting it.
- If the PING))) sensor is intermittently outputting zero or one, there is a device drawing too much current from it.
- If the status output is incorrect, adjust the code to account for the actual depth that the PING))) sensor reads.

14.2 XBee

The XBee module is connected directly to the main board and requires a 3.3 V DC input, a data in, and a data out input and output. It transmits all of the data from the microcontroller to the main XBee module which is connected to the database.

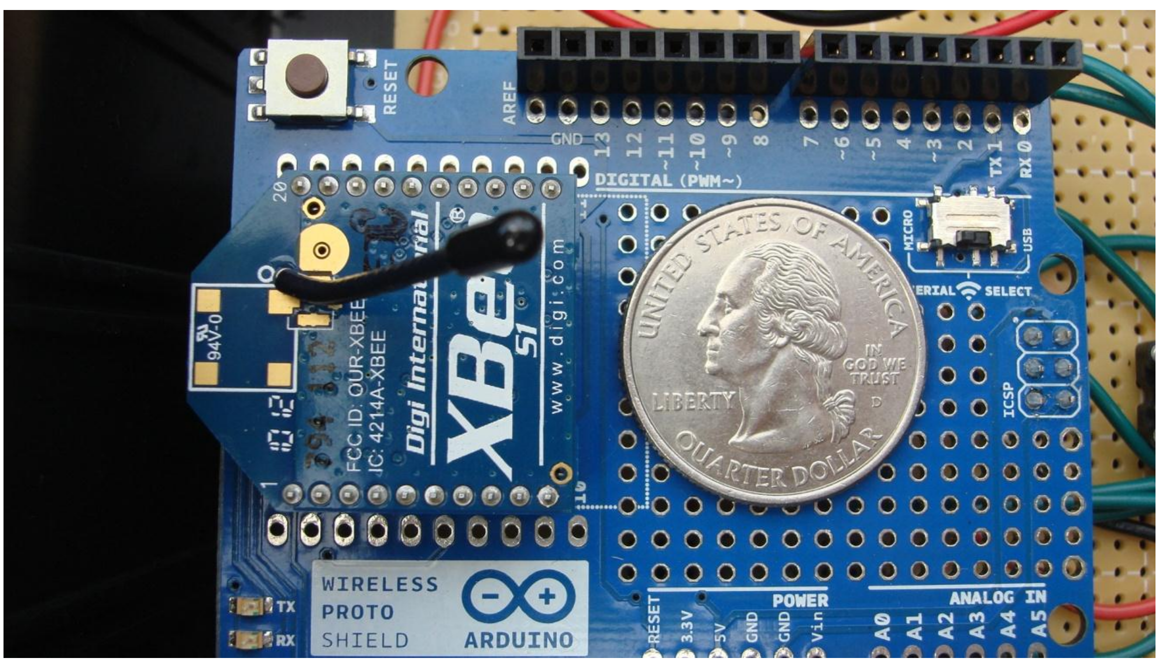
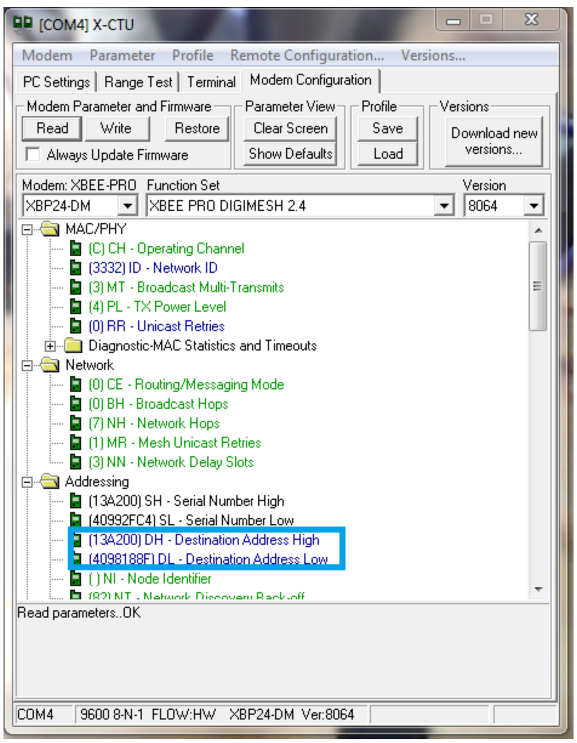


Figure 80: XBee Module on main board

14.2.1 Configuring XBee Hardware

To configure the XBee modules, each trashcan that is transmitting to the control system has to have their destination address match the control system's address. This is set all the trashcans', in the system, information to be sent to the control system.

- Open the XCTU program; go to the "Modem Configuration" tab.
- Click on the "Read" button in the top left hand corner.
- The field in each trashcan's wireless node is highlighted in Figure 81.
- The field in the control system that the destination address in the trashcans must match is highlighted in Figure 82.
- Click "Write" in the top left corner to save any configuration changes on the wireless node



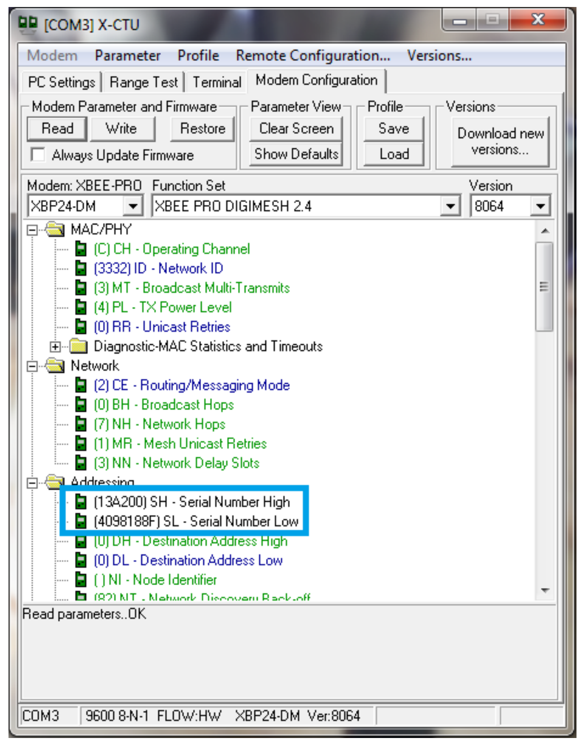


Figure 81: The destination field that needs to have the control system addresses (one to the left)
Figure 82: The control system address (one to the right)

14.2.2 Troubleshooting XBee Hardware

The main problems with the XBee are that it does not transmit or data is not received when it does transmit.

- If you encounter the above problems, perform a Range Test from the main XBee module in the XCTU program (pictured below). The RX light should stay illuminated. Stop the range test and the problem should be resolved.

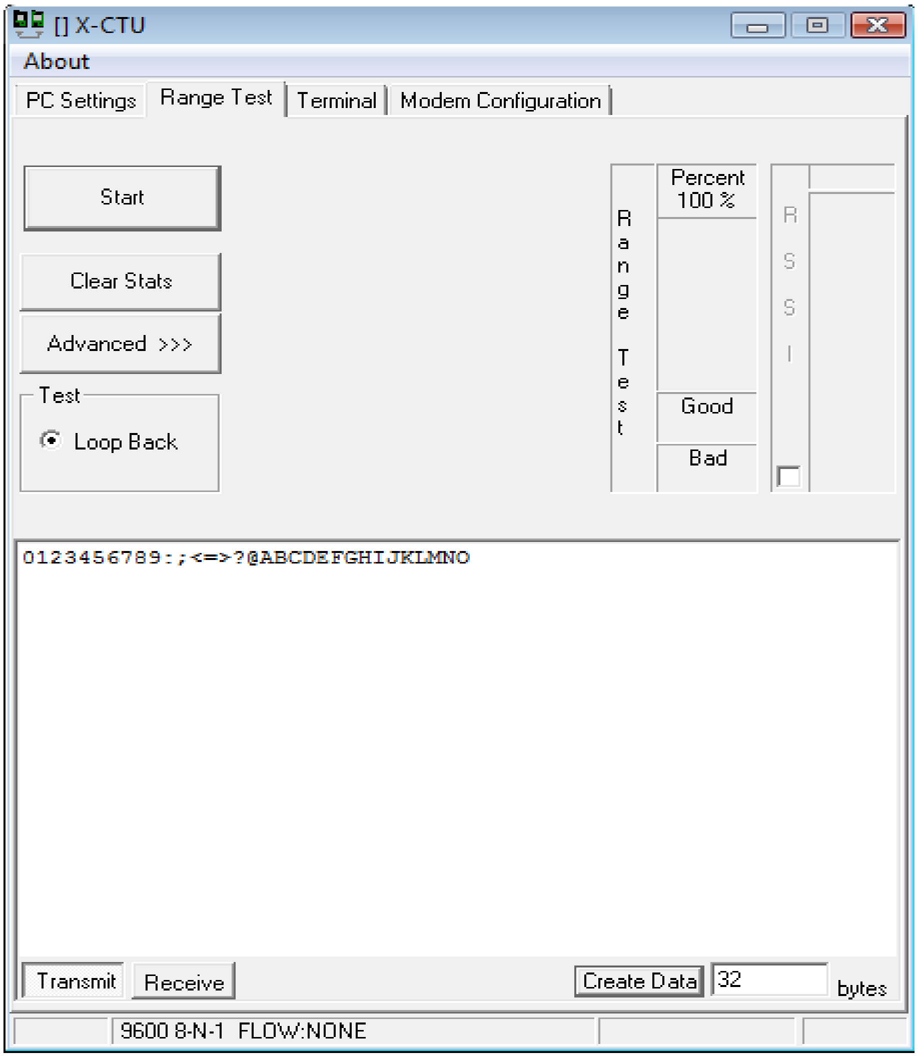


Figure 83: Range test in XCTU

14.3 GPS

The GPS chosen for the design was a Parallax 648. The power requirements for the GPS are 3.3-5V, the Parallax GPS has a built in rechargeable battery for memory and RTC (Real Time Clock) backup and is capable of 20 parallel satellite tracking channels. It is used to provide the location, time and date for the trash can.

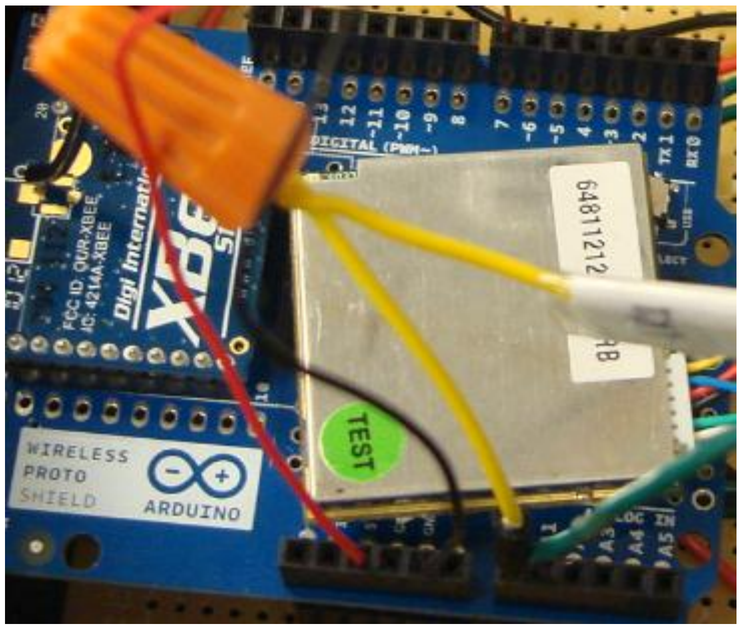


Figure 84: GPS mounted on main board

14.3.1Troubleshooting GPS

The main problems with the GPS are that it does not track or that it consumes too much current.

- If the GPS does not track, move the system outdoors to an open area. Wait up to ten minutes. If the system still does not track, reset it and repeat.
- If the GPS is consuming too much current, program it to stop tracking after it has locked on to a location.

14.4 Main board

The main board for Trash Talk is where all the sensors, GPS, XBee and power are connected. It is modeled after the Arduino Uno board and uses the same microcontroller; the Atmega 328 P-PU. It is mainly composed of the MCU, crystal oscillator and headers for the WIFI shield to plug into. Its sole purpose is to provide connectivity to the various components and regulate the voltage inputs.

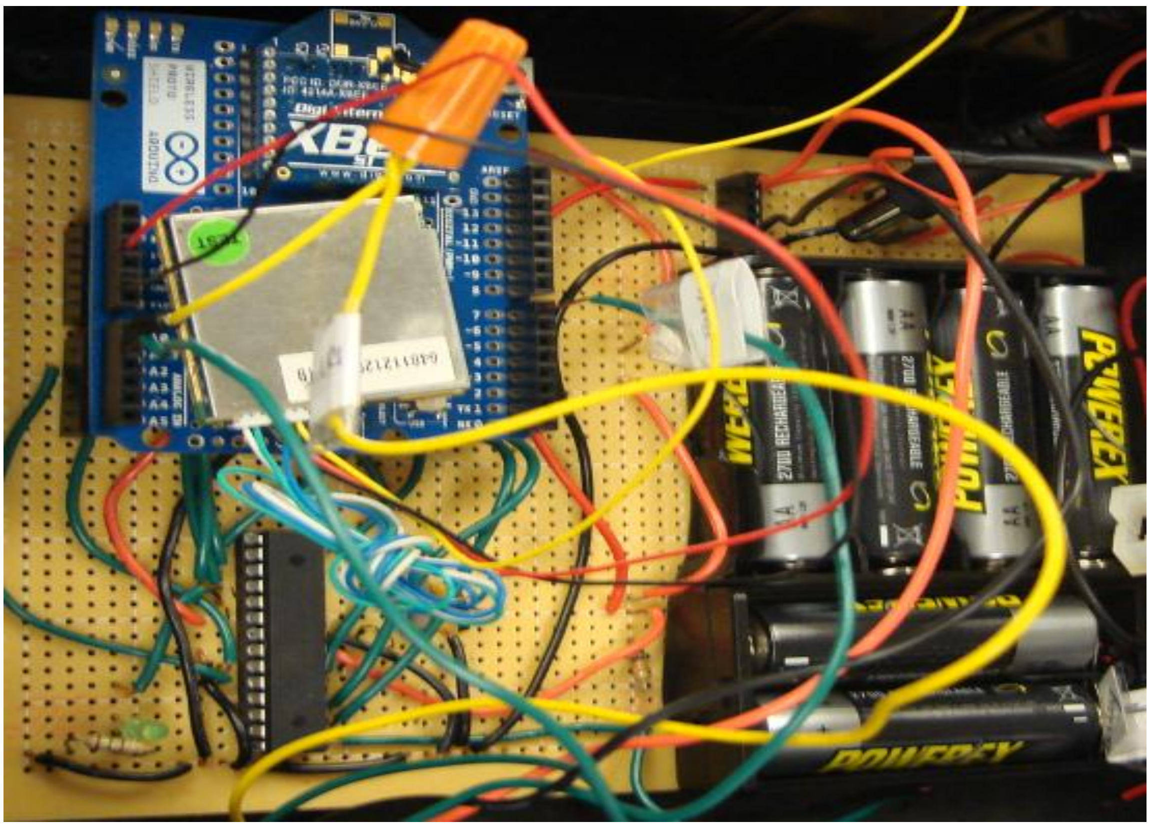


Figure 95: Main board (Vector Board Model)

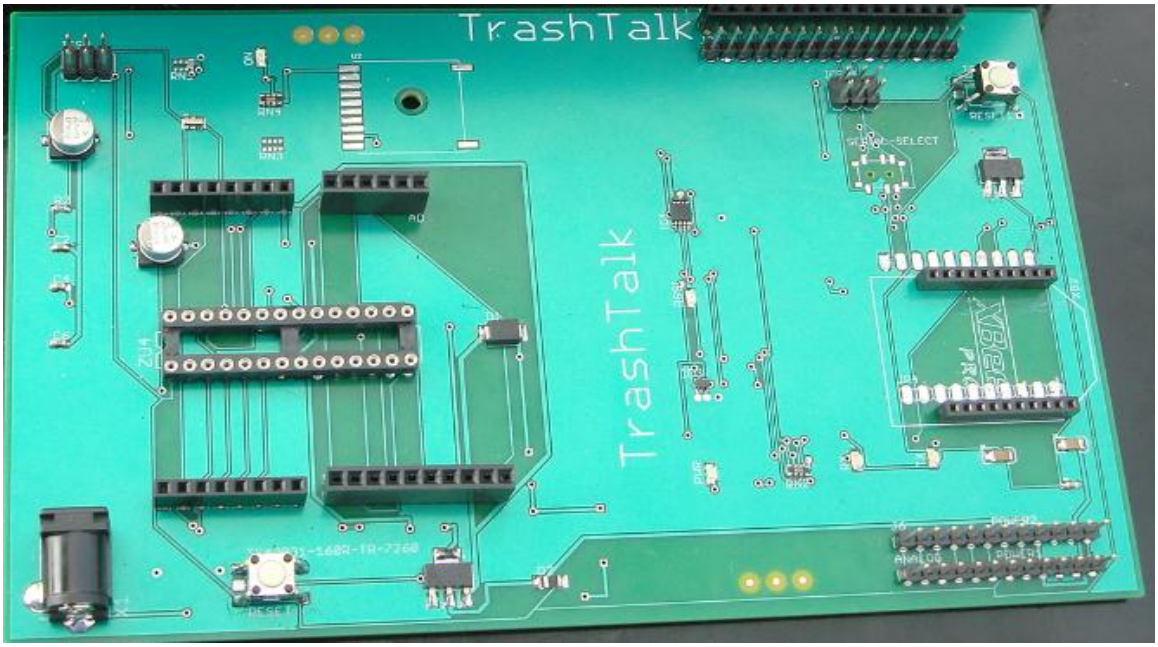


Figure 86: Main board (PCB)

14.4.1Troubleshooting Main Board

The main problem associated with the main board is making sure the proper amount of power is supplied.

- If everything is connected and the power LED is not illuminated, check the battery supply and the voltage regulators to ensure that they are secure.
- If the power LED is illuminated but the XBee is not transmitting, check the current being supplied from the batteries.
- Always check the signal wire inputs to verify that they are in the correct location.

14.5 Power Supply Unit

14.5.1 Batteries

The power supply unit consists of a battery terminal of 6 AA batteries connected in series that directly powers on the main board. The AA batteries are Nickel-Metal Hydride batteries. When completely charged, the total output voltage ranges between 7.2 volts – 8.1 volts. The range in voltage is due to each battery being rated at 1.2 v but easily reaching up to 1.35V.

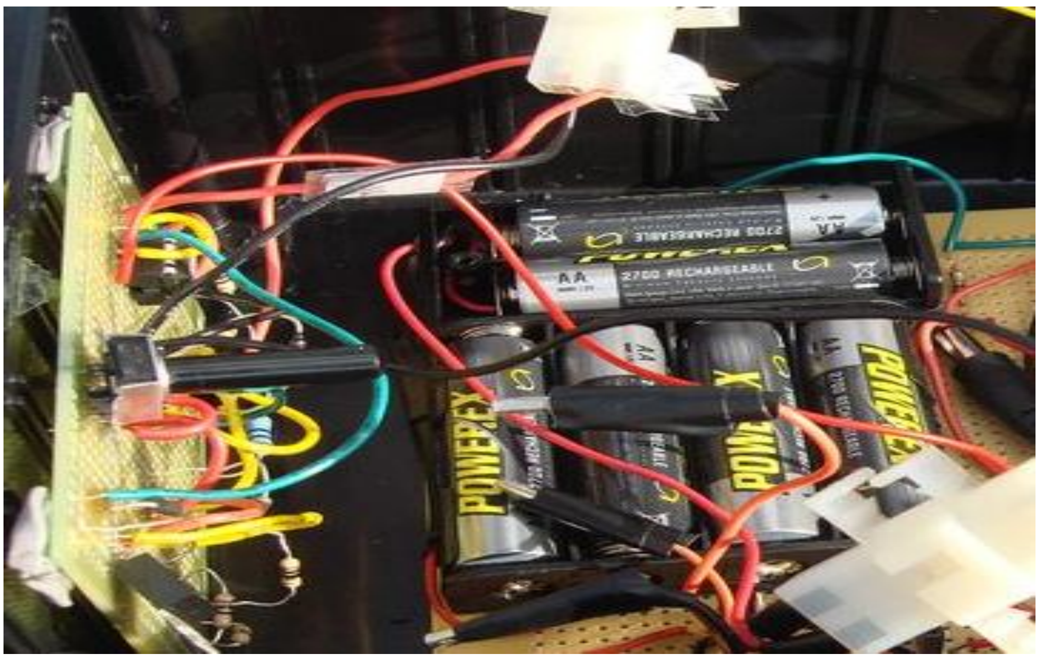


Figure 87: Battery terminal

14.5.2Solar Panel

The power system also utilizes a Solar panel rated at 12 volts 1 watt of power. The solar although rated at 12V easily exceeds beyond the 12V to a total of 21V on a really sunny day. The solar panel directly recharges the batteries whenever they reach a low depletion level not suitable to charge the main board. The solar panel also is equipped to take over and power the main board directly whenever the batteries are not operating correctly. When the solar panel takes over as primary source of power to the main board, it has to be in direct sunlight and only operates during the day.

Figure 88: Solar Panel

14.5.3 Trouble shooting the Power supply unit

Troubleshooting the Power supply is simply figuring out whether the battery terminal is not working correctly, the solar panel is not working correctly or a combination of both.

- Check and ensure that the male female power connection is securely connected between the power supply and the main board. Each connection is labeled for simplicity.
- Check the batteries for any visible corrosion or physical damage. Replace batteries if necessary to see if the system begins operating again.
- Check that the solar panel male female power connection is securely connected to the main board.
- Observe the surrounding area to ensure that nothing is obstructing a direct path of sunrays to the solar panel.

Software

To run the process on the OS system, the system must have the Visual Studio 2010 solution for TrashTalk. The solution must be opened and ran for the information through the wireless node to be received. To setup the serial port to be read, the user has to know which COM port that the wireless node is connected to. The GUI in Figure 89 is shown when the solution is running. One way to determine the COM port it is running on is to open the XCTU program mentioned above and see which COM port is active with the wireless node.

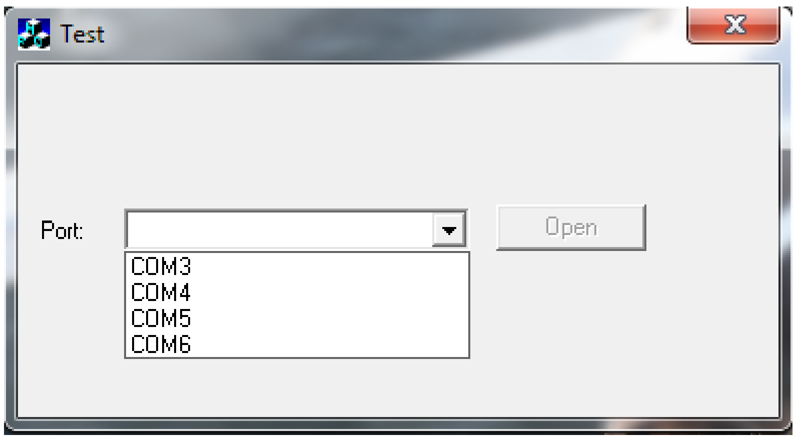


Figure 89: The GUI to read from the wireless node

15 Appendix

15.1 Permissions

From: jaquan hodge Hide
Subject: regarding circuit design
Date: November 19, 2012 9:49:27 PM EST
To: electroskan@yahoo.com

To whom it may concern,
I am currently doing my senior design project at the University of Central Florida and would like to incorporate your Automatic Battery charger circuit in my project design. I would like to ask for your permission to use both the circuit as well as the actual picture which were posted online. I will surely reference your online page and add your name to the picture design. Thank you in advance

electro schematics home comments contact us disclaimer lin

555 Arduino Audio Datasheet DIY Gadgets Hobby Light Measure Power supply Radio

The circuits on this site are collected from various sources and written by various authors. All these circuits are provided only for education purposes. We do not take any responsability for malfunctions or posible injuries suffered by those who test this electronic circuits.
If anybody have any issues with any of the circuits please mail to contact@electroschematics.com

From: Enrison Hilario [bok.egizmo@yahoo.com]
Sent: Saturday, December 01, 2012 6:06 AM
To: rahn.lassiter
Subject: Re: Request for permission to use design

the design and the printed circuit board design is free, you can use it for your projects..

From: rahn.lassiter <rahn.lassiter@knights.ucf.edu>
To: "janet.egizmo@yahoo.com" <janet.egizmo@yahoo.com>; "julie.egizmo@yahoo.com" <julie.egizmo@yahoo.com>; "bok.egizmo@yahoo.com" <bok.egizmo@yahoo.com>
Sent: Friday, November 30, 2012 3:27 PM
Subject: Request for permission to use design

To Whom It May Concern,

My name is Rahn Lassiter and I am a senior Electrical Engineering student at the University of Central Florida. I am emailing to request permission to use your through beam sensor design, proximity sensor and associated printed circuit board design for my senior design research paper and project. I appreciate your assistance and consideration in this matter. Thank you.

The associated links are below:

http://www.e-gizmo.com/ARTICLES/PTsensor/Throughbeam.htm

http://www.e-gizmo.com/ARTICLES/PTsensor/Sensors-Proximity.htm

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