University Of Central Florida

College of Engineering and Computer Science

Senior Design 2, Fall 2013

SMART WALKER

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1.0 EXECUTIVE SUMMARY

1.1 MOTIVATION

In recent years, we have witnessed the explosive growth in technology around the globe. New devices and ideas are being generated robustly along with the technology. As a group of electrical engineering students, we have learned that the engineering profession plays a very important role in the medical field. We have also observed that more and more senior citizens nowadays are often being left alone at their resident without much, or no assistance. Take Mrs. Patricia, who lives in Melbourne, Florida as an example. Mrs. Patricia, a 78 year old widow who fell in her bathroom while she was getting out of her shower at her house, alone. She was enduring so much pain that she couldn't move herself to the walker located just outside the door of the bathroom. The idea of creating an automatic walker to assist our senior citizen, or whoever in need of assistance with similar case, is our motivation to start The SmartWalker project.

The idea of the project itself is not new in these days. In fact, there are quite a few similar products in the market such as automatic/motorized walkers or wheels chairs. However, these technologies lack a couple of features that would be more helpful to the user. For instance, remote control over the internet or via mobile app, wireless monitoring, and self-navigation to a destination are some features that we would like to design and add to the SmartWalker. More importantly, designing and building such equipment requires a lot research, team-work and skills that will benefit us as engineering students. Also, the satisfaction and knowledge that one gets out of designing and actually building it yourself are invaluable.

Although the parts and devices required for this project are already available in the market with low cost and high performance, but the complexity of it is rather high. It requires us to have a lot of knowledge on several different subjects: system control, autonomous systems, range-finders, various types of sensors, and wireless communication systems. Due to the complexity of this project, we are most likely going to need some mentors and advisors. As it is in the early stage of the project, we currently have not acquired such assistance yet. However, as we progress, we will have to consult with some professors in the Electrical and Computer Science Department at UCF.

1.2 GOALS AND OBJECTIVES

The main goal, above all, for this project is to create a lightweight, portable multifunction walker whose main function is to navigate itself to the user when it is called by a simple press of a button from a station setup in a room. It will also have the ability to carry a significant amount of weight; up to 30 lbs. (The Walker itself is weighs approximately 12-16 lbs.) Due to the readiness ability of the *SmartWalker*, we should optimize its power consumption the best we can. This can be done by reducing charging time, putting the system into power-saving mode or support mode when it is not in use. Since we are building this project with the idea of helping senior citizens in mind, we should make it as light-weight and portable as possible, so that it is easy to be carried as the user travels to places. One more feature that we decided as a group to add to the SmartWalker is a lightweight compartment for easy storage of medicines, cups, reading glasses or any small necessary items.

The design should be done in the most efficient way in terms of power consumption, responsiveness and real-time readiness of the system. Effective engineering principles and values must be practiced carefully throughout the entire design to achieve the best possible solution using the least amount of resources, whether it is cost or labor. The complete and final product should be user-friendly and self-explanatory. Below is the summary of said goals and projected functions of the SmartWalker:

At the beginning of the second semester of Senior Design, the group realized that the original described above was very complicated to implement, prototype and develop in the given period of time (1 semester). In order for the walker to autonomously guide itself to the location of the user once it is called/activated, an indoor-positioning system such as RFID mesh-network, or WIFI network, rather than using existing GPS network, would have to be designed. Without a positioning system, the walker would not know its current location and would not be able to calculate its route to the target point.

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The complexity of developing the indoor-positioning system mentioned is high; and the cost of buying a similar existing system is also far outside the group's budget. Therefore, it was decided to redesign the SmartWalker.

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The group decided that instead of making the walker autonomous that it would be remote controlled. After doing some more research the group came up with a design that brought the remote controlled walker idea to reality. The user would hold a controller that would send commands to the walker. The HT12E RF encoder is used along with the RF433 radio frequency transmitter/receiver module, operating at 433 MHz, on the remote controller, and a RF decoder HT12D RF decoder on the receiver card which will be located on the walker. The remote control also features a two inch color display that will display video live streamed from a wireless camera mounted on the SmartWalker. The camera streams video back to the remote controller by using a 2.4 GHz Video Transmitter/Receiver. The advantage of this design is that there was almost no coding required for the system configurations. There was some configuration needed for the RF subsystem but an insignificant amount compared to other options using microcontrollers and components of that nature. However, it was realized that this design has limitations. This design does not allow for easy growth. Additional features, such as obstacle detection via ultrasonic or infrared sensors, are difficult to implement. This new design has mostly the same goals and objectives as the original design that are listed below. The only difference is that the walker is remote controlled by the user rather than having the ability to self-navigate.

- Be lightweight and portable
- Be able to self-navigate (avoiding objects on its path) to the user's location
- Be able to operate for an extensive amount of time without charging throughout the day
- The drive motor, or drive system must be able to drive a load of up to 30 lbs.

1.3 RISKS AND CHALLENGES

In any project there are always risks. The same goes for the development of the SmartWalker. In designing the SmartWalker the risks occur in a variety of areas. The first risk that will be discussed is the financial risk. Due to the fact that there are few sponsors available for the time frame in which the SmartWalker is being built, this project will more than likely be funded by the members of the group. In designing the SmartWalker there will be estimated costs for each part that will give the members of the group an idea of the total cost of the project. However, the members of the group are just college students and do not have a copious amount of financial resources to dedicate to the project. Knowing this, there is a risk that the design that is created to meet all of the specifications is too expensive for the group to fund and therefore cannot be built.

The next risk that the group faces in this project is that the group will not be able to follow the schedule for construction. Among the members of the group, there are only a few months of experience with hands-on work on electrical systems. With a lack of experience the group could face many setbacks with broken parts and delays in construction. The lack of hands-on experience could lead to the schedule of building the SmartWalker being thrown off due to delays in physical construction of the SmartWalker along with having to replace parts due to mishandling or incorrect installation. Along with group errors during constructions there is always the risk that other complications will be met during construction and the schedule will be set back.

The risks for the SmartWalker have not changed between designs.

1.4 REQUIREMENTS AND SPECIFICATIONS

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The following requirements and specifications are the guiding criteria that we must consider when designing every subsystem of the SmartWalker. Each of the constraints listed below are all physically possible in terms of current technology, as well as parts availability. More importantly, they are well within the scope of undergraduate electrical engineering major. These requirements and specifications will all be discussed in further details later as the project progresses. As of right now, we decided that the SmartWalker should accomplish the following requirements:

- Be able to support up to 400 lbs. of weight so that the user can lean on it and use it as a support when walking
- The total weight of the final product should not exceed 30 lbs.
- Be able communicate from transmitter to receiver up to a distance of 70-100 feet away
- Be able to detect and avoid obstacles that can make the SmartWalker get stuck
- Once activated, the *SmartWalker* must be able to self-navigate and avoid any obstructions
- Be able to reach the user's location within a reason able amount of time (2 to 3 minutes) depends on the distance it has to travel
- Be able to stop within 2 feet of the user
- Be able to sustain functionality for up to 6 hours without recharging
- Be user-friendly and self-explanatory

With the new design of the SmartWalker came new specifications and requirements. The new specifications and requirements are listed below.

- Weigh less than 50 pounds
- Be able to support up to 200 pounds of weight (Manual use)
- Travel no faster than 3 miles per hour
- Have no more than a 2 second delay in video streaming and control
- Be able sustain functionality up to 40 meters away from the walker
- Be able to sustain functionality for up to 2 hours without recharging (non-continuous use)

1.5 BLOCK DIAGRAM

Figure 1.1 below describes the projected course of action of the SmartWalker. From the functional block diagram of the system it can be seen that, once the SmartWalker is activated, the control signal will then be sent to the main microcontroller. From there the microcontroller will execute the collision avoidance algorithm through sensing units. Once the SmartWalker gets to the desired position, it will standby for further instruction. If the users want to use the walker, they just need to use it manually. The motors are forced to shut down at this time allowing the wheels to be free rolling. This feature will protect the motors and their components from damage. One extra luxurious feature that is being considered is that in case the users do not want to use it for some reasons (could accidentally activate the SmartWalker, or they just need to get their medical supplies stored in the walker), the walker will follow the user wherever they go. Even though this feature serves no necessary purpose, but it is found to be challenge and is a good experience to gain from the designing aspect of it.

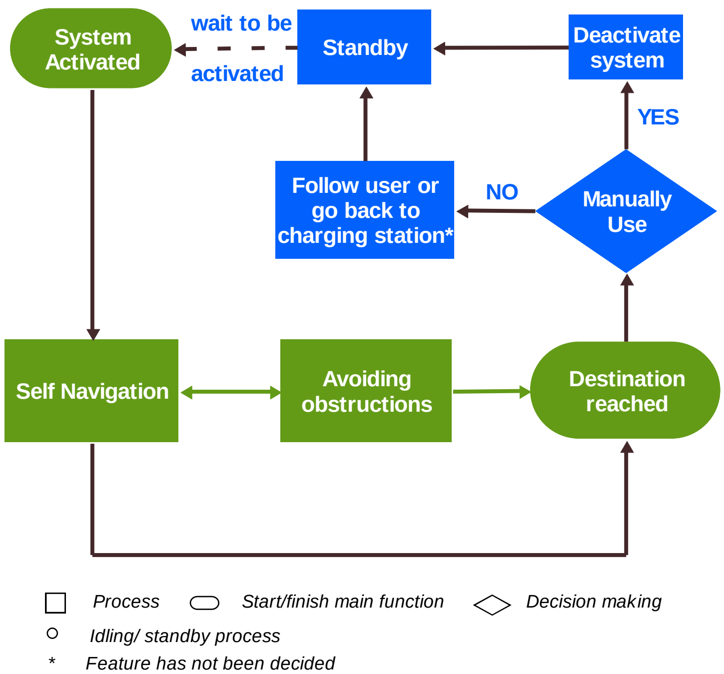

Figure 1.1: SmartWalker Functional Block Diagram

Figure 1.2 shows the overall system in terms of hardware. Each of the blocks represents a subsystem. Each member of the group will be in charge of research, design, and parts acquiring for their assigned blocks. Members are working on their parts simultaneously throughout the semester with others. Please note that all of the functions and feature may not be designed and implemented due to time constraint, financial situations, and, in some cases, part availability. The goal is to accomplish every feature possible.

An ultrasonic range finder will be mounted on a servo motor which is controlled by a motor controller (microcontroller). The communication between the distance sensors and the motor controller is bidirectional. Information received from the sonic range finder will be processed by the motor controller (microcontroller), who will then give instruction to the servo motor to turn in different scanning directions and angles. Once clear from the obstruction on its path, the motor controller will tell the motors to head to the clear-path direction. Each of the subsystems has different power requirements and consumption, therefore the power supply unit is grouped together (in green). Each of the subsystems will be discussed in great details in later chapters.

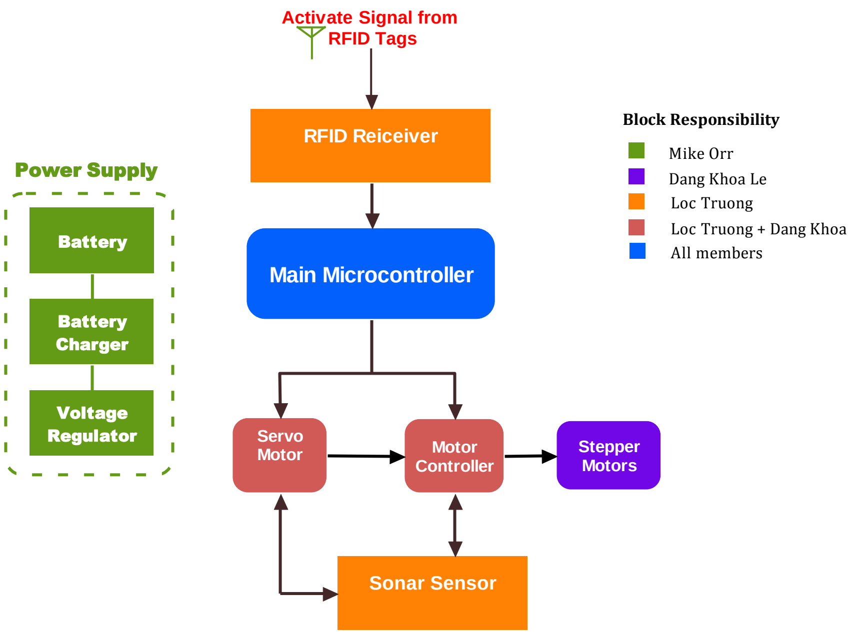

Figure 1.2: SmartWalker Functional Block Diagram

The system description and block diagram shown above in this section are no longer applicable due to the redesign. The system block diagram for the new design is shown below in Figure 1.3. The blocks are color coded to show which subsystems each group member is responsible for.

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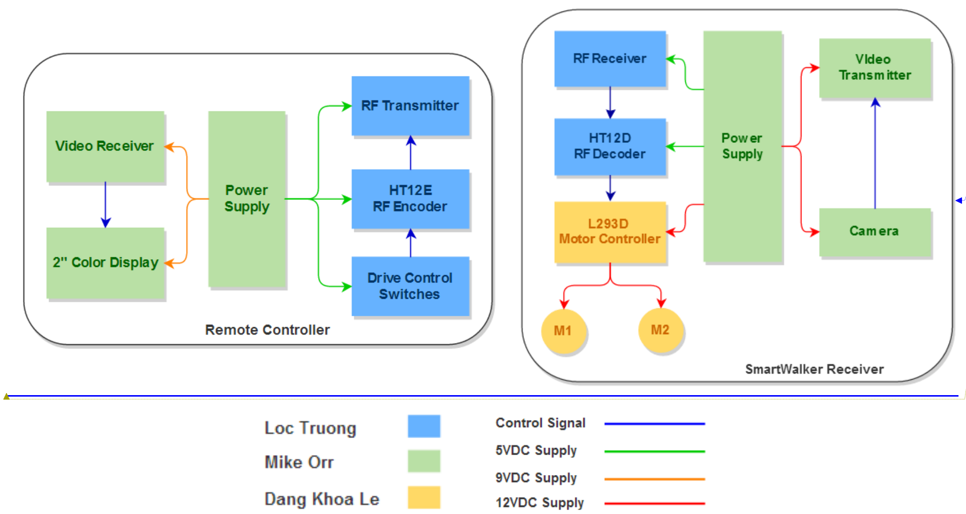

Figure 1.3: System Block Diagram with Task Distribution

Not shown in this task distribution figure is the physical construction of the walker. This part of the project was done primarily by Dang Khoa Le but all members contributed.

2.0 RESEARCH

2.1 EXISTING SIMILAR PRODUCTS AND DESIGNS

There are a few existing solutions for helping the elderly in movement via autonomous robots. In this section some existing solutions along with similar technologies will be examined.

At the Robotics Research Lab at the University of Kaiserslautern in Germany, the Autonomous Robot for Transport and Service (ARTOS) was created in order to assist the elderly. This machine was created to autonomously guide itself around the dynamic environment of a person's home in order to quickly detect emergency situations without a human caretaker having to be there. ARTOS is designed to be able to detect and analyze an emergency situation. After detection and analysis, ARTOS will make an emergency call to the caregiver in order to get immediate assistance. In addition to acting as an emergency situation detector and a channel for communication between elderly person and caregiver, ARTOS will act as a transportation unit and a service robot. This robot uses the A* algorithm to autonomously navigate its way through the environment and used RFID in

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Formatted: Font: (Default) Cambria, 12 pt, Not Bold, Font color: Auto order to know its precise location in the environment. ARTOS is also equipped with a laser range finder, ultrasonic sensors, tactile sensors, and a pan-tilt-zoom camera.

Another similar product is the Care-O-bot® being developed by Fraunhofer IPA. The Care-O-bot® is able to assist humans in their daily life. The third generation of this product is being developed. The Care-O-bot® 3 can act as an interactive butler, moving safely among humans, detect and grab typical household objects, and safely exchange them with humans. Care-O-bot® 3 has an omnidirectional platform with four steered and driven wheels. This allows the robot to move in any direction. Care-O-bot® 3 is also able autonomously plan an optimal, collision free path to a given target and follow that path. The robot uses sensors to detect and avoid objects, stationary or moving. Care-O-bot® 3 is equipped with a commercial arm that consists of a three-finger hand and seven degrees of freedom which allow it reach from the floor to high shelves and even around objects. This along with tactile sensors in the hand allow for handling of everyday objects. In addition to handling objects and avoiding obstacles, the Care-O-bot® 3 can open doors that block the way. Care-O-bot® 3 uses a wide variety of sensors ranging from stereo vision color cameras and laser scanners to a 3D depth-image camera for environment perception. These are used to locate objects and differentiate the relevant objects, for manipulation, and irrelevant ones. The robot is even able to learn new objects independently. The Care-O-bot® 3 is also interactive. It features a tray attached to the front end of the robot, which carries objects for exchange between the user and the robot. The tray includes a touch screen which retracts automatically when not in use. The robot also has a safety feature where if it detects people in the immediate vicinity of the robot it stops all movement of the arm and the wheels to prevent any undesired contact.

This next project isn't designed to aid the elderly. However, it does have some similar features that the SmartWalker is to have. In 2011, a senior design group from the University of Central Florida created the Knight Sweeper 4200. Knight Sweeper 4200 is a rover four wheeled platform, a microcontroller unit, infrared sensors, ultrasonic devices, GPS unit, wireless module, and a metal detecting unit all put together as an unmanned vehicle used to sweep for landmines.

With the new design no longer being autonomous, these examples of similar technologies are less applicable. However, there are similar products that exist today. Some similar products would be RC cars, planes, and boats that are used for recreational purposes. These cars also use a remote control in order to manipulate a moving device from a distance. Another example used for more serious applications would be robots used by the military and police for bomb disposal purposes. These robots are much more complex than your average remote controlled vehicle as they have moving arms but they are similar to the SmartWalker in that they are remote controlled and video stream to the user via wireless camera.

2.2 POWER SUPPLY SYSTEM RESEARCH

Since this project has many different components requiring different voltages and currents, a way must be found to meet all of those power requirements so that all of the components will be able to perform their functions properly. There are a few methods that could be used to distribute the power for the machine. Each method will be discussed in this section.

All research done for the power system of the SmartWalker applied even after redesign. The components of the SmartWalker changed but the power requirements for the components are similar.

2.2.1 POWER DISTRIBUTION SYSTEM

INDIVIDUAL POWER SOURCES

One method of obtaining the correct power for each subsystem would be to dedicate a separate power source for each subsystem. This method is simple and would be easy to design and implement as far as voltage/current calculations go. However, this brute force method is not the most efficient, it would cost more money to implement and would also consume more space, weighing down the walker.

EXTENSION CORD

The next method looked at for powering the SmartWalker is to have it plugged into a standard wall outlet via extension cord. This would be the simplest and least elegant design for a power supply even though it would provide infinite power. However since this project is directed towards helping the elderly and the physically impaired. Having an extension cord running on the floor wherever the walker went would introduce the risk of causing falls for the people the SmartWalker is trying to help. It would also make the autonomous motion of the walker more complicated due to the fact that the cord would have to be taken into account when considering the path selection algorithm.

INTEGRATED POWER SOURCE

Another method for power distribution would be to have one power source that powers all subsystem components using other parts such as voltage regulators and transistors. This method is the most difficult to design and implement. There is also a high risk of losing parts in the creation and testing of the circuitry involved in this method. However, it will be more cost efficient than the individual power supplies method and will provide a lightweight solution to the power distribution problem. After considering the options, it was decided to go with this method based on the cost and weight requirements of the project.

2.3 BATTERIES

In this section different types of batteries are reviewed and each ones strengths and weaknesses will be considered. In order to choose a battery for this project, an outline of the specifications for what is needed from the battery must be made. The primary needs for a battery are: high charge capacity, long cycle life, and low cost. The high charge capacity and long cycle life is so that the battery will allow the SmartWalker to operate for extended periods of time without recharging over as many recharge cycles as possible. The secondary needs would be: lightweight, short recharge time, low maintenance, and environmentally safe. Now a few types of batteries are discussed individually.

NICKEL CADMIUM BATTERY (NiCd)

NiCd batteries have been around since the 50's and are a reliable battery. Some major advantages and disadvantages are listed in Table 2.1:

Advantages	Limitations
• Fast and simple charge, even after prolonged storage. • High number of charge/discharge cycles. If properly maintained, the NiCd provides over 1000 charge/discharge cycles. • Good load performance — the NiCd allows recharging at low temp. • Long shelf life, in any state-of-charge. • Simple storage and transportation: most airfreight companies accept the NiCd without special conditions. • Good performance in low temp. • Forgiving if abused: the NiCd is one of the most rugged rechargeable batteries. • Economically priced: the NiCd is the lowest cost battery in terms of cost per cycle. • Available in a wide range of sizes and performance options. Most NiCd cells are cylindrical.	• Relatively low energy density compared with newer systems. • Memory effect: the NiCd must periodically be exercised to prevent memory. • Environmentally unfriendly: the NiCd contains toxic metals. Some countries are limiting the use of the NiCd battery. • Has relatively high self-discharge, needs recharging after storage.

Table 2.1: Advantages versus Limitations of NiCd Battery
(Content are acquired through Battery University)

NICKEL-METAL HYDRIDE BATTERY (NiMH)

One of the best characteristic that NiMH battery has is its high capacity and its environmental friendliness. However, its increased cost and complex charging are a problem. If this battery is not charged properly, it will lose some of its capacity. Also, multiple high discharge currents will reduce the cycle life of the battery which is a negative for this project since certain components of the SmartWalker need higher currents from the battery. Both of these bring the NiMH's durability into question which is something needed from the battery that is chosen. For better comparison between its pros and cons, let's consult Table 2.2. The information in Table 2.2 was acquired from Battery University which gives excellent information that could help in the decision making process.

Advantages	Limitations
• 30%-40% higher capacity over a standard NiCd. The NiMH has potential for yet higher energy densities. • Less prone to memory than the NiCd. Periodic exercise cycles are required less often. • Simple storage and transportation: transportation conditions are not subject to regulatory control. • Environmentally friendly: contains only mild toxins; profitable for recycling.	• Limited service life: if repeatedly deep cycled, especially at high load currents, the performance starts to deteriorate after 200 to 300 cycles. Shallow rather than deep discharge cycles are preferred. • Limited discharge current: although a NiMH battery is capable of delivering high discharge currents, repeated discharges with high load currents reduces the battery's cycle life. Best results are achieved with load currents of 0.2C to 0.5C (one-fifth to one-half of the rated capacity). • More complex charge algorithm needed: the NiMH generates more heat during charge and requires a longer charge time than the NiCd. The trickle charge is critical and must be controlled carefully. • High self-discharge: the NiMH has about 50 percent higher self-discharge compared to the NiCd. New chemical additives improve the self-discharge but at the expense of lower energy density. • Performance degrades if stored at elevated temperatures: the NiMH should be stored in a cool place and at a state-of-charge of about 40 percent. • High maintenance: battery requires regular full discharge to prevent crystalline formation. • About 20 percent more expensive than NiCd: NiMH batteries designed for high current draw are more expensive than the regular version.

Table 2.2: Advantages versus Limitations of NiMH Battery
(Content are acquired through Battery University)

LEAD ACID BATTERY

From Table 2.3, the advantages and limitations of the Lead Acid battery are appealing because of its low maintenance requirements and low cost. The battery will not be damaged by extended charging which is desirable. On the downside is the size factor. The battery can lose some of its charge capacity when fully discharged. In order to prevent this, a larger sized battery is preferred, which means more weight. In addition to the size, the cycle life and low charge density isn't the best among the options.

Advantages	Limitations
• Inexpensive and simple to manufacture — in terms of cost per watt hours, the SLA is the least expensive. • Mature, reliable and well-understood technology — when used correctly, the SLA is durable and provides dependable service. • Low self-discharge —the self-discharge rate is among the lowest in rechargeable battery systems. • Low maintenance requirements — no memory; no electrolyte to fill. • Capable of high discharge rates.	• Cannot be stored in a discharged condition. • Low energy density — poor weight-to-energy density limits use to stationary and wheeled applications. • Allows only a limited number of full discharge cycles — well suited for standby applications that require only occasional deep discharges. • Environmentally unfriendly — the electrolyte and the lead content can cause environmental damage. • Transportation restrictions on flooded lead acid — there are environmental concerns regarding spillage in case of an accident. • Thermal runaway can occur with improper charging.

Table 2.3: Advantages versus Limitations of Lead Acid Battery
(Content are acquired through Battery University)

LITHIUM ION BATTERY (LI)

Advantages	Limitations
• High energy density: potential for yet higher capacities. • Relatively low self-discharge: self-discharge is less than half that of NiCd and NiMH • Low Maintenance: no periodic discharge is needed; no memory.	• Requires protection circuit: protection circuit limits voltage and current. Battery is safe if not provoked. • Subject to aging, even if not in use: storing the battery in a cool place and at 40 percent state-of-charge reduces the aging effect. • Moderate discharge current. • Subject to transportation regulations: shipment of larger quantities of Li-ion batteries may be subject to regulatory control. This restriction does not apply to personal carry-on batteries. • Expensive to manufacture: about 40 percent higher in cost than NiCd. Better manufacturing techniques and replacement of rare metals with lower cost alternatives will likely reduce the price. • Not fully mature: changes in metal and chemical combinations affect battery test results, especially with some quick test methods.

Table 2.4: Lithium Ion Advantages/Limitations
(Content are acquired through Battery University)

The obvious upside to the LI battery is its high charge density and low maintenance. The downsides include the protection circuit required, which means additional design added to the project, along with the aging factor. It also tends to cost more than other types of batteries.

LITHIUM ION POLYMER BATTERY (LIP)

Advantages	Limitations
• Very low profile: batteries that resemble the profile of a credit card are feasible. • Flexible form factor: manufacturers are not bound by standard cell formats. With high volume, any reasonable size can be produced economically. • Light weight: gelled rather than liquid electrolytes enable simplified packaging, in some cases eliminating the metal shell. • Improved safety: more resistant to overcharge; less chance for electrolyte leakage.	• Lower energy density and decreased cycle count compared to Li-ion: potential for improvements exist. • Expensive to manufacture: once mass-produced, the Li-ion polymer has the potential for lower cost. Reduced control circuit offsets higher manufacturing costs.

Table 2.5: Advantages versus Limitations of Li-ion Battery
(Content are acquired through Battery University)

The last type of battery that will be discussed in this section will be the Lithium Ion Polymer Battery. The pros of the Li-Ion Polymer battery are the potential for it to have minimal size, negligible weight, and improved safety factor. However, the battery's energy capabilities may not be enough to meet the power needs of the project, especially for its higher cost.

Each battery has its own set of good and bad traits.

Shown below is a general set of characteristics for commonly used rechargeable batteries that will also help decide on a battery. Table 2.6 listed all of the battery (discussed in this section) and each of theirs characteristics. This table will aid the decision on which type of battery to use.

Information	NiCd	NiMH	Lead Acid	LI	LIP	Reusable Alkaline
Gravimetric Energy Density(Wh/kg)	45-80	60-120	30-50	110-160	100-130	80 (initial)
Internal Resistance (includes peripheral circuits) in mΩ	100 to 200[1] 6V pack	200 to 300[1] 6V pack	<100[1] 12V pack	150 to 250[1] 7.2V pack	200 to 300[1] 7.2V pack	200 to 2000[1] 6V pack
Cycle Life (to 80% of initial capacity)	1500[2]	300 to 500[2,3]	200 to 300[2]	500 to 1000[3]	300 to 500	50[3] (to 50%)
Fast Charge Time	1h typical	2-4h	8-16h	2-4h	2-4h	2-3h
Overcharge Tolerance	modera te	low	high	very low	low	Moderate
Self-discharge Month (room temp.)	20%[4]	30%[4]	5%	10%[5]	~10%[5]	0.3%
Cell Voltage(nominal)	1.25V[6]	1.25V[6]	2V	3.6V	3.6V	1.5V
Load Current peak best result	20C 1C	5C 0.5C or lower	5C[7] 0.2C	>2C 1C or lower	>2C 1C or lower	0.5C 0.2C or lower
Operating Temp. (discharge only)	-40 to 60°C	-20 to 60°C	-20 to 60°C	-20 to 60°C	0 to 60°C	0 to 65°C
Maintenance Req.	30 to 60 days	60 to 90 days	3 to 6 months[9]	not req.	not req.	not req.
Typical Battery Cost (US$, reference only)	$50 (7.2V)	$60 (7.2V)	$25 (6V)	$100 (7.2V)	$100 (7.2V)	$5 (9V)

Table 2.6: Characteristics of Commonly Used Rechargeable Batteries (Content are acquired through Battery University)

2.3.1 BATTERY CHARGING

In order to recharge the batteries of the SmartWalker, a battery charging system must be purchased. Therefore further research into different type of charging system is imperative. The size of the battery must be known. Since recharge time is one of the specifications that should be minimized for the SmartWalker, the charge rate of the battery will be taken into account when considering chargers. In addition to the charge rate, the cost and durability will also be taken into account. A few different types of battery chargers will now be reviewed.

SIMPLE CHARGER

The simple charger is exactly what it sounds like. It supplies a constant or pulsed power source to a battery in order to charge it. It doesn't vary its output in any way throughout the charging process. The advantage of this is that simple chargers are inexpensive. On the other hand, simple chargers take longer to charge batteries and present the risk of damaging the battery via over-charging.

TRICKLE CHARGER

A trickle charge is typically used for small capacity batteries. These chargers are not typically used for full recharging of larger capacity batteries but only to provide maintenance current. A trickle charge only charger would not be logical for the SmartWalker despite cost and simplicity.

TIMER-BASED CHARGER

A timer-based charger would be better for charging the SmartWalker compared to the previous two chargers. It would charge the machine for a set amount of time which would prevent over-charging if the SmartWalker were neglected while connected to the charger. However, with the duration of charge being determined by the user, there is a chance that the battery would be charged for a longer period of time than needed. The user could think that the battery is near empty and charge it for the full charge duration when it actually had a 50% charge. This would damage the battery over time. A timer-based charger would be a cheap, semi-effective solution to battery charging.

SMART CHARGER

Smart chargers are controlled by a microprocessor and can monitor the status of the battery it is charging. Smart chargers would prevent over-charging of the battery which would then increase the life of the battery that is selected. They would also have a good charge rate. The downside of smart chargers is that they are generally more expensive.

INDUCTIVE CHARGER

Inductive chargers use electromagnetic induction to charge the battery and remove the need for metal contacts between the charger and battery. This removes the risk of electrocution and shorting out the charger should it ever get wet. This would also make the charger more convenient without having to plug in any wires when charging the SmartWalker which appeals to our desired customers, elderly and disabled people. However, these chargers are inefficient, costly, and slow.

SOLAR CHARGER

A solar charge would save the customer money by not having to use power from their home to charge the SmartWalker. However, the charge rate would be very slow as solar charging is mostly used for trickle charging purposes. Also the convenience factor is low as the solar chargers generally only work in low light (cloudy) situations and would force the customer to go outside in the first place to charge the walker.

USB-BASED CHARGER

This type of charger uses the USB interface to provide voltage to the battery in order to charge it. This approach is typically used in small devices such as cell phones and mp3 players. It would be difficult to find or design a USB charger for the SmartWalker due to its higher power requirements.

2.3.2 VOLTAGE REGULATORS

Due to the fact that the power distribution system was decided to be done using an integrated power source, voltage regulators must be used in order to obtain the correct amount of voltage for each component in the SmartWalker's subsystems. Also, without voltage regulators there is a risk of damaging the electronics on the SmartWalker. In this section the different methods of regulating voltages will be reviewed. Each method's advantages and disadvantages will be looked at and a decision will be made on which regulators will be used for the power supply's regulation.

LINEAR REGULATOR

Among the different methods of voltage regulation, linear regulators are more often than not the smallest, cheapest, and least noisy. A linear regulator both steps down and regulates voltage supplied to it. However, they are generally less efficient than other methods of regulation which is a concern for this project. Another concern is that linear regulators aren't versatile. They can only take an input voltage and step it down. Should the need arise to output a voltage greater than that of the input or an inverted form of the input a linear regulator would not work.

The first kind of linear regulator looked at is the low dropout (LDO) linear regulator. This regulator requires an input voltage closer to the output voltage compared to other linear regulators. This is an efficient regulator. For example, the MAX1725 and MAX1726 are low supply current LDOs with a maximum quiescent current of 4.5 µA. This is a desirable trait as this regulator will not waste a lot of power thus increasing the battery life of the SmartWalker. In addition to increasing battery life, the high efficiency of the LDO regulator will produce less heat possibly removing the need for heat sink which then wouldn't weigh down the project. LDOs can have dropout voltages as low as 20 mV, quiescent currents as low as 2 µA, output voltages from -15 V to +28V, output currents from 20 mA to 4 A, and operate from -55 °C to +125 °C.

Other linear regulators include the standard linear regulator and the quasi-low dropout regulator. These are similar to the LDO regulator, but have slightly less desirable traits.

SWITCHING REGULATOR

Switching regulators are popular because of their excellent efficiency, versatility, and can handle higher load currents of up to 125 mA. On the other hand, switching regulators take up more space than linear regulators, unless the linear regulator requires a heat sink in order to dissipate heat losses. They also cost more and generate more noise than their linear counterparts. With some of our components requiring larger amounts of currents and the battery life being a key factor in the design of the SmartWalker, switching regulators are likely to be used whenever possible. The already small losses of the switching regulator can be reduced even more when used with a rectifier diode and/or MOSFET, which is called a synchronous configuration. An example of a switching regulator that uses this setup is the MAX15023. Some characteristics of the MAX15023 are shown below in Table 2.7.

Part Number	V_{IN} (V)	V_{IN} (V)	V_{OUT} (V)	V_{OUT} (V)	Max I_{OUT} (A)	DC-DC Outputs	Operating Freq. (kHz)	Price
	min	max	min	Max	≤			
MAX15023	4.5	28	0.6	28	15	2	1000	$2.99/1k

Table 2.7: MAX15023 Specifications
(Content are acquired through Battery University)

CHARGE PUMPS

Charge pumps are the least known of the voltage regulation methods. They work similarly to switching regulators only they use a capacitor to step down, invert, or boost the input voltage. Charge pumps come with both unregulated and regulated outputs. Charge pumps like the MAX1595 can handle having up to 125 mA of current drawn from them. Other charge pumps like the MAX889 can handle up to 200 mA. This can be a problem since some of our components draw much more than that amount. For these situations, switching regulators are more compatible. Another plus of the charge pump is that they create less noise than switching regulators.
In summary, linear regulators are simple and effective regulators but inefficient. Switching regulators are efficient and will increase the battery life but slightly more complex. Charge pumps are a lesser known technology and have potential of being useful for this project but the time spent learning the technology would slow down the design process.

After weighing all three options it was decided that linear regulators will be used for their simplicity. Knowing that linear regulators are less efficient and dissipate heat, the design must leave room for heat sinks in order to handle the dissipated heat. Shown below is an example of a heat sink attached to a linear regulator.

The linear regulators in the design of the SmartWalker will be physically connected with the heat sink using thermal tape. These heat sinks will stop the dissipated heat from the linear regulator overheating the electrical components inside of the SmartWalker.

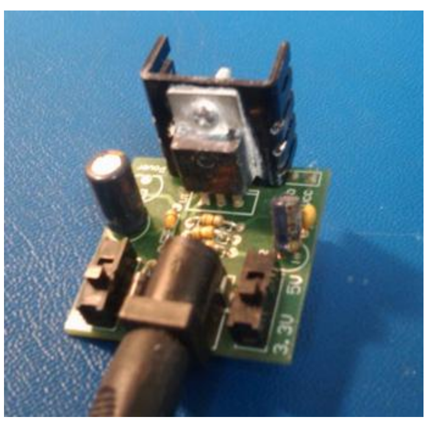

Figure 2.1: A heat Sink Attached to a Linear Regulator
(Content are acquired through All-Battery.com)

2.4 POSITIONING AND TRACKING SYSTEM

One of the key functions of the SmartWalker is its ability to autonomously reach the desired target when deployed, as described in previous sections. To achieve this functionality in the final product, it must be equipped with some type of tracking or positioning devices such as GIS, GPS, DGPS, LPS, IPS, RFID, WLAN, just to name a few. However, GPS and RFID are most commonly used by many engineers and designers for their projects. Because of the nature of this project, only GPS and RFID technology will be discussed. The comparison between the two will help determine which device and technology will be implemented in the final product.

The research done for the positioning and tracking system no longer applies to the SmartWalker due to the redesign. A positioning system is no longer needed since a wireless camera feed was implemented.

2.4.1 GLOBAL POSITIONING SYSTEM (GPS)

The GPS is a hybrid positioning system that is heavily used by both civilian and military operations to track and acquire the real time position of any object. In a nutshell, the GPS module is a receiver which receives signals from satellites orbiting around the earth. Each signal it receive contains two pieces of information: the time of the transmitted signal and the position of the satellite at time of transmit. The receiver will then use that information to compute its local location relative to the satellites using a navigation equation. Therefore, to accurately calculate the position, the GPS receiver will typically need to acquire information from three or more satellites. That means at any given time, three or more satellites must be "visible" to the unit. Note that for this project, no further details other than theory of operation and applications of GPS will be discussed for it is not necessary. Thus, for positioning and tracking outdoor, where there are minimal obstructions to the message signals communicating between the GPS receiver and satellite, GPS is mostly used.

However, due to the face that the SmartWalker is designed to operate indoors 99% of the time, using GPS as a method to track and positioning will not be the best choice. Moreover, GPS modules are quite expensive compared to other devices. An alternative Radio Frequency Identification (RFID) technology is a better solution for the SmartWalker.

2.4.2 RADIO FREQUENCY IDENTIFICATION (RFID)

Radio Frequency Identification is a technology that uses radio frequency (RF) to read information from tags, which can be attached to objects. Each tag contains a unit identification number (UID) that is digitally stored. These binary bits will be transmitted when a tag is read by the RFID reader. With larger memory RFID tags, more information than just the UID can be stored and transmitted. With the radio frequency wave's transmission, technology allows for the reading of tags from physical contact up to beyond the line of sight of the reader. This gives a huge advantage for in-door applications, the SmartWalker in particular.

A simple RFID system consists of a reader with a cable attached to an antenna and a tag that is read (interrogated) by the reader. RFID systems operate on a number of different frequencies that are permitted by government regulations. Some of the common RFID frequencies used in the United States are:

- 125 kHz, also commonly identified as Low Frequency (LF)
- 134.2 kHz (LF)
- 13.56 MHz, also commonly identified as High Frequency (HF)
- 433 MHz Ultra High Frequency (UHF)
- 915 MHz (UHF)—used in North America
- 2.45 GHz – 5.8 GHz Microwave Frequency (SHF)

Typically there are three basic types of RFID tags: passive, semi-passive (sometimes referred as semi-active) and active. Each of these types of tags will be discussed below for better understanding, which will help in making the hardware decision for this project.

PASSIVE RFID AND SEMI-PASSIVE TAG

Passive tags and semi-passive typically do not require any internal power supply or battery (some semi-passive tags are designed to have a battery as a power source). It uses power entirely built up from the electromagnetic wave (RF) transmitted by the reader. This power is enough to power the circuit in the tag to send back the UID information. The communication between the tag and the reader using Load Modulation in the near field (close range): LF, HF and some UHF. Also Backscatter is used for the far field (long distance) for UHF and microwave SHF. Therefore, the effective operating range for this type of tagging is low, about 3m to 5m, which is about 10ft to 16ft for LH. Outside the limit range, the tag will not have enough power to send the UID and other information to the reader. This can be a disadvantage if a passive tag is used for the SmartWalker. An average to above-average house size is from 1200-1700 square feet living area. Obviously the effectively reading range of 10-16ft is not a solution.

ACTIVE RFID TAGS

Unlike passive tags, active tags use an internal battery as a power source and are considered to be continuous. This on board power enables the active tag to transmit the UID and larger data bits (due to larger memory) automatically to the reader. Moreover, in the case of passive tags, which require relatively high signal strength, active tags require very little signal strength due to the fact that it doesn't need power "gathered" from the RF. Therefore the range of active tags is much larger. For UHF and SHF, the range is 100 meters or more. Table 2.8 shows the comparison chart of some parameters of the passive and active tags.

Information	Active RFID	Passive RFID
Power Source	Internal	Energy from reader transmitted RF
Power Availability	Continuous	Within filed of reader
Signal Strength (required from reader to tag)	Low	High
Signal Strength (available from Tag to Reader)	High	Low
Communication Range	100 meters or more	3 meters or less
Data Storage	Large read/write storage Data search and access capabilities.	Small read/write data storage (128 bytes)

Table 2.8: Comparison Chart of Active and Passive RIFD

2.5 RANGING METHODS AND RANGE FINDERS

~~2.5~~ Similar to the position and tracking system researched in the previous sections, the ranging methods and range finder research no longer applies to the SmartWalker due to the implementation of a wireless camera for obstacle avoidance.

2.5.1 INTRODUCTION

To make the SmartWalker able to detect any objects or obstructions on its path, a suitable ranging method must be used. It is imperative to have the SmartWalker effectively avoid collision at a high rate so that it can be a helpful assistant. This feature 100% relies on sensors, close range sensors, for object detection. With the advances and well-developed technology in the market today, there are so many devices that offer a wide range of ranging methods that can be utilized for this specific purpose. Details of these products that are relevant to our project must be studied before choosing the right device and ranging method for the SmartWalker. The specifications are:

- **Range**: Because the operating environment of the SmartWalker is indoors, could be in a bedroom, living room or kitchen. Therefore, effective ranging of these sensors must be from a few inches up to 3ft. This range will allow the SmartWalker to avoid collisions with common household objects such as: chairs, table, drawers and walls.

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- **Interfacing method**: The interfacing should be compatible with the microcontroller used in this project. Doing so will reduce time spent on configuring serial communications between the sensor module and the microcontroller. Another advantage for doing so is that it will provide faster data transfer rate and reduce response time.

- **Voltage, power consumption**: For power supply design specification parameters, power consumption must be as optimized because a small battery size (physical size) is desired for this project. Secondly, the microcontroller inputs must be able to support the analog signal of the sensors.
- **Physical size, installation and mounting**: The walker that will be used has limitations in spacing; therefore the physical size of the sensors must be small to provide some degree of freedom in mounting.
- **Beam pattern**: The construction of the walker is also a limitation for the design. The beam pattern, the line-of-sight, angle of scanning of the sensors should also be carefully reviewed.
- **Price**: Budget and financing is a determining factor in designing and building the final product. Therefore, comparison prices between available sensors must be considered.

The research for this portion is divided into two phases: initial and specific device research phase. During the initial phase, a broad studying of available ranging sensors in the market is conducted. A handful of candidates that met the specifications mentioned above is then selected for further research. It is shown that there are two main ranging techniques that are commonly used among designers and robotic hobbyists are: infrared and ultrasonic. The chosen candidates for this project are:

- **Infrared Sensor**: The Sharp IR GP2D12 and the Sharp IR Ranger GP2Y0A2YK
- **Ultrasonic Sensor**: Devantech SRF05, Devantech SRF08, and Devantech SRF10 Ultrasonic Range Finder

2.5.2 IR RANGE FINDERS

The first consideration is IR sensors. The technique of ranging for IR Ranging sensors is the triangulation method of receiving signals. A pulse of infrared light is transmitted from the IR sensors. The wave (infrared light) then hits the surface of any object that it encounters and reflects back to a receiver on the ranging module. Using the angle and direction of two light beams, transmitted and received light. With the known angle, the distance can be easily calculated. *Figure 2.2* illustrates graphically, in broad terms, how the IR sensors use light beams and the reflected light from objects to calculate this distance.

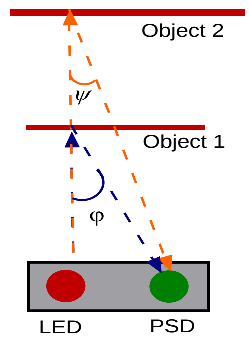

Figure 2.2: Illustration of Triangulation Ranging Method of IR Sensors

Just like any design, IR ranging sensors have their own advantages and disadvantages. One the advantages of using IR sensors for sensing objects to avoid collision is that it is almost safe from interference from ambient light and color of the objects. This is a very important aspect to be considered in designing the SmartWalker since household objects such as chairs, doors, walls, vacuums have a variety of different colors. Being able to "ignore" the color of objects will give a better input SNR to the microcontroller. Also light sources are different from room to room. The environment in which the SmartWalker will be operating in, throughout the day can be natural sun light or lights from incandescent or fluorescent bulbs. With the Sharp IR sensors, this has no effect on its functionality, and also will give better signals with minimum noise input to the microcontroller.
One of the most common issues, disadvantages rather, of using Sharp IR sensors is that if the object is in, or below the sensor range. The effective range of the Sharp IR module is 3 cm to about 130 cm. If the object, for some reason, is between 0 to close to 3 cm, the sensor will not be able to recognize it and therefore, will not be able to avoid collision. However, this drawback can be overcome by placing the sensors at the back of the SmartWalker. By placing the sensors a few inches back from the front of the product, it will bring the object being detected back in the effective range of the sensors.

SHARP IR GP2D12 RANGE FINDER

The Sharp IR GP2D12 is a ranging sensor with an integrated circuit with analog voltage output. This device uses standard JST 3 pin serial connector which is fully compatible to interface with most microcontrollers. The package shipped is small and it comes with mounting hardware and provides minimum effort in the installation portion of the project. *Table 2.9* shows the Sharp GP2D12 specifications.

Parameter	Rating
Operating Supply Voltage	4.5 to 5.5 VCC
Output Terminal Voltage	-0.3V to (VCC +0.3V)

Average Supply Current	33mA (Typical) to 50mA
Maximum Effective Range	30cm
Minimum Effective Range	4cm
Typical Response Time	39ms
Typical Start-up Delay	44ms

Table 2.9: The Sharp GP2D12 Specifications
Requested permission from Sharp

According the manufacture product specifications, the unit power consumption is fairly low and its power supply is within the project specification. The response time and delay start up time, 39ms and 44ms respectively, are also reasonable and provide enough time for the unit to avoid collision while reaching the target in an acceptable amount of time. However, this device has two major draw backs if utilized: effective measuring range and preciseness of angle measurements.

Effective Range: the maximum effective measuring range for this device is 30 to 40 cm (11-15 inch) is not enough for the SmartWalker application. It doesn't provide enough time for the system to compute the distance as well as perform calculations and execute the avoidance algorithm. Preventive collision is not very effective.

Angle Measurement Preciseness: Because the triangulation method used in the Sharp GP2D12, it will not be very accurate with the angle measurement if it is mounted on a constantly moving base. Although the SmartWalker is not moving at a high speed, but it has to move left and right at a jerky motion. This can be a problem for the sensors.

SHARP IR RANGER GP2Y0A2YK

The Sharp IR Ranger GP2Y0A2YK is a close family of the previous discussed Sharp IR sensor, but with some different ratings. As far as physical size it is considered bigger than the GP2D12 but economically cheaper. Interfacing is also fully compatible with most microcontrollers with standard JST 3 pin connection. The effective measuring range of this particular sensor is greater than the GP2D12, from 20 cm to 150 cm. Let's consult its specifications, shown in Table 2.10 for further detail comparison.

Parameter	Rating
Operating Supply Voltage	4.5 VCC to 5.5 VCC
Output Terminal Voltage	-0.3V to (VCC +0.3V)
Average Supply Current	33 mA (Typical) to 50 mA
Maximum Effective Range	150 cm
Minimum Effective Range	20 cm

Table 2.10: The Sharp GP2Y0A2YK Specifications

Requested permission from Sharp

With an effective minimum range of 20 cm, it lacks in short-range capability. Any object that falls below 20 cm, let's say 10 cm, is impossible to detect by the sensors. This a major disadvantage for the SmartWalker if it used and should be avoided. Also similarly to the GP2D12, object orientation and angle measurement preciseness, as discussed previously, is a factor to be considered very carefully when making decisions.

2.5.3 ULTRASONIC RANGE FINDERS

Ultrasonic sensors are sometimes referred to as transceivers due to the fact that the sensor module does both tasks: sending and receiving sound waves. The principle in which an ultrasonic transceiver operates on is similar to that of radar or sonar. Ultra sonic sensors generate a high frequency sound wave, around 20 kHz and above, and listen for the echoes that the sound wave bounced back off any objects. Unlike IR sensors with triangulation method to calculate for distance, ultrasonic sensors compute the time interval between the transmitting and receiving time to determine the object at a certain distance away. The echo listened will then be converted into electrical energy and result in an analog output signal by on-board integrated circuitry. One major advantage of using ultrasonic sensors over photoelectric IR sensors is that it can detect most objects such as metal, nonmetal, transparent or colored, and liquid. In short, any objects that have the ability to reflect sound are detectable by ultrasonic sensors. That brings up another point that contributes to the limitations of the sensors. Any object such as fabric, foam, soft compound or rubber, that has low sound reflectivity will create a problem for the sensors. However, in this particular project, this issue can be neglected because all typical household objects have sound reflectivity characteristic, more or less. Another point that should be paid very careful attention to is the angle at which the object reflects the sound wave generated from the transducer. Different angles give different measurements. It is also impossible to detect objects at some angles, or receive wrong information. Each ultrasonic sensor available in the market comes with different specifications, different effective detection ranges and angles, different sound wave frequencies. To have the best suitable solution for this project, each ultrasonic sensor is reviewed and studied carefully. Table 2.11 shows the comparison of three different Devantech Ultrasonic range finder products that are considered for this SmartWalker project.

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Information	Effective Ranging Distance	Interface	Power Requirements	Cost
Devantech SRF05	1cm to 4m	Positive TTL, level signal, width proportional to range	Volt.: 5V I: 4mA typical	$27.95
Devantech SRF08	3cm to 6m	I2C	Volt.: 5V I: 15mA typical 3mA standby	$54.30
Devantech SRF10	3cm to 6m	I2C	Volt.: 5V I: 15mA typical 3mA standby	$56.85

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Table 2.11: Devantech Ultrasonic Range Finders Specifications
(Granted permission to use the content from solarbotics.com)

DEVANTECH SRF05 ULTRASONIC RANGE FINDER

The SRF05 operates with effective range from 1 centimeter to 4 meters. It is also capable to interface with most microcontrollers. I^2C connections will give more degrees of freedom in choosing main microcontrollers for this project. SRF05 has two operation modes: Separate Trigger and Echo mode and Single Pin for Both Trigger and Echo mode. For this project, the different operation modes do not matter since saving pins on the microcontroller should not be a concern. However, using Separate Trigger and Echo mode is the simplest mode to use and implement. Similar to most devices in the family, SRF05 requires a 5VDC power supply. Typical maximum current rating is 4mA. Beam pattern and beam width is conical with the width of the beam. Figure 2.3 below shows the angle of the beam pattern of SRF05

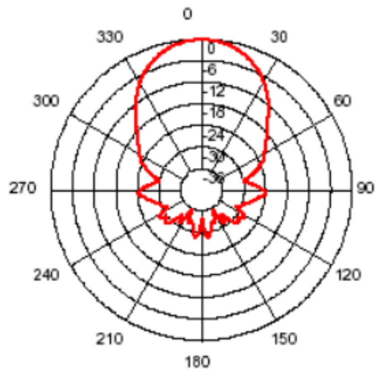

Figure 2.3: Devantech SRF05 Beam Pattern
(Granted permission to use the content from solarbotics.com)

According to the manufacturer data of the beam pattern, the SRF05 covers a range of 60 degrees. Along with the maximum effective range of up to four meters, this coverage rating is very reasonable and well suited for the SmartWalker application.

DEVANTECH SRF08 ULTRASONIC RANGE FINDER

Comparing with the SRF05, the SRF08 gives a longer range, up to 6 meters. This is a better the solution for the project. 6 meters, approximately 19.5 feet, is very good for the system to detect and avoid collision well within a larger room in the house. This is a huge advantage over any of the Sharp IR range finders discussed. Its interfacing is compatible with most microcontrollers via I^2C communication. Table 2.12 shows the specification of the SRF08 with more details.

Voltage	5V
Current	15mA Typical, 3mA Standby
Frequency	40KHz
Maximum Range	6 m
Minimum Range	3 cm
Max Analogue Gain	Variable to 1025 in 32 steps
Serial Communication	Standard I^2C Bus
Echo	Multiple echo, continuously seeking after first echo.

Table 2.12: Devantech Ultrasonic SRF08 Specifications

(Granted permission to use the content from solarbotics.com)

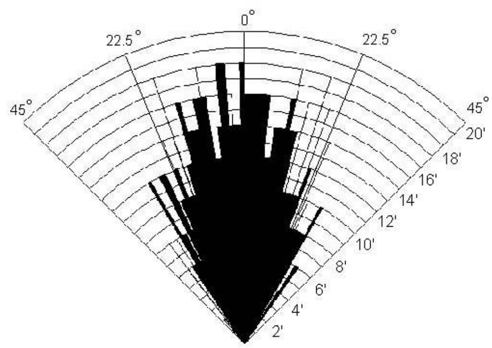

Figure 2.4 Beam Pattern of Devantech Ultrasonic SRF08
(Granted permission to use the content from solarbotics.com)

From Figure 2.4, the beam pattern of the SRF08, the effective range is about 45 degrees conic span area and 18 feet distance detecting range. It is also considered wide and long enough for this project. The black concentration illustrated in the diagram shows that this sensor is very effective at close range, from 4ft to 14ft at 45 degrees. This helps to detect any close and thin objects more effectively, thus the avoiding collision task will be more efficient. The SRF08 also requires a 5VDC power supply. However, power consumption is three times that of the SRF05. At most, the typical current is 15mA and the standby current is 3mA. The power requirements are fairly easy to meet for the power supply system.

DEVANTECH SRF10 ULTRASONIC RANGE FINDER

Very similar to Devantech SRF08, the SRF10 range finder generates a sound wave of 40 kHz, effective range is from 6 centimeters to 6 meters and interfaces with most microcontrollers such as PIC, OOPic, Stamp BS2p and others through the I^2C bus. Maximum analogue gain can be varied from 40 to 700 in 16 steps. The major advantage of using the SRF10 is the ability of ranging without using the microcontroller timer. Thus while the SRF10 is ranging, it is advantageous to the microcontroller to perform different computation or tasks simultaneously. The maximum range of SRF10, as well as the SRF08, can be changed by configuring its internal timer. According the manufacturer specification document, a range of 11 meters corresponds to 65m. This configuration is set as default when shipped. Therefore, with the application of the SmartWalker, the maximum range configuration can be reduced to have a better response time. Also, by reducing the maximum range configuration of the SRF10 (as well as SRF08), the microcontroller will be able to get the range information faster, therefore faster results in computation and command execution. The important details are shown in Table 2.13 below:

Voltage	5V
Current	15mA Typical, 3mA Standby
Frequency	40KHz
Maximum Range	6 m
Minimum Range	3 cm
Max Analogue Gain	Variable to 40 to 700 in 16 steps
Serial Communication	Standard I²C Bus
Echo/Timing	Fully timed echo with built-in onboard timer. Free host controller for simultaneous tasking

Table 2.13: Devantech Ultrasonic SRF10 Specifications.
(Granted permission to use the content from solarbotics.com)

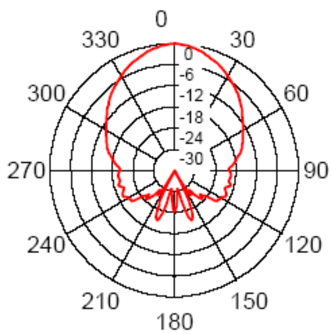

Figure 2.5: Beam Pattern of Devantech Ultrasonic SRF10
(Granted permission to use the content from solarbotics.com)

One of the minor differences of the SRF10 from the SRF08 is the conic span angle. The SRF10 has a 60 degrees span conic are, but with better short range sensing. The beam patter is shown in Figure 2.5. With the ability to configure effective ranging and wide angle sensing, this ultrasonic range finder can be best the option out of the different sensors and devices discussed so far.

This section's research was not used in the final creation of the SmartWalker as a range finding method was not needed. Instead of using range finders to avoid obstacles a camera system was implemented so that the user can view where the walker is going during remote use.

2.6 MOTORS

The research done for the motors still applies to the SmartWalker as the torque and power system remained close to the same between designs.

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2.6.1 INTRODUCTION

In this section, the primary focus will be about different types of motors, how they work, and how motors are chosen to be the best fit for the project.

Briefly, electric motors convert electrical energy into mechanical energy. In certain applications such as in the transportation industry with traction motors, electric motors can operate in both motoring and generating or breaking modes to also produce electric energy from mechanical energy. As described in the project description, the SmartWalker is built to assist senior citizens. It will act as a supply carrier which can locate and navigate itself to the location of the senior citizen. Due to the function requirements, the SmartWalker needs to be able to drive itself to the desired locations without any external help. With that being said, besides positioning and tracking system, motors and moving systems are very important to the project.

2.6.2 TYPES OF MOTOR

Beside electric motors, combustion motors are also very popular. Due to the big amount of torque the combustion motor can generate, it is more appropriate to use combustion motors for big machine such as transportation engines. The combustion motors usually run on oil or fuel which is not the source that will be used for this project. The combustion motors are also one of the most expensive engines so it's best to find other motors which offer lower cost and can generate the efficient torque for this project. This will then lead to the discussion of electric motors.

Electric motors are divided into three main groups: DC motors, AC motors, and other motors (which can use either AC or DC supply, or can self convert the power source). In general, electric motors operate through the interaction between the magnetic field and electric current to generate the force within the motor. For the better understanding of the motor before deciding to pick the motor that is the best fit for the project, let's look at different types of electric motors.

DC MOTORS

As its name a state, DC motors are the type of motor that run on the power of direct current. The power source might be any DC source such as batteries, DC power supplies, or AC-to-DC converters. DC motors are divided into two main categories: brush and brushless.

The brush DC motors generate torque directly from the DC power supplied to the motor by using internal communication, stationary magnets (permanent or electromagnets), and rotating electrical magnets. The brush DC motors have the torque produced by the Lorentz force. This type of motor has the advantages of its low initial cost, high reliability, and simple control of speed. But the number of brush DC motors in the market is decreasing due to the cost of maintenance (mostly for the replacement of brushes and springs which carry the electric current, as well as the cleaning or replacing the commutator) and the low life-span for high intensity uses.

The brushless DC motor design is simpler than the DC brush motor; it has the rotating permanent magnet in the rotor and the stationary electrical current/coil magnets on the motor housing for the rotor. Since this type of motor has no brush, it has a longer life span, little to no maintenance required, and high efficiency. The downside of this type is that the initial cost is high, and the controller is much more complicated to design.

Besides distinguishing DC motors into brush and brushless categories, DC motors can also be classified according to the electrical connections of the armature winding and the field winding. This separates them into self-excited and separately-excited. DC motors can also be distinguished by the way they are connected in the circuit that includes series connection, shunt connection, and compound connection.

Series DC Motor: This type has very high starting torque and is commonly used for starting high inertia loads, such as trains, elevators or hoists. Series motors which are called "universal motors" can also be used on alternating current. Since the armature voltage and the field direction reverse at essentially the same time, torque continues to be produced in the same direction. The speed is not related to the line frequency, making them lighter than induction motors of the same rated mechanical output. This is a valuable characteristic for hand-held power tools.

Shunt DC motor: This type connects the armature and field windings in parallel or shunt with a common DC power source. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor. It is typically used for industrial, adjustable speed, applications such as machine tools and winding/unwinding machines. Figure 2.6(a) and Figure 2.6(b) are the schematics of series DC motor and shunt DC motors, respectively.

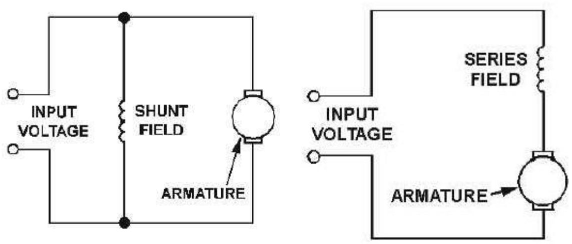

Figure 2.6: Schematic of (a) Series DC Motor and (b) Shunt DC Motor
(Reprinted under GNU from en.wikipedia.org)

Compound DC Motor: This type connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor. This motor is used when both a high starting torque and good speed regulation are needed. The motor can be connected in two arrangements: cumulatively or differentially. Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation. Differential compound DC motors have good speed regulation and are typically operated at constant speed. Figure 2.7 shows a simple schematic of a shunt DC motor.

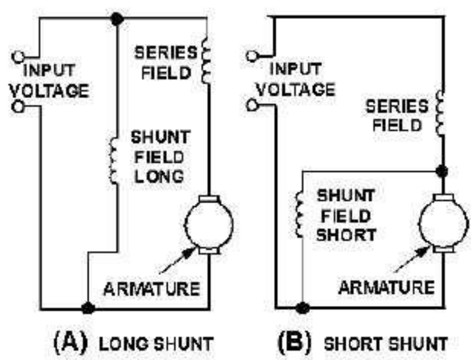

Figure 2.7: Schematic of a Compound DC Motor
(Reprinted under GNU from en.wikipedia.org)

DC motors have certain advantages that should not be overlooked even though AC motors are more popular now.

- DC motors can provide excellent speed control for acceleration and deceleration: power supply of a DC motors connects directly to the field of the motor allows for precise voltage control, which is necessary for the speed and torque control applications (DC shunt motor). The higher the armature voltage, the faster the rotation. This relationship is linear to the motor's maximum speed (DC series motor).

- Easy to understand: The design of the brushed DC motor is quite simple. A permanent magnetic field is created in the stator by either of the two means: permanent magnet or electromagnetic windings. If the field is created by permanent magnets, the motor is called "permanent magnet DC motor" (PMDC), and the motor is called "shunt wound DC motor" (SWDC) if the field is created by electromagnetic winding.
- Simple and cheap drive design: The speed of the DC motor can simply varied by a large enough potentiometer. Pulse-width modulation is an effective method for adjusting the amount of power delivered to an electric load.

Naturally, DC motors have some disadvantages that need to be taken into consideration prior to choosing them for any projects. These disadvantages are usually the main reasons for users not to pick DC motor for their projects.

- High maintenance required to maintain the mechanical interface used to get current to the rotating field. Maintenance includes the commutator, and the brushes themselves.
- Not suitable to use in an unclean environment: vulnerable to dust which decreases the performance.

AC MOTORS

Different from DC motors, AC motors are electric motors driven by alternating current. The AC motor commonly consists of two basic parts, an outside stator having coils supplied with alternating current to produce a rotating magnetic field and an inside rotor attached to the output shaft that is given a torque by the rotating field. There are many types of AC motors but they mainly fall into the two main categories: synchronous and asynchronous. The asynchronous AC motors have the magnetic field on the rotor created by the induced current. The synchronous AC motors do not rely on the induction, the magnetic field on the rotor is either generated by current delivered through the slip rings or by a permanent magnet.

Induction motors, or asynchronous motors, includes poly-phase cage motors, poly-phase wound motors, two-phase servo motors, and single phase induction motors. The actual RPM for an induction motor will be less than the calculated synchronous speed by an amount known as slip that increases with the torque produced. With no load, the speed will be very close to synchronous. When loaded, standard motors have between 2-3% slip, special motors may have up to 7% slip, and a class of motors known as torque motors are rated to operate at 100% slip (0 RPM/full stall).

On the synchronous motors, there are poly-phase synchronous motors, which can be used as alternators, single-phase synchronous motors, also known as reluctance motors, and hysteresis synchronous motors, relatively expensive and used when the exact speed as well as rotation is required with a very small amount of fast variation in speed.

AC motors have become very popular in today's technology due to their low cost, speed variation, high power factor, and reliable operation. But there are also some disadvantages of AC motors that should not be overlooked such as the requirement for the power source. AC motors require a generator in order to generate AC voltage for the input. Also, AC motors will produce eddy current due to the production of a back electromagnetic field. Most importantly, when it comes to the SmartWalker project, AC motors will hardly operate at low speeds, and is very poor in positioning control. Servo DC motors are more appropriate for these applications.

Besides DC and AC motors in general, there are many other types of motors including universal motors, series wound motors, repulsion motors, exterior motors, sliding rotor motors, electronically commutated motors, etc. These kinds of motors differ themselves by their power sources, way of winding, and specific requirements or uses. Figure 2.8 shown below is a breakdown of many types of motors. The figure is not able to list all the types of motors existing in the market today, but it should give a general idea about some different types of motors.

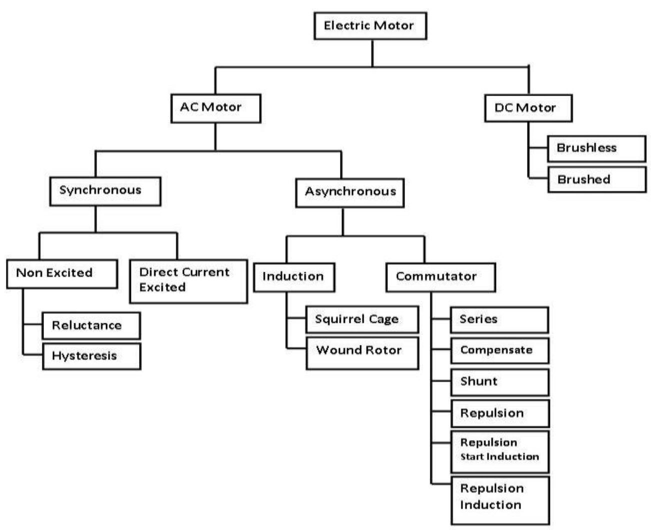

Figure 2.8: Types of Motors Block Diagram
(Reprint under GNU from en.wikipedia.org)

2.6.3 FUNDAMENTAL OPERATION OF DC MOTOR

Since DC motors have an edge over AC motors in this project based on the information above, this part will provide more insight into DC motors in order to help in picking the right DC motor for the SmartWalker. Between all DC motors, the most commonly used for mobile projects are stepper and servo motor. Both are technically called permanent-magnet synchronous motors (PMSMs). However, there are significant differences in the design operation and in the typical mode of operation, although both can be operated either in open-loop or closed-loop fashion. These differences will determine which one is more suitable for the SmartWalker.

STEPPER MOTOR

Stepper motor (or step motor) is a brushless DC electric motor that divides a full rotation into a number of steps. The motor position can be then commanded to move and hold one of these steps without any feedback sensor (an open-loop controller) as long as the motor is carefully sized to the application. Figure 2.9 illustrates the functional block diagram describing how a stepper motor is connected and controlled in the system:

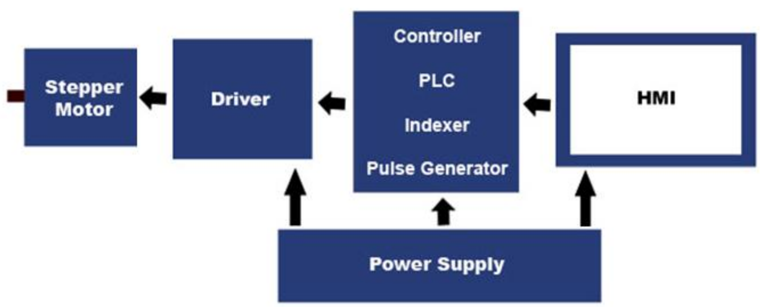

Figure 2.9: Functional Block Diagram of Stepper Motor
(Reprint under GNU from en.wikipedia.org)

Stepper motors are commonly used due to their advantages:

- The rotation angle of the motor is proportional to the input pulse.
- The motor has full torque at standstill (if the windings are energized).
- Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 to 5% of a step and this error is non-cumulative from one step to the next.
- Excellent response to starting/stopping/reversing.

- Very reliable since there are no contact brushes in the motor. Therefore the life of the step motor is simply dependent on the life of the bearing.
- The stepper motor's response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.
- It is possible to achieve very low synchronous rotation speed with a load that is directly coupled to the shaft.
- A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

And there are also some disadvantages of DC stepper motors that drive users/designers away to another motor product:

- Low efficiency. Motor draws substantial power regardless of load.
- Torque drops rapidly with speed (torque is the inverse of speed).
- Low accuracy. 1:200 at full load, 1:2000 at light loads.
- Prone to resonances. Requires micro-stepping to move smoothly.
- No feedback to indicate missed steps.
- Low torque to inertia ratio. Cannot accelerate loads very rapidly.
- Motor gets very hot in high performance configurations.
- Motor will not "pick up" after momentary overload.
- Motor is audibly very noisy at moderate to high speeds.
- Low output power for size and weight.

Inside the stepper motor, the phase changes will create the spins and also create the pulse as described in Figure 2.10:

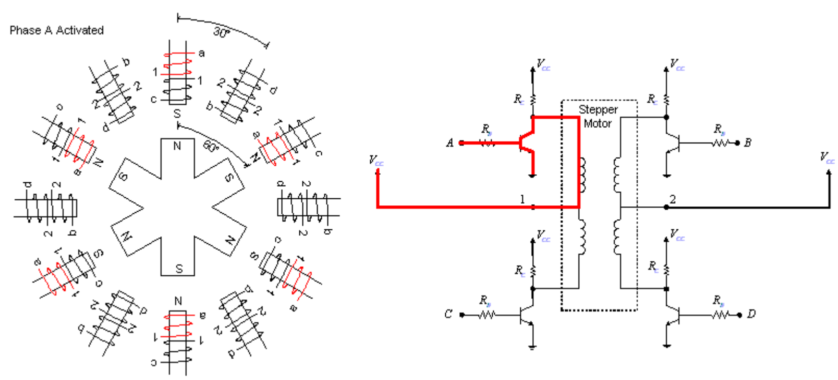

Figure 2.10: Basic Operation of Stepper Motor
(Source from www.applied-motion.com)

There are three main types of stepper motors: permanent magnet stepper (PM), hybrid synchronous stepper, variable reluctance stepper (VR):

- Permanent magnet motors use permanent magnet rotors and are commanded by electrical pulses. They are widely used in printers, copiers, scanners, and many other applications. They are also used to operate valves in household water and gas systems as well as drive actuators in automotive applications. One of the main benefits of the permanent magnet motor is that it requires no "teeth" that are typically found in the variable reluctance motor. This makes permanent magnet motor steppers a very popular choice for many applications. However, this special feature of PM motors just takes itself off the options for the SmartWalker project because the cart requires a motor to spin the wheels (which need "teeth"), and the speed needs to be smooth instead of pulsed.
- Variable reluctance stepper motors have a rotor that turns through a number of degrees and then stops. VR stepper motors move a physical object, connected to the motor's shaft, from one location to another using linear or rotary motion with high precision. VR stepper motors can be found in washing machine designs or the control rod drive mechanism of nuclear reactors.
- Hybrid step motors provide excellent performance in areas of torque, speed, and step resolution (range from 200 to 400 steps per revolution). This type of motor provides a combination of the best features available on both the PM and VR stepper motors. The hybrid stepper motors are widely used in modern technologies, especially in robotic design, and pulse action machines.

The stepper motors seem to have some applicable features for the SmartWalker such as high precision in control, excellent in starting/stopping/reversing (very helpful in making turns to avoid objects) when it comes to building an automobile, but the stepper motors also have some restrictions in providing smooth speed. Before making any decisions, let's take a quick look at the other type of DC motor which is servo motor.

SERVO MOTOR

A servo motor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback through a reduction gearbox. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servo motors are closed-loop servomechanisms that use position feedback to control its motion and final position. Being a closed-loop control motor, servo motors need an encoder to provide position and speed feedback. So the input control of servo motors is a signal from the encoder. This signal can either be analogue or digital. The signal will then represent the position commanded for the output shaft. Figure 2.11 below illustrates how a simple brushless DC servo motor works in a design.

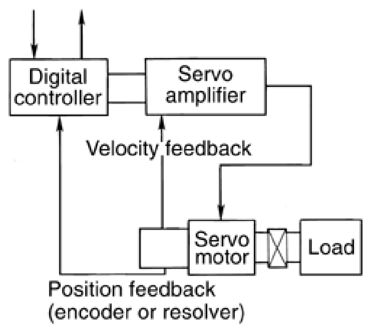

Figure 2.1~~0~~1: Servo Motor Connections Diagram (from www.applied-motion.com)

For the SmartWalker, the preferred motor type is brushless, so only brushless DC motors will be considered while choosing amongst DC servo motors. Brushless DC servo motors offer users/designers some certain advantages over other type of motors:

- Internal Permanent Magnet (IPM) rotor design to avoid the surface mount magnets disadvantaged.
- Patented rotor structure to have super low cogging torque performance for IPM servomotor.
- No skewed slot on stator and rotor, it can increase reliabilities and reduce product costs.
- Energy efficiency motor adopts the high magnetic energy permanent magnet to have high power and torque density, and small size structure.
- Electrical commutation can perform low noise, low EMI and no brush maintenance.
- Lower rotor inertia and good heat dissipation. Windings of Brushless DC servomotors are in the stator. In a brush-type motor, the winding is in the rotor.
- Power and torque density are much higher than the conventional motors.
- Without mechanical commutation, motor speed can be over 10,000 rpm.
- The innovating structure has an excellent feature in energy saving during heavy-load operation and high torque at low speed driving. The high efficiency range is much wider than conventional motors.
- Standard Servo motors are built with NTC thermistor for motor temperature feedback.

While offering so many advantages, there are also some limitations of DC servo motors that should not be overlooked:

- Requires "tuning" to stabilize feedback loop.
- Motor "runs away" when something breaks. Safety circuits are required.
- Complex. Requires encoder.
- Brush wear out limits life to 2,000 hrs. Service is then required.

- Peak torque is limited to a 1% duty cycle.
- Motor can be damaged by sustained overload.
- Bewildering choice of motors, encoders, and servo-drives.
- Power supply current 10 times average to use peak torque. See (5).
- Motor develops peak power at higher speeds. Gearing often required.
- Poor motor cooling. Ventilated motors are easily contaminated.

DC HYBRID STEPPER MOTOR

As a reminder for the different types of DC stepper motors, variable reluctance magnet type of motors is not picked because micro-stepping is not generally applicable to variable reluctance motor. While micro-stepping is very important to the project because it allows positioning to a fraction of a step, and it also allows smooth, jerk-free moves from one step to the next, can be both applied to permanent magnet motors and hybrid motors. Even though permanent magnet stepper motors seem to have an advantage in cost but their resolution usually range from 30^o - 3^o/ step when hybrid stepper motors are more expensive but they do offer much better resolution, it's about 1.8^o/step and smaller. The reasons above combined will support the decision of choosing DC hybrid stepper motor for the SmartWalker, the DC hybrid stepper motors are simple in design, have a high resolution, and can operate full, half, or micro-stepping with low noise and considerable cost. And to select the right DC motor, the following should also be put into consideration:

- Determine whether the load will be driven at motor speed (direct drive) or at some other speed that will require gearing, coupling, pulley, belts, etc. based upon the maximum load speed.
- Calculate load torque requirements.
- Calculate motor horsepower, speed and full load torque requirements.
- Based on the speed-torque and load requirements, select the motor type.
- Determine the operational requirements: start/stopping, acceleration/deceleration, open/closed speed loop, braking (and holding), type of controller, etc.
- Select the motor enclosure based on environmental considerations and cooling requirements.
- Select mounting configuration: flange-mounted or foot-mounted.

With the information provided above, it seems that DC brushless servo motor is a better alternative compared to stepper motor, but if that's the case, why is there still a very high number of products that still use stepper motors as their main motor? The comparison table below should help the user choose between the two types of motors when they both have the same power rating and same quality. Side-by-side comparison between DC brushless servo motors and DC hybrid stepper motor is shown in Table 2.14:

Characteristics	DC Brushless Servo Motor	DC Hybrid Stepper Motor
Cost	The cost of servo motor is usually higher than stepper motor.	This feature stepper motor has an edge since it's much cheaper with the same power rating
Versatility	Servo motors are versatile in their use for automation and CNC applications	Because of their simplicity, stepper motors are more versatile and can be found in anything from printers to clocks
Reliability	Servo motors reliability usually depends on the environment and how well they're protected	Stepper motor might seem more reliable since they don't require the encoder which may fail.
Set Up Complexity	Servo motor require turning of the (PID) closed loop control to obtain the correct function.	Stepper motors are almost plug-and-play. They require only the motor wires to be wired to the stepper motor driver.
Motor Life	The encoder might need to be replaced.	The bearing on stepper motors are the only wearing parts.
Low Speed - High Torque	Servo motors will do fine with low speed applications given low friction and the correct gear ratio.	Stepper motors provide most torque at low speed (RPM)
High Speed - High Torque	Servo motors maintain their rated torque to about 90% of their no load RPM	Stepper motor lose up to 80% of their maximum torque at 90% of their maximum RPM
Repeatability	Servo motors can have good repeatability if set up correctly, the encoder quality also affect the repeatability	Because of the way stepper motor are constructed and operate, they have very good repeatability with little to no tuning required.
Overload Safety	Servo motors may malfunction if overloaded mechanically	Stepper motors are unlikely to be damaged by mechanical overload.
Power To Weight/Size Ratio	Servo motor is excellent in this feature given their efficiency	Stepper usually has smaller a smaller power to weight/size ratio
Flexibility In	Since the servo motors have	Stepper motors usually have 1.8

Characteristics	DC Brushless Servo Motor	DC Hybrid Stepper Motor
Motor Resolution	encoder, they have a wider range of resolutions available.	or 0.9 degree resolution. This can increase through the micro stepping, and depended on the stepper driver as well
Torque to Inertia Ratio	Servo motors are very capable of accelerating loads.	Stepper motors are also capable of accelerating loads, but it may stall and skip steps if the motor is not powerful enough
Least Heat Production	The current draw of the servo motors are proportional to the load applied, so the heat production is very low.	Stepper motor draw excess current regardless of load. The excess power then is dissipated as heat.
Reserve Power and Torque	A servo motor can supply about 200% of the continuous power for short periods.	Stepper motors do not have reverse power. However they can brake very well.
Noise	Servo motors produce very little noise.	Stepper motors produce a slight hum due to the control process. However a high quality driver can reduce noise
Resonance and Vibration	Servo motors do not have vibrate or resonance issues.	Stepper motors vibrate slightly and have some resonance issue due to the way they operate
Motor Simplicity	Servo motors are more complex due to their internal parts and the external encoders	Stepper motors are very simple in design with no designed consumable parts
Direct Drive Capability	Servo motors usually require more gearing ratios due to their high RPM. It is very rare to see a direct drive servo motor setup.	Stepper motors will work fine in direct drive mode. Many cases the motor shaft attached directly to the lead-screw or ball-screw.

Table 2.14: Side-by-Side Comparison between Stepper and Servo Motor
(Source from www.applied-motion.com)

The table above provided solid advantages and disadvantages for both DC servo motors and DC hybrid stepper motors as well as making comparisons to help the users in picking the right motor for their projects. For the SmartWalker in particular, the DC hybrid stepper motors seem to have an edge over servo motors. The DC hybrid motors will help keep the cost for motors on the low side, the motion of the SmartWalker can also be smoothed using the micro-stepping feature, and the design of the motors will also be much simpler and easier and are more likely to be compatible with other parts of the whole machine (include power system, micro controller, and motor controller). After choosing DC hybrid stepper motors as the main motor for the project, it is important to choose from different DC hybrid stepper motors that are available on the market.

2.6.4 MOTOR DRIVEN METHODS

For the SmartWalker, the cart will be driven under microstepping driving mode, the weight that it should be able to carry the weight ranges from 20 lbs to 25 lbs, and the speed/RPM of the cart should be, these values will determine the amount of torque the motors need to produce (as well as the load the motor or the cart able to carry). The cart will need two motors installed on the two front wheels to drive and control the directions, the two back wheels will support the weight and the moving part. The microcontroller for the SmartWalker will be the Dual Motor Driver PICAXE 18X and SN754410. This microcontroller will use the differential drive method to control the cart. There's another topic to discuss, more details about the microcontroller, but in general, the basic principle is to control two drive wheels independently and steer by either stopping or reversing one wheel while continuing to operate the opposite wheel in the forward mode.

Among all the methods to control the stepper motor include: wave drive or Single-Coil Excitation, full step drive, half stepping, and microstepping. The microstepping drive method is the most common method to control stepper motors nowadays. The idea of microstepping is to power the coils of the motor, not with pulses like other methods but, with a waveform similar to a sine wave. This is what distinguishes the microstepping method from other methods because it will drive the motor smoother when it moves from one step to the next. This method also makes the stepper motor become suitable for use in high accuracy applications such as CNC positioning systems (the SmartWalker system is also a positioning system). Also the microstepping method significantly decreases the stress of the parts connected to the motor, as well as the stress on the motor itself. Simply put, microstepping method can rotate the DC stepper motor almost continuously, like simple DC motors. The waveform that coils are powered with is similar to an AC waveform, the high resolution digital signal can be a match substitution for the AC input. The figure below shows how high resolution digital signal waveform can replace the AC input.

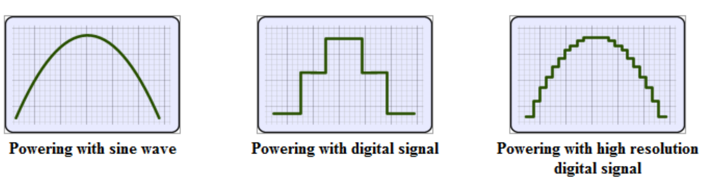

Figure 2.12: Sine Wave Input Replacement with High Resolution Digital Signal (Source from www.anaheimautomation.com*)*

And the next figure will show the actual winding and coils of the microstepping method.

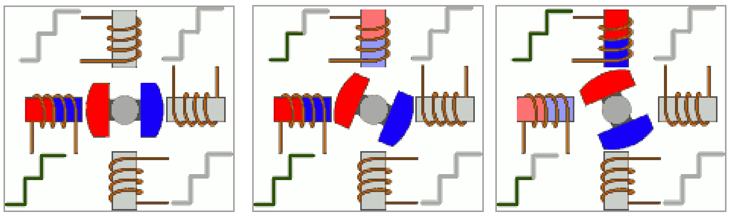

Figure 2.13: Details of the Coils and Winding in the Microstepping Method (Source from www.anaheimautomation.com)

For the SmartWalker project, the total load that the motors should be able to handle is ranging from 20-25 lbs. The SmartWalker will shut down when there's more pressure applied to the cart. And as discussed above, the cart has two motors connected to the two front wheels and using differential drive mode, meaning each of them should be able to generate a torque of 25 lbs.-in(the maximum torque of these motors can be higher than 25 lbs.-in for the acceptable weight error) . And in the differential driving mode, when the cart makes a turn, one motor stops and the other one will make a wide turn, this make each motor need to be able to carry the total load of the cart itself. This amount of weight is included in the motors themselves, the power generator(in this case will be the batteries which generate DC output), the positioning system, the object avoiding system, and the medicine or any first aid kits that can provide emergency assistances to senior citizens.

Along with the driving method and the torque the motor can provide, the power efficiency is one of the most important aspects that should not be overlooked. But this specification of the motor is hardly decided before the torque generation, so when it comes to picking the right motor, a better way is to choose the same torque and pick the one with the higher power efficiency.

The cost of the motors is also another very important concern. The SmartWalker up until now is an unsponsored project, so all the expense will be covered by the members of the group. With the selection of motors, the one with lowest cost would be the best choice for the project. Now with all the standards references for the DC stepper motors, the next part should be comparing the options of motors available on the market and actually picking the motor for the SmartWalker project.

The drive method research still applies to the SmartWalker since the physical shape of the walker and type of motor did not change between designs. Also, the type of motor used on the SmartWalker is the same type as the motor for the original design.

2.7 MICROPROCESSOR VS. MICROCONTROLLER

Taking data from a range finder, giving instructions to the motor controller, and performing calculations of a collision avoidance algorithm requires the use of microprocessors or microcontrollers. Each brain of the system is in in fact made of one or more microprocessor and microcontroller. Although the term microprocessor and microcontroller are sometimes confused or mistakenly used interchangeably, they offer unique advantages, and disadvantages depends on the application at hand. Therefore, understanding how each of them contributes to the solution of a problem is very important.

The microprocessor and microcontroller research did not apply to the SmartWalker in the redesign process as microprocessors and microcontrollers were not considered for controlling the SmartWalker. The group decided not to use them in order to increase the simplicity of the design and to save time on programming.

2.7.1 MICROPROCESSOR

A microprocessor is an IC designed to take digital input then process data, perform calculations through programmable tasks. Extra peripherals must be added to meet specific desired goals of the designer. Microprocessors handle many more instructions than microcontrollers because of the additional space for memory such as RAM, ROM, Flash memory added to it along with the high speed clock (at MHz level), the microprocessor is designed to do very complicated calculations or tasks. Designing a system with a microprocessor is typically more complicated than with a microcontroller. More detail about microcontrollers will be discussed in the next section.

In other words, microprocessors are for general purposes while microcontrollers are more for specialized purposes. The SmartWalker does not require any complicated calculations that it should use a microprocessor. Besides the amount of tasks and research involved in designing the system with a microprocessor is quite large and the cost per unit plus peripherals needed is much more than that of a microcontroller. In the next section, microcontrollers and different product of microcontrollers will be discussed in detail so that it will help in choosing the right hardware for this project.

2.7.2 MICROCONTROLLER

A microcontroller, in a nut shell, is a small computer in a single integrated chip. It has everything needed for simple tasks, more specialized application and it is cheaper compared to a microprocessor. For this project, microcontrollers should be used in the design because it is more suitable for the project. It is cheaper and require less effort in time and labor to design. Here is the list of common features that most of the microcontrollers have in the market today. They are also the reason why microcontrollers are the best choice for this project.

- Central Processing Unit: ranging from small and simple 4 bit processors to complex 32- or 64-bit processors
- Volatile memory (RAM) for data storage
- ROM, EPROM, EEPROM or Flash memory for program and operating parameter storage
- Discrete input and output bits, allowing control or detection of the logic state of an individual package pin
- Serial input/output such as serial ports (UARTs)
- Other serial communications interfaces like I^2C, Serial Peripheral Interface and Controller Area Network for system interconnect
- Peripherals such as timers, event counters, PWM generators, and watchdog
- Clock generator - often an oscillator for a quartz timing crystal, resonator or RC circuit
- Many include analog-to-digital converters, some include digital-to-analog converters
- In-circuit programming and debugging support

Choosing the right microcontroller for this project will not only save time and money, but also keep the effort in design to a minimum. There are many of microcontrollers available on the market that can work for this project. Moreover, the microcontroller that will be used should support the I^2C communication, the interfacing with the sensors, motor controller and meet the power requirements. Several microcontrollers from the initial research phase are enticing. They are the ATMEL ATmega 328, Texas Instruments TI MSP430G series, Microchip Technology PIC16F877A, PIC18F4550

ATMEL ATmega328 MICROCONTROLLER

ATmega328 microcontroller is high performance 8-bit, programmable with flash memory microcontroller. The core feature of this microcontroller is that it has 8 channel 10-bit ADC (in TQFP packaging) and 6 channel 10-bit ADC if bought in PDIP packaging. With 6 channel 10-bit ADC input, it is enough for 6 different analog sensors to be used at the same time. ATmega328 also I^2C compatible. This microcontroller also has some special features of interest such as ADC noise reduction, power saving mode, idle mode and standby. These features will be something that the SmartWalker can use. Table 2.15 summarizes the key parameters of the ATmega328 of interest.

Parameters	Value
RAM	2 kb
Pin Counts	32
Max. Operating Frequency	20 MHz
Max I/O Pins	23
I^2C Interface	Yes
Operating Voltage	1.8V-5.5V

Table 2.15: Features of ATmega328 Microcontroller
(Content from www.en.wikipedia.org under GNU)

TEXAS INSTRUMENTS TI MSP430G MICROCONTROLLER

MSP430G are 16-bit, RISC based microcontrollers made by Texas Instruments (TI). MSP430 has an ADC module that can support 200 ksps analog –to- digital conversion, 10-bit or 12-bit. Also it has an SAR core with 16 input channels. Operating voltage is 1.5V-2.5V. This is a low-power microcontroller. More importantly, it supports I^2C communication. MSP430 clock speed is at 16 MHz, 10 I/O pins comes with different packaging, 128 bytes. Key features of this ultra-low-power device is shown in Table 2.16.

Parameters	Value
RAM	128 Bytes
Max. Operating Frequency	16 MHz
CPU	16-bit
Max I/O Pins	10
USB Interface/Speed	Yes
I^2C Interface	Yes
Operating Voltage	1.8V-5.5V

Table 2.16: Key Features of MSP430 Microcontroller
(Source from www.ti.com)

MICRO TECHNOLOGY PIC16F877A MICROCONTROLLER

PIC16F877A is considered to be easy to program among designers and hobbyists because of its 35 single word instruction structure. It is an 8-bit, 8 channels 10-bit ADC and the capability to be configured as 3 wire serial peripheral interface SPI or I^2C. This allows more freedom in choosing sensors and other hardware for the project. The PIC16F877A analog features such as: the ability to program on-chip voltage reference module, programmable input multiplexing from device inputs and internal VREF, comparator outputs are externally accessible, make it the best choice thus far. Consider Table 2.17, taken from the manufacture data sheet for some key feature of the PIC16F977A.

Parameters	Value
Program Memory Type	Flash
Program Memory (KB)	14
RAM	368 bytes
Data EEPROM	256 bytes
ADC	8 channel, 10-bit
Temperature Range (C)	-40 to 125
Operating Voltage Range (V)	2V to 5.5V
I^2C Interface	Yes
Pin Count	40

Table 2.17: PIC16F877A Key Parameters
(Source from microchip)

MICRO TECHNOLOGY PIC18F4550 MICROCONTROLLER

The PIC18F4550 is very similar to PIC16F877A discussed above but with bigger RAM size. This allows for buffering and enhanced flash program memory and makes it the best solution for any control design that requires periodic connection. It also has USB connection for data upload and download. Table 2.18 provides the summary of main features that can be used to make decisions. One of the huge advantages of using PIC18F4550 is that programming through USB is possible. This reduces time to design and connect the serial communication to the computer for programming the device.

Parameter	Value
Program Memory Type	Flash
Program Memory	32 KB
Clock Speed (12 MIPS)	48 MHz
RAM	2,048 bytes
Data EEPROM	256 bytes
ADC	13 channel, 10-bit
Comparators	2
Interface	I^2C, SPI
USB Interface	1 Channel, Full Speed, USB 2.0
Operating Voltage Range (V)	2V to 5.5V
Pin Count	40

Table 2.18: Key Parameters of PIC18F4550 Microcontroller (Source from microchip)

3.0 OBJECT DETECTION METHODS

The object detection method research did not end up applying to the SmartWalker due to the fact that a wireless camera was implemented rather than range finders.

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In Chapter 2, different type of range finders and the technology applied to them was discussed. Both IR range finders and ultrasonic range finders are just sensors that input analog data into a microcontroller. The microcontroller then takes the data and executes its program to determine the SmartWalker's courses of action. To effectively design the object detection and avoidance system for the SmartWalker, a unique technique or method must be used. There are many of ways to use the output data of range finders to determine the behavior of the system. For this project, it is decided amongst group members that there are three schemes, or methods that can be considered. They are the Triangulation method using IR range finders, Potential Field method using ultrasonic range finder and Fuzzy Logic Control with ultrasonic sensors.

3.1 TRIANGULATION METHOD WITH SHARP IR RANGE FINDER

The Triangulation measurement technique was discussed in the previous chapter. This section of Chapter 3 is about how to use it in the design. Before putting it into the design of the system, sensors characteristics and how it is used for this specifically function of the project must be fully understand.

The Sharp IR range finders, both GP2D12 and GP2Y0A2YK sampling rates are not much, only a few samples per second. Therefore the ADC of most microcontrollers are good enough for it. The number of bits used for ADC output must also be determined. Figure 3.1, the distance versus voltage plot, shows that if distance measured from the IR sensor changes from 80 cm to 70 cm is about 0.06V. The output then is about 0.006(V/cm). Most of the microcontrollers use a voltage reference of 5VDC. For an 8-bit ADC with 5V, each of the bit correspond voltage level can be determined as:

$$\frac{5V}{2^8} = 0.0195\ V/\text{bit}$$

Therefore it is calculated at 1 bit change in output of the ADC of the microcontroller will result in about 2cm to 3cm change. With maximum output voltage of the GP2D12, or GP2Y0A2YK, being 3V, (each bit now is about 0.0117V), then 1-bit change in output of ADC will result in about 2 cm. It is clear that at short distance the object is, the more accurate it will be for the system because the plot of distance versus output voltage curve in Figure 3.1 indicates that it is not a linear term. Thus the larger the distance, the lesser the accuracy will be, for 1-bit change results a larger distances.

This conversion of voltage output level to binary representation can be used to determine the direction of the SmartWalker.

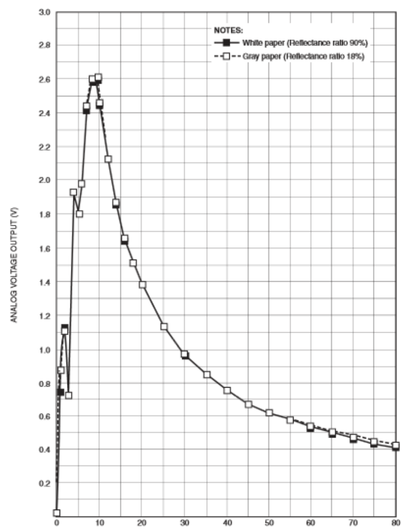

Figure 3.1: Voltages vs. Distance Curve of GP2D12 IR Range Finder (Source from Sharp)

Using that configuration, a look-up table can be made to predetermine the course of action for the SmartWalker. If 5 sensors are used, that means the system will have 5-bits output from ADC into the microcontroller. 2^5 predetermine states (32 states) can be made accordingly. For example, if the output from the ADC is 0000, which corresponds to no detected object from all sensors, the decision to the motor controller should be forward. If 00100, sensor number three goes high, meaning it detects an obstacle within range, then decision to motor controller can either go left an angle, or right at a determined angle. With this technique, all 32 predetermined courses of action can be made accordingly and through experiment, this rule can be optimized for the environment in which the SmartWalker will be operating in.

3.2 FIXED ULTRASONIC RANGE FINDER SYSTEM

In this method of path planning, two ultrasonic sensors are used. They are mounted at the two corner of the design. Because effective scan angle of the ultrasonic is with 60 degrees, each of the ultrasonic sensor's line of sight should cross each other in front of the design (in our case, the SmartWalker) so that it form an angle of 30 degree with the extended line from the frame of the design. Figure 3.2 illustrates the angle and the position of the two sensors.

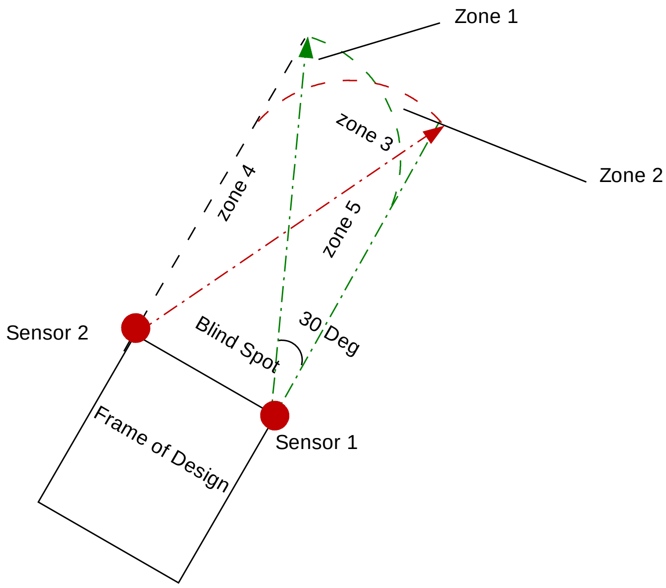

Figure 3.2: Configuration of Fixed-Mount Ultrasonic Sensors

With zones mapped out in the scanning area, each zone is programmed differently so that it will effectively guide the body of the design around or away the object detected in that zone. For example, if object is detected in zone 1, it is programmed so that it will steer the whole body toward zone 2, which is in the opposite direction and vice versa. If for some reason an object is detected in zone 3, the system should do something effective, such as backup or steer harder to the right or left, depending on the environment in which it is operating at and how it is programmed.

This is considered an inexpensive way for design and implementation. However, it has some limitations that could lead to failure to avoid collision. Because the way of the beam of the ultrasonic sensors is set up, if a large object laying at an angle with the beam, and across the zones, the sensors will only the detect the point closest to it. Also, if the object is at an angle with sensor 1 and it only picks up the closest distance to object. Therefore it thinks that there is an object in front of it and to the right (in front of sensor 1), and gives instruction to guide the SmartWalker to the left and go forward in that direction. However, because the object is still in front of it, it will not have enough time to recalculate in reroute itself to avoid hitting that object. Another limitation that should be considered is that the reflection of the beam sometimes can go through large objects or pass through a surface. Thus the sensor will not be able to detect the obstruction a head.

3.3 ROTATING ULTRASONIC RANGE FINDER SYSTEM

For this type of system, ultrasonic sensors are mounted on a servo motor for sweeping actions.

Once the main microcontroller is triggered, it will send out a control signal to the motor controller (servo motor obviously is used for this type of system). The servo motor controller after receiving the reading value from the sensors will then execute its programmed algorithm and take control of the servo motor. The servo motor is moved to predetermine angles accordingly to the algorithm. The ultrasonic sensors is mounted on the servo motor with its line-of-sight line up straight with the angle of the servo motor. This configuration will allow the system to scan, or measure any distance at desired angles. Simultaneously, the motor control will feed readings data obtained from sensors back to the main microcontroller. Direction to drive motor will be given by the main microcontroller after each scanning action.

Common algorithms for this type of system is fuzzy logic algorithm with different variations and potential field method. However, potential field methods, sometimes is referred as PFM, has been quite popular among designers and researchers in the field of robotics. In potential field methods objects scanned by the sensor exert a repulse onto the system while the target applies and attractive force to the system. The sum of these repulsive and attractive forces will determine the direction and the speed of travel.

$$R = F_{repulsive} + F_{attractive}$$

This type of system is implementable due to the simplicity and fairly easy-to-understand concept. A look up table with predetermine angles and direction for the SmartWalker can be made and programmed to the main microcontroller and motor controller as the technique to avoid objects for the SmartWalker.

Each of these methods discussed here is relevant and possible to implement for the SmartWalker project. However each has its own advantages/disadvantages, pros/cons as well as level of difficulty in design. Further discussion and evaluation of each system should be used among group members is required. The decision will be discussed in detail in the next chapter.

4.0 PRODUCT PROTOTYPE DESIGN DETAILS

In the previous chapters, all the candidate main components such as power supply (including battery, battery charger, and voltage regulator), RFID, range finder sensors, motors, motor controllers and main microcontroller has been discussed briefly. This project is divided into ~~three~~ subsystems, each with different components to be considered. To effectively pick out the specific components needed for the project, communication between each group members is maintained regularly through each phase of the design.

4.1 THE WALKER

There are many walkers available in the market with various type, make and model to choose from. However, for this project, the walker that will be used is not required to be too advanced or have luxury additions and expensive. The SmartWalker will be driven by differential drive technique and therefore is required to have at least two wheels installed on them. Also the walker has to be lightweight and portable as stated in the project specifications and requirements section. After doing some searching and evaluating different walkers, the team decide to use the Basic Rollator Walker (Figure 4.1) manufactured by Medline.

Figure 4.1: Medline Basic Rollator Walker
(Permission granted by Medline)

The Medline Basic Rollator Walker is lightweight with a frame made of aluminum; the total product weights about 14 lbs. One of the reason this walker is chosen is that it comes with four wheels which make it less effort for the team to figure out a way to install the two motor-driven wheels and the two support wheels. Specifications of the Basic Rollator Walker is listed in Table 4.1 from the manufacture website.

Specifications	
Basket Belonging Bag Included	Yes
Inside Walker Width	17.5"
Product Weight	14 lbs.
Walker Height Range	31"-35"
Walker Style	Rollator
Walker Type	Basic
Weight Capacity	250 lbs.
Wheel Size if included	6"

Table 4.1: Medline Basic Rollator Walker Specifications (Permission granted by Medline)

The two front wheels (label 4 in Figure 4.1) will be replaced with different 6 inches in diameter wheels capable of accepting motor drive shaft. The two back wheels will be retained for maximum support. Also this walker comes with a convenience basket for extra carry storage, as shown in item 3 in Figure 4.1. This basket can be removed to create more space for any necessary hardware components such as circuit board closure box, or battery, if needed.

An aluminum base, 17.5” x 15” (shown in label 3 from Figure 4.1) will be mounted right below the convenience basket. This base will provide mounting surface for both motors (on bottom surface of the base), electrical components and battery (on the top surface of the base).

The rollator modified into the SmartWalker was a standard rollator. The mounting platform did change during redesign. Rather than just having a flat plate mounted to the bottom of the walker, a flat plate was welded underneath the walker and a bottom tray was connected to the bottom of that flat plate by side panels. This was created in order to support the motors. The bottom tray is similar to a box with missing sides. The figure below shows the platform.

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Figure 4.1-2: Smart Walker Platform

4.2 OBJECT AVOIDANCE SYSTEM

The object avoidance system was not implemented in the SmartWalker due to the redesign. A wireless camera was implemented instead. The camera subsystem will be explained later in this document.

4.2.1 THEORY OF OPERATION

Section 3.3 in previous discussion briefly described how the rotating Ultrasonic Ranger Finder operates. After re-evaluating all options, the team has agreed on this rotating sensor base method. Consider the system functional block diagram shown in Figure 4.2.

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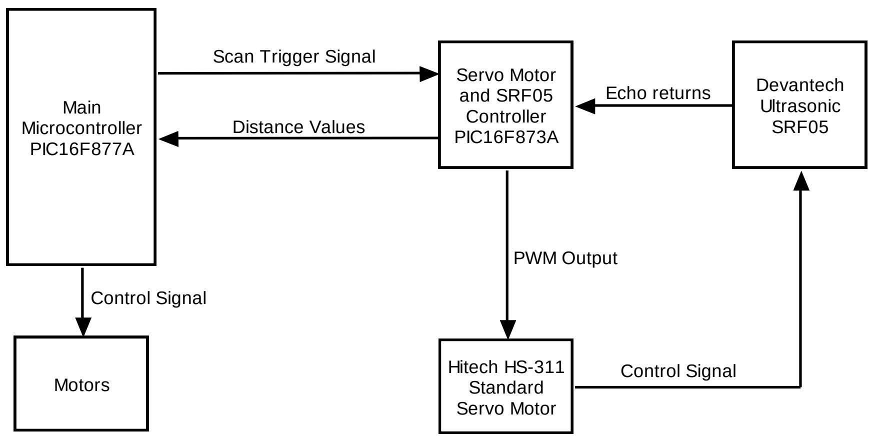

Figure 4.2: Object Avoidance System Functional Block Diagram

As described in previous chapter, the object avoidance system principle of operation is based on the Potential Field Method, sometimes referred to as Potential Field Path Finding Method. The main microcontroller—the brain of the over system, once activated will send a trigger scan signal ~~(Figure 4.1)~~ to the Servo/Sonar Sensor Controller to start scanning the front surrounding of the SmartWalker. This microcontroller PIC16F873A controls the both the servo and the sensors while communicating with the Main Controller. The design detail of each subsystem or components of the Object Avoidance System will be discussed in the next section. A flow chart is made to describe the operation in detail is shown in Figure 4.3.

The pulse signal is fetched from the SRF05 Ultrasonic Sensor to the Servo/Sonar Sensor Controller then essentially to the Main Controller. At that time, the Main Controller is programmed to recognize any objects are in a predetermined distance, a threshold distance D_{TH}. If the object is within this threshold value, the SmartWalker will be instructed to reverse, also at a predetermined distance during the programming process. Using the data obtained, the Main Controller will calculate the horizontal and vertical components (Field Potential Method) as well as the angle of the Cartesian coordinates. At this point, ideally, the SmartWalker is clear from obstruction with the angles calculated and the Main Controller sends a forward signal to the set of stepper motors and drives the SmartWalker forward on the clear path. In the case of there is no object that is within the threshold distance, calculation of X, Y Cartesian coordinate is executed immediately and the system follows the rest of the flow chart.

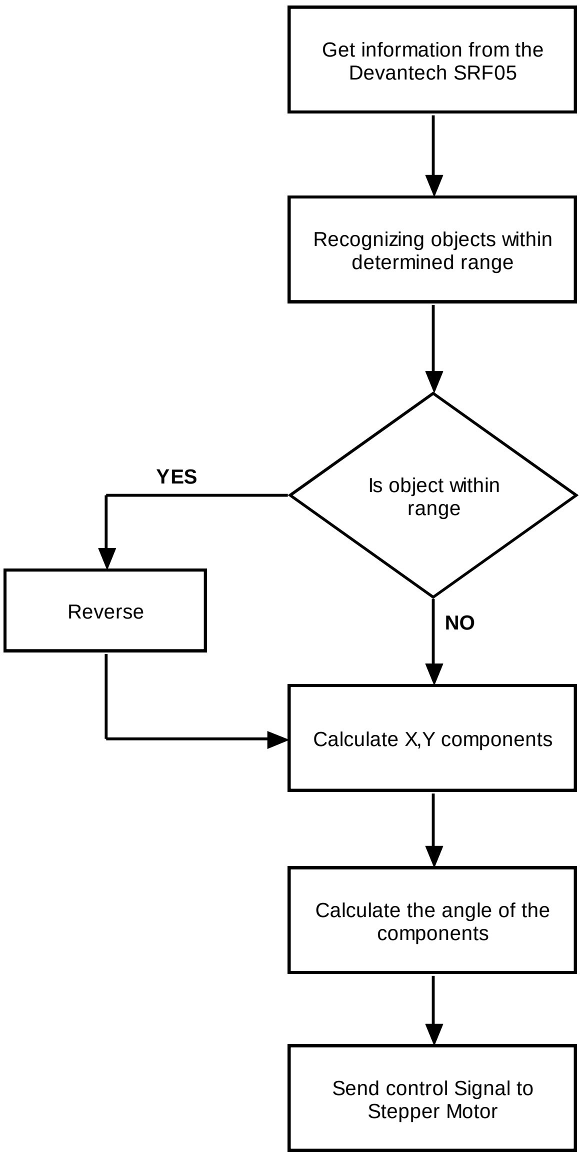

Figure 4.3: System Operation Flow Chart

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4.2.2 COMPONENT AND DESIGN DETAILS

PIC16F1947 MAIN MICROCONTROLLER

The PIC16F1947 microcontroller is the main controller for the SmartWalker. With 28kB in program memory, 17 channels 10-bit ADC, it is sufficiency to control a servo motor controller, SRF05 ultrasonic sensor, two stepper motors, 2 L298HN Full Bridge chip and a active RFID reader. Comparing with the other three consideration for main microcontroller, the PIC16F1947 effectively performs the same functions as other ones do but with less memory. The project itself does not require a large memory to process its data. Plus the fact that the PIC16F1947 is fairly costs less than the others.

The reason to use the PIC16F1947 as main controller instead of the PIC16F877A is due to the fact that 2 USART digital communication peripheral is needed. One set of the USART is used to connect the PIC16F873A Servo/Sensor controller. The other set of USART is used to communicate with the RFID reader (From RS232 of RFID reader to MAX232 transceiver). Also 8 digital I/O is needed for the two L298 Bridge Motor controller for differential drive mode of the two stepper motor. Thus, choosing the PIC16F1947 as the main controller for this project is justified and, at this time, is the best approach to the design aspect of the SmartWalker.

PIC16F873A SERVO AND ULTRASONIC SENSOR MICROCONTROLLER

This 28 pins PDIP microcontroller is used to control the servo motor actions and to communicate between the SRF05 sensor and the main PIC16F877A microcontroller. The 8-bit PIC168F87A has 5 10-bit ADC channel and features 2 10-bit Pulse Width Modulation PWM output for controller the servo motor. With these features, it is more than enough for this application. Figure 4.4 shows the 28 pins PDIP PIC16F873A pin diagram.

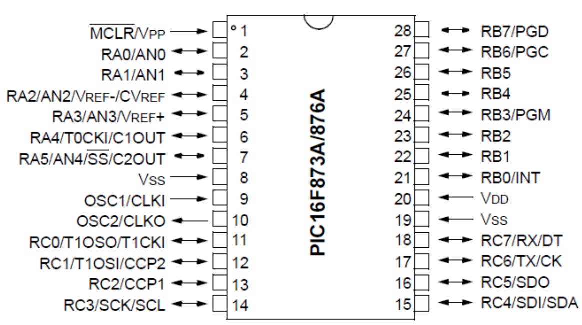

Figure 4.4: PIC16F873A Microcontroller Pin Diagram (Source from microchip)

To trigger and get readings from the ultrasonic sensor, Pin 5 RA3 and Pin2 RA0 is connected to the echo output and trigger input of the Devantech SRF05, respectively. Pin 11 RC0 is connected to the servo motor. Pin 21 RB0 is connected the interrupt from main microcontroller (Pin 18 RC3 of PIC16F877A). And lastly, USART TX output at Pin 17 RC6/TX is connected Pin 26 RC7 of the main microcontroller. Pin numbers and description for the PIC16F873A is listed in Table 4.3.

I/O	PIN Name	PIN Number	Description
Inputs	RA0	2	Echo Output from SRF05
	RB0	21	Interrupt from Main Microcontroller Pin 18 RC3
Outputs	RA3	5	Trigger input to SRF05
	RC6/TX/CK	17	USART TX to Main Microcontroller Pin 26 RC7
	RC0	11	PWM output to servo motor

Table 4.3: I/O Pin Names, Number and Description PIC16F873A

DEVANTECH ULTRASONIC RANGE FINDER SRF05

The SRF05 is an easy to connect and implement device which offers 2-Pin connection configuration for Trigger/Echo mode. Compared to others SRF series and other higher ends sonic sensors, this SRF05 is not as “smart” as others. However, it offers very effective reading for close range and up to 400cm. Cost of the device is also very reasonable and within budget, estimated at $27 to $30, it is much less expensive than the others, i.e. SRF10 and SRF08 at twice of the cost. Thus the SRF05 sonar sensor is the best selection. Figure 4.5 shows the front/back.

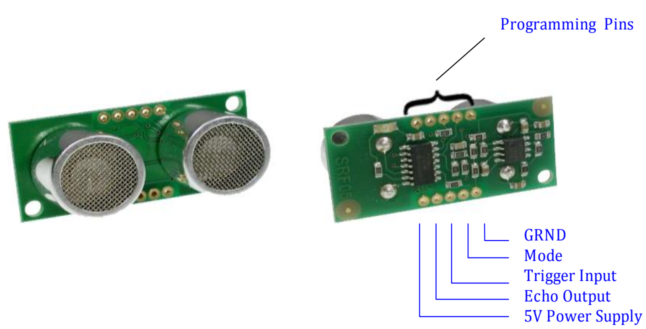

Figure 4.5: Devantech SRF05 Sonar Sensor with 2-Pins Trigger/Echo Mode Connection (Granted permission to use content from solarbotics.com)

The SRF05 can be configured as 3-line or 4-line mode. In 3-line connection mode, trigger and echo pins are connected together and combined into one function. This is harder to implement because the trigger and echo is combined into one line. The trigger/echo line has to be hold high for at least 12 μs then back to low, this will create a trigger signal, or initiate a pulse. It is then switched from input to output. When an echo is received, the trigger/echo line goes low again. The data received by the microcontroller will then be used to convert to distance.

However, in 4-line connection mode, trigger and echo is used separately. Two I/O lines are needed for this configuration. This isn't an issue since the PIC16F873A has 5 10-bit ADC and only one sonar sensor will be used. Moreover, writing functions and code implementation for this 4-line mode is considered less difficult then any other line mode connection as mentioned above. In this configuration, the mode pin is not used (Figure 4.4). Each trigger and echo pin require separate I/O pins. The device is triggered by sending a 10μs pulse to the trigger input pin. Once received, the echo from the pulse bouncing off of objects (or not), typically from 100μs to 25ms and the echo output sends this 10μs pulse to the PIC16F873A microcontroller. The pulse received from the device by the microcontroller will then be converted to distance by dividing by 58 for distance in centimeters or by 148 for measurements in inches.

$$\text{distance (cm)} = \frac{\text{echo received } (\mu\text{s})}{48}$$

$$\text{distance (in)} = \frac{\text{echo received } (\mu\text{s})}{148}$$

Figure 4.6 shows the timing diagram in this 3-line mode configuration:

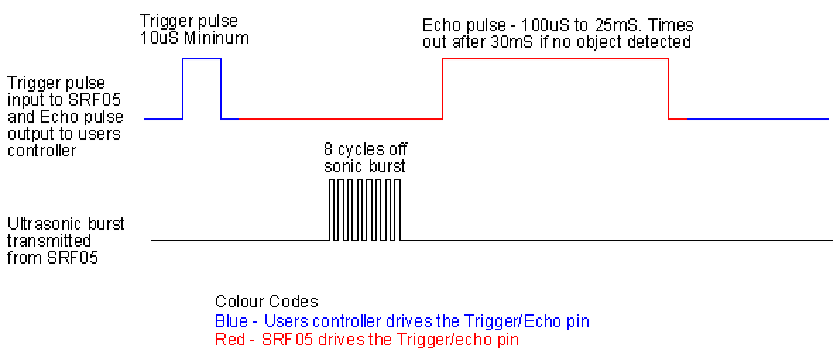

Figure 4.6: Timing Diagram for SRF05 3-line Mode Configuration
(Granted permission to use content from solarbotics.com)

Hitec HS-311 STANDARD SERVO MOTOR

The servo motor is used to turn the SRF05 ultrasonic sensor to different angles to get effective distance measurements from the object to the SmartWalker in order to avoid collision. The sensor will be read at 5 predetermined angles (0, 45, 90, 135, and 180 degrees). At each position, 4 different reading will be taken from the sensor then averaged for better accuracy.

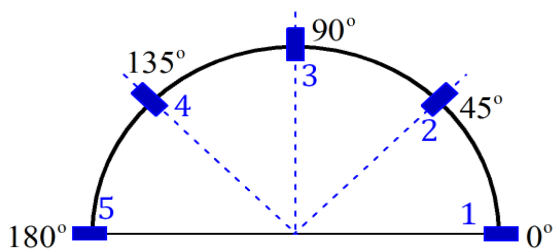

Figure 4.7: Scan Angle Configuration for HS-311 Servo Motor

The HS-311 is a 3 wire standard servo motor: 1 wire for control signal, 1 VCC +5V supply and a ground wire. The servo motor angle turning actions will be determined by the pulse control signal sent from the motor controller PIC16F873A (3 to $5V_{PP}$). A pulse is given every 20ms according to the datasheet. Table 4.4 shows the duration of the pulse at each location. These will be used to compose the code for software implementation.

Position	Pulse Width Duration
3	1.70ms
5	0.90ms
4	1.30ms
1	2.10ms
2	2.50ms

Table 4.4: Pulse Durations

4.2.3 OBJECT AVOIDANCE SYSTEM CIRCUIT

Figure 4.8 is the circuit of the Sensory System, a part of the Object Avoidance System being configured as described in Section 4.1 to Section 4.2.2. Note that the 5V power supply shown in this circuit is actually from the voltage regulator from the Power System. A 4 MHz crystal oscillator with maximum operating frequency of the PIC16F873A is used. Pin 18 and Pin 8 are VSS and are connected together with system ground.

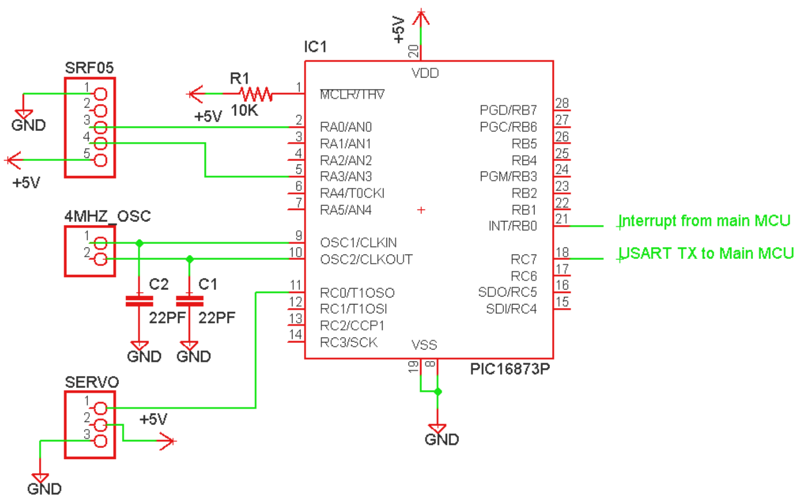

Figure 4.8: Sensory System Circuit created with EAGLE

4.3 RFID SYSTEM

The RFID system that was chosen for the original design was not implemented in the SmartWalker due to the redesign. A wireless camera was implemented instead. The camera subsystem will be explained later in this document.

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In order for the SmartWalker to use RFID technology as positioning system, a RFID Tag and RFID Receiver are needed to transfer location data, and other information if desired, between the tag and the SmartWalker. There are many different types of RFID tags that come in various shapes and sizes but they all operate on the same principle. For the practical application of this project, a wristband RFID tag with a push button is considered. The wristband RFID Tag is an active RFID device therefore it will require a small battery to power the circuit inside the wristband. The push button, once pushed, will send a control signal to its receiver mounted on the SmartWalker. The RFID system is now triggered and is programmed to send out a signal to the main microcontroller to get the SmartWalker going.

4.3.1 2.45 GHz ACTIVE RFID WRISTBAND TAG

The 2.45 GHz active RFID wristband is widely used in the medical and healthcare field due to its feature set. The wristband is tamper proof and water resistant (light/minor water or liquid splash when in shower and washing hands). The most desired feature of this wristband active RFID tag is that it is designed with a call button that can be pressed to send an alert if attention is required. This works perfectly for the SmartWalker. The user will have to wear the wristband at all times. When care is needed and the SmartWalker is at a distance, the user can just simply press the call button. That is the reason the 2.45 GHz Active RFID Wristband Tag is the best solution for this project. Figure 4.9 shows the product with battery status display on the face of the wristband.

Figure 4.9: 2.45 GHz Active RFID Wristband Tag
(Source from gaorfid.com)

Along with key features, the wristband RFID tag also has extra options:

- Capable of tracking person wearing the wristband
- Alert when the strap of the wristband is tampered with
- Batter status display on the face of the wristband
- Low power consumption

Consider Table 4.5 which shows the specifications of the 2.45 GHz Wristband Active RFID Tag from the manufacture datasheet

Read Range	0 to 100 m
Frequency	2.5 GHz ISM
RF Output Power	0 dBm
Power	12 to 18 μA, 3 V
Modulation	GFSK
Data Rate	1 Mbps
Anti-collision	100 tags simultaneously
Operation	Read only
Battery Life	Up to 4 years

Table 4.5: 2.45 GHz Active RFID Wristband Specifications
(Source from gaorfid.com)

With the battery life up to 4 years, this RFID wristband is an excellent choice. RF output power is considered 0 dBm which poses no health issues to the users. Operation range from 0m to 100m, approximately 0ft to 320ft. satisfies the design specification and requirement.

4.3.2 2.45 GHz GAIN ADJUSTABLE ACTIVE RFID READER

To receive information from the 2.45 GHz Wristband Active RFID Tag, a receiver with operating frequency must be UHF 2.45 GHz. With a large amount of effort spent on searching and comparing with different products in the market, the team has decided to consider the 2.45 GHz Gain Adjustable Active RFID Reader. This active RFID has some key features that is of interest. Let's consider Table 4.6, the receiver technical specification.

Direction	Omni-directional, standard whip antenna
Range	0 to 100 m adjustable
Frequency	2.4 GHz to 2.5 GHz ISM (UHF-Ultra High Frequency)
RF Output Power	0 dBm
Sensitivity	-90 dBm
Power	50 mA, 9 V
Modulation	GFSK
Modes	Direct Mode and Buffering Mode. In direct mode, the reader uploads messages to the host system in real time. In buffering mode, the reader save messages, which are uploaded only when requested by the host system
Dimensions	126 x 104 x 28 mm
Buffer Capacity	800 latest messages
Data Rate	1 Mbps
Interface	TCP/IP (RS232 is optional)
Operating Temperature	-40 °C to 80 °C
Operating Humidity	95% Non-condensing
Multi-Detection	100 tags/sec

Table 4.6: 2.45 GHz Gain Adjustable Active RFID Reader
(Source http://www.gaorfid.com/RFID-PDF/217001.pdf)

The reader is equipped with built-in standard whip omnidirectional antenna, which allows communication with tags from all direction. This feature is needed, or required rather, for the SmartWalker application. It will ensure that help from the SmartWalker in emergency situation when needed is available in any situation. With unidirectional antennae, there can be an issue where the RFID receiver cannot effectively read from the tags and vice versa. This 2.45 GHz Gain Adjustable Active RFID Reader can interface via TCP/IP protocol or Serial Communication RS232. To use TCP/IP protocol, extra peripherals are needed and will add cost and complexity to the design. For this project, interfacing the active RFID reader using standard RS232 will be used.

Figure 4.10: 2.45 GHz Gain Adjustable Active RFID
(Source from http://www.gaorfid.com/RFID-PDF/217001.pdf)

The 2.45 GHz Gain Adjustable Active RFID is rated for low power consumption and large memory capacity of can store up to 800 of the latest tag's information. Though such function it is not necessary but it can be an advantage for future uses.

4.3.3 INTERFACING WITH MAIN MCU

The main microcontroller used in the project is the 8-bit PIC16F877A with I^2C bus. Thus a MAX232 RS323 Transceiver chip must be used to convert RS232 connection to make it compatible with I^2C bus of the main microcontroller. Typical operating circuit configuration of MAX232 Circuit is found in the TI datasheet. Figure 4.11(a) shows PIN layout and Figure 4.11(b) shows the typical operating MAX232 circuit.

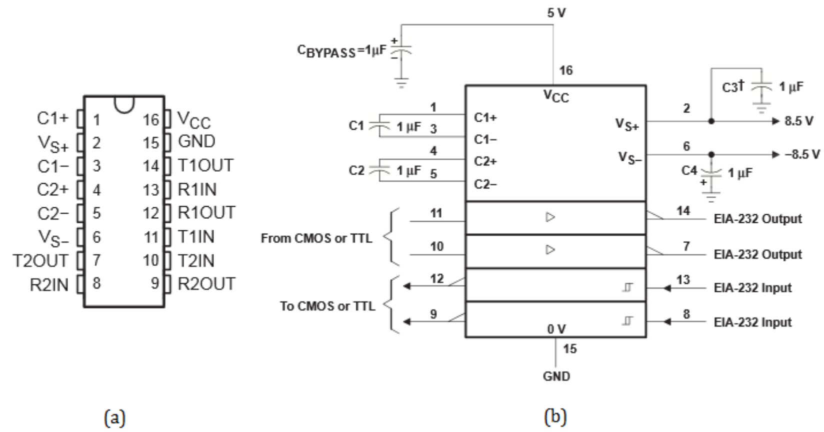

Figure 4.11: (a) Pinout and (b) Typical Operating Circuit of MAX232
(Source from http://www.ti.com/lit/ds/symlink/max232.pdf)

Using Figure 4.11(a) and 4.11(b) along with MAX232 datasheet, the MAX232 transceiver is used to interface the active RFID receiver with the PIC16F877A. The circuit configuration is shown in Figure 4.12. Pin 11 (TIN) is connected RX Pin and Pin 12 (R1OUT) is connected to TX Pin of the PIC168F22.

The RS232 from the RFID reader is a standard 9 pin Serial Communication RS232. The Pinout of the RS232 as followed:

Pin 1: Data Carrier Detect (DCD)
Pin 2: Receive Data (RxD)
Pin 3: Transmit Data (TxD)
Pin 4: Data Terminal Ready (DTR)
Pin 5: Signal Ground (GND)
Pin 6: Data Set Ready (DSR)
Pin 7: Request to Send (RTS)
Pin 8: Clear to Send (CTS)
Pin 9: Ping Indicator (RI)

To send interface to the RS232 and the PIC16F877A main microcontroller, only Pin 2 (RxD), Pin 3 (TxD) and Pin 5 (GND) are used. The circuit in Figure 4.12 shows how the MAX232 and the output RS232 of the 2.45 GHz Gain Adjustable Active RFID Reader are connected.

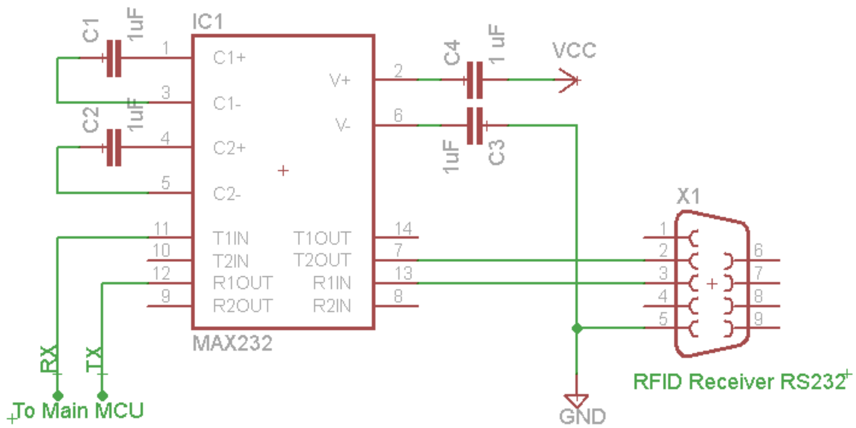

Figure 4.12: RFID Receiver Circuit

4.4 POWER SYSTEM

4.4.1 BATTERY AND CHARGER

The SmartWalker has many subcomponents that require voltages as high as 12-24 volts and currents up to 6 amps. In researching different types of batteries the ideal battery that was desired was the one with the most capacity, longest cycle life, fastest charge time, and lowest cost while having the least amount of maintenance. Our research revealed many pros and cons of each battery type but in searching for physical parts, certain types were found to be unusable for this project. It was found that NiCd batteries were light and useful but couldn't deliver the power needed for this project. It was also found that Lithium ion batteries and Lithium-Polymer batteries were better suited for this power system. After this research the decision has been narrowed down to 3 batteries. Table 4.7 shows the different batteries and their attributes:

	Tenergy 25.9V 10000mAh	NiMH Battery	Tenergy 25.9V 12000mAh Heavy
Description	Heavy Duty LIPO Rechargeable Battery Pack w/ PCB Protection	Pack: 24V 2200mAh (20XAA) Battery for Robot	Duty LIPO PCB Protected Battery Pack w/ Molex Connector
Voltage: P-P	25.9 29.4	24	25.9 29.4
Capacity (mAh)	10000	2200	12000
Discharging Current Continuous: Max:	50 A 70 A	1.8 A 3.5 A	6 A
Weight	< 2000 grams	623 grams	2267 grams
Dimensions	190 x 85 x 65 mm	142 x 50.3 x 28.8 mm	170 x 135 x 41.5mm
Max Charge Rate		1.5 A	
Recommended Charger	e-Station BC-6 AC/DC Balancing Charger	Universal Smart Charger (1.5A) for 19.2-24V NiMH/ NiCd Battery Packs with Tamiya Connector	e-Station BC-6 AC/DC Balancing Charger
Power Leads:	100mm 18 AWG wire with Tamyia Connector & 200mm 18AWG bare leads wire	6” 22 AWG open end wire for charge/discharge functions	11” 16 AWG wire w/ Molex 44441-2002
Cost	Must contact seller for price	34.95	Must contact seller for price
Over Charging Detection Voltage	4.28 volts/Cell	32 volts	29.4 volts
Over Discharging Detection Voltage	3.0 volts/Cell		17.5

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	Tenergy 25.9V 10000mAh	NiMH Battery	Tenergy 25.9V 12000mAh Heavy
Over Discharge Detection Current	83 A	4 A	6 A
Short Circuit and Wrong Protection Polarity	Yes	Yes	Yes
Additional Notes		Charger includes temperature sensors to monitor over-charging	Also has two 9 A poly-switches installed to limit discharge current at 18 A

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Table 4.7: Different Batteries Types and Attributes
(Content are acquired through Battery University)

Something of note about the battery in column 1 is that it is actually made of 7 Lithium Polymer 3.7V 10Ah 5C Battery Cell connected in series. Some specifications pieces that make up the column 1 battery are shown below:

- Typical Capacity: Nominal – 10500 mAh Minimum – 10000 mAh
- Nominal Voltage: 3.7 volts
- Charge Current:
    - Standard – 0.2 C_5A
    - Max – 1 C_5A
- Charge cut-off Voltage: 4.2 ± 0.05 volts
- Discharge Current:
    - Continuously: 5 C_5A
    - Max: 10 C_5A
- Discharge cut-off Voltage: 2.75 volts
- Cell Voltage: Approx. 3.7-3.9 volts
- Impedance: ≤ 10 Ω
- Weight: Approx. 210 grams
- Dimensions: 156mm x 59mm x 9.7mm
- Weight: 205 grams
- 500-1000 times cycle life
- UN approved

Option 1, in Table 4.7 shown above, would be a good choice for the project because of its high capacity, high power capabilities, and protection circuit. However, this battery has the capability of delivering a lot more current than needed. According to the specifications, the maximum discharging current is 70 amps which is far above the needs of this project. The protection circuit does not even detect the current until it reaches 83 amps which by then would have fried every other electronic part in the project and possibly harm the user or anyone else nearby. However, the protection circuit does have short circuit and wrong polarity protection to safeguard the battery from user errors such as improperly disconnecting the battery or hooking up the battery to the charger with the polarity's opposite of what they should be. This leads to the next disadvantage of this battery. The battery has a 100mm 18 AWG wire with a Tamyia connector and a 200mm 18 AWG bare leads wire. This means that the charger would have to be very close to the battery for charging. This will make the plan for mounting the battery on the SmartWalker much more difficult and could involve having the user remove the battery each time the battery needs charging which is highly undesirable. Another disadvantage is the battery is listed at <2000 grams. It must be assumed that the battery is close to that weight and will therefore weigh down the SmartWalker making our weight requirement difficult to meet. On top of that, more weight would have to be added to the project if the battery would dissipate too much heat and a heat sink is required. There is also a safety risk with this battery. With the specifications of this battery is a caution that says improper use like overcharging and over discharging can cause explosion and/or fire. The specifications of this battery state that the user of this battery should have sufficient Li-polymer charging experience and technical knowledge. This is not good because the intended user of this battery most likely will not have the sufficient experience that the specifications of this battery desire.

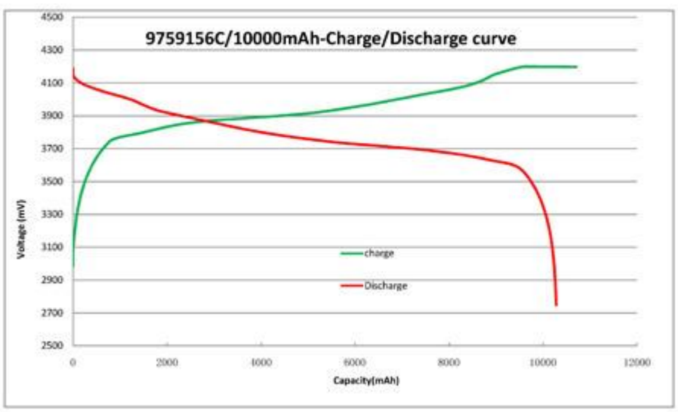

Figure 4.~~9~~13: Charge/Discharge Curve
(Source from http://www.all-battery.com/37volt-10000mah5cli-polycell-1.aspx)

The charger recommended for options 1 and 3 is the e-Station BC-6 AC/DC Balancing Charger. This is a universal charger that can handle NiMH, NiCad, Li-Po, Li-ion, Li-Fe, and SLA batteries. It has a USB port that can be used to monitor and acquire data from your computer about the battery you are charging. Some specifications for this charger are shown in Table 4.8 below:

Specifications	
Operating voltage	DC: 11-18 volts AC: 100-240 volts (50/60 Hz)
Max Charge/Discharge Power	50/5 W
Charge Current	0.1-5.0 A
Discharge Current	0.1-1.0 A
Dimensions	160 x 120 x 40 mm
User's setting-up parameters	
Battery temperature cut-off	20-80 ^{o}C
Waste time between charge/discharge	1-60 min
Integral timer limit for safety	10-720 min (or OFF)
Max Charging Capacity Limit for Safety	10-9990 mAh (or OFF)
Key beep and buzzer sound	ON/OFF
Input DC power low alert	10-11 volts

Table 4.8: Battery Specifications

Option 2: is the NiMH Battery Pack: 24V 2200mAh (20XAA) Battery for Robot. This is the cheapest of all options and can output the voltage required for this project. The battery pack consists of 20 high quality AA size 2200 mAh cells. This battery back contains a 65^{o} thermostat in the charging terminal in order to protect the battery from overcharging. The thermostat connects between the battery and charger using a BEC connector. Option 2 is not designed for high current drain applications which works well with the SmartWalker as none of the parts, except for maybe the motor, should draw a lot of current. This battery pack is considerably smaller and has significantly less weight than the other two options listed above. This will make the mounting of the battery easier. The battery pack in option 2 is also environment friendly. There is one 3.5 A polyswitch installed in the battery pack which will limit the current to 4 amps. If this threshold is passed then the polyswitch will cut off power from the battery for its protection. This will save time and money when it comes to the testing and construction phases of the SmartWalker because the battery will not be able to burn itself or other parts up by allowing too much current to flow through the circuitry.

Shown below in Figure 4.14~~1~~ is the charge curve for the smart charger recommended for the NiMH Battery Pack: 24V 2200mAh (20XAA) Battery. This is a universal charger and is reliable and safe. It would extend the life of the battery with its overcharge protection. However, this charger is a little slower and is sensitive to high temperatures.

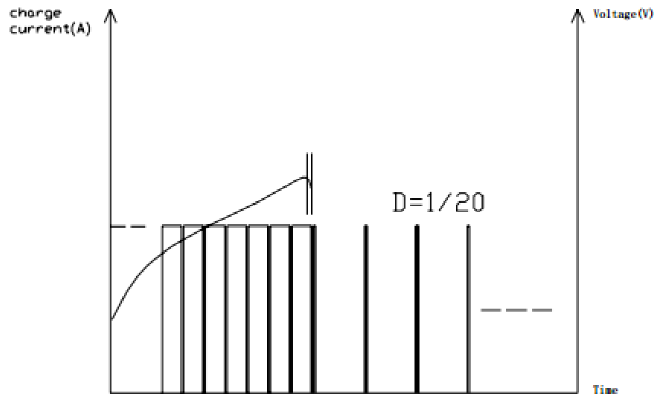

Figure 4.14~~1~~: Charge Curve for 24 Volts Smart Charger
(Source from http://www.batteryspace.com/prod-specs/2701.pdf)

Like the battery in column 1, the Tenergy 25.9V 12000mAh Heavy Duty LIPO PCB Protected Battery Pack w/ Molex Connector is made of multiple pieces in series. This battery is made of fourteen 6000mAh Polymer Li-Polymer single cells in series.

Option 3: shown above is the Tenergy 25.9V 12000mAh Heavy Duty LIPO PCB Protected Battery Pack w/ Molex Connector. This battery pack would be a good choice for the SmartWalker because of its high capacity and a good discharge rate. The capacity is 12000 mAh which is the highest of all of our options. The discharging rate is limited to 6 amps due to the protection circuit. The protection circuit prevents damage to the battery due to short circuits and wrong polarity connections just like option 1. It also helps to prevent over-charging and outputting more voltage than desired. In addition to the power and safety features, the leads on this battery are 11 inches long with a Molex connector on the end. This will make charging easier for both the designers and the users of the SmartWalker. However, also like option 1 is it cautioned that the user of this battery should have Li-polymer charging experience and technical knowledge as improper use can cause explosion and/or fire.

After taking these three final options under consideration, it was decided that option 1 would be the best option for this project due to its high capacity and current limiting features. The size is reasonable and the weight is a concern but its power capabilities will make it worth it in the long run as the battery capacity will allow for longer use of the SmartWalker's automated features. In addition to that, the safety features will also allow the battery life to be maximized reducing the need for maintenance on the battery itself along with any other parts that could be damaged from powering issues. This battery is designed for super long external power purposes which is exactly what is needed for the SmartWalker.

The battery chosen in the original design was not used in the final SmartWalker design primarily due to its cost and change in component voltage needs. Instead, a cheaper yet still effective battery was found. The final battery used for the SmartWalker was the Pitsco TETRIX 12-Volt Rechargeable NiMH Battery Pack. The Pitsco has a 10 cells that combine to get a 3,000 mAh capacity and also features a built-in 20-amp fuse for safety purposes. The battery was purchased in a package with the charger. The charger detects battery pack voltage and adjusts in order to prevent damage to the battery from over-charging.

4.4.2 VOLTAGE REGULATORS

It was decided in the previous section that a 25.9 volts battery will be used to power the SmartWalker. Now that voltage must be regulated in order to power each of the individual subsystems. This will be done using voltage regulators. In this section different types of voltage regulators will be reviewed and a decision will be made on which ones will be used. The individual components of the SmartWalker need input voltages ranging from 5 volts to 24 volts. These same subsystems also need different input currents ranging from 30 milliamps to 6 amps. These along with other characteristics such as noise must be taken into account when choosing a voltage regulator. For parts that have low noise tolerance, a linear regulator should be used due to the fact that switching regulators generate more noise. For parts that don't have low noise tolerance a switching regulator should be used because they are more efficient and will save power thus extending the time the SmartWalker can be used before charging is required.

Shown below are the final three options for linear regulators and their specifications:

LM7805 LINEAR VOLTAGE REGULATOR

Electrical Characteristics (LM7805)

Refer to the test circuits. $-40°C < T_J < 125°C$, $I_O = 500mA$, $V_I = 10V$, $C_I = 0.1\mu F$, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	$T_J = +25°C$		4.8	5.0	5.2	V
		$5mA \le I_O \le 1A$, $P_O \le 15W$, $V_I = 7V$ to $20V$		4.75	5.0	5.25	
Regline	Line Regulation[1]	$T_J = +25°C$	$V_O = 7V$ to $25V$	–	4.0	100	mV
			$V_I = 8V$ to $12V$	–	1.6	50.0	
Regload	Load Regulation[1]	$T_J = +25°C$	$I_O = 5mA$ to $1.5A$	–	9.0	100	mV
			$I_O = 250mA$ to $750mA$	–	4.0	50.0	
I_Q	Quiescent Current	$T_J = +25°C$		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	$I_O = 5mA$ to $1A$		–	0.03	0.5	mA
		$V_I = 7V$ to $25V$		–	0.3	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift[2]	$I_O = 5mA$		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	$f = 10Hz$ to $100kHz$, $T_A = +25°C$		–	42.0	–	$\mu V/V_O$
RR	Ripple Rejection[2]	$f = 120Hz$, $V_O = 8V$ to $18V$		62.0	73.0	–	dB
V_{DROP}	Dropout Voltage	$I_O = 1A$, $T_J = +25°C$		–	2.0	–	V
r_O	Output Resistance[2]	$f = 1kHz$		–	15.0	–	mΩ
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_A = +25°C$		–	230	–	mA
I_{PK}	Peak Current[2]	$T_J = +25°C$		–	2.2	–	A

Figure 4.15~~2~~: LM7805 Electrical Characteristics
(Source from http://www.fairchildsemi.com/ds/LM/LM7805.pdf)

The LM7805 is the linear regulator that was used by the members of the group in their classes when first learning about voltage regulators. They are most familiar with these regulators which will save time by removing any learning curve that may be needed when designing the voltage regulating circuit. The LM7805 is a simple and reliable regulator that will get the job done. It creates very little noise and would not be likely to break. However, the LM7805 isn't very efficient as its quiescent current is fairly high and it can create up to 15W of power. Due to the difference between input and output voltage the regulator is likely to dissipate a lot of heat and will require a heat sink that will have to be taken into account when planning the layout of the physical mounting on the SmartWalker. The heat sink required to dissipate the heat will take up more space and add more weight. The LM78XX series also has regulators that can have fixed voltages of 6, 8, 9, 10, 12, 15, 18, and 24 volts. They can also be made to have adjustable outputs with minimal external hardware. Figure 4.15~~1~~ is the electrical characteristics of the LM7805 taken from the manufacture datasheet.

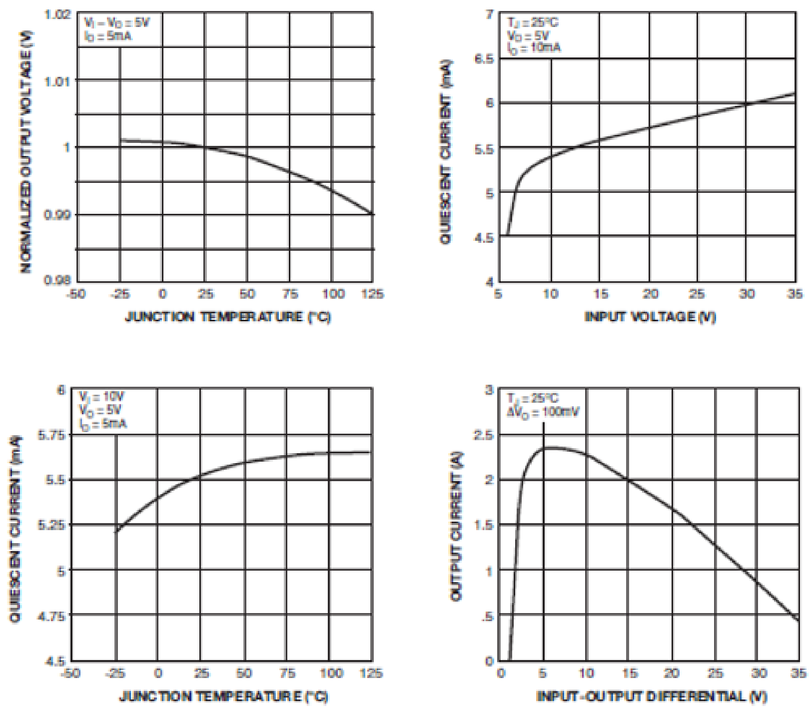

Figure 4.15~~3~~: Typical Performance Characteristics of LM7805
(Source from http://www.fairchildsemi.com/ds/LM/LM7805.pdf)

LM7836-5.0 LINEAR VOLTAGE REGULATOR

The LM2936 series has other regulators with outputs of 3.0 and 3.3 volts and 50mA. The benefits of the LM2936-5.0 are that it is more efficient than most linear regulators due to its low dropout voltage and low quiescent current. With higher efficiency, less power is wasted on the regulator itself and less heat will be dissipated. This removes the need for heat sink which will improve the weight and space taken up by the linear regulators needed in the power supply system.

LM117HV LINEAR VOLTAGE REGULATOR

The LM117HV/LM317HV is a 3-terminal adjustable regulator that can have outputs as low as 1.2 volts and as high as 57 V with a specified output current of 1.5 amps. This is a regulator that can be turned into a simple adjustable switching regulator. This regulator is highly efficient and versatile. The LM117HV/LM317HV could be used for multiple purposes which would make the ordering of parts and easier and could even save some cost by getting discounts for ordering higher numbers of one part usually comes with a discount. This part would regulate the voltage needed to just about any part in the SmartWalker. However, for this part to perform its different tasks it requires some external hardware which would make the design more complicated and would take up more space on the circuit board.

Shown below are our final three options for switching regulators and their specifications:

- LTC3610
- LT1934
- LTM8052

LTC3610 SWITCHING VOLTAGE REGULATOR

The LTC3610 is a synchronous, monolithic step-down DC/DC converter that is capable of regulating an input voltage ranging from 4 volts to 24 volts while being able to deliver a current of up to 12 amps. This switching regulator has a great transient response by using valley current control architecture to deliver very low duty cycle operation at high frequencies. The LTC3610 can be configured for different modes of operation. It can be configured for forced continuous operation which reduces noise and RF interference. It can also be configured for discontinuous mode which provides high efficiency (Figure 4.12) by reducing switching losses at light loads. This regulator also contains safety measures such as output overvoltage protection, an optional short-circuit shutdown timer and fault protection by internal fold-back current limiting. Figure 4.15 shows various plots of the switching voltage regulator LTC3610 characteristics. Overall, this regulator has efficiencies reaching up to around 95% which would extend the battery life of the SmartWalker. With the LTC3610's wide range of power capabilities, it would be a good option for the SmartWalker.

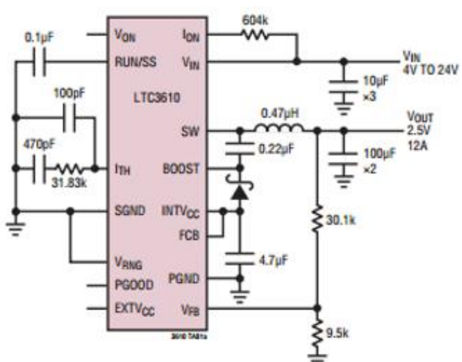

Figure 4.146: High Efficiency Step-Down Converter Configuration
(Source from http://www.fairchildsemi.com/ds/LT/LTC3610.pdf)

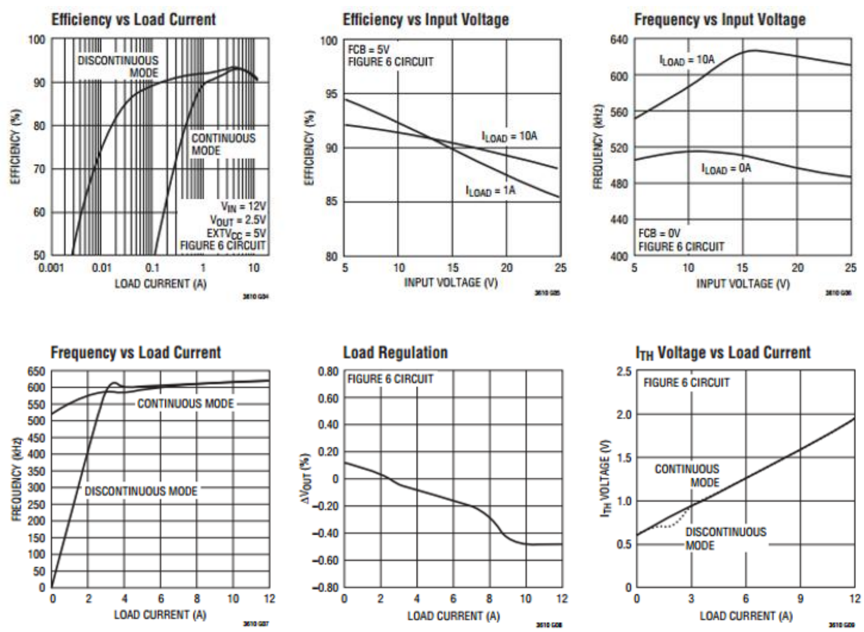

Figure 4.1~~5~~7: LTC3610 Switching Voltage Regulator Characteristics
(Source from http://www.fairchildsemi.com/ds/LT/LTC3610.pdf)

LT1934 SWITCHING VOLTAGE REGULATOR

The LT1934 is a micro-power step-down DC/DC converter. It is packaged in a low profile Thin SOT and uses an internal 400mA power switch. It's wide range of inputs and ability to regulate a wide variety of power sources is what made this regulator appealing. The LT1934 can provide up to 300mA of output current while only having 12 μA of quiescent current. The LT1934 also has a modification called the LT1934-1 which has a lower current limit. This version would be ideal for the subsystem components with required currents of less than 60 milliamps. The LT1934 protects itself and other parts on the same circuit via fast current limiting along with a zero current shut-down mode that disconnects the load from the source, simplifying the power management of the SmartWalker. Since most of the components on the SmartWalker require less than 60 milliamps it is more likely that the LT1934-1 will be used. The main difference between the LT1934 and the LT1934-1 is the peak current through it. The lower peak current provides the advantage of a smaller ripple current at the input along with the ability to use smaller components for the input capacitor/inductor and output capacitor. Consider the electrical characteristics chart shown in Figure 4.16

SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Undervoltage Lockout	 $-40°C \le T_A \le 85°C$ $-40°C \le T_A \le 125°C$	 ● ●		3 3 3	3.2 3.6 3.6	V V V
Quiescent Current	$V_{FB} = 1.3V$ $-40°C \le T_A \le 85°C$ $-40°C \le T_A \le 125°C$	 ● ●		12 12 12	22 26 26	µA µA µA
	$V_{\overline{SHDN}} = 0V$			0.01	2	µA
FB Comparator Trip Voltage	V_{FB} Falling $-40°C \le T_A \le 85°C$ $-40°C \le T_A \le 125°C$	● ●	1.22 1.21	1.25 1.25	1.27 1.27	V V
FB Comparator Hysteresis				10		mV
FB Pin Bias Current	$V_{FB} = 1.25V$ $-40°C \le T_A \le 85°C$ $-40°C \le T_A \le 125°C$	● ●		2 2	±15 ±60	nA nA
FB Voltage Line Regulation	$4V < V_{IN} < 34V$			0.007		%/V
Switch Off Time	$V_{FB} > 1V$ $V_{FB} = 0V$		1.4	1.8 12	2.3	µs µs
Maximum Duty Cycle	$V_{FB} = 1V$ $-40°C \le T_A \le 85°C$ $-40°C \le T_A \le 125°C$	● ●	85 83	88 88		% %
Switch V_{CESAT}	$I_{SW} = 300mA$ (LT1934, S6 Package) $I_{SW} = 300mA$ (LT1934, DCB Package) $I_{SW} = 75mA$ (LT1934-1, S6 Package) $I_{SW} = 75mA$ (LT1934-1, DCB Package)			200 225 65 70	300 120 	mV mV mV mV
Switch Current Limit	LT1934 LT1934-1		350 90	400 120	490 160	mA mA
BOOST Pin Current	$I_{SW} = 300mA$ (LT1934) $I_{SW} = 75mA$ (LT1934-1)			8.5 6.0	12 10	mA mA
Minimum Boost Voltage (Note 3)	$I_{SW} = 300mA$ (LT1934) $I_{SW} = 75mA$ (LT1934-1)			1.8 1.7	2.5 2.5	V V
Switch Leakage Current					2	µA
$\overline{SHDN}$ Pin Current	$V_{\overline{SHDN}} = 2.3V$ $V_{\overline{SHDN}} = 34V$			0.5 1.5	 5	µA µA
$\overline{SHDN}$ Input Voltage High			2.3			V
$\overline{SHDN}$ Input Voltage Low					0.25	V

Figure 4.1~~6~~8: LT1934 Electrical Characteristics

LTM8052 VOLTAGE REGULATOR

The LTM8052 is a constant-voltage, constant-current switching regulator that is capable of delivering up to 5 amps of output current. This regulator is also a 2-quadrant device so it has the ability to source and sink current. This will allow for a more accurate regulated voltage. It has an output voltage of range of 1.2 to 24 volts which covers all of the components in the SmartWalker and an input range of 6 to 36 volts which covers the input voltage of the chosen battery. The output current is adjustable which gives more flexibility in the design. The switching frequency is selectable within the range of 100 kHz to 1MHz. The LTM8052 is desirable for the SmartWalker because of its high efficiency, which you can see from the figures above can be close to 95%, and flexibility due to its wide range of inputs/outputs and its adjustable output current.

In summary, the regulators shown above are reliable and have the capability of working for the SmartWalker. After considering the options, it was decided that the SmartWalker will use the LM78XX series to regulate the voltage from the battery to the various components of the subsystems. This option was chosen because of its simplicity and reliability. However, the LM78XX linear regulator series isn't very efficient and will generate some heat that will require heat sinks to dissipate the heat generated from the regulators without damaging other parts. Therefore, the linear regulators in the design of the SmartWalker will be physically connected with the linear regulators using thermal tape. These heat sinks will stop the dissipated heat from the linear regulator overheating the electrical components inside of the SmartWalker.

The voltage regulators listed above were not used in the SmartWalker due to changing components in the redesign. The battery now supplies 12 volts instead of 25.9 and the components no longer required 12 volt regulation. Instead, the uA7805CKC was used in order to regulate the 12 volts coming from the battery into 5 volts which was needed for the RF, camera, and motor subsystems.

4.4.3 POWER SYTEM CIRCUIT

MULTISIM SIMULATION

The power system will be wired up accordingly to the simulation diagram shown in Figure 4.17. The simulation circuit is built using Multisim software package.

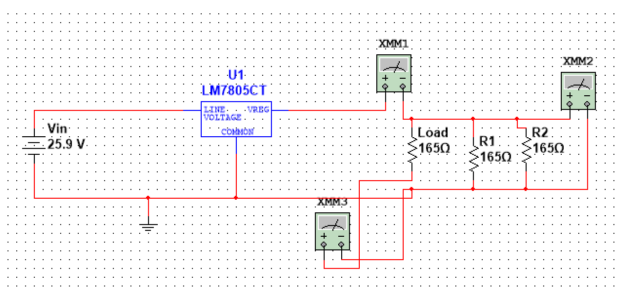

Figure 4.19~~7~~: Power Supply Schematic

This schematic shows the voltage regulator with the battery as its input and its output going to the multiple components of the SmartWalker. The components are modeled as resistors for this simulation. As in the schematic the input for each component will have its input connected to the linear regulator and its ground pin connected to a common ground. This schematic is for the LM7805 which will regulate the input to 5 volts. For components that require a different input voltage, a different regulator of the LM78XX series will be used.

EAGLE CIRCUIT SCHEMATIC

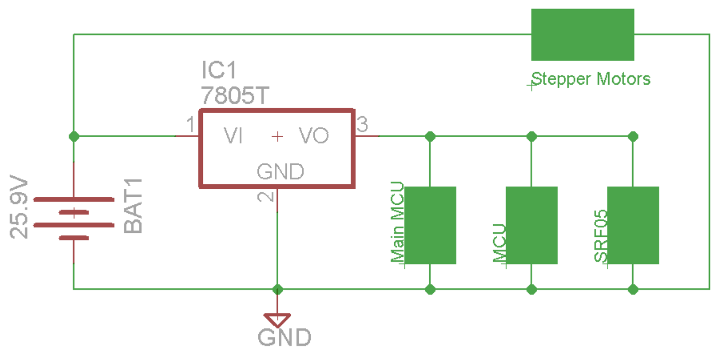

Figure 4.~~18~~20: EAGLE Circuit Layout of 5V Power Supply with LM7805

The power system circuit describe above in this section was not used in the SmartWalker due to the redesign. The new power system block diagrams are shown below in figures 4.19 and 4.20.

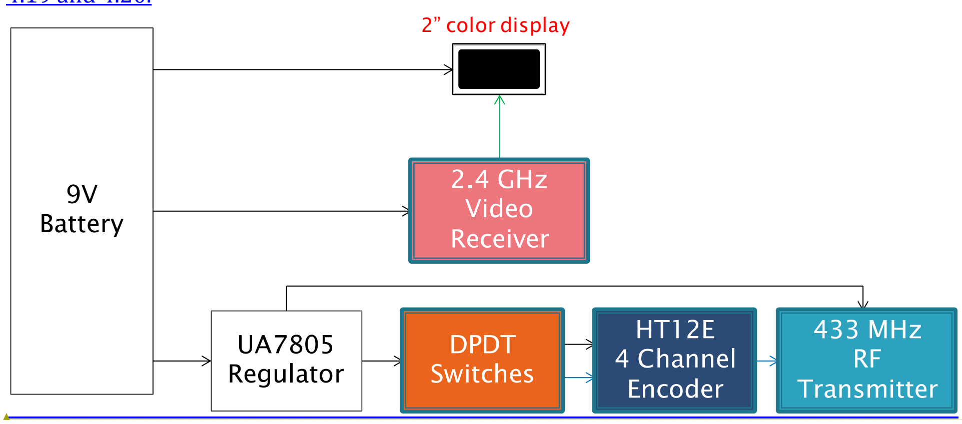

Figure 4.21: Remote Control Power System Block Diagram

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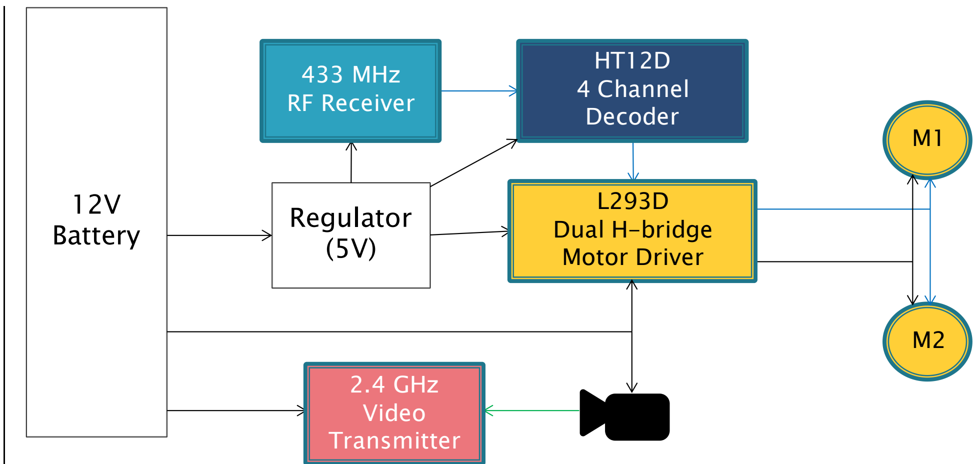

Figure 4.22: Receiver Power System Block Diagram

The power consumption and battery life calculations for the new power system will be described later in this document.

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4.5 MOTORS AND MOTOR CONTROL SYSTEM

4.5.1 Motor and Hardware Selection

With the specifications and requirements for the SmartWalker in mind, several stepper motors are considered for the project. Each different make and model of different stepper motors has their own specifications and advantages/disadvantages. Therefore, careful comparison between motors must be studied before making a final decision. Among all make and model of stepper motors available, three of them are to be considered for the SmartWalker:

- NEMA 23 Stepper Gear Motor
- KL34H260-06-4A Hybrid Stepper Motor
- 34D Series-NEMA Size 34 Round Stepper Motor

NEMA 23 STEPPER GEAR-MOTOR (PART NO.:23820-2-18S)

The 23820-2-18S stepper gear-motor is a NEMA 23 step motor and 18:1 gearhead pre-assembled for ease-of-use. This gear-motor can generate a good amount of torque compare to the side of the motor itself. The Figure 4.19 below is the outside look of the motor.

Figure 4.~~19~~23: NEMA 23 Stepper Gear-motor
(Source from www.kelinginc.net)

This motor can be purchased at www.applied-motion.com" for the price of $150.00. In the Table 4.9 below is the specifications of this motor:

Motor Length	3.65 inches
Number of Lead Wires	6
Lead Wire Configuration	Flying leads, no connector
Lead Wire/ Cable Length	18 inches
Lead Wire Gauge	22 AWG
Unipolar Holding Torque	480 oz.-in = 30 lbs.-in
Bipolar Holding Torque	480 oz.-in = 30 lbs.-in
Step Angle	1.8 deg (can be micro stepped)
Input Speed	1000 RPM
Integral Gearhead	Yes
Gearhead Ratio	18:1
Gearhead Continuous Torque	480 oz.-in
Gearhead Peak Torque	665 oz.-in
Gearhead Efficiency	80%
Weight	3.3 lbs. (2 motors would weight 6.6 lbs.)
Storage Temperature	-40 to 70^{o}C
Operating Temperature	-20 to 50^{o}C
Maximum Radial Load	15 lbs.
Maximum Thrust Load	20 lbs.
Radial Play	0.002
End Play	0.010

Table 4.9: Specifications of NEMA 23 Stepper Gear-motor
(Source from www.kelinginc.net)

The advantages of this NEMA 23 Stepper Gear-motor are listed below:

- It is cost effective gear-motor
- 18:1 ratio amplifies step motor torque
- Offset parallel output shaft
- High torque design

- Strong composite gearhead body

This NEMA 23 motor also has some certain disadvantages, including:

- The price for one motor is still on the expensive side (2 motors will cost $300.00).
- The NEMA 23 is no longer in production (meaning it is currently in the close-out sale) making it hard to purchase.

KL34H260-06-4A HYBRID STEPPER MOTOR

This motor is one a standard DC hybrid stepper motors, it requires a small input voltage and current which is good for power frequency. The torque can be generated for this motor is also quite impressive. Below, in Figure 4.2~~0~~4 is the front and back cover of this motor.

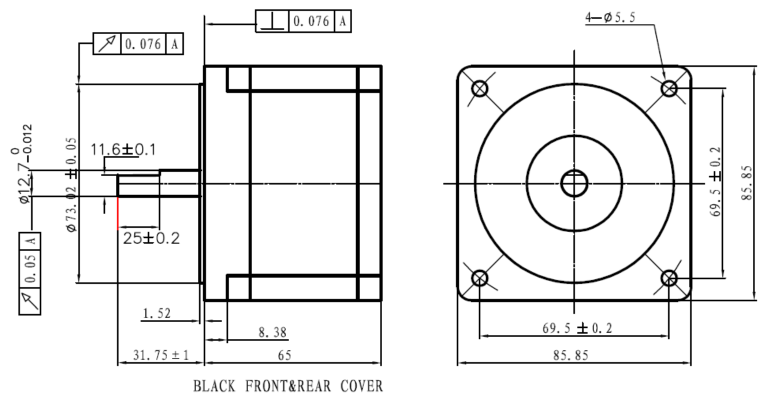

Figure 4.2~~0~~4: The front and rear cover of the KL34H260-06-4A Hybrid Stepper Motor (Source from www.kelinginc.net)

This motor can be purchase at "www.kelinginc.net" for the price of $79. Table 4.10 provides the specifications of this motor:

Phase	2
Step Angle	1.8 (can be micro stepped)
Current	6A
Resistance	0.29 Ohms
Inductance	1.7 mH
Holding Torque	465 oz.-in
Rotor Inertia	1000 g*cm^2
Weight	1.7 Kg = 3.747 lbs.
Number of Lead Wires	4

Table 4.10: Hybrid Stepper Motor Specifications
(Source from www.kelinginc.net)

The advantages of this motor are listed below:

- Low cost for a very good performance
- Generate high torque
- High power efficiency

On the other hand, a disadvantage for this type of motor is that it is a little heavier than the others so it might increase the overall weight of the SmartWalker. Also the listing part number of the motor on the website is different from the specification sheet (KL34H260-06-4A vs. KL34H260-60-4A) so it might cause confusion when purchasing the motor.

34D SERIES-NEMA SIZE 34 ROUND STEPPER MOTOR

The 34D Series Stepper Motor is a standard (round-bodied) style stepper motor. They have lower rotor inertia than square high torque motors which allow them to accelerate faster and offer higher torque at speed greater than 25 revolutions per second. These motor are an excellent choice to replace many of the round stepper motors that were popular for many years. The motor can also be customized the winding to perfectly match voltage, current, and maximum operating speed of the project upon request. Figure 4.21 below is the picture of the 34D Series Stepper Motor:

Figure 4.2~~1~~5: 34D Series Stepper Motor
(Source from www.kelinginc.net)

The 34D Series Stepper Motor can be purchased at "www.anaheimautomation.com" for the price of $240.45 (the part number is 34D207S). Table 4.11 gives the specifications in detail of the 34D Series Stepper Motor:

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Step Angle	1.8 (can be micro stepped)
Torque	Up to 630 oz.-in (for the part number the torque can generate is 420 oz.-in)
Series Current	2.5 A
Unipolar Current	3.5 A
Parallel Current	5.0 A
Unipolar Inductance	4.25 mH
Rotor Inertia	0.0195 oz-in-sec^2
Shaft Diameter	0.375
Number of Lead Wires	6
Weight	5.5 lbs.
Length	3.70 inches

Table 4.11: 34D Series Stepper Motor Specification
(Source from www.kelinginc.net)

The 34D Series Stepper Motor (34D207S) offers certain advantages over the previous model that been discussed so far, these advantages are:

- Generates a very good amount of torque while maintain high speed.
- The seller can help customize the motor to match voltage, current, and maximum operating speed required by the project.

Even with the advantages this type of motor also seems to have some disadvantages, especially with the SmartWalker in mind, these disadvantages include:

- The cost for the motor is much higher compared to those discussed earlier.
- The weight of the motor is 5.5 lbs. (two motors will make it 11 lbs.), this will increase the overall weight of the SmartWalker, and making it difficult to meet the weight specification of the design.

After carefully taking all of the pros/cons, cost and specifications of each motor discussed above into consideration, the DC stepper motor type seems to be the best fit for the SmartWalker. Among all the options available for DC stepper motors, the KL34H260-06-4A Hybrid Stepper Motor is the final choice for the SmartWalker due to its low cost, high torque, and high power efficiency. The options have also been discussed between members of the group, and the features of the KL34H260-06-4A Hybrid Stepper Motor make them the best choice for the project.

After redesign it was discovered by the group that the motors chosen in the original design were not strong enough to drive the SmartWalker at the speed desired by the group. The group went with the Wondermotor 12V DC Reversible Electric Gear Motor. This motor is rated at 11.5 N*m for torque and 50 RPM for rotational speed. This motor proved to be strong enough to drive the motor at a speed in the desired range of the group.

4.5.2 MOTOR AND MOTOR CONTROL DESIGN

Now that the hybrid stepper motor KL34H260-60-4A is chosen for the Smart Cart project, the next step is to put the motor and motor controller into the system circuit to complete it as a whole. In this project, the main control of the Smart Cart project will be PIC16F1947 PDIP package. The reasons for this particular controller to be chosen have already been discussed on the previous part of the document. Along with this controller, the motor controller will be used is L298HN H-Bridge. The L298HN chip has a non-standard pin-out. It has total 15 pins but the stepper motors might not use all of the pins. The chip is manufactured by ST and that is where the chip can be purchased. This L298 will connect to the stepper motors and directly control the motors. The L298HN acts as H-Bridge to control the current flow (speed) and direction based of PWN inputs to Input pin 1-4. The output pin will then connect directly to the stepper motor. The instructions the L298HN H-Bridge received will come from the main control which is the PIC16F1947. The control will be programmed to meet all the specifications and requirements for the Smart Cart to function properly.

Talking about the L298HN H-Bridge and the stepper motors in the circuit, it's easy to see that the motors have two phases, and each phase requires two output from the L298HN H-Bridge. Through the earlier discussion about number of motors will be used for the projects, two motors will drive the whole cart. So there're two L298HN H-Bridge chip will be needed. Each L298HN H-Bridge will drive one motor, and how the motors drive the cart will be controlled by the main controller which is the PIC16F1947. Below is the figure showing the schematic of the L298HN H-Bridge.

The output 1 and output 2 will go to one phase of the stepper motor, and the output 3 and output 4 will go to the other phase of the stepper motor. The supply voltage pin will connect to the power supplier, GND will connect to ground, and Logic supply voltage will connect the source of 5V (as a turn on voltage for the L298HN H-Bridge. The stepper motor schematic will be shown in Figure 4.26~~2~~:

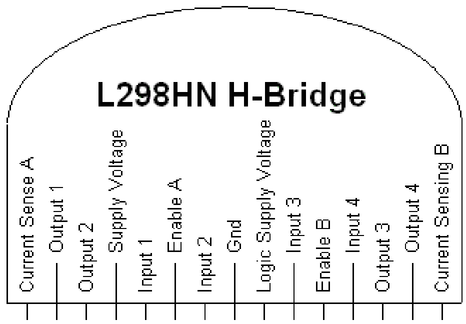

Figure 4.26~~1~~: L298HN H-Bridge Pinout

The final motor drive selected for the SmartWalker was the L293D. It is also a H-Bridge motor drive. It features a 16 pin setup and is designed for use with DC motors which made the implementing it very easy for the group. The actual driving of the wheels of the SmartWalker became more complicated than expected. In order to prevent expanding the width of the walker to an unreasonable amount, the motors had to be mounted in between the wheels on each side. With this location of the motors it was impossible for them to drive the wheels of the walker directly. In addition to the location being a problem, the motor selected is geared, therefore when the motors are not power they will not spin. In order to allow the walker to still be used manually as it would not modified at all a disc-rod system was implemented. The motors have two discs on the rotor. The inner set of discs, closer to the motor, are driven by the motors and the outer discs are able to spin freely about the axis of rotation. Those freely spinning discs are connected to another set of discs that are mounted on the outside of the walker's back wheels with a belt, creating a pulley system. In order to keep both manual and motor driven use of the SmartWalker, metal pins will be inserted through both sets of discs on the motor. This way when the motors are powered and turn the inner discs, the metal pin will cause the outer discs to rotate which will then drive the walker wheels and the walker through the pulley system. Figure 4.27 below shows the final product of the motor drive system.

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Figure 4.27: SmartWalker Drive System

4.6 Camera and Video Transmission

The camera subsystem of the SmartWalker was chosen to be used instead of the RFID positioning system and Ultrasonic Sensor object avoidance system in order to implement the remote controller effectively. The wireless camera allows the user to see where the walker is going if it is not within their line of sight. The camera and video transmitter/receiver that were implemented into the SmartWalker was the Q-SEE Security Camera along with the 2.4 GHz Wireless Video/Audio Module. This camera was chosen because of it's good picture quality and RCA compatibility. This transmitter/receiver module was chosen because of its high transmission frequency, low power consumption, and RCA connectors. The screen chosen for the remote control was the OEM Colour TFT Monitor. This is a two inch color display that is big enough to be visible and small enough to keep the size of the remote controller to a minimum. The RCA compatibility between the camera, screen, and video transmitter/receiver made the camera subsystem much simpler. Rather than using WiFi or another form of wireless transmission which requires an available wireless network and administrator rights to that network, the camera utilizes the RCA connectors of the transmitter inside of the remote controller and hardwires directly to it. The transmitter then sends the video signal to the receiver which in turn is hard wired to the screen which then displays the live stream video.

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5.0 DESIGN SUMMARY

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5.1 RFID SYSTEM

One of the main feature of SmartWalker is the ability to be called while it is on standby. And once it is called, or activated, the SmartWalker must be able to know where it is heading to. To be to do able to this, a tracking, localizing, or global positioning system must be implemented. Several options has been considered and discussed through the designing phases between the team members. They are Wi-Fi, GPS, and RFID Technology. Wi-Fi tracking is expensive to build and design. Plus it is sometimes not so convenience because Wi-Fi is not always available. GPS is another considerable method for this feature. However, GPS operates excellent in outdoor environment, where open fields are available. GPS does not work very well and sometimes is unable to receive satellite signals indoors. For this reason, GPS is quickly eliminated. RFID, on the other hand, is the best solution for this project. As stated in the motivation section, the SmartWalker is designed to help the users at a distance and are in need of their walker. And the ability to call for it by the push of a button is essential. The 2.45 GHz Wristband Active RFID Tag and the 2.4 GHz Gain Adjustable Active RFID Reader offers such desired function.

To interface the 2.45GHz Gain Adjustable Active RFID Reader with the PIC16F1947 Main Microcontroller, a MAX232 is needed in order to use the USART RX and TX protocol from the RS232 Serial Communication of the RFID receiver. Figure 5.1 is the circuit of the MAX232 connected with the RS232 from the RFID receiver. This circuit will allow the RFID receiver interface with the main microcontroller through USART RX, and TX Pin.

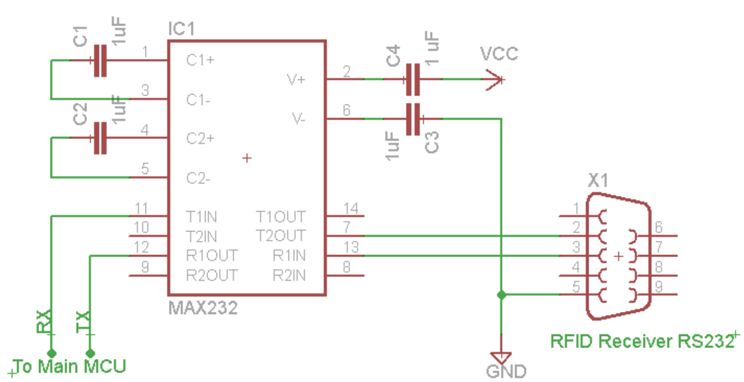

Figure 5.1: RFID Receiver Circuit with MAX232 to allow interfacing with Main MCU

The RFID system of the original SmartWalker design was not implemented due to the redesign. The camera system was used instead.

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5.2 OBJECT AVOIDANCE SYSTEM

The Object Avoidance System can be considered the heart of the SmartWalker. The system consists of a servo motor, an ultrasonic range finder that is mounted on the servo for sweeping actions at five different angles (0, 45, 90, 135, 180 degrees). The method for collision avoidance used is the Potential Field Method, in which a repulsive force from the echo sound that is bounced back from the object is used to calculate the distance and angle of the object as reference to the position of the SmartWalker. At each angle, four different measurements are taken then averaged out for better result. The operation of the system is described in the previous section.

To implement the scanning routines, flow chart in Figure 5.2 describes necessary steps for coding procedures.

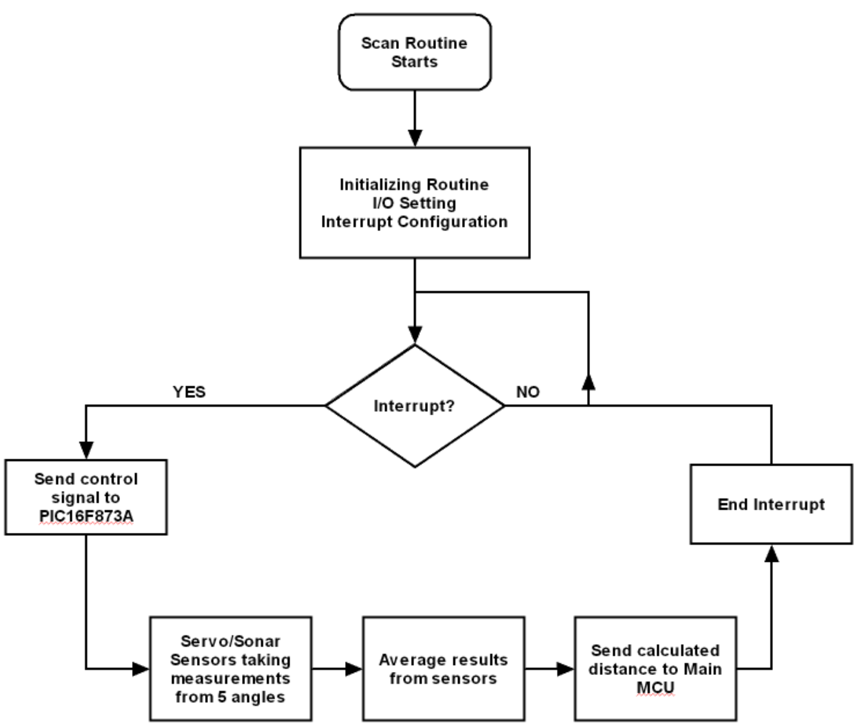

Figure 5.~~3~~2: Implementation of the Object Avoidance System

The PIC16F873A is used as the controller for both servo motor and the Devantech Ultrasonic Range Finder. The Servo/Sensor Controller (PICF873A) will then interface with the main microcontroller through TX output. Though the main microcontroller PIC16F1947 has the capability to interface directly with both the Servo Motor and the ultrasonic sensor, however breaking the circuit into two separate subsystems can be easier to implement later on. Plus each person of the team can work in different parts simultaneously this way. Plus the cost of each microcontroller is not that expensive therefore budgeting is not an issue. The circuit for this subsystem is shown in Figure 5.4.

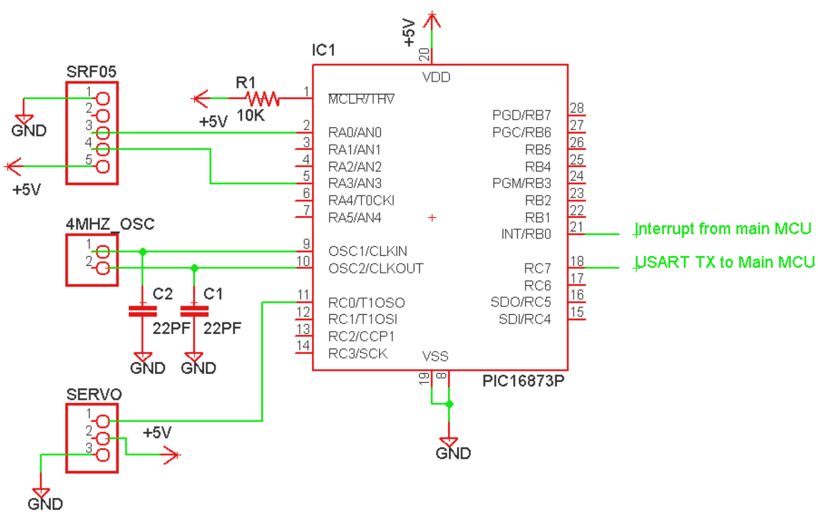

Figure 5.~~4~~3: Servo/Ultrasonic Sensor Controller Circuit

This object avoidance system of the SmartWalker's original design was not implemented due to the redesign. The camera system was used instead.

5.3 POWER SYSTEM

The SmartWalker has multiple components that require a unique amount of voltage and current in order to function properly. This section will summarize the design created in order provide the power necessary for all of the components to operate together and make the SmartWalker work. Shown below in Figure 5.5 is a block diagram describes the general operation of the power supply for the SmartWalker.

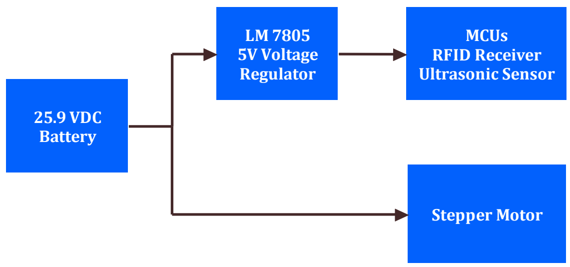

Figure 5.~~5~~4: Power System Block Diagram

As the design in Figure 5.5 suggests the battery's output voltage is regulated to 5 volts by the linear regulator for the smaller components that require that specific voltage. The motor is rated for 6 amps which is much more than any of the LM78XX series can deliver. Therefore the motor will be connected straight to the battery. The motor is rated for 1.74 volts but can handle 20 to 25 times that amount as an input voltage so connecting it to the battery is allowed. The motor will pull 6 amps of current while the smaller components combined shouldn't pull more than 8.5 mA.

Shown below in Figure 5.6 is a schematic of the power system circuit created in Multsim. Each component that the battery will be supplying is modeled as a resistor with a value that will pull an amount of current equal or close to the max amount of current that the component will pull (e.g. the ultrasonic range finder sensor pulls a maximum of 35 mA therefore the resistor value used for it is 143 Ω).

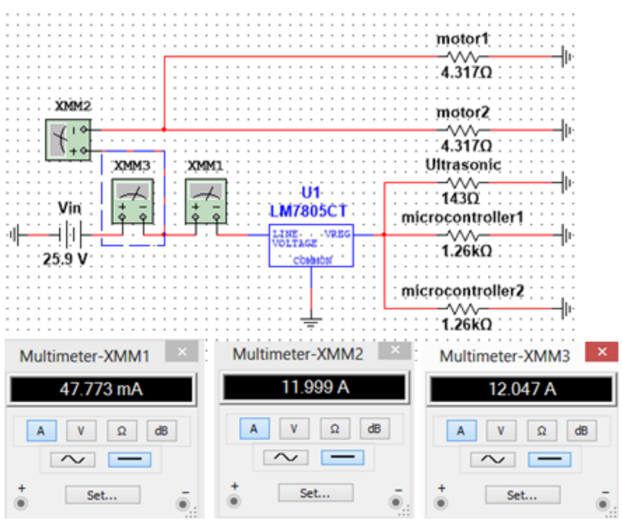

Figure 5.5~~6~~: Power Supply Schematic

In the figure above, multimeter XMM1 shows the amount of current through the regulator for the ultrasonic range finder and the two microcontrollers. Multimeter XMM2 shows the current pulled from the battery by the two motors. Multimeter XMM3 shows the total current pulled from the battery.
Due to the fact that the LM7805 is not the most efficient regulator there will be power loss. This power loss comes in the form of heat. This heat poses a threat to the linear regulator along with the other components of the SmartWalker that are sensitive to heat. Therefore, heat sinks will be used to help cool the linear regulator and avoid any overheating. The power system will be created on a PCB board using the Eagle PCB design software to create the layout and then ordered from a manufacturer to fabricate in order to save time on learning how to create a PCB board and to ensure accuracy of fabrication.

The power system described above in this section has been altered during the redesign. The new power system block diagrams are shown in the previous power system section.

5.4 CONTROL SIGNAL TRANSMISSION

In order to get the control signals from the user to the walker, RF transmission is used. Specifically the HT12E, HT12D, and RF433 Transmitter/Receiver Module. From the DPDT switches, the HT12E encodes the signals to prepare them for tranmission. The wiring schematic for the encoder is shown below.

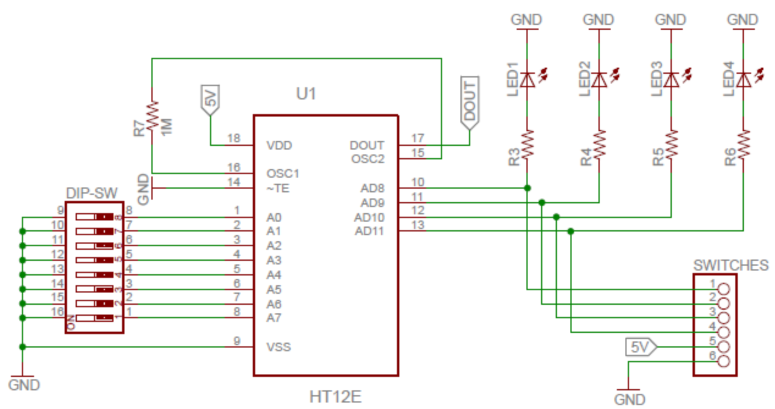

Figure 5.6: HT12E Encoder Wiring Schematic

The signal is then transmitted through the RF433 module. Once received, the signal is decoded by the HT12D. The wiring schematic for the HT12D is shown below.

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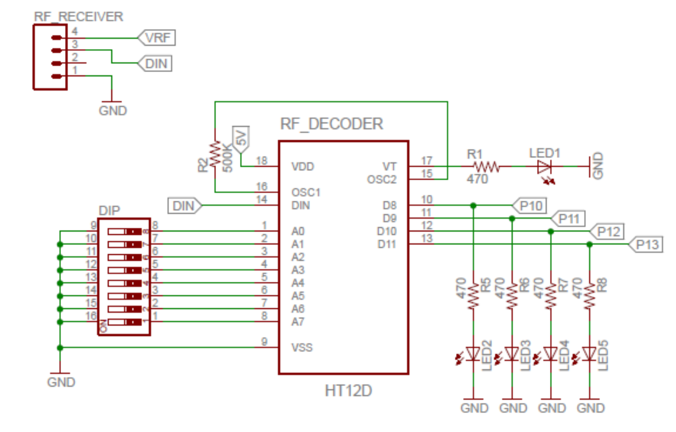

Figure 5.7: HT12D Decoder Wiring Schematic

Once decoded, the signals are used by the L293D to drive the motors in the desired motion.

~~5.4~~5.5 MOTOR AND MOTOR CONTROL SYSTEM

For the Smart Cart project, the PIC16F1947 is the brain of the whole project, and the stepper motors are the moving parts which are the feet of the project. The PIC16F1947 will control the hybrid stepper motor through the L298HN H-Bridge chips (motor controller), and the motor feedback to the main controller will also go through these chips. So with the main controller programmed correctly, the motor and motor controller should be able to connect to each other and function properly by moving the cart follow the instructions from the main controller. Figure 5.7 shows the schematic of the stepper motor and control circuit. Figure 5.7 shows one motor connected to a L2908. The overall system consist of two stepper motor circuits connected to digital I/O of the main microcontroller.

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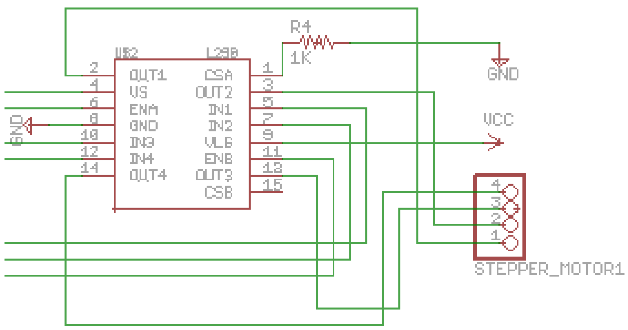

Figure 5.~~7~~8: Stepper Motor and L298HN Circuit

The motor and motor control system described above was not implemented. The new design allows the user to send control signals using a remote controller. The remote controller features two double pole double throw (DPDT) switches that will control the left and right motors. When the user presses the switches forward the motors will drive in the forward direction and vice versa. With this setup, a simple "tank-driving" mode is used to turn the walker. If the user presses only the left switch forward the left motor will turn and the right motor will remain still thus causing the walker to turn right. The opposite is done for left turning. This steering method can achieve a very small turn radius by turning the switches in opposite directions. The control wiring schematic for the DPDT switches is shown below.

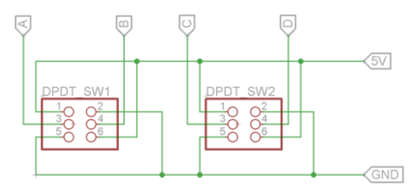

Figure 5.9: DPDT Switches Wiring Schematic

Once the user presses the switches for the desired action, the signals are encoded in the HT12E and transmitted to the receiver through the RF433 module. Once that signal is received by the RF Receiver, the HT12E decodes the message and gives the control signals to the L293D Motor Driver which then powers the motors accordingly. While that is happening, the independent camera subsystem is streaming the video from the camera to the display on the remote controller thus allowing the user to see where they are driving the walker. The layout of the remote control is shown below in the following figure.

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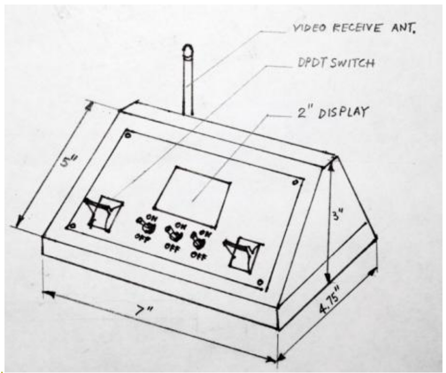

Figure 5.10: Remote Controller Layout

~~5.5~~5.6 OVERALL SYSTEM SCHEMATIC~~CIRCUIT~~

Figure 5.11~~8~~ shows the over-all system schematic built by using EAGLE.

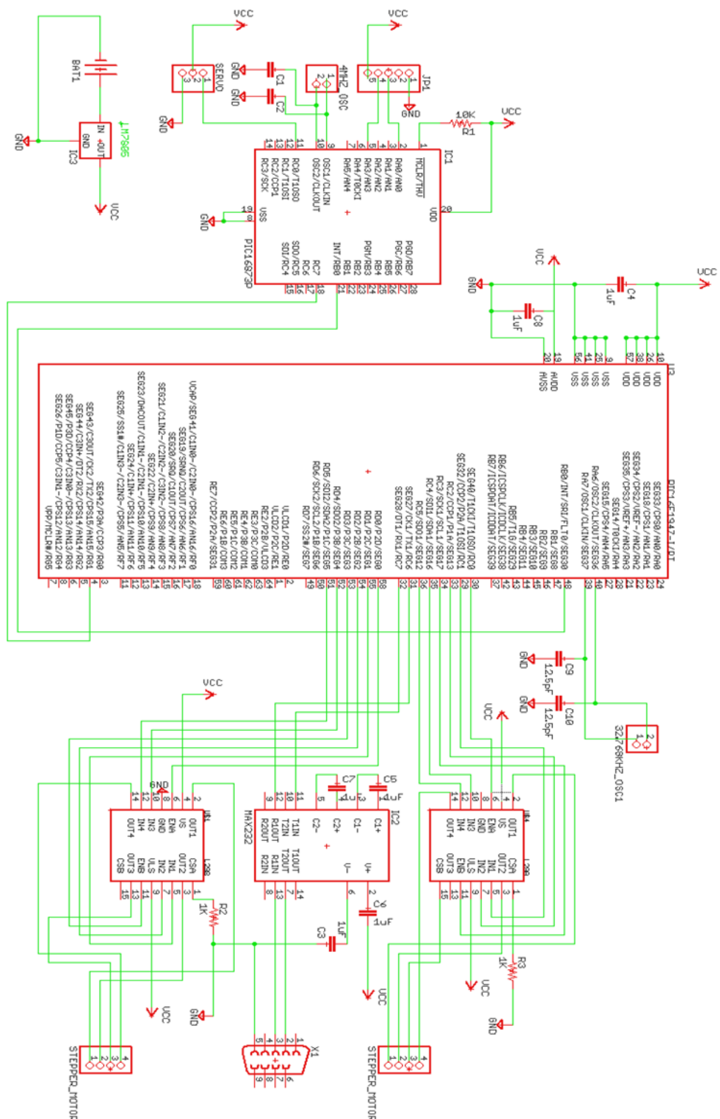

Figure 5.~~8~~11: Overall System Schematic

The schematic shown above is no longer applicable to the SmartWalker project as it was not implemented. The final schematics for the remote controller and receiver are shown below in the following figures.

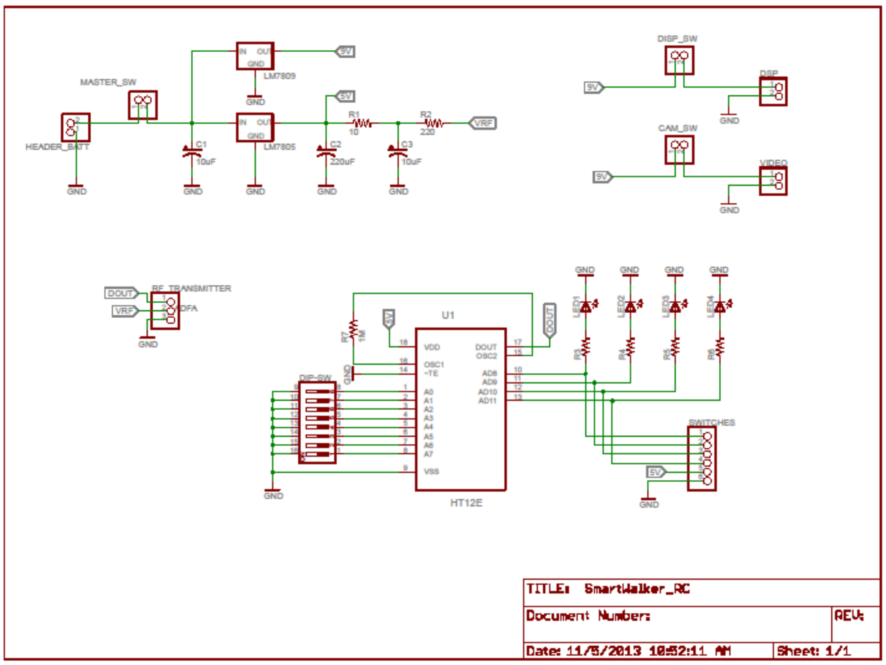

Figure 5.12: Remote Controller System Schematic

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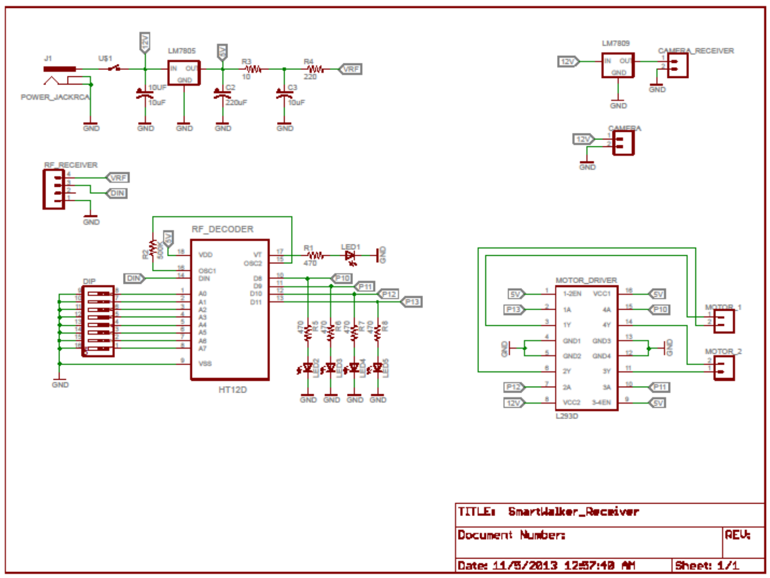

Figure 5.13: Receiver System Schematic

The components described in the previous sections of this document were mounted onto two Protective Circuit Boards (PCB), one for the remote controller and one for the receiver on the walker. The layouts for those PCB's are shown below.

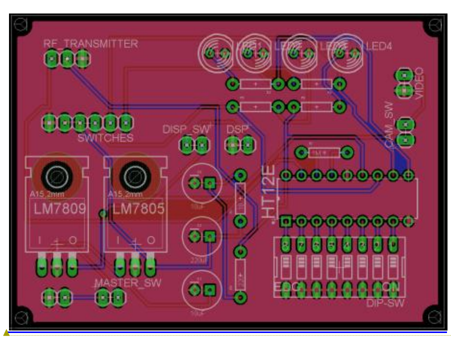

Figure 5.14: Remote Control PCB Layout

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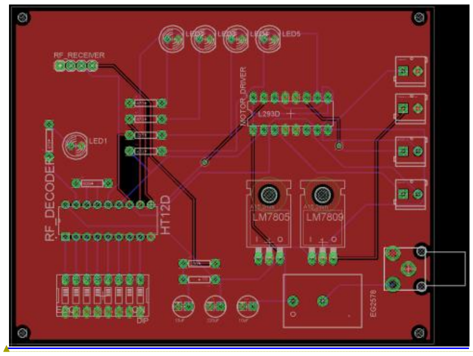

Figure 5.15: Receiver PCB Layout

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6.0 PROTOTYPE TESTING

In order to ensure that all parts in the design of the SmartWalker will work according to plan they must be tested individually and together. Without testing, there is no way of telling if the parts chosen for the design will accomplish the desired goal. This section will go over how each part of the SmartWalker will be tested.

6.1 COMPONENT TESTS

6.1.1 TESTING ENVIRONMENT

Once the hardware for the SmartWalker has been acquired each part must be tested for electrical and/or mechanical functionality. Electrical components such as the battery, charger, and regulators will be tested using a breadboard, multimeter and oscilloscope similar to the electronics lab that the members of the group are familiar with. The breadboard environment will give a preview of the design parts performance in a real world situation before putting the parts together where it will be more difficult to diagnose any problems that may arise from part failure.

6.1.2 SPECIFIC TESTS

POWER SUPPLY TEST

~~The battery will be testing by connecting it to a variety of load resistors and using a multimeter to test the voltage and current on the load. The data from this simple test circuit will tell if the battery is delivering the correct amount of power to whatever load it is connected to. Table 6.1 is used to record the data of this test is shown below.~~Before testing the battery the expected power consumption of the SmartWalker was calculated. These calculations exceed the actual power consumption of the SmartWalker as these calculations were done assuming rated values of all components and that all components are constantly in operation and not on standby. The result of our calculations is shown in the table below.

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Device	Voltage (V)	Current (mA)	Power (mW)
HT12E	5	5	25
HT12D	5	5	25
RF Receiver	5	5	25
RF Transmitter	5	5	25
L293D (1) - chip	5	0.1	0.5
L293D (2) - chip	5	0.1	0.5
Left Motor	12	2400	28800
Right Motor	12	2400	28800
Video Transmitter	9	30	270
Video Receiver	9	30	270
Camera	12	600	7200
Video Display	9	216	1944
		Total Power:	67.385 Watts
~~Battery Voltage (V)~~	~~Load Resistor (kΩ)~~	~~Load Voltage (V)*~~	~~Load Current (A)*~~
~~25.9~~	~~.500~~		
~~25.9~~	~~1~~		
~~25.9~~	~~2~~		
~~25.9~~	~~5~~		
~~25.9~~	~~10~~		

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Table 6.1: ~~Power Supply Test Record~~
*~~*To be filled when perform testing procedures~~SmartWalker Power Consumption Calculations*

After computing power consumption of the SmartWalker, the group calculated the worst-case scenario battery life of the power supply. Our calculations are shown below.

$$Battery\ Life = \frac{Battery\ Capacity\ in\ Milli\ amps\ per\ hour}{Load\ Current\ in\ Milli\ Amps\ per\ hour}$$

$$Battery\ Life = \frac{3800}{5696.2}$$

$$Battery\ Life = 0.467\ Hours^{*}$$

*calculated for all components running constantly at maximum ratings

This is not a good result as it is desired for the SmartWalker to be able to run for an extended period of time without recharging. However, this is the worst-scenario. During testing, the power supply was able to last up to an average of two hours during non-continuous use.

The simulations shown below are not applicable due to the redesign of the SmartWalker's power supply.

A simulation schematic created in Multisim is shown in Figure 6.~~2~~1. This simulation will give the expected values for the test.

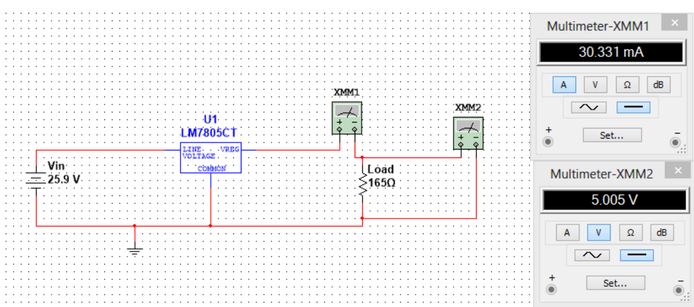

Figure 6.~~2~~1: LM7805 Simulation in Multisim

The circuit above uses a load resistor of 165Ω. Using this resistance will pull a current of about 30 mA, which is similar to that of the ultrasonic sensors to be used on the

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SmartWalker. Once it is determined that the battery is delivering the correct amount of power to a single load, it will be connected to our LM78XX regulators with multiple load resistors in parallel with resistance values that will pull an amount of current close to that which will be pulled once it is connected to the other components of the SmartWalker. This will show if the battery is correctly delivering the voltage and current necessary for all of the components to work properly. This test circuit will also be left connected to test how long the battery will run before it needs to be charged. This will be a worst-case scenario battery life since with only resistors connected in parallel, they will be constantly pulling current which is would be equivalent to the motors always running when they aren't running constantly in a real world situation. With this test, the power delivering capabilities, minimum battery life, and regulator functionality will be tested. The schematic used in simulation shown in Figure 6.2~~3~~ is used to test the multiple loads.

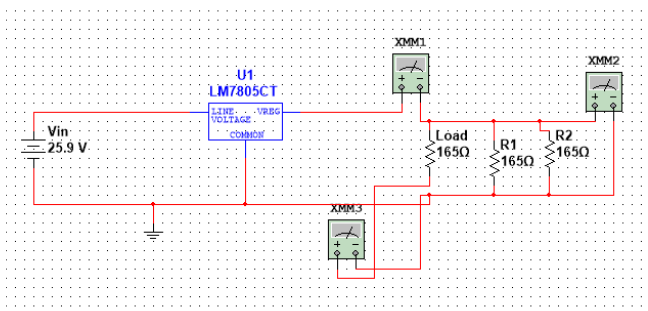

Figure 6.2~~3~~: LM7805 with Different Loads

Once the battery is at the point where it needs to be charged, the charger's functionality will be tested by connecting to the battery and seeing whether or not it will charge the battery. The amount of time it takes the battery will be recorded and the charge time for the battery will also be tested.

DEVANTECH ULTRASONIC RANGE FINDER TEST

The Devantech Ultrasonic Range will be tested in the breadboard environment via oscilloscope and manually moving an inanimate object closer to and farther away from the sensor. A 5 VDC power supply will be connected to the sensor to give it power and the oscilloscope will be placed such that when the sensor detects the object the oscilloscope will read the output from the sensor. Ideally, the sensor will detect the object once it is range and output a pulse with a width that corresponds to the distance of the object and amplitude of 5 volts. The width of the pulses and distance of object will be recorded and the data will tell whether or not the ultrasonic sensor is working properly.

Due to the fact that the range finder system was not used, this section is not applicable.

MOTOR TEST

In order to test that the motor is working it will be connected to a 5 volt power supply. If the motor is working properly it will spin. Besides spinning, with the motors connected to the SmartWalker, they need to be able to hold the required weight (in this case the least amount of weight will be 25 lbs.) and the additional weight (in case of emergency requires more items the cart need to carry which is up to 30 lbs.). Therefore with different loads applied and the motors still able to carry the whole cart, they are working correctly. Another factor that needs to be tested is the speed of the motor. As provided in the motor research section, the weight of the load will affect the speed of the motors (more weight will decrease the speed of the motors (RPM)). So with the load applied, besides generating the same torque desired, the motors also need to drive at the desired speed which is around 5mph. The motor's interface with the microcontroller in order to test its functionality will be covered more in the next section.

This motor test was performed, however, the motor was connected to a 12 volt power supply instead of a 5 volt. The group decided this would better test the motor for its expected performance.

MICROCONTROLLER POWER TEST

Once the microcontroller is received it will be connected to the 5 volt power supply. This will simply be to test if the microcontroller will turn with power applied to it. The functionality of the microcontroller will be tested along the lines of the procedure in the next section.

Due to the redesign of the SmartWalker, the microcontroller was not used and this test is not applicable.

6.2 PROTOTYPE TESTS

Once all of the parts have been received they will be put together and mounted onto the walker as our design states. Once the prototype of the SmartWalker has been put together it must be tested. In order to test the functionality and accuracy of the SmartWalker a series of tests must be created. This section will go over test procedures that will test the SmartWalker and its ability to meet the specifications and requirements listed above.

6.2.1 WEIGTH SUPPORT TEST

The first test that will be designed is to test the walker's ability to support the amount weight specified in section 1.4. This will be done by a member of the group physically leaning on the walker and moving. This will simulate its use by an elderly person that would put most of their weight onto the walker when trying to move. In addition to the member of the group's force on the walker, weights of different values will be placed on the walker in order to simulate more weight being put on the SmartWalker. Four different trials will be completed using weights of 10, 25, and 50 pounds. In each trial the mobility and stability of the SmartWalker will be observed.

This test was performed and it was found that the SmartWalker could drive with a load of up to 25 pounds.

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6.2.2 RFID SYSTEM TEST

The next test that will be designed is to test the SmartWalker's ability to read the RFID tags in order to obtain locational information once programmed to a certain environment. This will be done by programming one of the RFID tags with an arbitrary piece of information. Then the tags will be held at various ranges and angles relative to the reader on the SmartWalker. The ability of the SmartWalker to read the data will then be observed. The tags will be held at distances of 5, 10, 15, and 20 feet. At each distance the tag will be held directly in front of the receiver, to the left of the receiver at angles of 15^{o}, 45^{o}, and 60^{o}, and to the right of the receiver at an angle of 15^{o}, 45^{o}, and 60^{o}.

This test was not performed because of the redesign. The RFID system was not implemented.

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6.2.3 AUTONOMOUS MOVEMENT TEST

In order to test the autonomous movement of the SmartWalker, multiple tests must be set up. One experiment will be to test the automatic starting and stopping of the SmartWalker in a straight line. This will be done by activating the wristband RFID tag to instruct the servo motors to move the SmartWalker towards the tag. The distance that is desired will be measured out before the trial and after the SmartWalker has moved along the path the displacement from the wristband will be measured for accuracy. If the SmartWalker is not within 2 feet of the wristband's location, adjustments must be made until the SmartWalker can within the 2 foot range.

After the ability to start and stop as desired has been tested the SmartWalker's ability to avoid obstacles will be examined. This will be done by having the SmartWalker travel to the wristband RFID tag. However, there will be a single obstacle in the direct path. The SmartWalker will have passed the test if it detects the object and avoids it while traveling to its destination.

This test was not performed because of the redesign. Instead of an autonomous movement test. The SmartWalker's remote control capabilities were tested through demonstration of driving forward, backward, left and right.

6.2.4 FINAL PROTOTYPE TEST

Once each part of the total functionality is tested individually the entire operation of the SmartWalker will be tested. An environment will be set up similar to that of an ordinary household. The environment will contain multiple obstacles such as tables, chairs, and doorways. The SmartWalker will then be instructed by the wristband RFID tag to move through that environment. If the SmartWalker hits an obstacle than adjustments must be made until it can avoid all obstacles. In addition to testing the object avoidance requirement, the time of the SmartWalker's navigation through the obstacle course will measured as well. This will test the ability of the SmartWalker to reach its destination within 3 minutes of departure. If the SmartWalker takes longer than this then adjustments must be made in order to speed up the travels of the SmartWalker. The SmartWalker will travel to the RFID wristband which will be at distances of 20, 30, 50 and 100 meters. Each trial will have obstacles placed in various patterns and will be timed.

This test was not performed because of the redesign. The SmartWalker is no longer autonomous.

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7.0 ADMINISTRATIVE DETAILS

7.1 MILESTONE

In this section a tentative schedule for the both the design and construction processes will be reviewed. The table for senior design 1 will show the projected finish dates for defining the project, similar technology research, parts research, part selection, design, and paper finalizing. The schedule for senior design 2 will show the projected finish dates for part gathering, construction, testing with redesign if necessary, implementation, and presentation.

Task Description	End Date
Define parameters of Smart Walker	1/22
Research:	3/15
Research of Similar/Existing Technologies	1/29
Power Supply System Research	2/8

Task Description	End Date
Positioning and Tracking System Research	2/16
Object Avoidance System Research	2/26
Motor Research	3/6
Control Research	3/15
Parts Selection:	3/31
Power System Parts Selection	3/18
Positioning and Tracking Systems Parts Selection	3/21
Object Avoidance System Parts Selection	3/24
Motor Selection	3/27
Controller Parts Selection	3/31
Design:	4/19
Power System Design	4/4
Positioning and Tracking System Design	4/8
Object Avoidance System	4/112
Motor/Motor Control System Design	4/19
Paper Finishing:	4/25
Source citations/permissions	4/21
Fix formatting/grammatical errors	4/24
Print/Bind	4/25
Turn in SD1 Paper	4/25

Table 7.1: Senior Design 1 Milestones

Task Description	End Date
Part Acquiring	9/6
Construction	10/4
Testing	10/18
Redesign(if necessary)	10/25
Re-Testing(if necessary)	11/8
Implementation	11/29
Presentation	**12/1**

Table 7.2: Senior Design 2 Milestones

The group slipped on some milestones for the Senior Design 2 phase but did complete the major milestone of the presentation.

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7.2 BUDGET AND FINANCING

At this time, our project is not financially supported by any sponsored. The SmartWalker project at this point is 100% self-financed. One way to make it fair for everyone is to distribute the cost evenly among the group members. An estimated bill of materials will be created and kept current. It will also serve as a way to balance our budget and more importantly, it will keep our product cost effective. Also for each purchase that will be charged on the group must be agreed by the group members.

However, throughout this Summer Semester until Fall Semester, the team members will pay more effort to look for financial supports from private sectors such as Medline Medical Supply, Walgreens and other Medical Supply chains.

The group was unable to find a sponsor for the SmartWalker project and was funded by the members of the group.

7.3 ESTIMATE BILL OF MATERIAL

The SmartWalker project is divided into sub-systems and parts. Each member will be responsible for their assigned parts to include: research, design, planning for testing procedures, and estimate cost of materials. The responsibilities are broke down to three main categories:

- Power System
- Object Avoidance System
- Motor and Motor Control System

Bill of material for each of the categories mentioned above will be created and maintained during the design phase. That will allow the team to know the status of the project financially, and to help with making decision on parts selection.

Item	Description	Cost
POWER SYSTEM		
Tenergy 25.9V 12000mAh Heavy Duty LIPO PCB Protected Battery Pack w/ Molex Connector	Battery	Waiting for Seller Reply
e-Station BC-6 AC/DC Balancing Charger for NiMH/NiCd/Li-PO/Li-Fe/SLA	Charger	$169.95
LM7805 Linear Voltage Regulator	Regulator	1.32 (minimum order of 45 from Mouser but I still have one from Electronics 2 lab)
AWG18 wire	Connection wires	$9.05 total (estimate)
MOTOR AND MOTOR CONTROL SYSTEM		
Hybrid Stepper Motor KL34H260-60-4A	Stepper Motor	$79/each unit Total: $158.00
L298HN H-Bridge	Motor Controller	$6.95/each Total: $14.00
Weber 3620 6-inch heavy duty wheel	Wheels	$8/each Total: $32.00
Walker	Medline Walker	$90.00
OBJECT AVOIDANCE SYSTEM		

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Item	Description	Cost
PIC16F1947	MCU	$2.00
PIC16F873A	MCU	$2.00
2.45 GHz Active RFID Wristband Tag	RFID Tag	Contact for price $7.50/each
2.45 GHz Gain Adjustable Active RFID Reader	RFID Reader	Contact for price Est.$75.00
2MHz and 33 KHZ Oscillators	Oscillators	$15.00
Devantech Ultrasonic Range Finder	Sonar Sensor	$55.00

Table 7.3: Senior Design 1 Bill of Materials Estimate

The above estimate of cost for the project is incorrect due to redesign. The final cost of the SmartWalker project is shown in the table below.

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Item	Unit Price	Ordered	Price
Video Transmitter/Receiver	$32.00	1	$32.00
RF Transmitter/Receiver	$4.12	1	$4.12
HT12D/HT12E		1	$0.00
UA7805CKCS	$0.49	1	$0.49
LM7809	$0.67	1	$0.67
Pitsco TETRIX 12-Volt Rechargeable NiMH Battery Pack and Charger	$84.90	1	$84.90
Video Display	$42.31	1	$42.31
22 pF capacitor (30pk)	$2.43	1	$2.43
QSEE Security Camera	FREE	1	$0.00
Wondermotor 12V DC Gear Motor	$59.99	2	$119.98
L293D	$2.50	2	$5.00
DPDT Switches	$5.00	2	$10.00
PCB	$48.36	2	$96.72
Miscellaneous (bolts, screws, welding etc)	$100.00	1	$100.00
Total			$498.62

Table 7.4: SmartWalker Bill of Materials

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8.0 APPENDICES AND CITATATIONS

REFERENCE AND CITATIONS

"How Do I Pick a Battery Charger!" *BatteryStuff Articles*. BatteryStuff.com, 11 Sept. 2012. Web. 24 Apr. 2013. <http://www.batterystuff.com/kb/articles/charging-articles/how-do-i-pick-a-battery-charger.html>.

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PERMISSION REQUESTS

Brandon Crick [Brandon.Crick@cadex.com]
Tuesday, April 16, 2013 10:57 AM

To: mikeorr@knights.ucf.edu

Hello Michael,

Absolutely, we would just ask that you cite a reference to Battery University and the author, Isidor Buchmann.

Thanks!

Brandon Crick| Marketing Communications Manager

Cadex Electronics Inc.
22000 Fraserwood Way, Richmond BC V6W1J6
604.231.7777 x319 phone | 604.231.7755 fax | www.cadex.com

Request for permission from Funspark.com

mikeorr
Wednesday, April 24, 2013 12:51 PM

To: Level 1 [level1@sparkfun.com]

Hi Michelle,

Thank you for your quick response. I have another permission request. This time for the picture of the heat sink attached to a linear voltage regulator used in the article whose link I've put below.

https://www.sparkfun.com/quiz/3

Thanks for your help,
Mike

mikeorr

Wednesday, April 24, 2013 12:44 PM

To: service@all-battery.com

To Whom It May Concern:

My name is Mike Orr and I'm current pursuing my degree in Electrical Engineering. I am writing a paper that discusses different battery's and their chargers. I have referenced one of the chargers from your website and wanted to use one of the figures on the link below:

http://www.all-battery.com/37volt-10000mah5cli-polycell-1.aspx

Would it be alright if I used the charge/discharge curve figure in my paper?

Best Regards,
Mike Orr

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Figures from: LTC3610, LT1934, LTM8052

Permission Pending

mikeorr

Wednesday, April 24, 2013 11:58 AM

To: mylinear@linear.com

To Whom It May Concern:

My name is Mike Orr and I am currently pursuing my Electrical Engineering degree at the University of Central Florida. I'm writing a paper that discusses different switching regulators and their specifications. In this paper I have used the LTC3610, LT1934, and LTM8052. Would it be alright if I used some of the tables and figures from their datasheets in my paper?

Best Regards,
Mike Orr

[#WHX-208-80120]: Permission to use information of SRF05, SRF08 and SRF10

From: **RobotShop Inc.** (supportcenter@robotshop.com)
Sent: Mon 4/15/13 8:04 AM
To: truongchiloc@msn.com

Hi,

We thank you for contacting RobotShop regarding use of the images on our website. Unfortunately we are not in a position to give such a permission since we are able to use the images because we are directly associated with Devantech as a distributor. Devantech (Robot-Electronics) would be able to provide such authorization. They can be contacted here:
support11@robot-electronics.co.uk

Hope this helps,

Coleman
Technical Team - Équipe Technique
RobotShop inc.
Putting Robotics at Your Service!®
La Robotique à votre Service!®
Web: www.robotshop.com

Sign in at robotshop.helpserve.com to see your full support history.
Visitez robotshop.helpserve.com pour voir votre historique de support complet.

Sign in at http://robotshop.helpserve.com to see your full support history.
Visitez http://robotshop.helpserve.com pour voir votre historique de support complet.

Ticket Details

Ticket ID: WHX-208-80120
Department: Education / Teachers
Type: Issue
Status: Answered
Priority: Support

Re: Permission to use some information from your publication

danieljohnsimon@gmail.com on behalf of Dan Simon [d.j.simon@csuohio.edu]
Sent: Wednesday, April 17, 2013 9:46 AM
To: Loc Truong [truongchiloc@knights.ucf.edu]

```
You can feel free to use images from the thesis, as long as you
include a reference. I will not have time to help you during the
summer, but good luck with your research.
--
Dan Simon
Department of Electrical and Computer Engineering
Cleveland State University


On Tue, Apr 16, 2013 at 9:35 PM, Loc Truong
<truongchiloc@knights.ucf.edu> wrote:
>
> ________________________________
> Good afternoon,
>
> My nam is Loc Truong.  I am currently a senior student at University of
> Central Florida majoring in BsEE. While doing my research, I came across a
> great thesis written you, the autonomous Robot using Fuzzy Logic. I would
> like to some images and the derived mathematical equation for the Robot
> using Fuzzy Logic Control. This is for the purpose of academic
> only--research for Senior Design. Is it possible if you can be our group
> mentor during the summer?
>
> Please let us know if we have your permission to do so.
>
> Sincerely,
>
> LocTruong
```

Re: Fwd: Permission to use Product Images and Information

From: **Dan Gates** (support@solarbotics.com)
Sent: Tue 4/23/13 3:58 PM
To: Loc Truong (truongchiloc@msn.com)

By all means, you have our permission for this application.

Regards,
Dave Hrynkiw

On 4/23/2013 9:38 AM, Tech Support wrote:

> Sent from my iPod
>
> Begin forwarded message:
>
> > **From:** Loc Truong <truongchiloc@msn.com>
> > **Date:** April 23, 2013, 6:51:34 AM PDT
> > **To:** "support@solarbotics.com" <support@solarbotics.com>
> > **Subject: Permission to use Product Images and Information**
> >
> > Good Morning, I am a senior student at University of Central Florida major in BsEE. I would like to ask for permission to use the images of the Devantech SRF05 Sonar sensors found at in this link:
> > https://solarbotics.com/product/40310
> > The information will be used for academic purpose only. Please let us know if we can have your permission to include the images of the product named above.
> >
> > Sincerely,
> >
> > Loc,