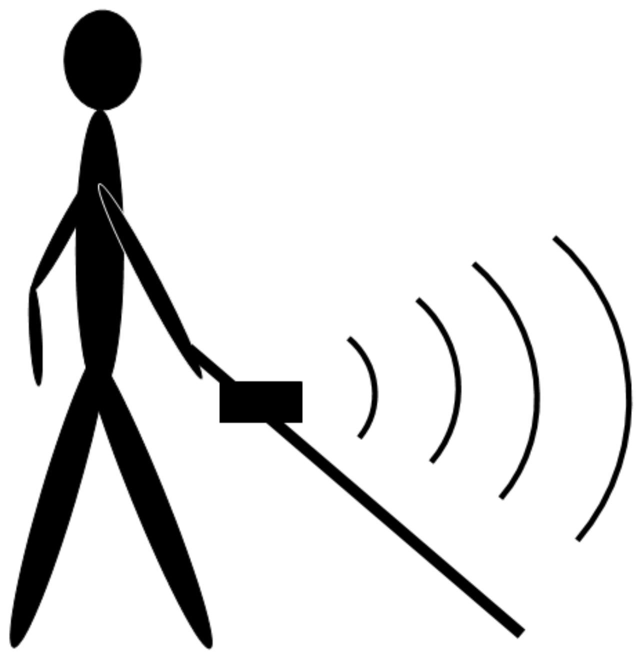
SenseWalk



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1. Executive Summary

Visually impaired individuals have long had the issue of struggling with independent mobility in the course of their day to day lives. As technology has progressed often certain members are left behind as the market is too small or their problems go unnoticed to the normal populace. One of the groups affected by this unfortunate problem consists of those that have experienced significant vision loss. Vision is a natural gift that many people take for granted as they go about their lives. It is what people use to be independent and go about their day which includes many vision-oriented abilities such walking to places, using objects and tools, etc. To compensate for their disabilities, many low-tech methods of independence have been offered to them that range from seeing-eye dogs to using a walking cane called a “white cane”. A white cane is used to feel around a few steps ahead of the blind individual by tapping the cane around them. However, this lack of technological innovation for the vision-impaired community is a hindrance for improvement as modern age technology offers many tools that can be used to enhance the day-to-day lives of those individuals.

According to data provided by the American Foundation for the Blind, there are 1.3 million Americans that are classified as legally blind, meaning that they experience significant vision loss [19]. Of those 1.3 million Americans, it is estimated that about 10,000 use a white cane to go to work, school, and run their errands [19]. How the white cane is used is that the person using the cane taps the ground as each step is taken to ensure that there is no obstruction in their path or even a hole or step to make them trip. Many visually impaired people use to cane to get a sense of “feel” for the terrain around them. This helps them negotiate their path as they walk about. The seeing-eye dogs also work as guides for those with visual issues. However, the dogs are very limited in what they can do. They can learn routes exceptionally fast and can avoid obstacles better than a cane can detect. Sometimes, a blind person may even use both a white cane and a guide dog at the same time. However, the dogs take a lot of time to care for and certain people might be afraid of large dogs. As mentioned before, the methods of independence are extremely limited.

The cane is an alternative to seeing-eye dogs or personal assistants as it doesn’t compromise independent mobility. It allows the individual to blend into society with little assistance or help from others. With a cane, they are able to be independent and not rely on others for their everyday needs. However, danger is still prevalent in the inability to distinguish between safe paths and hazards, thus presenting the opportunity for the cane to be perfected by modern-day technology.

To combat the limitations of the cane, this group has proposed the implementation of a “sensing” walking stick called “SenseWalk” that integrates voice-guided GPS navigation and proximity detection of its surroundings. The cane will be comparable to a standard cane used for the blind, which is long enough to reach from the person’s sternum to the ground. Sonar will be used to sense the surroundings of the individual and their proximity to any objects. A microcontroller will be integrated into the cane’s design that will aid in sonar detection and alerting the individual as they come close to an object by a voice-automated message. The individual may choose to connect their Bluetooth-enabled headset to the cane so that they can better hear messages emitted as they traverse a certain path. The user may also input a specific address (within walking distance) into the computing system component of the cane to calculate and direct a route for the user to undertake by receiving such instructions to hear from their headset. The entire apparatus may be affixed to any cane by strapping the console nearby the handle.

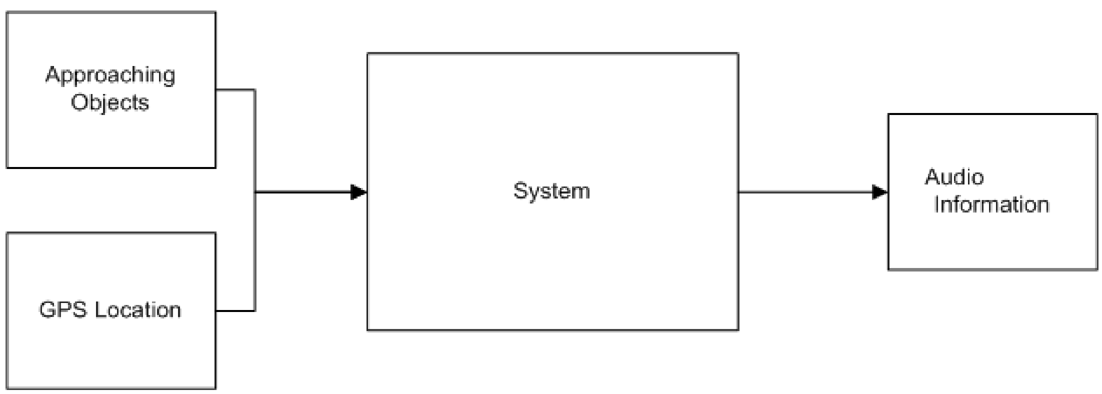

Figure 1.a-High-level block diagram of design

2. Project Description

This section will provide an overview regarding details to the project’s implementation and design in accordance to the goals and motivation that the group has outlined.

2.1 Project Motivation and Goals

The motivation for this project comes from the need to give back to the community. Engineering design applications that are helpful to humanity and affect individuals in a positive manner are one the reasons of why the engineering profession exists. This group wanted to design a product that can be used to help others in need that cannot help themselves and might not have constant support. Those with disabilities often only want to blend into society and not have others noticing their everyday struggles. Independence, greatly valued by such individuals, is integral to their identity and should be attained with any possible means with the help of whatever tools are available. This group stands to provide a new tool to help those with vision loss rely less on others and give them the ability to do more than they could before.

The group hopes that the implementation of the “SenseWalk” cane will be considered to be a helpful tool to the visually-impaired community. The main goal of this project is to improve the current use of the white cane by integrating frequently-used technology into its implementation. The use of GPS and the means of proximity detection through sonar will hopefully make travel easier and more efficient for these individuals.

2.2 Objectives

As mentioned before, the overall purpose of the project is to design and implement a console that can be attached to any standard white cane. Therefore, the console must be lightweight and must not interfere with the user as they use their cane. The console must also be able to use GPS-navigation that communicates to the user through Bluetooth headset step-by-step instructions guiding them along a provided or stored route. Furthermore, the console should have proximity detection that will communicate to the user through beeps that will again be heard through the user's headset. The overall goals that the system must perform are shown in Figure 2.2.a. If there is an upcoming obstruction in the path of the user, the “SenseWalk” console will alert the user with a “beeping” noise that they are about to step into it. The proximity detection must also be able to detect any dips or holes that the user might walk into soon. This detection should be designed to detect these various obstacles up to a minimum safe distance with enough timing to alert the individual to change their path before coming across the obstruction. The choice of how detection will be implemented may be done through using either sonar, infrared sensors, or by using a laser range finder. Overall, all of these components will need to be processed by a microcontroller that will take in information from the GPS, the proximity detection, and lastly it must process audio information to be sent out through Bluetooth connection to the user's headset.

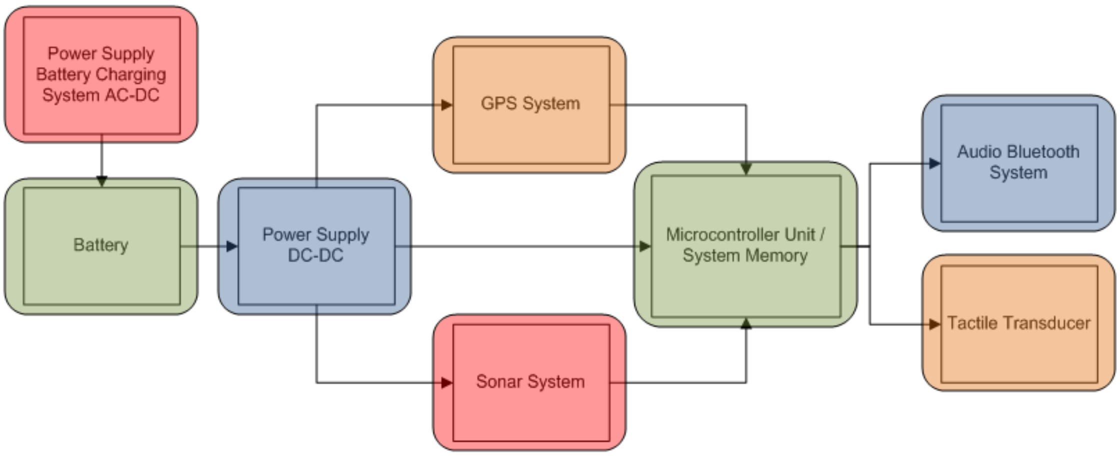

Figure 2.2.a-Mid-level block diagram

Because this project design is a mobile application, the “SenseWalk” console needs to be battery-powered. The console must be able to run on the battery pack for about 4 hours, allowing the user to recharge the console when the “SenseWalk” is not at use by simply plugging it into any standard wall socket. The charge time should not take too long as the “SenseWalk” should be readily available for whenever the user needs it. Overall, this means that every component must use as little power as possible in order to be energy efficient. The choice of possible batteries to employ includes the popular lithium ion battery option, nickel-metal hydride, or nickel-cadmium batteries. A low-power microcontroller, Bluetooth controller, and GPS are objectives that need to be researched in order for the entire console to run on batteries alone for that established time frame. Furthermore, power regulation must be established through the power supply design that will help meet this objective.

Many people in their day-to-day lives have a typical, established routine that may include routes going from home to work or going from one classroom to another. For those that use a white cane, it would be deemed useful to store some of their frequently used routes into the “SenseWalk” console through the means of external memory such as with a SD memory card. The GPS will keep track of the user as they go about a certain route that they have selected and instructions transmitted via Bluetooth will notify the user constantly of where they currently are and what direction they need to take soon. Even for when the option of not using a stored route is chosen, the GPS can help the user in keeping them informed of their current whereabouts. The GPS will need to use a software that offers access to maps in order to configure routes and pinpoint the user's location in real-time.

Due to of the lack of relying on vision, other senses are heightened for visually impaired individuals. One of these senses that is most advantageous to them is the sense of hearing. Thus, the “SenseWalk” design hopes to take advantage of this by transmitting necessary audio information to the user as they wear a headset while using the “SenseWalk” console on their cane. Bluetooth communication from the console to the user is an objective that the group hopes to achieve through the design. Wireless communication will be more efficient and less of a hassle for the user than having a wire run between the console and user. There are two things that need to be communicated to the user. This consists of instructions directed by the GPS for a given route and beeps that notify the user that they are about to come across an obstruction in their current path soon. It is important that the beeps do not interfere with the instructions to the point that they confuse the user or have them focus on one rather than the other. Users also have the option of not using the GPS and simply use the proximity detection feature of the “SenseWalk” to alert them of any nearby obstacles as they traverse their path. This option will be available to them with a button that they can press. The microcontroller will process this information and help transmit it with the assistance of a Bluetooth controller. This interface is necessary in order for the “SenseWalk” to be useful to a visually-impaired person.

2.3 Project Requirements

This section details the individual technical requirements to implementing the “SenseWalk” design. Since this design is divided into various components, there will be an examination of each individual component’s requirements and how it interfaces with the other components as a whole. Detailed analysis of what to expect from each component is provided with realistic expectations. This is to ensure that nothing the group has detailed is impossible to accomplish without limitations by the software, hardware, or engineer.

2.3.1 Power Supply Requirements

The “SenseWalk” will be a portable electronic device which will be powered by a rechargeable battery system. There will be multiple power conversion stages which each have specific requirements. There are two main subdivisions for the “SenseWalk” power supply design, AC-DC and DC-DC regulators. Since the “SenseWalk” will operate on a rechargeable battery, there is need for an AC-DC battery charging system. The AC-DC battery charging system will provide the means to recharge the “SenseWalk” battery supply when depleted. The “SenseWalk” will require multiple DC-DC regulators to power the various subsystems, such as the Sonar detection system, microcontroller unit, and the

Bluetooth unit. Below is a bulleted list of all the “SenseWalk” power supply design requirements.

- The AC-DC battery charger will have a minimum efficiency of 60%.
- The AC-DC battery charger must produce a desired regulated output.
- The AC-DC battery charger must have a universal operating range 90Vac - 280Vac.
- The battery must be light weight to provide a friendly user experience.
- The Battery must power the “SenseWalk” for a minimum of 1.5 Hours.
- All DC-DC converters must produce an accurate regulated output voltage.
- All DC-DC converters must be able to operate in typical environment operating temperatures.
- All DC-DC switching converters must have a minimum efficiency of 80%.

2.3.2 Object Proximity Sensing Requirements

The primary function of the “SenseWalk” is to alert a visually impaired user of approaching objects. Because the typical “SenseWalk” user will not be able to forecast approaching objects, the “SenseWalk” will provide this information audible. There are many ways to implement an object proximity circuit. Sonar, Laser, infrared, and visual are just a few viable options. No matter what option is implemented, there are specific requirements which must be met. Below is a list of the “SenseWalk” object proximity requirements.

- The object proximity system must successfully detect stationary large objects at a distance of 10 feet. (Large object defined as 1 cubic foot of surface area.)
- The object proximity system must successfully detect stationary large objects at an angle of 55 degrees.
- The object proximity system should not produce faulty information.
- The object proximity system should be a low power design, consuming less than 500mW maximum power. (For prolonged battery life)
- The object proximity system must not consume more than 6 square inches of PCB space. (For user convince)
- The object proximity system must weigh less than 0.25 pounds. (For user convince)

2.3.3 GPS Navigation Requirement

The GPS is the heart of the walk sense. It provides the main capability and usefulness to the visually impaired user. The "SenseWalk" will be using a GPS module to receive latitude and longitude coordinates that will be sent to the MSP430 microcontroller for processing
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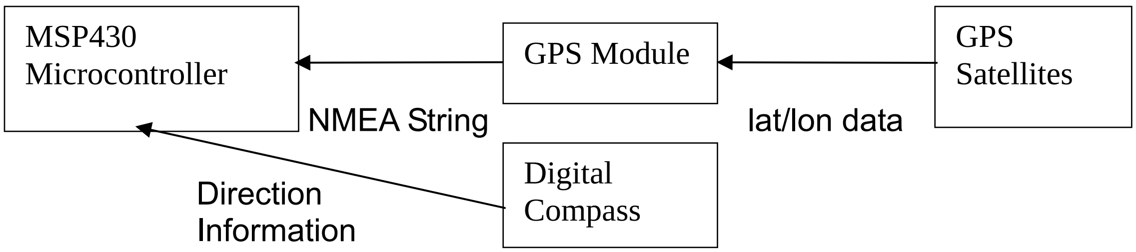

Figure 2.3.3.a: Flow of information from GPS satellites to MSP430

The "SenseWalk" requires the production of real-time directions and routing information to the user of the walking-stick. This is accomplished using an embedded GPS monitoring system that can learn the routes that the user wants and can reroute the user, if necessary, if they are led astray. The specifications for "SenseWalk" are very stringent. The reasoning is to keep the design lightweight, portable, and powerful while being able to run off of a battery.

The group will be using a GPS card made by Texas Instruments in order for it to seamlessly integrate with our MSP430 microcontroller also made by Texas instruments. All of this will be processed mostly using Open Source software that is easily available on the internet and requires no special permissions or licensing. Code Composer will be used in order to program the MSP430 microcontroller. This allows the group to program the software using higher level languages at the price of memory. Below is a bulleted list of "SenseWalk" GPS requirements:

- GPS module must interface with MSP430
- GPS module must output location/position data in NMEA industry format
- GPS module must have accuracy of at least 3 meters (if possible)
- GPS module must have target acquisition of less than 1 minute from power on
- GPS module must have hot start of less than 5 seconds
- GPS module must be independent, have all processing done within the module, and cannot require outside computational power
- Software must be able to select user waypoints and create a route
- Software must be able to output waypoint data using OpenStreetMap data

- Embedded software must be able to read CSV formatted file and load waypoint information from CSV formatted file
- Embedded software must be to accurately route user in real-time to within 10 meters of declared waypoint
- Embedded software must be able to send message to the user via Bluetooth-enabled headsets.
- GPS module must be low power (Power Consumption TBD)

3. Research

As with any engineering design process, research of current methods and designs is needed in order to analyze the most effective design implementation. Each subsection details research for all sub-systems of the “SenseWalk.”

3.1 Existing Design Solutions

There are multiple methods which the “SenseWalk” could implement to measure the distance of objects. The first method is called “Time of Flight” which is most commonly implemented with a laser range detector. This method simply sends several laser beams usually in a pulse, out to the object which needs to be detected. The time it takes for the laser beam to bounce off the object and back is then stored in the microcontroller. Since the speed of light is constant, the distance can then be calculated. This method is very accurate however this method can only work on longer distances usually over 100 meters because the speed of light is so fast. Another method to measure distance is called Triangulation. For triangulation a beam usually Infrared (IR) or laser is sent out and then it bounces off an object and is returned at another angle. The angle of the return and the distance can then be calculated using geometry. The last method is called ultrasonic time-of-flight or sonar. This method sends out a sound wave which then bounces off an object and is returned back to a sensor. The distances can then be calculated because of the constant speed of sound. Since the speed of sound is much slower than the speed of light, this method works with much smaller distances [20].

One system that we found similar to the “SenseWalk” is the K-Sonar Bat. This system is mounted on a walking cane and used sonar was well. This system alerts the user with sounds through a pair of head phones. This system does not have any of the GPS or Blue tooth like the “SenseWalk”. We believe that the “SenseWalk” will be able to accomplish all that the K-Sonar Bat can do and do much more to help the visually impaired.

3.2 Object Proximity Detection

One of the main key sub-systems which the “SenseWalk” will implement is an object proximity detection system. It will be very helpful for the visually impaired user to have access to information relating to approaching or stationary objects within the users walking path. Because the “SenseWalk” user will be unable to visually observe approaching objects, the “SenseWalk” must be able to detect this information and audibly relay it to the user. There are different options which could be implemented to detect an object’s proximity, such as Sonar, Infrared, or Laser methods. Each of these three methods has advantages and disadvantages which will be investigated and discussed below in more detail. Some of the important factors to decide the correct object proximity detection method are accuracy, size and weight, cost, and operating limitations.

3.2.1 Sonar

Sonar, also referred to as ultrasonic, systems have been around for many years. The operation of sonar works on the basics properties of sound propagation. Sonar is used to detect objects by emitting a sound wave through a transducer. The emitted sound wave will propagate through a medium until contacting an object. When the sound wave reaches an object, it is reflected back to the direction from which it was transmitted. Once the sound wave has been transmitted and received, the time of flight can be measured and then used to calculate the objects distance from the transmitting transducer.

Shown below in figure 3.2.1.a is a general block diagram for a sonar transmitter circuit. The microcontroller block is used to control the sound transmissions. Typically a sonar system will transmit a set number of sound pings, and then sound transmission will be shut off in order to detect the reflected signal. The microcontroller will allow for a burst of pings to be transmitted at the desired intervals.

The sound pings are generated by providing an oscillating signal to the sonar transducer. Typically a square or sinusoidal wave is used to excite the transducer. The required signal frequency will depend on the specific transducer and application. It is very common to use a frequency in the range of 20-60kHz.

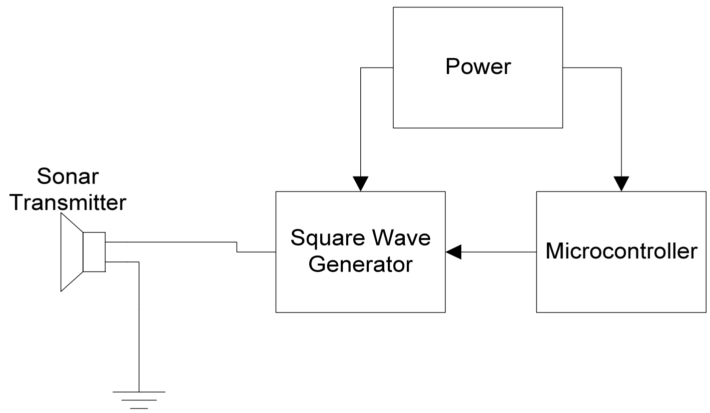

Figure 3.2.1.a (Sonar Transmitter Block Diagram)

Shown below in figure 3.2.1.b is a general block diagram for a sonar receiver circuit. A sonar transducer can also be used as a receiver to detect the reflected sound wave. The strength of the received signal will be vastly lower than the strength of the transmitted signal, because the sound wave is losing energy as it propagates through the medium. For this reason, the received signal will need to pass through an amplification block. Once the signal has been amplified to the desired level, it will need to be filtered. The filter network is necessary to remove any coupled noise that the signal could have picked up during the course of its transmission path. The filter network is designed based on the transmitting signal frequency. This signal can then be compared to the original transmitted signal to validate that a sound wave has been transmitted and received successfully. Finally, the microcontroller can recorded the time of flight and then calculate the object distance.

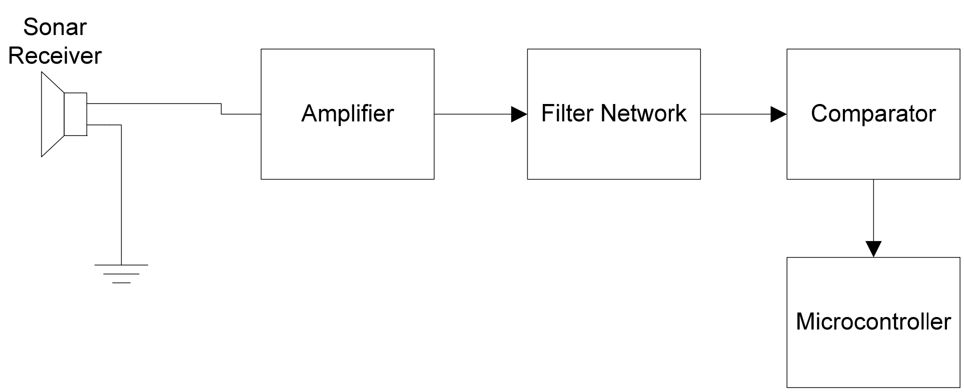

Figure 3.2.1.b (Sonar Receiver Block Diagram)

3.2.1.1 Ultrasonic Sensors

There are many different sonar transducers and manufactures. Certain transducers will allow for longer range sensing and a larger degree of sensing. Figure 3.2.1.1.a below shows a typical sound propagation pattern for a sonar transducer.

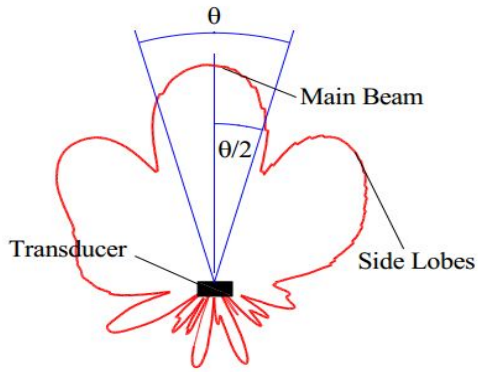

Figure 3.2.1.1.a-Transducer Sound Propagation Diagram
Permission Pending from Midas Components

The “SenseWalk” will require a sensing angle (theta) of 30 degrees and a sensing length of 10 feet. Both of these requirements should be achievable with the correct sonar transducer selection.

3.2.1.2 Sonar Software

The sonar will compose of a large software portion. The microcontroller will be responsible for controlling the sonar transmission timing and processing the received signal.

First the microcontroller must allow for a quick burst of pulses to excite the sonar transmitter. Once about 15 to 20 pulses have been emitted, the microcontroller will need to briefly shut down the sonar transmitter circuit. Once the microcontroller has disabled the transmitter for a designated time period, it will allow the sonar transceiver to “listen” for a returning sound wave, referred to as an echo. Because the signal strength of a propagating sound wave will weaken with transmission length, a circuit will need to be designed to amplify the signal. Since the signal beginning received will be at different strengths the amplifying circuit will need to be able to adjust the gain.

Once the microcontroller has received an echo signal, it must process the data.

To calculate the distance of a detected object, the microcontroller will use the time measured to receive the echo after transmitting the original sound wave. Because the speed of sound of a wave propagating through air is known, the distance can be calculated. Once a valid distance has been calculated, the microcontroller will need to send the data to the Bluetooth system where it can be converted to audible information for the user.

The microcontroller sonar software will also be responsible for detecting any faulty measurements. It is often possible for an echo to bounce around the room and returning to the receiver a few cycles after initially being sent. The microcontroller will need to recognize that the signal took too long to be received and must be a faulty measurement. Also the microcontroller will need to have a special case where a detected object is not approaching. If a detected object is not approaching, there is no reason to alert the user continually, as this would be very annoying for the user. This could be a possibility when the user is standing stationary and there is a stationary wall within the minimum detection distance.

3.2.1.3 Sonar Advantages/Disadvantages

Sonar has many advantages that will complement the design requirements of “SenseWalk”. The design cost for a fully functioning sonar system should be relative low. A set of sonar transceiver and receiver should cost less than $15. Besides from low cost, the sonar network can be designed on a small PCB with little added weight. The size and weight of the object detection system are very important. The “SenseWalk” needs to be extremely light weight and small so that it is not hassle for the user to carry the extra weight on their cane. Another strong advantage for sonar is its relatively low power requirements. It is vital to reduce the overall system power requirements to prolong battery life, and reduce the required battery size and weight.

Sonar has some disadvantages that will need to be overcome. Sonar is vulnerable to noise, so additional filtering will be required. Also, sonar can tend to display faulty readings due to echo noise. When the sound wave is transmitted it can bounce off lateral objects and result in faulty object detection. Even with the mentioned disadvantages, sonar should prove a good solution for object proximity detection for the “SenseWalk”.

After weighing all of the advantages and disadvantages, it has been decided that sonar will be a solid technology choice for the “SenseWalk” object detection system.

3.2.2 Infrared Sensors

Infrared range finding works based on the use of triangulation. An IR light beam is set out to detect the presence of an object. The beam is usually at a pulse of 850nm ± 70nm. The beam is then reflected off an object and back to the sensor. The angle of the beam is then determined and the distance is calculated from the measured angle. This is shown in figure 3.2.2.a below. This is done by a special lens in the receiver. The light beam passes through this lens and into a linear CCD array. The triangulation will be done and the range will be outputted in an analog form. The analog signal will then be able to be read by the microcontroller. In order to get rid of interference, a modulated frequency is emitted from the transmitter. This solution makes the IR beam able to determine ranges in any type of light and off of any object despite the objects color.

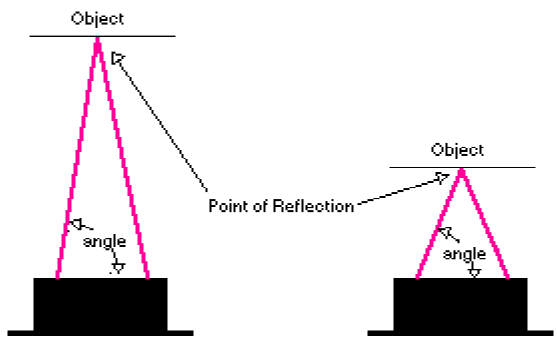

Figure 3.2.2.a-Beam reflection diagram
Permission Pending from Society of Robots

The biggest difference between sonar and Infrared is accuracy when operated in natural sunlight. The IR system typically tends to produce lower accuracy when operated in natural sunlight. This could be a big disadvantage since the "SenseWalk" will need to operate in direct sunlight [21].

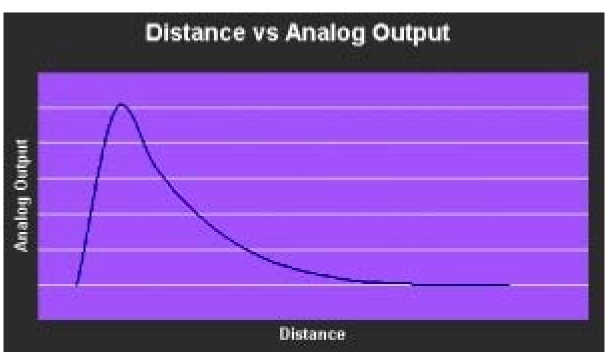

Figure 3.2.2.b-Distance vs Analog output for infrared
Permission Pending from Society of Robots

A disadvantage of IR range finding is that the analog output is non-linear. As shown in figure 3.2.2.b above. The graph shows that the IR range finder cannot detect close distances, as seen below in figure 3.2.2.c below. When designing an IR range finder the sensing range must be tuned with the proper operating range. When an object is the closer than the minimum range the IR range finder will act as if the object is much further than what it actually is. This can cause several problems with the “SenseWalk”.

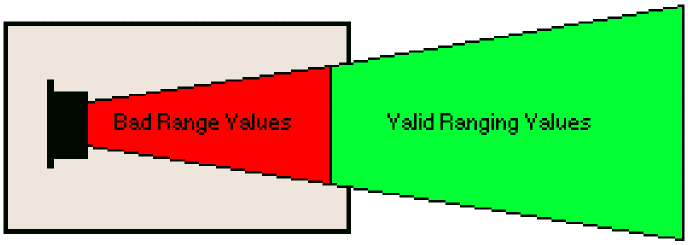

Figure 3.2.2.c-infrared range
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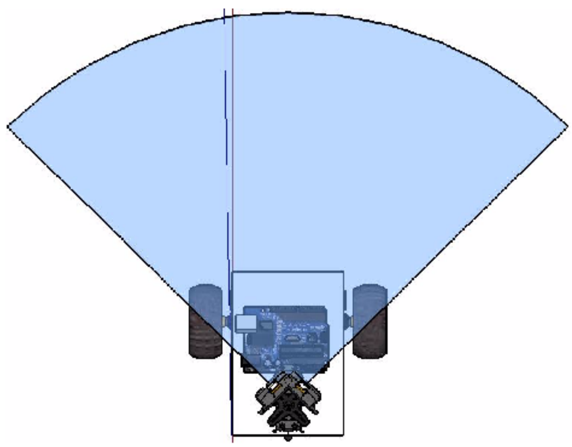


Figure 3.2.2.d-range of detection beam
Permission Pending from Society of Robots

The range of the detection beam is shown above in Figure 3.2.2.d. The advantage is that it has a wide angle and is capable of sensing objects anywhere in the range. If an object appears outside of the detection range, it cannot be detected. With a narrow range angel like sonar the location of the object can be much more easily determined but the device has to be pointed directly at the object.

Infrared triangulation for range finding is an effective solution to identify distances accurately. This in addition to the sonar will be the best combination to identifying distances. Since the infrared sensor is not necessary, this is a possible feature that may be added on in our final design.

3.2.3 Laser Range Finder

After researching the laser range finder technology, the minimum detection distance will not be sufficient for the “SenseWalk”. Because the speed of light propagates at too high of a velocity, the minimum measurable distance is too large for the “SenseWalk” requirements.

3.3 Microcontroller

The center of operation for the “SenseWalk” cane is the microcontroller, which will basically regulate and process incoming signals and output necessary functions. Certain criteria must be outlined in order to select the correct microcontroller for the “SenseWalk” project. These criteria correlate to the architecture, analog to dc conversion capabilities, memory capacity, and development tools associated with the microcontroller.

3.3.1 Architecture

First and foremost the group must have architecture considerations with regards to instruction set and instruction size. The microcontroller must be either 16- to 32-bit in order to process instructions from the incoming signals of the provided inputs in an efficient, timely manner in adherence to the proper pacing of the user’s walking with the cane. The choice of determining whether to pursue a reduced instruction set computing (RISC) versus complex instruction set computing (CISC) would be a minor factor when it comes to the design stage of the project as it may assist in programming the microcontroller if programming in assembly is needed at some point. It is common for CPUs with RISC architectures to implement faster due to the lesser complexity in their instructions and addressing modes unlike CISC architecture.

Many of the microcontrollers on the market today mostly utilize RISC. However, many microcontroller code compilers now give the option of writing microcontroller programs in either a high-level programming language like C or assembly so it should not present itself as a major issue in design development. Companies that offer microcontrollers also offer integrated development environments (IDEs) that have available tools to develop working software for their embedded systems. TI, for example, offers Code Composer Studio, which is based on the popular open source IDE, Eclipse, allowing users to program, compile, and debug their embedded system in C. For ease of use relative to maintenance and debugging, most of the programming for the project will be done in the C language in the IDE environment.

3.3.2 A/D Conversion

There are various inputs that will be communicating and sending information to the microcontroller to process and output back to the respective inputs interfacing with it. Thus, it is important to consider a microcontroller with enough general purpose input/output (GPIO) pins that will accommodate Bluetooth, GPS and sonar detection. These components will act as inputs and send signals to the microcontroller to process.

The microcontroller must be able to have direct interfacing with any analog components that are present. A microcontroller that has an analog to digital (A/D) converter with enough channels to accommodate any incoming analog devices is a necessity for the project. Most A/D converters utilize a successive approximation register which continuously takes in an analog signal and through a series of trial and error determines the correct digital approximation via a binary search. The entire chip itself must also require a low power supply as the cane is a mobile application and will be battery powered.

3.3.3 Memory

With regards to memory size, a common concern is finding the right chip that has a sufficient amount of memory that will contain all of the program code written for our application as the program will have to compensate taking in signals from the sonar detection, GPS, and Bluetooth controller. RAM and flash memory is a factor to research with regards to re-programmability. It's highly likely that code will be constantly rewritten and uploaded into the flash memory numerous times as software is being developed and debugged for the project. Typically, the higher line of a microcontroller family will offer more memory with regards to flash and RAM. If however, during testing, the need for more memory presents itself, adding external memory chips is an option however; the downside is that it can make things more complex with regards to memory management between our microcontroller and the external memory.

3.3.4 Development

A development board will be necessary for implementing the microcontroller with all necessary circuitry for the hardware. Programs will be uploaded through the development board to the microcontroller so that it can be ensured that the program has correctly met all design requirements. Any errors in the code can be monitored and fixed through this method. Many microcontroller manufacturers already offer development boards and kits designed for a specific family of their microcontrollers so applicability to a chosen microcontroller should not be an issue. A development board will allow becoming acquainted with programming and implementing the microcontroller. In addition to this, the board will allow the connection of peripherals that will communicate with the microcontroller such as connecting a Bluetooth module or external memory chips if needed.

3.4 GPS Software

The GPS software is the brain of the “SenseWalk”. Without the finely tuned algorithms, the navigation will not be possible. Much thought and work went into the research of many different software combinations that could seamlessly work together to take a selected route and guide the user.

This section details all of the possible software for two different plans. One plan involves using available software to provide an elegant solution to the routing issue. The second plan uses less overhead to accomplish the same task but is not as effective and will be much less mature than the first plan. The software detailed below will be included in one of the two plans.

3.4.1 TinyOS

TinyOS is an operating system that was made for low power and remote device operation. TinyOS sprang from the need of a lightweight dependable operating system for wireless motes that can run for some time without being monitored. It is completely open source and available for anyone to use. The language it is written in is NesC, which is based in some part on the C programming language. TinyOS was the result of time and effort between three groups: the University of California, Berkeley, Intel Research, and Crossbow Technology. It is now controlled by the TinyOS alliance, which monitors and steers its development in the industry.

NesC was chosen because it is optimized for the tiny memory capabilities that remote sensors and their networks contain. Other libraries and tools for NesC exist written in Java and shell scripts. The NesC compiler and its tool chain is written in C.Programs in TinyOS rise out of hardware abstractions and other software components. Many different components of a network are connected using interfaces. Packet communication, routing, sensing, storage and actuation are all built into the TinyOS libraries.

TinyOS only has one stack in memory from which it draws from. It is also non-blocking. The result of being non-blocking with one stack is that TinyOS can have high concurrency and parallelism but gives up simplicity. Programmers must include complex logic to handle many small event handlers. All inputs and outputs that last more than a few fractions of a second are asynchronous and have a resulting callback to verify transmission and receipt of any messages. In order to increase efficiency, the native compiler uses NesC to link any callbacks statically.

TinyOS provides tasks to allow for larger computations. A component can post a task which can be arranged to run at a more appropriate time by the scheduler. The tasks that it generates are non-preemptive and therefore do not force any other task out of order. The tasks are organized in a FIFO manner. The result is a simple platform that is very good with systems that have a lot of input and output but have a low CPU usage rate. TinyOS would falter with any application that becomes extremely CPU intensive. This has led to the new inclusion of threading libraries to TinyOS called TOSThreads.

Code generated in TinyOS is linked statically with the program code that it is running. The result is compiled by the GNU tool chain into a lightweight binary which is very small and stripped of any unnecessary features. Other features and utilities are provided to form a working platform for engineers to use and develop programs with TinyOs.

Installation Details
Path structure

```
/opt/tinyos/
          sources/
                 tinyos-2.x
                 tinyos-msp430
          root/
          scripts/
                  envsetup.subr
/opt/msp430/
somewhere/build/
         scripts-tinyos-msp430/
                             config.subr
                             toolchain.sh
         scripts-msp430/
                       config.subr
                       toolchain.s
```

Figure 3.4.1.a-Path Structure of TinyOS

/opt/tinyos:

This is where the whole TinyOS-related components will live in. This directory is configurable by prefix variable within the scripts-tinyos-msp430/config.subr.

/opt/msp430:

This is where whole MSP430 tool chain related parts will live in. This directory is configurable by prefix variable within the scripts-msp430/config.subr.
somewhere/build:

This is the directory where all build scripts will be executed from. In building process, a couple of source tar balls will be downloaded here and also a couple of repositories will be checked out here. One does not need to keep this directory's contents after building and installation are finished. One can install TinyOS and MSP430 tool chain by:

```
$ mkdir -p somewhere/build
$ cd somewhere/build
$ git clone https://code.google.com/p/tinyos-msp430.scripts-tinyos/ scripts-tinyos-msp430
$ git clone https://code.google.com/p/tinyos-msp430.scripts-msp430/ scripts-msp430
$ ./scripts-tinyos-msp430/toolchain.sh
$ ./scripts-msp430/toolchain.sh
$ ./scripts-tinyos-msp430/toolchain.sh cleanup
$ ./scripts-msp430/toolchain.sh cleanup
```

Figure 3.4.1.b-Installation of TinyOS and MSP430 tool chain

/opt/tinyos/root:

This is TOSROOT directory. Both the TinyOS main stream source tree and tinyos-msp430 source tree will be merged under this directory by stow command.

/opt/tinyos/sources/tinyos-2.*:

This is the TinyOS main stream source tree.

/opt/tinyos/sources/tinyos-msp430*:

This is the tinyos-msp430 source tree which will be merged with TinyOS main stream source tree.

/opt/tinyos/scripts:

This directory has scripts to setup the TinyOS development environment. You can source scripts/envsetup.subr shell script from login or session shell to set environment variables, such as PATH and TOSROOT etc.

```
# in your ~/.bashrc
source /opt/tinyos/scripts/envsetup.subr
```

/opt/msp430/scripts:

This directory has scripts to setup MSP430 development environment. You can source scripts/envsetup.subr shell script from login or session shell to set environment variables, such as PATH and MANPATH etc.

```
# in your ~/.bashrc
source /opt/msp430/scripts/envsetup.subr
```

[1]

3.4.2 TakaTuka

TakaTuka is a Java virtual machine (JVM) that was created to be used in wireless sensors motes. A sensor mote is a single node in a larger network of nodes that can do some limit processing onboard. The output data is either recorded or stored for analysis. A Java virtual machine is a program that can run on a particular OS and hardware so that Java byte code can be compiled and executed. Together with the Java API, it forms the JRE or Java Runtime Environment, where executed code is compiled. TakaTuka focuses its design on smaller devices so it is very lightweight and its API only contains classes necessary for the functionality of small, remote sensors.

TakaTuka was created by the University of Freiburg in Germany. It was published to Source Forge in 2009 and now is currently available to whoever wants to download it. Its purpose was to lessen the time it took for software engineers to develop sensor networks and associated applications by introducing Java across all the motes in the networks. Therefore all the sensors were easier to develop, maintain, and could communicate more easily with each other and other PCs.

The JVM takes the standard Java libraries and stores them into a stripped and compacted form called ‘Tuk files’. These files remove any needless fields of data, names, and class information. What is left of the classes is the bare minimum needed for runtime initialization. Not only is excess code removed, it undergoes byte code compaction that has smaller file size and much improved execution times. It uses a Split VM architecture that is similar to the Squawk virtual machine.

Currently it can support devices that have 4 KB or greater of RAM and more than 48KB of onboard flash memory. This flash memory can be internal or external to the board with the proper configurations. CLDC library support is currently available and compatible with all TakaTuka JVM software [2].

3.4.3 Code Composer

Code Composer is a special development environment created and maintained by Texas Instruments. This environment is strictly meant for use on the MSP430 microcontroller family suite. Code Composer has many features that make it an ideal product to use when programming a MSP430. A source compiler, code editor, build environment, profiler, simulators, real-time OS, and other features are currently available that allows the user to efficiently and effectively code on the microcontroller. A simple IDE points the user through the development process and allows for fast acclimation which speeds up development time and reduces costs. The associated tools and interfaces are very user friendly and allow for increased productivity.

Code Composer is based on Eclipse, which is open source software. Eclipse allows for easy addition of outside tools and libraries that other IDEs do not allow. The Eclipse framework is an ideal platform for creating new software environments and is becoming more commonplace throughout the software industry. Code Composer takes the advantages that Eclipse provides and adds in the special functionalities that TI provides in its tools. The result is an excellent tool with advanced abilities and a rich software environment for the end user. It is fast becoming a favorite with developers in the microcontroller community.
Code Composer Studio runs on both Windows and Linux Operating Systems so no matter what the preference is one can code in either OS. However, Linux currently does not support all of the functionality that is available for the Windows Operating System [3].

Features:

- Resource Explorer
- Grace™ – Peripheral Code Generation
  Grace is a feature of Code Composer Studio that allows MSP430 users to generate peripheral set up code within minutes
- SYS/BIOS is an advanced, real-time operating system for use in a wide range of TI digital signal processors (DSP), ARM microprocessors, and microcontrollers
- Compiler
  Code Composer Studio includes C/C++ compilers tailored for TI's embedded device architectures. Compilers for C6000™ and C5000™ digital signal processor devices get the most out of the powerful performance potential of those architectures

- Linux/Android Debug
  Code Composer Studio supports both run mode debug and stop mode debug of Linux/Android applications.
- System Analyzer
  System Analyzer is a suite of tools that provide real-time visibility into the performance and behavior of application code, and allow for analysis of information that is collected from software and hardware instrumentation.
- Hardware Debugging
  TI embedded processors include a selection of advanced hardware debugging capabilities.

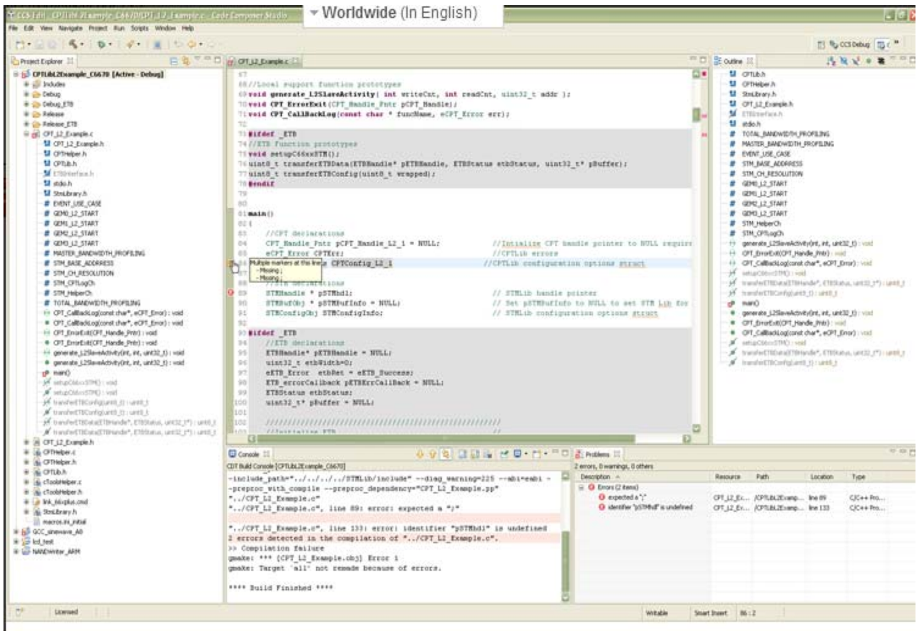


Figure 3.4.3.a-Code Composer IDE
“Courtesy of Texas Instruments”

3.4.4 GPX

GPS data is shared amongst many different applications and interfaces so the need to standardize GPS data was needed. The result is GPX, a XML format to store latitude/longitude data, tracks, elevation, and other data that can easily transferred between GPS devices, the internet, and other services. GPX was released in 2002 and is now used by tens of software programs for analysis, mapping, and geocaching.

The main features of the GPX format are:

- Waypoints: a single point containing a latitude and longitude.

- routes : A route is a group of waypoints with straight lines between sequential waypoints.
- tracks : A track is an actually traveled set of waypoints or a set of waypoints that are recorded as you follow a route.

The way the format works is that the user either manually creates a definitions file or generates it using a number of software or web services that contains waypoints, tracks, or routes. The resulting file is compared against a XML schema to determine if the data in the definitions file is valid and the data was generated correctly. One of the benefits of using GPX is the fact that it is based on XML, an open standard, which has a vast community and ample support by developers across the planet [4].

GPX is very easy to learn by someone with little programming experience, and yet it is extremely powerful in the ability to recreate extremely intricate geographical topography. People are emboldened to help further the standard and its evolution. An example of the GPX format is shown below in figure 3.4.4.a. From looking at this example the XML style format is apparent.

```
<wpt lat="42.454401" lon="-71.120990">
 <ele>66.696655</ele>
 <time>2001-11-28T21:05:28Z</time>
 <name>5254</name>
 <desc><![CDATA[5254]]></desc>
 <sym>Dot</sym>
 <type><![CDATA[Dot]]></type>
</wpt>
```

Figure 3.4.4.a- Example GPX Formatted Waypoint

3.4.5 OpenStreetMap

OpenStreetMap is project to document all of the corners of the planet in a free, editable, concise, and accurate map. The project is worldwide in scope and has many people contributing to its success. There are two major reasons why OpenStreetMap has become popular. The first is the need for accessible map data, which is usually licensed and extremely expensive. The second is the appearance of cheap, mobile guidance devices that is within reach for most segments of the populous.

The maps are constantly being tweaked and updated with data from many different outlets including aerial photos, local knowledge, GPS locators, and other free sources. Mobile applications on phones and other devices contribute the GPX data to the OSM database.

OpenStreetMap is stored in the .osm file format. There are multiple ways a user can download a preexisting file of a country or even the entire planet. Planet extracts are sections of different regions from around the planet. Every region that is updated in the OpenStreetMap database is updated frequently with new data. Many websites such as GeoFabrik and CloudMade have maps available for download. The full planet.osm is commonly found online. However, the file is very large and unmanageable for many applications. It is usually well over 10 gigabytes of data in most common versions.

Roma contains OpenStreetMap data as a read-only database that mirrors the OpenStreetMap database. Using Roma and a downloaded API, segments of a region can be filtered which allows for custom maps that are more lightweight than downloading a full region of data. It is much faster than the OpenStreetMap database and has less traffic to the website. The only downfall is that a custom extract being created is generally slower than downloading a larger region of data. OsmXapi is an interface that can be used for supporting larger areas than other APIs that are available. Osm2GpsMid and OsmXapi are able to interact and share data. Figure 3.4.5.a shows a screenshot of the Osm2GpsMid interface. It is from this interface the user can manage the output from the OpenStreetMap. As stated before the user can select any number of sizes, regions, output formats, and many more options exist [5].

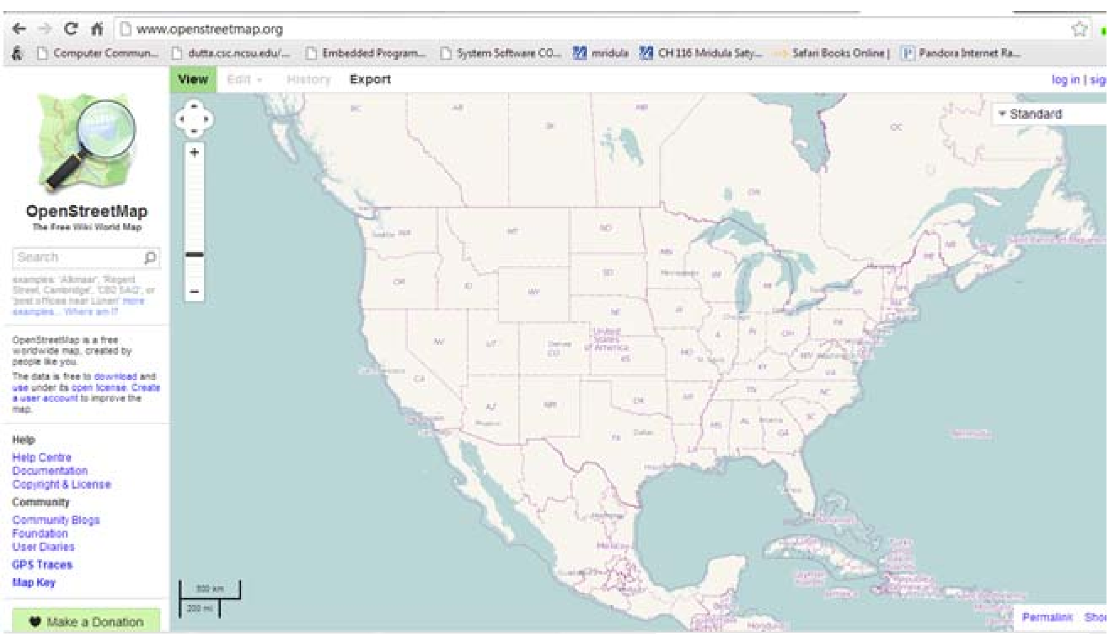


Figure 3.4.5.a- OpenStreetMap Screenshot © OpenStreetMap contributors
“Reprinted with permission from Open Source Private Policy”

3.4.6 Osm2GpsMid

Osm2GpsMid is an open-source desktop GUI that uses the OpenMapData database to create waypoints information. It is a simple-to-use interface that makes creating maps easy for any person with limited knowledge of the computer software. This application has the ability to read in any size OpenStreetMap data file whether it's the entire planet or a country, extract only the area the user is interested in, convert the data, and write the J2ME application and the JAD-file. (http://gpsmid.sourceforge.net/osmtogpsmid.html)

The output of the program is stored in GPX format within special portable files called midlets. A midlet is simply a storage container for the onboard OpenStreetMap data that is uploaded, processed, and displayed on the walking stick using GpsMid software. Figure 3.4.6.a shows the Osm2GpsMid graphical user interface. It is from this interface the user can select a waypoint, route, track, or just simply search around the Osm2GpsMid options. It is very simple to use and takes no time for the user to figure out how to use the individual features to output what they need for guidance.

Osm2GpsMid is a complementary program to GpsMid, which is commonly found on mobile electronics, PDAs, tablets, etc. The GpsMid project is the designer and originator of this software therefore they are designed to work with each other without issue. Osm2GpsMid takes an .osm file from OpenStreetMap or any other database of the planet and is able to create the data from this file. The resulting output file is then able to be parsed by the GpsMid embedded software in the “SenseWalk” [6].

Figure 3.4.6.a- Osm2GpsMid
“Reprinted with permission from Open Source Private Policy”

3.4.7 GpsMid

GpsMid is the software that will be used in onboard memory to process an OSM2GpsMid midlet. The resulting information will be used along with the current GPS coordinates of the CC4000-TC6000 in real-time to route the user of the “SenseWalk”. The midlet contains the route and its associated waypoints, which GpsMid knows how to process and parse the XML formatted data.

GpsMid is an Open source program the uses vector based maps and runs in a JM2E or Java environment with Android. It can have data outputted to a LCD screen that can be configured by the user. Features such as zoom can be used to explore the map as routes are being traveled. All data is compacted as the target devices that this application is used on have low amounts of onboard memory available.

It currently uses the OpenStreetMap database for its vector based map data. OpenStreetMap is still currently being developed everyday so its accuracy is only as good as the data that is inputted. So new roads and infrastructure development is not expected to be readily available for download and routing with the GpsMid or Osm2GpsMid applications.

One of the main features that are useful is the voice commands. Currently over 20 commands are stored in the GpsMid source code. This allows for routing using external Bluetooth devices or speakers mounted in the device that the user is currently using. GpsMid also provides support to add new voice commands in case you wanted other dialogue used for routing or communication to the user.

Figure 3.4.7.a shows the GpsMid user interface. This is how the select route is displayed to the user. This will be convenient for debugging so we can see if the “SenseWalk” was able to correctly parse the input route but it will not be used visually on the “SenseWalk”. The GpsMid will simply run in the background of the device as the user walks the provided route. Directions will be provided audibly via Bluetooth so the visual user interface will not be relevant to the impaired. [6]

Currently supported features:

- Vector rendering of the roads, areas and points of interest
- Displaying the map either north on top or in the direction of driving
- Centering the map to a position received from your GPS:
- NMEA GPS-unit with Bluetooth connection.
- Based on Cell-ID (using opencellid.org)
- Zooming in and out to arbitrary levels of detail.

- Displaying the name of the street you are on and the maximum speed you may travel.
- Searching for a name (street, city or POI) and jumping to it on the map
- Searching for close by points of interest
- Calculating a route to a target street and navigate to it with voice guidance and textual instructions
- Adding and deleting of waypoints to the map
- Recording and displaying of track logs
- Importing and exporting track logs and waypoints to and from GPX [6]

One of the issues with using this software is the fact that it will require a java environment from which to run in. The simplest way to implement this software will be to run a java virtual machine. However, running this JVM will require a lot of overhead on the MSP430 and might run into an issue with memory allocation between running the GpsMid, JVM, and other features of the “SenseWalk” such as sonar at the same time. This issue might require the use of the stellaris or other high end microcontroller to combat the memory issue.

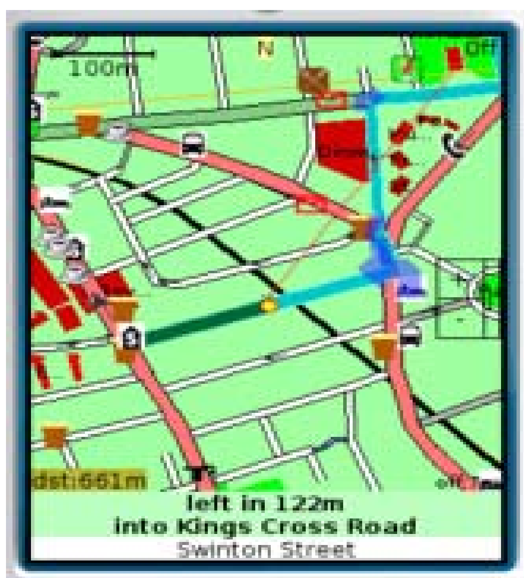


Figure 3.4.7.a- GpsMid Route
“Reprinted with permission from Open Source Private Policy”

3.5 Wireless Communication

Two methods of wireless communication are used in the “SenseWalk” design. These methods consist of Bluetooth and GPS. The use of Bluetooth for audio communication between the console and the user eliminates the nuisance of a wire running between the user and the console. GPS is another wireless communication that will allow the “SenseWalk” console to communicate with GPS satellites in order to procure route configuration and guidance to the user. With both of these methods used in accordance with each other, they will provide the main interface between the console and user.

3.5.1 Bluetooth Communication

A Bluetooth controller chip will be needed to communicate audio information wirelessly to a Bluetooth headset that the user will be wearing while operating the cane. That way, the user will be given voice-guided instructions on a given route. Thus, it will be required of the controller to obtain instructions from the GPS and transmit the string of instructions on a given route into an audio signal for the user to receive and hear from their headset. Bluetooth works on a range of up to 100 m with a Class 2 Bluetooth device. However, only a range of up to 10 m with a Class 1 device is needed due to the close proximity that the user is at with their cane in their hands at all times during use.

Bluetooth uses a radio frequency that operates on the 2.4 GHz unlicensed (industrial, scientific, and medical) ISM band of radio frequencies. This allows the console to communicate with many possible Bluetooth-enabled devices if needed. Typically, a Bluetooth device can establish a connection with up to 8 devices all at the same time. This means that any Bluetooth-capable headset should be able to easily interface with the “SenseWalk” cane.

The Bluetooth controller has software that holds and implements the Bluetooth protocol stack. All Bluetooth controllers have the three mandatory protocols already intact that are relative to finding other Bluetooth devices and setting up connection. This is called the Bluetooth protocol stack and a standard stack for Bluetooth is shown in figure 3.5.1.a below. These protocols are the link management protocol (LMP), the logical link control and adaptation protocol (L2CAP), and the service discovery protocol (SDP) as shown in the figure below with an audio protocol included. The protocol stack holds various profiles in addition to the mandatory protocols to use information relative to the purpose of protocol profiles to determine what devices to connect to. This happens only if they hold the same protocol profiles. For this specific case, our Bluetooth controller of choice must also have an advanced audio distribution profile (A2DP) that designates that this chip has the given feature of transmitting audio information. The headset itself must also hold the same A2DP profile in order to properly receive and make sense of the audio-related transmission.

The controller that is need for the project design must also hold a synchronous connection-oriented link (SCO) for establishing the transmission of voice data since the GPS instructions will be transmitted as voice instructions for the user to hear. Furthermore, the controller must have a host/controller interface (HCI) protocol that allows it to communicate with the microcontroller through a universal asynchronous receiver/transmitter (UART) connection. In addition to this necessary feature, one of the best advantages to Bluetooth is that it consumes little power, making it a perfect attribute for the battery-powered console.

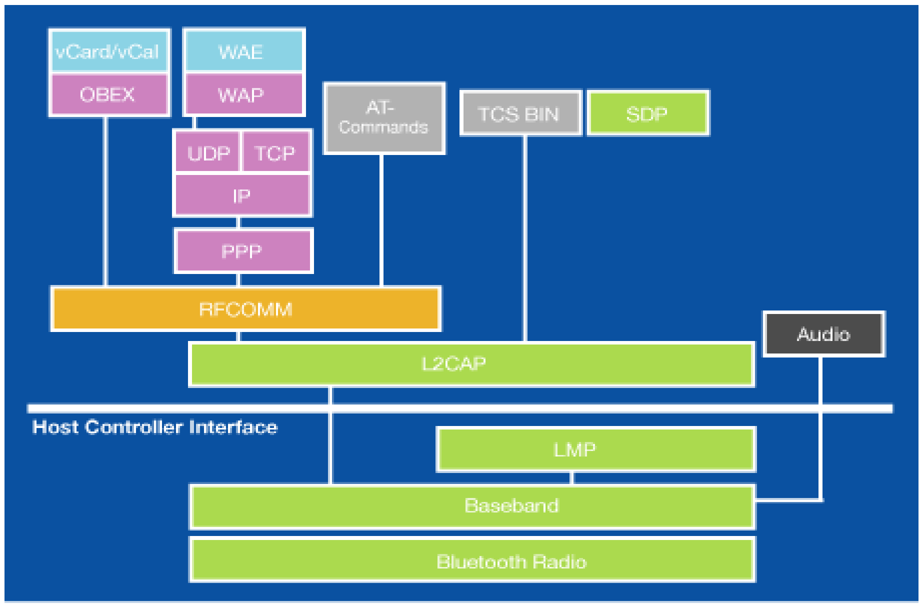


Figure.3.5.1.a-Bluetooth Protocol Stack
Permission pending from “bluetomorrow.com”

The chip will be a transmitter sending information to the headphones set. Because Bluetooth connection has a master/slave type relationship, the main console of the “SenseWalk” cane which holds the Bluetooth chip, will be the master controlling unit. The headset that the user will be wearing will be the only device that will need connecting to and will be the slave unit. No information will need to be sent from the headset to the “SenseWalk” console. Therefore, communication will be established in one-direction and there is no need to have to worry about being forced to only finding a transceiver-type Bluetooth controller. Instead, it is only necessary to find a transmitter-type controller with a high data rate established. However, a transceiver module is also sufficient.

How the communication process works is the personal-area network (PAN) or piconet will be set up between the two units according to the link management protocol (LMP) on the controller that dictates the speed and size of data being sent. Interference between other neighboring Bluetooth devices should never be an issue due to the method of spread-spectrum frequency hopping that Bluetooth utilizes. Frequencies constantly change thus making interference from unconnected Bluetooth devices unlikely. If, by some rare occurrence, that interference does occur, software has been written into the Bluetooth controller stack protocol that handles and prevents such errors.

As of right now, the most current version of Bluetooth design specifications is Bluetooth v4.0. This version is backwards compatible with previous Bluetooth versions and many of the available controllers on today's market are version 4. Thus, it would be within our best interests to use a version 4.0 controller. This version consists of implementing the Bluetooth low energy (BLE) feature while being able to simultaneously communicate data at a high speed, the enhanced data rate (EDR) feature. As the versions of Bluetooth progressed, they've adopted other modulation implementations to use. For this given application, however, whatever modulation method the controller utilizes should not present itself to be an issue during design and testing. Typically, BLE utilizes Gaussian frequency-shift keying modulation while EDR implements differential phase-shift keying (DPSK). The controller that is needed for this design will have to offer a dual-mode, allowing the use of both of these protocols.

3.5.2 GPS Communication

The GPS module will determine its location by contacting the Global Positioning satellite network. The network currently consists of 24 orbiting satellites. 3 satellites are needed to determine the latitude and longitude of the “SenseWalk” user. The satellites and module then use triangulation to determine the exact position of the module and sends the appropriate information back to the module. From then on the module does internal calculations and will relay the results back in the standard NMEA formatted string.

There are multiple reasons for using GPS. The fact that is free and requires no subscription to use its service other than buying the GPS module allows it to be cheap yet effective. GPS is extremely accurate. Today’s GPS receivers are getting the correct location from within 10 feet. Another feature is the ability for GPS to work no matter rain, sleet, snow, or cloud cover. This allows our user to always rely on the fact that the GPS will not suddenly stop working unless the battery dies out or the satellites become inactive.

There are a few downsides to using GPS in the “SenseWalk”. One major issue is that if the user happens to travel underneath any solid structure or within a building then the GPS signal can be lost. The signal does not travel through solid materials effectively. If the number of visible satellites drops below 3 then the GPS module will have issues receiving lat/lon information. Errors also happen due to a few reasons. Tall buildings reflect the signal and add to delay. Slight timing errors between the transmitter and receiver can lead to inaccuracies in the reported position. Orbital errors of the satellites position add to the inaccuracies of the GPS signal. (http://www8.garmin.com/aboutGPS/)

3.6 Power System

The "SenseWalk" will be a light weight portable electronic device which will require electrical power for operation. Because the "SenseWalk" will be portable, the system must be able to fully operate on a small lightweight rechargeable battery. There are many battery technology options available such as NiCd, NiMH, and Lithium Ion. Each battery technology will be researched and described below in section 3.6.1. This will allow for the optimum battery technology selection for the "SenseWalk" application. Factors to be considered for battery selection are size and weight, price, charge duration, and charge lifetime.

The "SenseWalk" will have many sub-systems, such as microcontroller, GPS, Bluetooth and Sonar each sub-system will require a specific constant supply voltage. Since it is not feasible to have a designated battery, with a specific voltage for each sub-system, DC-DC converters will be utilized. DC-DC converters will allow for multiple supply voltages to power the sub-systems. There are two types of DC-DC converts, linear and switch mode, it is important to understand DC-DC converters and the many topologies, therefore a full description has been provided below.

As mentioned above, the "SenseWalk" will be powered by a rechargeable battery; therefore an AC-DC battery charger needs to be designed. Most all consumer portable electronics require an AC-DC battery charger. As the battery is depleted, the user will need to recharge the battery. Because of the easy access to AC outlets, batteries are charged from AC voltage. But batteries cannot be directly charged from AC voltage, DC voltage is required. For this reason there is need for an AC-DC converter, and a full description has been provided below.

Often for user convenience and battery protection, battery charging systems utilize charge level detector. There are many manufactures who produce fuel gauge IC's. The fuel gauge IC will be interface to the microcontroller. Provided below in is a description on battery charging and fuel gauge measurement circuits.

3.6.1 Battery Technologies

The "SenseWalk" is a portable device that will need to be powered by a rechargeable battery. The common choices of batter technologies are NiCd, NiMH and Lithium Ion. The advantages and disadvantages of the various battery technologies will be discussed in the sections directly listed below. Since the battery will only have a limited battery life, there will be a need to alert the visually impaired person as to how much battery is left in the “SenseWalk”. The “SenseWalk” will incorporate a button that can be pressed to audibly project how much battery life is left on a 0% to 100% scale in intervals of 10%.

3.6.1.1 NiCd

NiCd is a type of battery called nickel-cadmium. NiCd is a rechargeable battery that uses nickel oxide hydroxide metallic cadmium. This battery is durable and is easy to work with. NiCd has several advantages one is that is has longer life cycle. The battery also has a fast charge time even after being stored for a long time. NiCd can be charged and discharged over one thousand times. Even though the NiCd has a good storage life it will lose charge after storage without use for a period of extended time. It also operates well in cold temperature down to 20 degrees Fahrenheit. It also has little to no drop off voltage at the end of the charge so that you can get constant performance throughout the charge. NiCd has some disadvantages. The first is that it is quite heave are large for the amount of charge. The battery should be discharged all the way before charging again. If the battery is only discharge half way and charged to full gain this can lead to damaging of the battery. Also if not disposed of properly the NiCd can have a negative environmental effect.

3.6.1.2 NiMH

The nickel metal hydride which can be abbreviated NiMH. This battery uses a hydrogen-absorbing alloy for the anode and nickel for the cathode. An internal diagram is shown in Figure 3.6.1.2.a. NiMH is a much newer battery technology compared with NiCd. NiMH has several advantages the first is that it is light than NiCd. That NiMH has 40% more energy per mass as compared to NiCd. A second advantage of the NiMH is much more environmentally friendly over both NiCd and Li-ion. It is also cheaper than Lithium Ion batteries. NiMH also has several disadvantages. The amount of life cycles are fewer than NiCd batteries. NiMH also performs poorly in cold weather. When the battery reaches the end of its charge the voltage will drop off which can reduce the performance of the device. NiMH also has a higher self-discharge rate than NiCd.

3.6.1.3 Lithium Ion

The last battery that was looked at is Lithium ion (Li-Ion). The battery is the newest and the most popular today over the NiMH and the NiCd. Despite the advantages of NiMH, Lithium ion is the best battery for the “SenseWalk” design. The Lithium ion also beats the other two batteries in temperature and can have great performance down to zero degrees Fahrenheit. It also is very light weight and has the best size to energy ratio than the other two batteries. Since size and weight are a great concern in the “SenseWalk” design, there is need to reduce these specifications. The life cycles are also the longest among the three. It also has very fast charge times. The disadvantages come with the designing the circuit used for the battery. With the lithium ion batteries, if the battery is over charged or over discharged this can damage the battery. So protection circuits are need.

We have decided go with the lithium ion battery for the Sense Walk because of all the advantages it offers over the other batteries. We have chosen as 7.2V 2600 mAh battery pack with a protection IC. This will result in great performance over a long time. Since a protection IC is included the chances of damaging the battery are greatly reduced.

3.6.1.4 Battery Charging

With most rechargeable batteries the cycle of charging and discharged has a great impact on the battery. With Lithium Ion batteries this is not the case. Lithium Ion batteries can be charged and discharged with almost no effect on the life of the battery. However in order to maintain this long life several precautions need to be taken. The first is that the Lithium Ion battery cannot be overcharged. This is because anything over the specifications of the battery will cause stress and damage to the Lithium Ion battery. For this reason a voltage limiting circuit needs to be used.

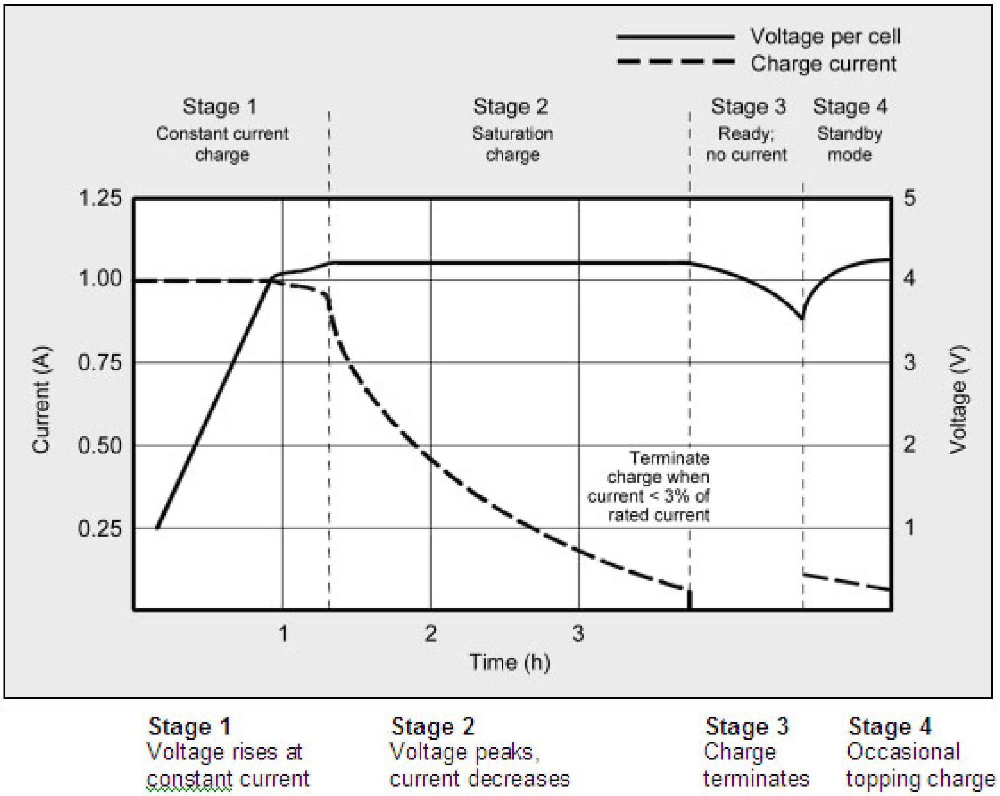


Figure 3.6.1.4.a-Four stages of a Lithium Ion battery
Permission pending Battery University

The Figure 3.6.1.4.a above shows the four stages of a Lithium Ion battery. In the first stage, the battery charges and the voltage increases while the current stays the same. In the second stage the voltage has peaked and stays constant while the current decreases till it is <3% of the rated current. At this point the current drops off while the voltage starts to decrease, this is the third stage. And in the fourth and final stage a topping charge is applied to make sure the battery stays at a full charge [22].

During the first stage the battery is charged at a rate of 0.5 to 1 coulomb at efficiency of 97% to 99%. Some batteries might see a temperature increase of 5 degrees C, this is usually due to the internal resistance and the resistance of the protection circuits around the battery. When the current is increased the amount of time in stage 1 will decrease while the time in stage 2 will increase. This is because the battery will reach the peak voltage faster but the saturation in stage 2 will take longer.

A Lithium Ion battery, unlike a lead acid battery does not need to be fully charged in order to function properly. Actually the opposite is true; in order to avoid stresses on the batteries, it is better to not fully charge the battery. The

“SenseWalk” will have the option to use a quick charger that will charge 85% of the battery in about an hour. Or the “SenseWalk can use a standard charger that will result in almost 100% of the batteries value but will take longer to charge. Because the “SenseWalk” will need to make the battery last as long as possible, it has been decided to use a standard charger instead of the quick charger. Because of this the “SenseWalk” will need to incorporate a protection circuit to make sure the battery is not overstressed. Adding full saturation at the set voltage boosts the capacity by about 10 percent but adds stress due to high voltage.

Charge V/cell	Capacity at cut-off voltage	Charge time	Capacity with full saturation
3.80	60%	120 min	65%
3.90	70%	135 min	76%
4.00	75%	150 min	82%
4.10	80%	165 min	87%
4.20	85%	180 min	100%

Table 3.6.1.4.a-Battery capacity information
Permission pending Battery University

Table 3.6.1.4.a above shows different charge thresholds. Some manufactures will list the thresholds lower than they actually are to avoid overstressing the battery and thus increasing the life of the battery.

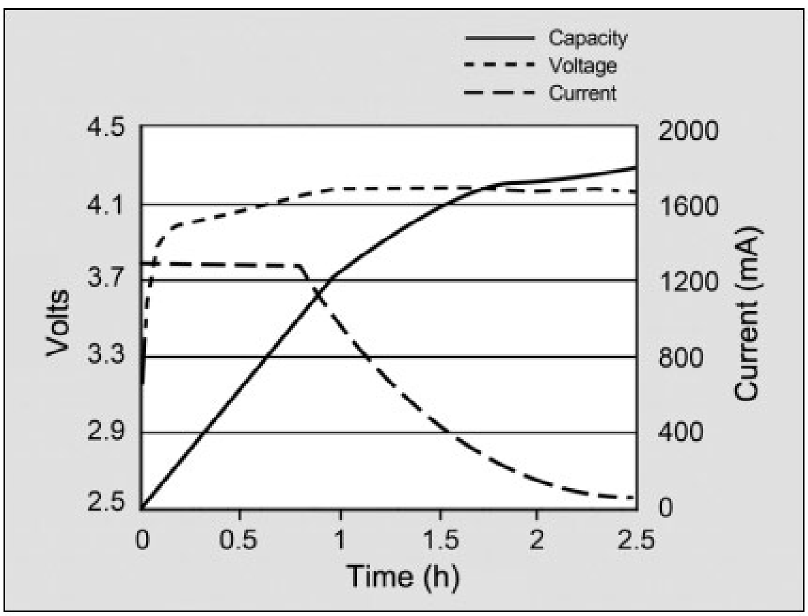


Figure 3.6.1.4.b-Charge thresholds
Permission pending Battery University

When a charge is first placed on a battery, the voltage will increase very quickly at first and then will begin to level out as time increases. The charge will increase at a more constant rate as time progresses. While the current will start high and constant, as time progresses the current then will decrease as a function of time. Figure 3.6.1.4.b shows this change in current. The “SenseWalk” will need to be able to measure the state of charge.

Overcharging the Lithium Ion can result in a reduced life cycle. On the other hand if the Lithium Ion battery is discharged too low this can also damage the battery. The “SenseWalk” will also have a safe guard circuitry in place to prevent over charging or discharging.

There are two types of circuits that can be used to measure the capacity of the battery. One is the Closed Circuit Voltage (CCV) and the other is the Open Circuit Voltage (OCV). OVC is the potential difference in voltage of the two terminals on the battery when no load is connected to the battery. CCV is the potential difference in voltage when the battery is under a load. It is important to be able to measure the charge of the battery. CCV is one of the easiest methods but can be inaccurate.

The individual cells can have different chemical compositions which can give off different results. In addition, temperature affects the reading. Higher temperature can raise the voltage reading and lower temperature can lower the voltage reading in the OCV method. Because of the volatility with the chemicals inside the battery it is recommended to wait from 4 to 24 hours in order to get a proper reading. Because of the long wait time this method will not be efficient for the “SenseWalk” design.

An alternative method is called Coulomb Counting. This is the method that most laptops and other portable devices implement to calculate the State of Charge of the battery. This method works by simply measuring the amps into the battery and the amps out. If ‘A’ number of amps are put into the battery over time ‘T’ then ‘A’ number of amps should be outputted over the same ‘T’ time. This method can be inaccurate towards the end of the charge.

3.6.2 Power Regulation

Every electronic system will require the design of a power supply in order to power the device. Power supply design is a vast and complicated field that requires much knowledge for a successful design. The two main sub-divisions in power supply design are AC-DC and DC-DC. There are also designs that require DC-AC, but this application is not as common as the first two listed. Power supply designers face many new challenges, such as size constraints, high efficiency, and high Power Factor requirements.

There are numerous numbers of circuit topologies that can be implemented in power supply design. The designer will choose the correct topology based on the specific application, design requirements, and available cost. There are two types of regulators, linear and switch mode regulators. Linear regulators were being used many years before switch mode regulators.

Both regulators provide the same function, but the designs and performance will differ between the two. In recent years, switch mode power supplies have become a very popular choice for designers. Switch mode power supplies are used in many applications, ranging from powering CPU's and smart phones to drivers for LEDs. Every electronic device will require power management.

The "SenseWalk" will require DC-DC linear and switching regulators and also an AC-DC switching converter. All DC-DC regulators will convert the input voltage from the lithium ion battery to the required output voltage. The AC-DC converter will convert 90Vac – 280Vac to the required voltage to charge the lithium battery.

3.6.2.1 Linear regulators

There are three main forms of linear regulators; they are the Standard Linear Regulator, Low-Dropout (LDO) Regulator, and Quasi-LDO Regulator. Figure 3.6.2.1.a below shows a schematic representation of a LDO Regulator.

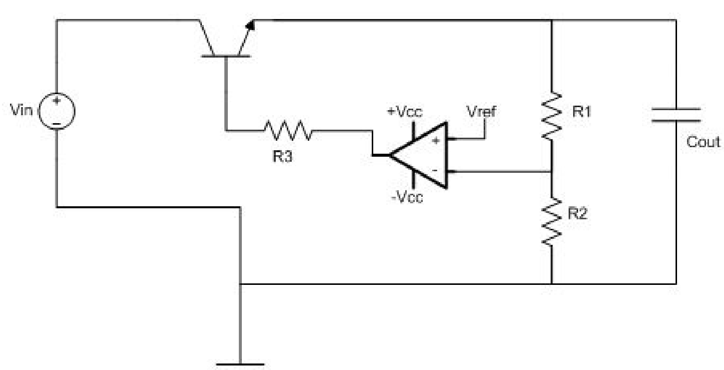


Figure 3.6.2.1.a-LDO Voltage Regulator Schematic

Linear regulators operate by applying a stable reference voltage to the non-inverting pin of the error amplifier. A divided voltage from V_out is applied to the inverting pin of the error amplifier. The amplifier tries to keep the inverting and non-inverting pin at approximately the same voltage by adjusting the voltage of the output pin. As the output pin of the error amplifier adjusts, V_out is forced to regulate. An important condition for V_out to regulate is known as the dropout voltage. If the voltage goes below the minimum dropout voltage then V_out will no longer regulate.

3.6.2.2 Switching Regulators

There is a long list of topology choices for Switch Mode Power Supplies. Circuit topology refers to the arrangement of active and passive electrical components. There is not a “one size fits all” SMPS design; the correct topology selection depends on the specific application and requirements. In consumer electronics, the most commonly used DC-DC topologies are the Buck (Figure 3.6.2.2.a) and the Boost (Figure 3.6.2.2.b); while the most commonly used AC-DC topology is the Flyback (Figure 3.6.2.2.c).

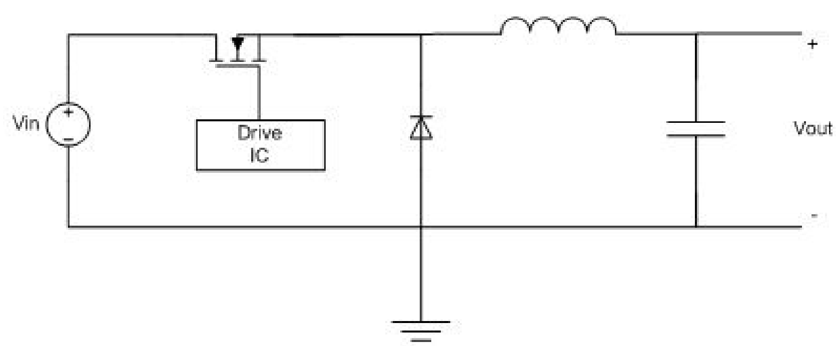


Figure 3.6.2.2.a-Buck Regulator Schematic

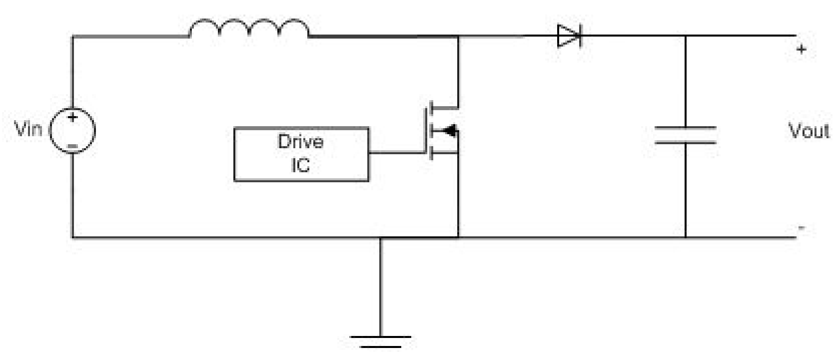


Figure 3.6.2.2.b-Boost Regulator Schematic

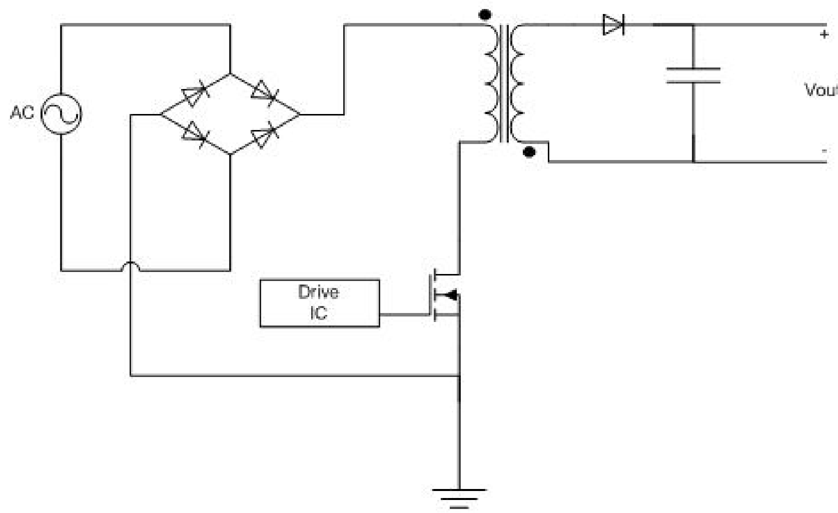


Figure 3.6.2.2.c-FlyBack Regulator Schematic

It is necessary to understand the operations and limitations of the all the fundamental Switch Mode Topologies. With the circuit fundamentals understood, an engineer is able to choose the correct SMPS topology for the given application. Without understanding the operations of the various SMPS topologies, a design will suffer in functionality and efficiency.

When selecting the correct topology, many factors need to be considered. SMPS topology selection is based on required input voltage, output voltage, output power, number of outputs, isolation, non-isolation, max load current, design cost, design complexity, inverted polarity, and size constraints. Each variable needs to be considered in order to select the correct topology for the given application. A poor selection in topology will result in a failed design. Figure 3.6.2.2d below is a general flowchart that is useful for selecting the correct SMPS topology for the given application. This is a general guideline that covers most applications and most topologies.

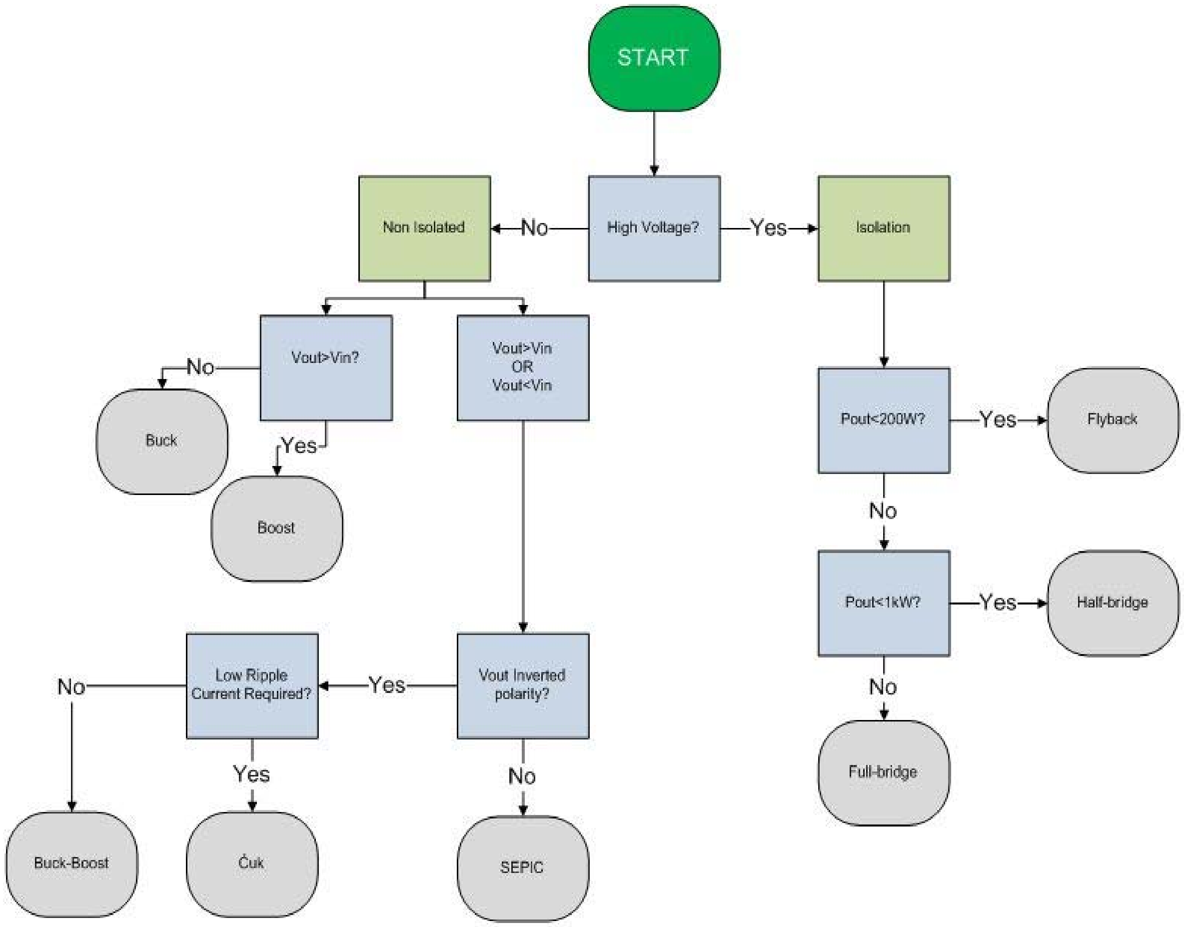


Figure 3.6.2.2.d-SMPS Topology Selection Flowchart

It is out of the scope of this paper to provide an in depth understanding of all of the SMPS topologies; it is useful to have a breadth of knowledge in order to understand the topology selection process.

The “SenseWalk” product will operate on a rechargeable type battery. This will require an AC-DC converter to recharge the battery; also this will require a DC-DC converter to regulate the battery voltage to the required load voltage. The above flow chart can be used to choose the correct topology for the AC-DC battery charger. Since the design requires high efficiency, there is need to use a SMPS. The AC-DC converter will be high voltage, (115-240 V_ac); therefore full isolation will be required. Also the output power will be low, well below 200 watts; therefore the most fitted topology will be the Flyback. The exact requirements will depend on the specific battery used, but there is enough information present to suggest the use of the Flyback topology. Since the Flyback will be used, there is need to fully understand the operations of the topology. Without fully understanding the Flyback, the performance and efficiency of the design will suffer.

The above flow chart can also be used to choose the correct topology for the DC-DC voltage regulators. Since the design requires high efficiency, there is need to use a SMPS. Typically a battery powered device will implement a Buck topology. Since the Buck will be used, there is need to fully understand the operations of the topology. Without fully understanding the Buck, the performance and efficiency of the design will suffer.

Another type of switching regulator not mentioned above is referred to as a Charge Pump. The above listed switching topologies are based on the use of an inductor; the Charge Pump is based on the use of a capacitor. Figure 3.6.2.2.e below shows a basic schematic of a Charge Pump voltage booster. The Charge Pump topology is able to increase the input voltage and provide either an inverted or non-inverted output voltage. Charge pumps are easier, than inductor based topologies, to design. The disadvantage of Charge pumps is that they offer a lower efficiency with a varying input voltage range and often are required to operate on a lower load than inductive based switching topologies.

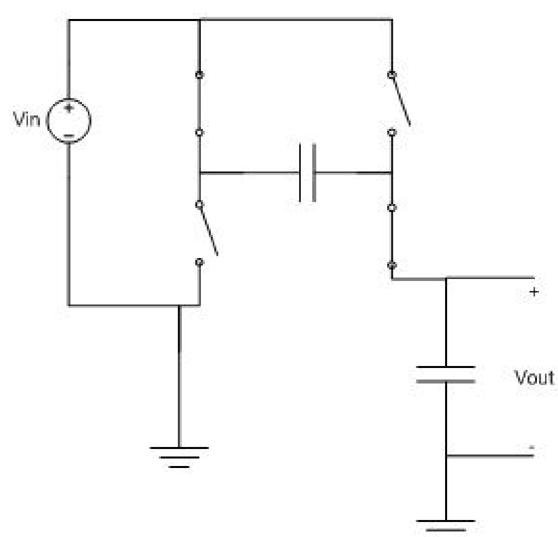


Figure 3.6.2.2.e-Charge Pump Schematic

3.6.2.3 AC-DC Flyback

In order to complete a functioning and highly efficient Flyback converter design, the fundamental circuit operations must be fully understood. Figure 3.6.2.2.c above displays a basic schematic of a Flyback converter. Notice that full wave rectification is provided to convert the input AC voltage to a DC voltage which is then pulsed through the primary side of the transformer. Large input capacitors are used to smooth the ripple voltage and generate a more pure DC signal.

In the FlyBack topology there are two states of operation, the on state and the off state, which refer to the state of the power switch. When the power switch (MOSFET) is on, flow of current is permitted in the primary side of the transformer. When the power switch is off, referred to as “Flyback operation”, current no longer flows in the primary side, instead current flows in the secondary side of the transformer. Energy is built up and stored in the primary side of the transformer when the power switch is on and when the power switch turns off, the stored energy is transferred to the secondary side of the transformer.

The switching duty cycle must vary appropriately for changes in input (line) or output (load) conditions to maintain constant voltage regulation. The duty cycle is adjusted by the use of feedback. The output voltage is feedback to the control IC and the duty cycle is adjusted accordingly. Feedback is done through the use of an optocoupler. The optocoupler and the transformer allow for complete isolation between the input and output terminals. Isolation is needed due to the high input voltage, for safety precautions.

It is important to understand the transformer operation in the Flyback topology. There are two modes in which the transformer can operate, Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM). In CCM the inductor current on the primary and secondary side never falls to zero. Since the current does not drop to zero, the inductor has residual energy at the beginning and end of the switching cycle. There is always energy stored, even when the switch is off. This is the primary operation of the transformer in CCM.

In DCM the inductor current on the primary and secondary side discharges to zero. Since the current falls to zero, all of the stored energy is transferred from primary to secondary on each switching cycle. Since the Inductor has zero energy at the beginning and end of the switching cycle, the transformer is said to be operating in DCM.

Both CCM and DCM transformer operating modes provide advantages and disadvantages. The main disadvantage of operating in CCM is that it generates a Right Half Plane Zero (RHPZ). The introduction of a RHPZ requires additional compensation in order to achieve feedback stability. CCM requires the crossover frequency to be adjusted much lower than the RHPZ frequency, which lowers the closed loop bandwidth. The result is a poorer transient response to load and line variations. [ON Semiconductor Training Material]

One advantage of operating in CCM is that the required peak and RMS currents are lower than in DCM for the same output power. This provides less ringing and lower power losses in conduction paths. The second advantage of operating in

CCM over DCM is the decreased transformer size. Since DCM requires higher currents, the transformer size is increased to withstand larger flux swings and increased core losses. The advantages and disadvantages of CCM and DCM need to be considered when designing a transformer for a Flyback converter. The transformer used in the FlyBack converter for the “SenseWalk” will be designed to operate in DCM to simplify the compensation network. [ON Semiconductor Training Material]

Most AC-DC power supplies are designed to allow for Universal input voltages. So the Flyback converter often needs to support input voltages between 90 and 270 Volts at 50/60 Hz. The variation in input voltage is due to the fact that different countries have various standards. For example, in Japan the typical AC voltage is 100V at 50Hz, in the United States it is 120V at 60Hz, and in Europe it is 220V at 50Hz. Every country has a set standard which the local power company adheres to. Since most electronics are now portable, it is convenient for the consumer to have a universal power supply. If a power supply is designed to function with an input voltage range between 90V and 270V at either 50Hz or 60Hz, it is classified as a universal design. The “SenseWalk” designers will be aware of the required input voltage range to ensure a robust design.

3.6.2.4 DC-DC Buck

In order to complete a functioning and highly efficient Buck converter design, the fundamental circuit operations must be fully understood. Many of the Buck circuit operations are similar to the Flyback operations listed above, such as CCM and DCM. CCM and DCM are very similar for the Buck as for the Flyback, except the Buck implements an inductor and the Flyback a transformer. It is important to understand the Buck circuit operation and switching states, also control loop consideration are of high importance.

Figure 3.6.2.2.a above shows a basic schematic representation of a Buck regulator. There are two stages of operation to examine with the Buck regulator. The buck is implemented by the use of an inductor, a FET, and a diode. The FET acts a switch, turning on and off. The gate of the FET is driven typically by a control IC. When the gate of the FET receives a voltage, the inductor is connected to the input voltage and the diode is turned off due to the polarity; this is referred to as the “on” state. During the “on” state the inductor begins to store up energy.

Since the properties of an inductor offer reluctance to change in current, when the inductor is turned from the “off” state, where current is equal to zero, to the “on” state, the output voltage is forced to drop. The inductor resists the change in current by decreasing the voltage. As the current increases over time, the voltage drop across the inductor is reduced and the output voltage is increased. When the converter is switched to the “off” state, the input voltage is removed and the inductor begins to release its stored energy. This allows for a reduced output voltage that is regulated.

Often to improve efficiency, the buck regulator topology is slightly modified to the Synchronous Buck Regulator. The Buck is converted to a Synchronous Buck by replacing the freewheeling diode with a second MOSFET. Figure 3.6.2.4.a below shows a basic schematic representation of a Synchronous Buck Regulator.

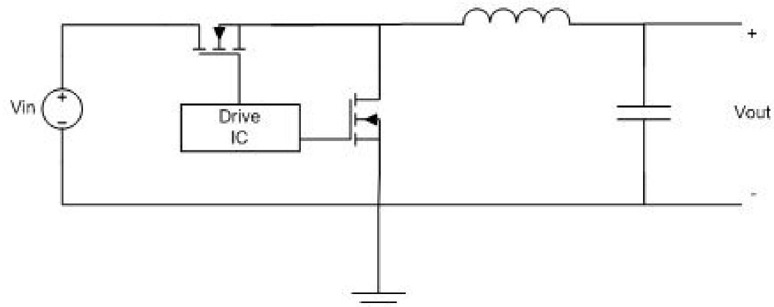


Figure 3.6.2.4.a-Synchronous Buck Regulator

There are three types of control circuits often used in the Buck regulator; they are called Type 1, 2, and 3. Control loops are needed to regulate the output voltage to a constant value by adjusting the MOSFET drive signal accordingly. Advanced control loop design is too large of a topic to cover in this write up, so provided below is a brief understanding of control implementation in the Buck regulator. Since Type 3 compensation is commonly utilized, Figure 3.6.2.4.b below shows a schematic of the Type 3 compensation network; an explanation will follow.

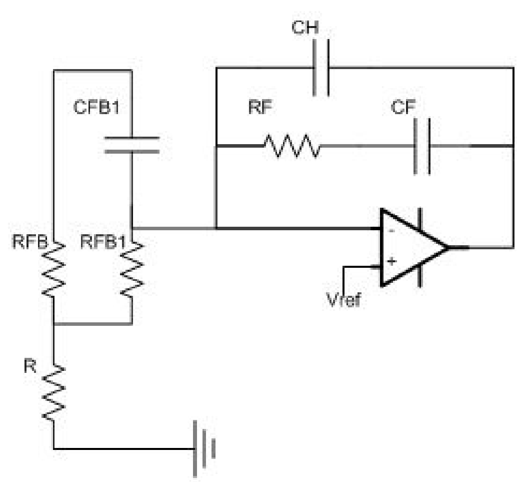


Figure 3.6.2.4.b-Type 3 Compensator

It is important to note the effects of each component in Figure 3.6.2.4.b. Without careful compensation design, the regulator could become unstable and have poor transient response performance. The following statements are from experience, the mathematics is too heavy of a topic to discuss in this section. RF is the dominant loop gain element followed by CFB1. CFB1 also has an impact on the initial response of the system. CF impacts the frequency of the system gain. A smaller value for CF results in a higher frequency gain. RFB1 acts as a limiter to CFB1 gain, also RFB1 provides system dampening. CH is responsible for limiting the upper bandwidth, also CH impacts jitter and sub-harmonic oscillation. [ON Semiconductor Training Material]

It is useful to understand the function of each element in the control loop. Understanding each component effect will greatly help with tuning the system for dynamic responses. There is too much mathematical derivation to cover in depth for designing Type 1, 2, and 3 control systems. A basic understanding has been provided and it should suffice for tuning the regulator control loops implemented in the “SenseWalk”.

The basics of the Buck converter have been laid out above. This should provide a solid understanding of the operation and control of a Buck Regulator.

3.6.2.5 AC-DC Flyback Design and Optimization

The mathematical derivation for designing a transformer for a Flyback application is a complicated process. Much care needs to be taken when designing the transformer or the Flyback regulator will have poor efficiency and loss of functionality. The first consideration is to determine the peak (primary side) current for a given output power requirement. Next is to determine the primary side inductance needed to achieve the desired output power. Also it is important to know the number of primary and secondary turns. The number of turns on the primary and secondary form a ration equal to the voltages.

There are many factors and equations that need to be considered in transformer design like calculating the length of air gap, size of the transformer, cross sectional area, etc.; the transformer manufacturer should be able to aid in transformer design. It is also important to consider the materials that the transformer is constructed from. There are many options available for core materials. Certain material allow for higher inductance which may be required to maintain small transformer size. Also consider the wire size and type. The wire needs to be large enough to handle the required current flow. For high frequency operation, Litz wire is often used to reduce the skin effect. As the frequency is increased, the electrons start to travel on the surface (skin) of the conductor only.

Since the area is reduced for current flow, the design is choked and the converter takes a large efficiency loss. Litz wire has many strands of wire wrapped together, this allows for increased surface area and better current flow, resulting in improved efficiency.

Electromagnetic interference (EMI) is a large challenge for certain Flyback applications. Engineers often need to reduce the effects of EMI to meet design specifications. EMI originates in the rapid ON/OFF transitions of the voltage and current. Harmonics of these waveforms then couple into nearby “receivers” either through conduction or radiation. This can cause many design problems; therefore a designer needs to understand the options available to reduce EMI in the Flyback converter.

Available options that designers can utilize to reduce EMI include Hot-Cold Ground Capacitor (Y-Capacitor), Common-Mode Choke, Line-Line Capacitor (X-Capacitor), Transformer Snubber (Diode Resistor Capacitor), Ferrite Beads (EMI suppression type), and Schottky Rectifiers or Ultra-Fast Rectifiers. All of these options can be implemented into the design to reduce EMI issues if required. [ON Semiconductor Training Material]

EMI is a large design issue that cannot be fully covered in this write up. With that being said, here are some general suggestions to reduce EMI. The designer should try to suppress the noise at the source. Also try slowing down the rise and fall times of the waveforms. This typically will reduce EMI, but will also reduce efficiency. The tradeoff between reducing EMI and efficiency will depend on the system specifications.

An important step in the optimization phase is implementing Snubber circuits. A Snubber is typically used to combat switch node (SWN) ringing. Since the FET is rapidly turning on and off, there are overshoots, undershoots, and ringing issues. The overshoot is very important because the voltage might rise above the maximum allowed voltage of the MOSFET, which could result in damage to the device. The Flyback topology generates a very high voltage on the MOSFET. Typically 600 to 800 volt MOSFETs are used. Still it is important to ensure the overshoot does not cross the maximum voltage rating of the FET. For this reason, the designer will need to optimize the Snubber circuit to meet SWN ringing specifications to ensure a robust design.

Another useful step in the design optimization phase is to test the thermal performance of the parts, chips, and the board. An infrared camera is often used to spot out hot spots. Knowing the hot spots will allow the designer a visual look at where the efficiency is being lost. Also it is important to know if a component is getting too hot, because each component has a maximum allowed temperature.

The last step in the Flyback optimization phase is for the designer to set specific protection logic. The desired settings for Over Voltage Protection (OVP), Over Current Protection (OCP), Under-Voltage Lockout (UVLO) need to be set.

3.6.2.6 DC-DC Design and Optimization

Once a general design has been produced, the engineer needs to go through a design optimization phase in order to meet all required specifications. This section will provide a general optimization process for DC-DC converters.

The first step in optimizing a DC-DC design is to initially tune the control loop for stable transient response. This might also require the designer to consider thermal compensation if needed. This step only provides a temporary tuning of the control loop; the loop will need retuned as changes are made to the inductor and output capacitors to ensure an optimized design.

The second step is for the designer to optimize the input filter to meet the given design specifications. The designer should test the input ripple voltage for worst case conditions; worst case input ripple occurs at the maximum load current (Imax). If the measured input ripple is too high then the input capacitance needs to be increased to reduce the ripple value. If the measured input ripple is well below the design specifications then the input capacitance should be reduced to lower the Bill of Materials (BOM) cost.

The third step in the optimization phase is for the designer to experiment with the inductor and output capacitor selection. The design specifications will require a balance between efficiency, transient response, and output ripple performance. It is not possible to optimize all three variables, so the designer will need to balance the variables to meet specifications. When the designer increases output capacitance the output ripple will decrease, but an increase in capacitance will increase BOM cost. Increasing the inductance value will improve output ripple, but decrease efficiency due to a higher associated DCR of the larger inductor. When optimizing the inductor and output capacitance, the designer should test at worst case conditions, minimum output voltage and maximum input voltage.

The fourth step is for the designer to experiment with switching frequency (Fsw) if available. Adjusting the Fsw will provide an optimal setting for efficiency versus ripple performance. Not ever control IC provides the option to adjust the Fsw. As Fsw is increased, the switching losses start to dominate over conduction losses, therefore MOSFET selection becomes of great importance.

The fifth step in DC-DC design optimization is MOSFET selection. If a synchronous topology is being implemented, the designer will need to consider both the high side and low side MOSFETs. The most important factor in the high side FET is switching losses. Typically in the high side FET switching losses dominant over conduction losses. The main factors to impact switching losses are the device rise and fall times and capacitances. Therefore to combat switching losses, the high side FET should have low rise and fall times, and low parasitic capacitances such as the gate capacitance. In the low side FET conduction losses dominate over switching losses. The main contributions to conduction losses are due to the “on resistance” of the FET, called Rds(on). For this reason, the low side FET should have minimum Rds(on) to combat conduction losses. MOSFET selection is a vital part of DC-DC SMPS design. If the incorrect MOSFETs are selected, the efficiency will take a large hit.

The sixth step in the optimization phase is to consider Snubber circuits. A Snubber is typically used to combat switch node (SWN) ringing. Since the FETs are rapidly turning on and off, there are overshoots, undershoots, and ringing issues. The overshoot is very important because the voltage might rise above the maximum allowed voltage of the MOSFET, which could result in damage to the device. Ringing is also important because the noise can be coupled and carried to the output. To reduce these unwanted problems, a Snubber circuit is implemented. A Snubber will decrease SWN ringing and overshoot, but also decrease efficiency. For this reason, the designer will need to optimize the Snubber circuit to meet SWN ringing specifications without causing a larger decrease in efficiency.

The seventh step in the design optimization phase is to test the thermal performance of the parts, chips, and the board. An infrared camera is often used to spot out hot spots. Knowing the hot spots will allow the designer a visual look at where the efficiency is being lost.

The eighth step is to tune the control loop for a final and optimal transient response. The designer should test for the required dynamic load step to ensure specifications are met. Also the designer should check for high load frequency sub-harmonics by doing a frequency sweep. Then the tuning loop needs to be tested for sensitivity. The compensation values should be varied by 10 - 20 percent to ensure a robust design.

The Ninth and final step in the DC-DC optimization phase is for the designer to set specific protection logic. The desired settings for Over Voltage Protection (OVP), Over Current Protection (OCP), Under Voltage Lockout (UVLO), etc. need to be set.

These above nine steps provide a solid process for DC-DC optimization. Extra steps can be added and steps can be skipped depending on the application and topology.

3.6.2.7 Energy Standards

With the large increase in global population, energy demands are at an all time high. The number of electronics per person has also largely increased. With the increase in power demand and a limited supply of power generation, efficient electronics have become a necessity. Governments and green environmental organizations have established energy efficiency standards.

ENERGY STAR has become the largest most recognized international standard for energy efficient consumer products. The standard originated in the United States in 1992 when it was created by the Environmental Protection Agency and the Department of Energy. Depending on the specific device, there are standard requirements for a consumer product to be labeled with the ENERGY STAR mark. A specific set of guidelines and requirements has been constructed in order for an AC-DC power supply to be labeled with the ENERGY STAR mark. A full chart of Energy-Efficiency requirements can be found at http://www.energystar.gov/.

3.6.3 Battery Charge Detector Circuit

In order to let the user know how much battery life is left in the device, a circuit will need to read the charge of the lithium ion battery. In order to accomplish this we will be using Texas Instruments bq3055. This integrated circuit provides a wide range of features to manage the power of lithium ion batteries. This device can measure the capacitance, voltage, current and temperature of the battery. It also provides overvoltage and under voltage protection at a software level. In addition there is hardware short circuit protection as well as over current discharge protection [24].

4. Project Hardware/Software Selection and Design Details

With research being done, the next step of the engineering design process involves parts selection. For the application of this project, this relates to software and hardware selection. The hardware that has been researched and chosen for selection incorporates the power supply system including battery, sonar hardware, microcontroller, Bluetooth module, and GPS module. With regards to software selection, software correlating to programming the microcontroller, GPS module and Bluetooth module are needed. As a result, all sub-system selections are discussed in this section.

4.1 Proximity Sensing Hardware Selection

The proximity sensing hardware selection discusses the selection process for the different possible sonar configuration circuits that can be incorporated into the "SenseWalk" object proximity design.

4.1.1 Ultrasonic Transducer Selection

For the Sonar system, the "SenseWalk" will need a transducer to transmit and receive the signal. Sonar works by a transducer emitting a sound and then that sound bounces back from the object. The time it takes the sound to be received by transducer is then calculated using the speed of sound.

For the "SenseWalk", two different Ultrasonic Sonar Transducers were compared. The first was the Senscomp 600 Series instrument grade and the second was the Air Ultrasonic Ceramic Transducer 400ST/R160.

	Senscomp 600	Air Ultrasonic 400ST
Thickness	0.46"	0.472"
Diameter	1.69"	0.63"
Frequency	50kHz	40kHz
Voltage	200V	20V
Operating Temperature	-40 to +85^{o} C	-40 to +80^{o} C
Beam Angle	15^{o} at -6dB	55^{o} at -6dB
Capacitance	400-500pF	2400pF
Receiving Sensitivity	-42dB at 50kHz; 0dB=1volt/Pa	-65dB at 40kHz; 0dB=1volt/μbar

Table 4.1.1.a-Comparison between Sensors

Both devices will generate the sonar beam needed. The Air Ultrasonic part is over an inch smaller in the Diameter than the Senscomp part, this is a huge advantage since size and weight are important factors. The optimal frequency of 50 kHz on the Senscomp 600 and 40 kHz Air Ultrasonic 400ST are both good frequency since there is not a lot of other external signals at these frequencies. The Air Ultrasonic 400ST only requires a maximum of 20 volts were the Senscomp 600 need a voltage of 200 volts. Since we are only using a 7.2V battery stepping up the voltage from 7.2 is much harder and more dangerous than stepping up the voltage to 20 or the 10 volts which we will be using in the "SenseWalk". Both parts have a similar operating temperature. The beam angel at -6dB is much different for both devices. For the Air Ultrasonic 400ST at 55 degree beam angle offers a wide range of detection while the Senscomp 600 at

15 degrees is quite narrow and the visually impaired user will have to sweep a wider range to identify objects [25]. The capacitance of 2400pF for the Air Ultrasonic 400ST is much larger than the 400-500pF for the Senscomp 600. This will be an important parameter when building the final design to factor in the circuit analysis. The receiving sensitivity is much better for the Air Ultrasonic 400ST than the Senscomp 600. Both parts will be able to identify objects in the range required by the “SenseWalk”.

Because of the much small size and the smaller voltage, the Air Ultrasonic Ceramic Transducers 400ST160 has been chosen for the “SenseWalk”. This transducer can be used to both transmit and receive the signal. In addition, transducers are relatively small, which is an advantage since the “SenseWalk” will need to be mounted on a walking cane. This transducer is PCB mounted with mounting legs of a length 10mm and a diameter of 1mm. The small size allows for the transmitter to be placed on the “SenseWalk” without interfering with any of the other electronics. The transducer has a center frequency of 40 Khz and a Vrms of 20 volts. For the transducer, the receiving sensitivity is -65dB. All of these specifications are desirable to generate and receive the signal. In Figure 4.1.1.b, the graph below shows that the best operational frequency is 40 Khz.

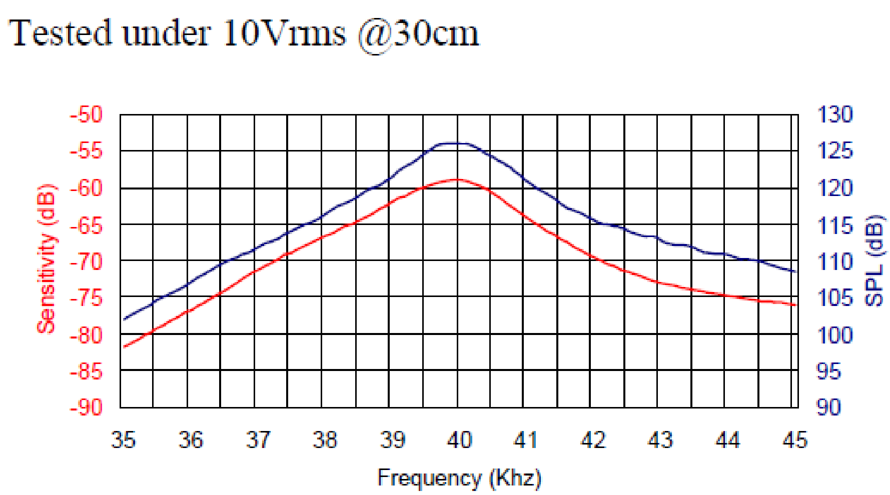


Figure 4.1.1.b-Graph showing optimal frequency as tested under 10 Vrms
Permission pending from Robot-Electronics

In figure 4.1.1.c, the graph shown below demonstrates the sensitivity of the sonar. The range of the sonar is about 60 degrees. This is good as the width allows for the proper sensitivity [26].

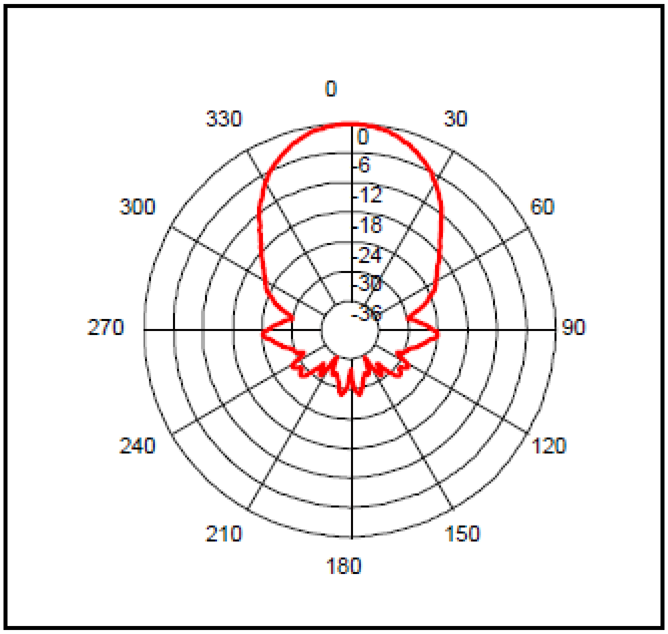


Figure 4.1.1.c-Sonar range graph
Permission pending from Robot-Electronics

4.1.2 Ultrasonic Driver Circuit Selection

To generate the sonic wave which will be sent and received from the transducer, a circuit to create a square wave at 40kHx with a 10% duty cycle is needed. In order to accomplish this, the group examined phase shift oscillators, Wien-bridge oscillators, Schmitt Trigger oscillators and a 555 timer. The phase shift oscillator uses three operational amplifiers as shown in figure 4.1.2.a below.

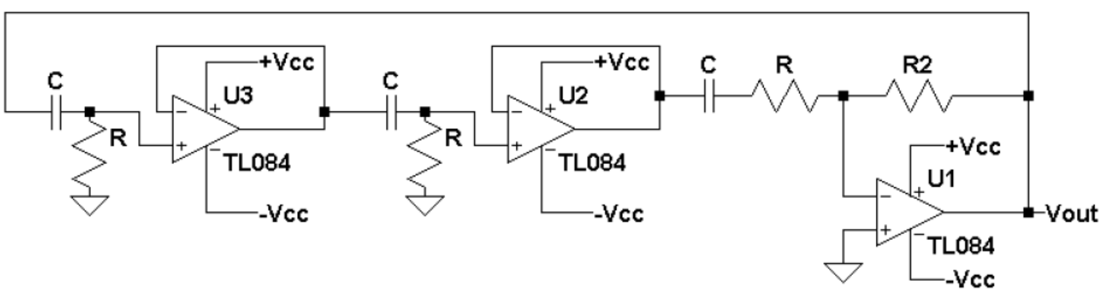


Figure 4.1.2.a-Phase shift oscillator
Reprinted with permission from Electronics 2 Lab Manuel

This circuit uses TL084 as the op amp selected. Any general op amp can be used as a phase shift oscillator. The first two op amps are an RC filter with an inverting op amp as the third. The phase shift oscillator provides a 180 degree phase shift. For this oscillator, there is no input voltage. The output voltage is looped back around. The frequency of oscillation is given by f=1/ [2π*(3^1/2)*RC] for the circuit in order to achieve oscillation R2/R>8. Since it cannot generate at a 10% duty cycle, the phase shift oscillator will not be used.

The next type of oscillator that was examined was the Wien-bridge oscillator. This oscillator is shown in figure 4.1.2.b. The Wien-bridge oscillator uses a single amplifier in a non-inverting configuration with an additional two resistors and compactors. Like the phase shift oscillator, the Wien-bridge oscillator uses no input voltage. The output voltage is looped back to the positive and negative terminals on the op amp. The frequency of the oscillator can be calculated using the formula f=1/ (2πRC). To get a square wave on the Wien-bridge oscillator, a value of R2/R1>8 must be used. Like the phase shift oscillator, the Wien-bridge oscillator cannot generate a duty cycle of 10%.

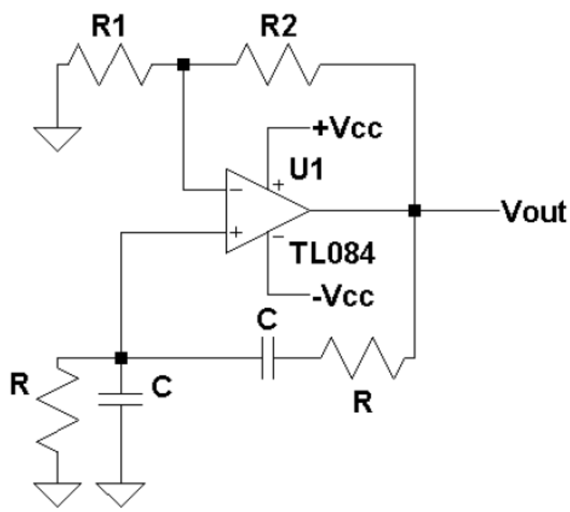


Figure 4.1.2.b-Wien-bridge oscillator circuit
Reprinted with permission from Electronics 2 Lab Manuel

The Schmitt Trigger oscillator is another popular type of oscillator. It uses one op amp with three resistors and a single compactor. A picture of the Schmitt Trigger oscillator can be seen below in figure 4.1.2.c.

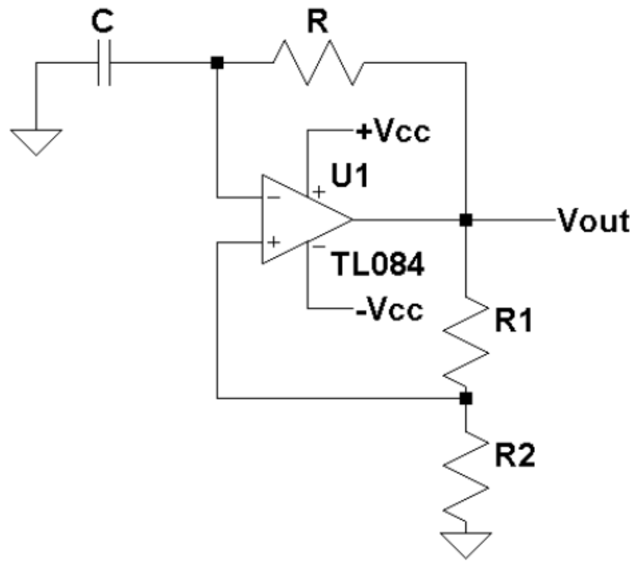


Figure 4.1.2.c-Schmitt Trigger oscillator circuit
Reprinted with permission from Electronics 2 Lab Manuel

The Schmitt Trigger Oscillator can generate three different wave forms from a single op amp. The first is a square wave at Vout. The amplitude of this wave is equal to the VCC. The next is another square wave at the V^+ terminal of the op amp with amplitude of VCC/2. The third wave is a triangle wave with amplitude of VCC/2. Since a VCC of 10 volts and need a square wave of 10 volts is need, the Vout signal is the only object of interest. The frequency can be found by the formula f=0.455/RC. Like the other two oscillators discussed above, the duty cycle cannot be adjusted to 10%. So this circuit will not be implemented in the design.

The last solution to find a method to generate a square wave at 40 kHz with a 10% duty cycle is a 555 timer. The 555 timer has a wide range of applications. These applications include: oscillator, pulse width modulator, either single or variable width. The 555 timer will be used to generate a 10 volt square wave at 40 kHz.

The timer has 8 pins: VCC, GND, Discharge, Threshold, Control Voltage, Trigger, Output, and Reset. Figure 4.1.2.d shows the pin layout of the Texas Instruments 555 timer. The VCC pin has a voltage range from 4.5 Volts to 16 Volts. The design will use a voltage of 10 Volts.

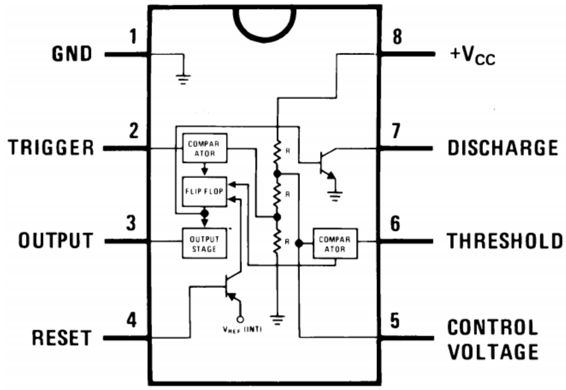


Figure 4.1.2.d-555 timer diagram
"Courtesy of Texas Instruments"

To generate a square wave, a circuit using a 555 timer will be used. The supply voltage to the 555 timer will be turned on and off with the use of a MOSFET. The microcontroller will provide the voltage to the gate to open the MOSFET to allow current to flow. A block diagram is shown in Figure 4.1.2.f.

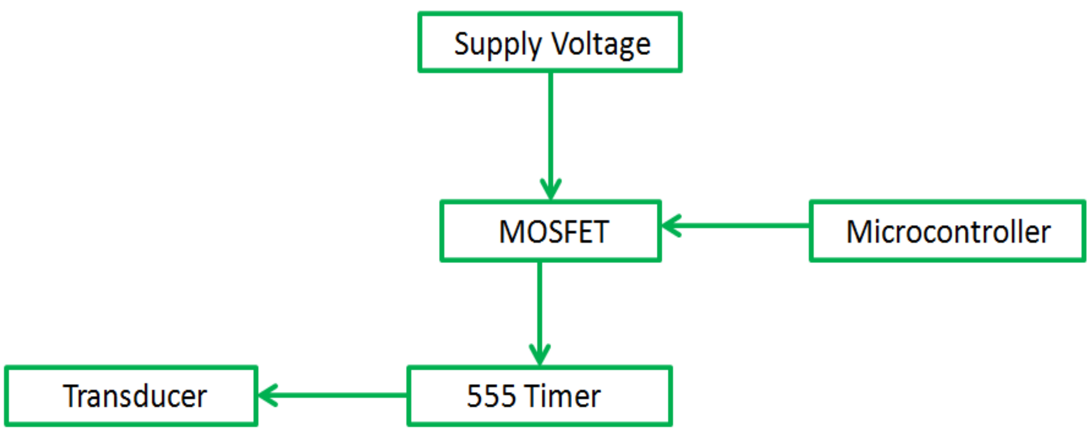


Figure 4.1.2.f- Sonar wave generator block diagram

The details for how the 555 timer will be implemented, is shown in figure 4.1.2.g. The values R1, R2, and C will be chosen to get the proper frequency and the proper duty cycle. A frequency of 40 kHz will be desired and a duty cycle of 10% will also be needed. This way, small pulses will be sent from the transducer. To achieve this, several formulas will be used. The first is for the frequency: f=1.4/[(R1+R2)*C]. In this formula, C, the capacitor value, will be chosen first at about 0.01μF. Then, the resistor values can be calculated. To calculate the duty cycle, the formula: Duty=R1/(R1+R2) will be used. The diode across the R2 resistors is so that a duty cycle of less than 50% can be achieved. We will be using a +VCC value of 10 volts for this design. The VCC pin will be connected to the 10 volts generated from the Boost converter in Section 6.2.3. The output pin shown will be connected to the transducer. Between the VCC pin shown below and the 10 volts, a MOSFET will be there to interrupt the 10 volts. This MOSFET will be controlled by the micro controller. [27] The time when the sonar sends out the signals and amount of pulses can be controlled.

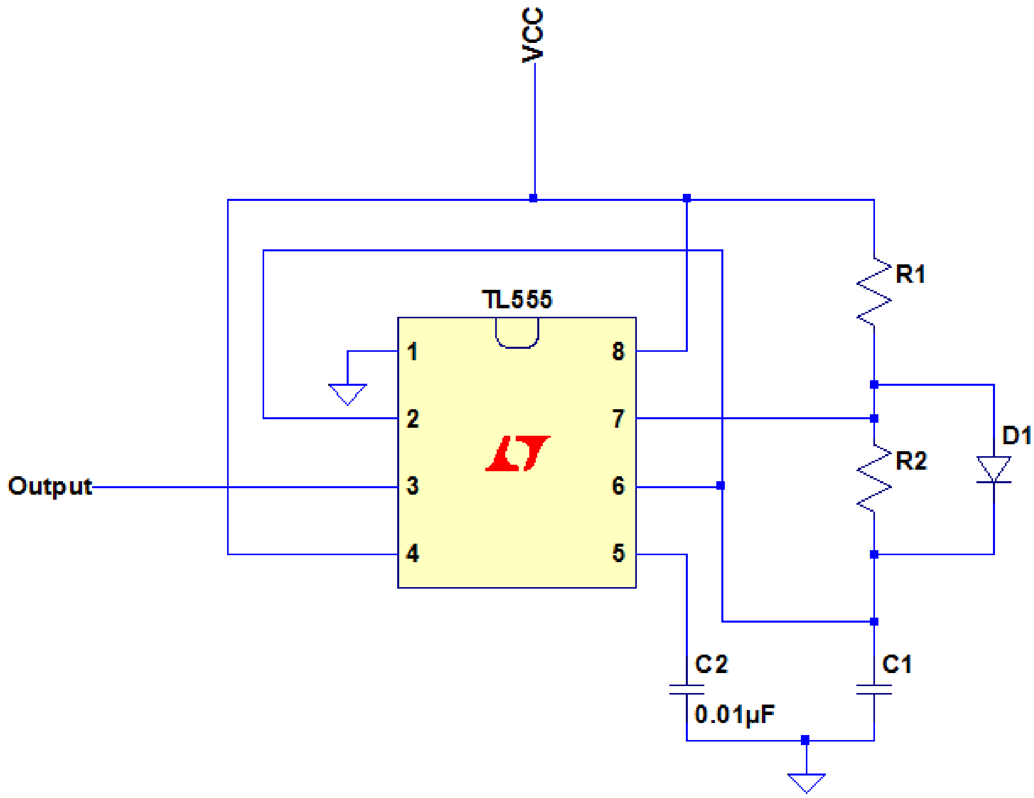


Figure 4.1.2.g- Sonar wave Generator Circuit

From the 10 Volts generated from the boost circuit and the 555 timer a MOSFET to control when the square wave signal will be generated. The gate voltage of the MOSFET will be controlled by the microcontroller. Since max output voltage from the microcontroller is 3 volts, an op amp will need to be used to amplify the voltage to all current to pass from the drain to the source on the MOSFET. To amplify the signal a simple non-inverting amplifier will be used gain will be equal to Vin/Vout = R4/R3+1. This circuit is shown in 4.1.2.h.

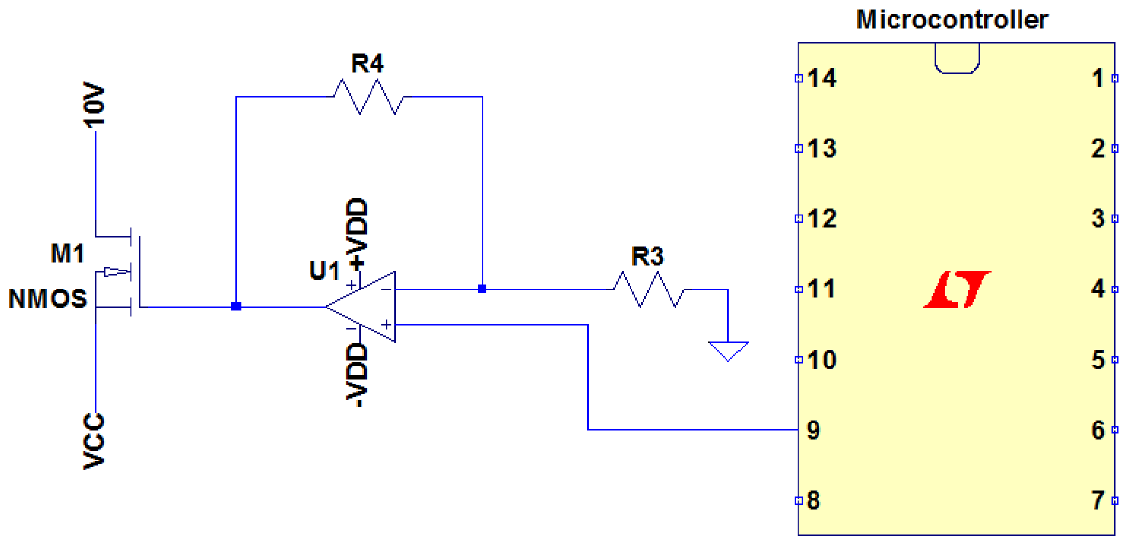


Figure 4.1.2.h- 555 timer power control circuit

4.2 GPS Module Hardware Selection

The GPS card selection is essential. An appropriate module must be chosen in order to ensure all “SenseWalk” requirements are met or exceeded. Proper selection between GPS cards will guarantee that accurate, reliable data is being received that can be read on the microcontroller. Selecting a card that is NMEA compliant will allow for easy integration with the MSP430.

4.2.1 CC4000-TC6000

The TC6000GN is an extremely advanced and robust GPS module that uses the Simple Link™ GPS CC4000. The data received from this chip allows for a high degree of accuracy for measurements including speed, velocity, position, acceleration, and time.

The NMEA protocol is used for output data formatting, which is the standard in the GPS industry and around the world. Startup and satellite acquisition time are vastly improved by the use of warm start and hot start functionality. A PPS generator allows for high precision timing on the module. The generator is fully integrated into the module. The microcontroller does not do any calculation relating to the coordinates and measurements of the GPS.

Everything is done onboard in the GPS driver and firmware which is integrated into the standalone module. This allows for reduced resource allocation to the GPS design and helps in reducing system complexity. Without these features it would be impossible to run on very low power 8-bit and 16-bit MCUs. The CC4000 is a complete package designed to save cost, speed development, and allow anyone of minimal technical expertise to work with the module. (CC4000 document)

Key Features:

- NMEA Messages Supported: Pulse-Per-Second (PPS) Generator
- Time, Position and Data Timing Applications with Accuracy <100ns
- GLL: Latitude, Longitude, UTC Time of (nominal) Position Fix and Status
- Host Interface: UART
- GSA: GPS Receiver Operating Mode,
- Dimensions: 10mm x 9mm x 2.3mm
- Operating Temperature Range: –30°C to +70°C
- VTG: Course and Speed Information – EEPROM
- Autonomous Cold Start TTFF 35 Seconds • Asset Tracking
- Autonomous Hot Start TTFF ~ 1 Second in • Portable Navigation
- Tracking Accuracy Better than 3 Meters
- Precision Timing
- – GPS Tracking Sensitivity: –162 dBm
- Push-to-Fix: Single GPIO Activates Power

[8]

4.2.2 GPS Card PW-GPS06

The PW-GPS06 is another GPS module that is very affordable, ultra-low power consumption, and is designed for a wide spread of different applications. The chip uses the NEMERIX chipset solution which is designed for extended low power usage. The module tracks upwards of 16 satellites at one time and has fast location acquisition capability. Its efficient design allows it to meet the specifications for car navigation, handhelds, and many other solutions including those that use batteries. This design uses surface mount technology and high level circuit integration to enable higher performance while maintaining lower battery use than its competitors. It also outputs its data in the industry standard NMEA protocol.

Features

- Built-in high performance NEMERIX chipset
- Average Cold Start in 60 seconds

- Ultra Low power consumption (PW-GPS06
- 22mA typ. @3.3V)
- 16 channels "All-in-View" tracking
- On chip 4MB flash memory
- TTL level serial port for GPS receiver command
- message interface
- Compact board size
- PW-GPS06 26.5x26.5x3.0mm
- PW-GPS06-P 26.5x26.5x8.7mm
- PW-GPS06-LP 26.5x26.5x6.7mm
- Support standard NMEA-0183 V3.0
- Option accurate 1PPS output signal aligned with
- GPS Timing
- Multi-path mitigation hardware
- Optimum clock drift adjustment
- External antenna open/short detector
- Support WAAS (PW-GPS06WA)
- Support dual antenna with built-in auto-detect RF
- switch (PW-GPS06P/LP)
  [9]

4.2.3 GPS Module Final Selection

Between the two GPS modules, the specifications are very comparable. Both offered very fast acquisition times, low power, and transmitted data in the NMEA standard. The decision is made easier when the option of staying with the same manufacturer of the microcontroller is available. This in theory would allow for easier integration and the knowledge that these pieces have been integrated together before in another solution. . The team also received a TI student credit of $200 to put toward any purchases made.

The CC4000-TC6000 and the MSP430 family have been seamlessly integrated countless times on the internet and troubleshooting is readily available online for any potential issues that might arise. The group has found multiple help tutorials detailing step-by-step instructions on integration with the MSP430. These examples often have code snippets describing how to interface using the software functions to get communication established between the two embedded devices.

The decision to select the CC4000-TC6000 was not easy but the potential benefits of staying with Texas Instruments for easy integration and the student credit outweigh any other benefits the PW-GPS06 might have. Another benefit of using the CC4000-C6000 is that the team is allowed to enter in a Texas Instrument sponsored contest that requires the use of Texas Instrument microcontrollers and peripherals.

4.3 Power Systems Hardware Selection

The “SenseWalk” is a portable electronic device which will be powered by a rechargeable battery. Due to system constraints the battery will need to have minimum size and weight, but also long battery life. There are many batteries available which offer advantages and disadvantages. Listed below in section 4.3.1 is an explanation for the battery selection.

Battery selection is important, but voltage regulation is also an important factor to consider. The various “SenseWalk” sub-systems will require specific operating voltages. The microcontroller will require 2.6 Volts, the Sonar will require 10 Volts, the GPS will require 1.8 Volts, and the Bluetooth will require 1.8 Volts and 2.6 Volts. Shown below in Table 4.3.a is a listing of all expected DC-DC power requirements. The supply current represents the maximum expected current draw; this value does not represent continues current draw.

	VCC MIN (V)	VCC MAX (V)	Operating VCC (V)	Supply Current MAX (mA)	Power (W)
Microcontroller	1.8	3.6	2.6	10	0.026
GPS	1.7	1.95	1.8	76	0.137
Bluetooth	2.2 and 1.62	4.8 and 1.92	2.6 and 1.8	40	0.132
Sonar	NA	NA	10	275	2.75
Total	NA	NA	NA	401	3.05

Table 4.3.a-Power Requirements DC-DC

Shown below in Table 4.3.b is a list of the three DC-DC converters that the “SenseWalk” will incorporate. The Linear regulator will be used to supply 1.8V for both the GPS IC and the Bluetooth IC. The Linear topology was chosen to reduce component count and BOM cost. The Buck regulator will be used to supply 2.6V for both the microcontroller and the Bluetooth IC. The Buck topology was chosen to provide higher power conversion efficiency and the Buck will allow for tight transient load specifications. The boost regulator will be used to provide 10V for the sonar subsystem. Section 4.3.2 will provide insight for the specific IC selections.

	Operating VCC (V)	Load Current (mA)
Linear	1.8	76
Buck	2.6	50
Boost	10	350

Table 4.3.b-Operating Voltage & Current DC-DC Converter

All operating voltages will be supplied by the single rechargeable battery. Linear and switching regulators will be utilized for voltage conversions. There are many manufactures and various voltage regulator Ics. Section 4.3.2 below shows the DC-DC regulator IC selection phase.

The “SenseWalk” will also require an AC-DC battery charger to recharge the system battery. Section 4.3.3 below shows the AC-DC IC converter selection phase. Also an important feature is a battery charge detection circuit and section 4.3.4 below discusses the battery gauge IC selection process.

There are many Semiconductor manufacturers who produce Power Management Ics. Some of the major producers are Texas Instruments, Maxim Integrated Products, ON Semiconductor, and Linear Technology. Each company has a different product portfolio with Ics that are better suited for a specific application. It has been decide to focus are Power IC selection on Texas Instruments and ON Semiconductor. These two companies offer a wide range of Power Management Ics, and will be included into the “SenseWalk” design.

4.3.1 Battery Selection

For the “SenseWalk” the group looked at two different Lithium Ion Batteries. Both of these batteries included a protection IC. One is a 7.2V and 2,600mAh and the other is 3.7V and 4,400mAh. The Table 3.1.6.5.a shows the similarities and differences between the batteries.

	3.7V: 4,400mAh	7.2V: 2,600mAh
Working Voltage	3.7 Volts	7.2 Volts
Peak Voltage		8.4 Volts
Max Charging Current	6 Amp	1 Amp recommended (Max 2 Amp)
Max Discharge Current	10 Amp	2 Amp
Length	2.6 inches	2.8 inches
Width	1.46 inches	1.45 inches
Height	0.71 inches	0.8 inches
Weight	6 Oz	3.5 Oz
Protection IC	YES	YES
Capacity	4.4 amps per hour	2.6 amps per hour

Table 3.1.6.5.a – Comparison between 3.7V and 7.2V Lithium Ion Batteries

The battery that the “SenseWalk” will use is the 7.2V battery shown in the Table 3.1.6.5.a. This battery is chosen because it is lighter weight and it will be easier to work with the higher voltage since we will need 10Volts for the Sonar transmitter transducer. The voltage will only need to be boosted up 2.8 volts instead of 6.6 Volts. The disadvantage is of this battery is the smaller capacity. During the testing of the “SenseWalk” if more Capacity is need than another 7.2V batter can be wired in parallel with this one to double the capacity.

The battery pack has two Lithium Ion 18650 cells together placed in parallel. This battery pack only weighs 3.5 ounces. The protection IC included will protect against over charge and over discharge. This will prevent damage to the battery and increase the battery life. In addition the IC protection will not allow the battery to draw more than 2 amps. Figure 3.1.6.5.b shows an image of the battery that we will be using [23].

Figure 3.1.6.5.b-Battery Pack
Permission pending from Mega Batteries

4.3.2 DC-DC IC Selection

The “SenseWalk” DC-DC converters can be split into three sections based on circuit topology. The three DC-DC converters which are implemented are step down linear regulator, Buck switching regulator, and Boost switching regulator. A fully explanation of the three DC-DC regulators has been provided in section 3.6.2 above.

It has been decided that a Linear Regulator will be used to provide power to the GPS system. The GPS chip (Part Number: CC4000-TC6000) will require only 1.8V to operate and 76mA max current draw. Because the required supply voltage (1.8V) is well below the battery voltage, there is need for a converter to step the voltage level down. Since the maximum required supply current will be only 76mA, it has been decided to use a Linear Regulator. The Linear Regulator offers simplicity and minimum component count. A Switching Buck Regulator would provide higher efficiency, but due to the low operating power of the GPS chip, the benefits of using a switching regulator would be negligible. Also the design complexity, component count, and BOM cost would be increased with the use of a switching regulator.

It has also been decide that a Linear Regulator will be used to provide power to the Bluetooth IC. The Bluetooth chip (Part Number: CC2560) will require two separate voltage levels, 1.8V and 2.6V. A Linear regulator will be used to supply the 1.8V.The maximum required supply current will not exceed 40mA. For the same reasons as the GPS chip discussed above, the Bluetooth IC will also be powered by Linear Regulators. Since the same supply voltage (1.8V) is required by both the Bluetooth IC and the GPS IC, it will be supplied by a single linear regulator.

Show below in Table 4.3.2.a is a comparison of two Linear Regulators produced by ON Semiconductor and two produced by Texas Instruments. The table highlights the basic specifications for each Linear Regulator IC. It has been decide to incorporate ON Semiconductor’s CAT6202 to provide regulated supply voltage to the “SenseWalk” GPS and Bluetooth Ics. It was decided to implement the CAT6202 because it offers a simply design solution and a current limit protector. The current limit function will provide extra protection for both the Bluetooth and GPS Ics.

	Part Number	$V_{In(max)}$ (V)	V_{DO} (V)	V_{out} (V)	I_{out} (A)	Fault Output Indication	Current Limit
ON Semiconductor:	CAT6202	16	0.25	Adjustable	0.5	Yes	Yes
	NCP3334	16	0.34	Adjustable	0.5	No	Yes
Texas Instruments:	TL5209	16	0.5	Adjustable	0.5	No	Yes
	LM2937	26	0.5	5	0.5	No	No

Table 4.3.2.a-Part Comparison

It has been decide that a Switching Buck Regulator will be used to provide power to the microcontroller Unit. The microcontroller (Part Number: MSP430xxx) will require 2.6V to operate. It has been decided to use a Buck Regulator to improve the power conversion efficiency and thus extend battery operation time. The Buck regulator will also provide the required 2.6V for the Bluetooth IC.

Show below in Table 4.3.2.b is a comparison of two Buck Regulator Ics produced by ON Semiconductor and one produced by Texas Instruments. The table highlights the basic specifications for each Buck Regulator IC. It has been decide to incorporate the TPS62050 to provide regulated supply voltage to the “SenseWalk” microcontroller and Bluetooth IC. It was decided to implement the TPS62050 because the part offers a high efficiency up to 95%, with minimum external components.

	Part Number	$V_{In(max)}$ (V)	F_{SW}	V_{out} (V)	I_{out} (A)	Efficiency	Logic Protection
ON Semiconductor:	NCV2575	40	52 KHz	Adjustable	1	85%	No
	LV58063MC	28	370KHz	Adjustable	1	90%	No
Texas Instruments:	TPS62050	10	1.2 MHz	Adjustable	0.8	95%	Yes

Table 4.3.2.b-IC Comparison

It has been decide that a Switching Boost Regulator will be used to provide power to the Sonar sub-system. The Sonar system will require 10V to drive the ultrasonic transducer. Because the required supply voltage exceeds the battery voltage, it has been decided to use a Boost Regulator.

Show below in Table 4.3.2.c is a comparison of two Boost Regulator Ics produced by ON Semiconductor and two produced by Texas Instruments. The table highlights the basic specifications for each Boost Regulator IC. It has been decide to incorporate Texas Instrument’s LM2621 to provide regulated supply voltage to the “SenseWalk” Sonar sub-system. It was decided to implement the LM2621 because the part offers high efficiency, up to 90% and meets all general requirements.

	Part Number	$V_{In(max)}$ (V)	F_{SW}	V_{out} (V)	I_{out} (A)	Efficiency	Logic Protection
ON Semiconductor:	CS5172	30	280KHz	Adjustable	1.5	NA	Yes
	MC34063A	40	100KHz	Adjustable	1.5	85%	Yes
Texas Instruments:	LMR61428	14	Adjustable	Adjustable	2.85	90%	Yes
	LM2621	14	Adjustable	Adjustable	1	90%	Yes

Table 4.3.2.c-IC Comparison

4.3.3 AC-DC IC Selection

The “SenseWalk” AC-DC battery charging system can be split into two sections, the Flyback AC-DC converter and the battery fuel gauge detection circuit. A full explanation of the Flyback has been provided in section 3.6.2 above and the battery charge detection system has been covered in section 3.6.1.4 above.

It has been decide that a Switching Flyback Converter IC will be used to convert 90-240V_AC to the required DC battery charging voltage. The rechargeable lithium ion battery will require 8.4V and 1.2A. The Flyback topology has been selected to provide full isolation between high voltage AC and DC output voltage. Also the Flyback topology is ideal for applications requiring less than 150W. A linear charging system could have been chosen, but this was decided against due to the low conversion efficiency. The market has begun to demand energy efficient power supplies that meet ENERGY STAR requirements, the Flyback will allow for higher energy efficiency.

Show below in Table 4.3.3.a is a comparison of two Flyback Converter Ics produced by ON Semiconductor and one produced by Texas Instruments. The table highlights the basic specifications for each Flyback Converter IC. It has been decided to incorporate ON Semiconductor’s NCP1014 to provide Constant Voltage Constant Current (CVCC) to the “SenseWalk” rechargeable lithium ion battery. The NCP1014 was decided based on many factors and considerations.

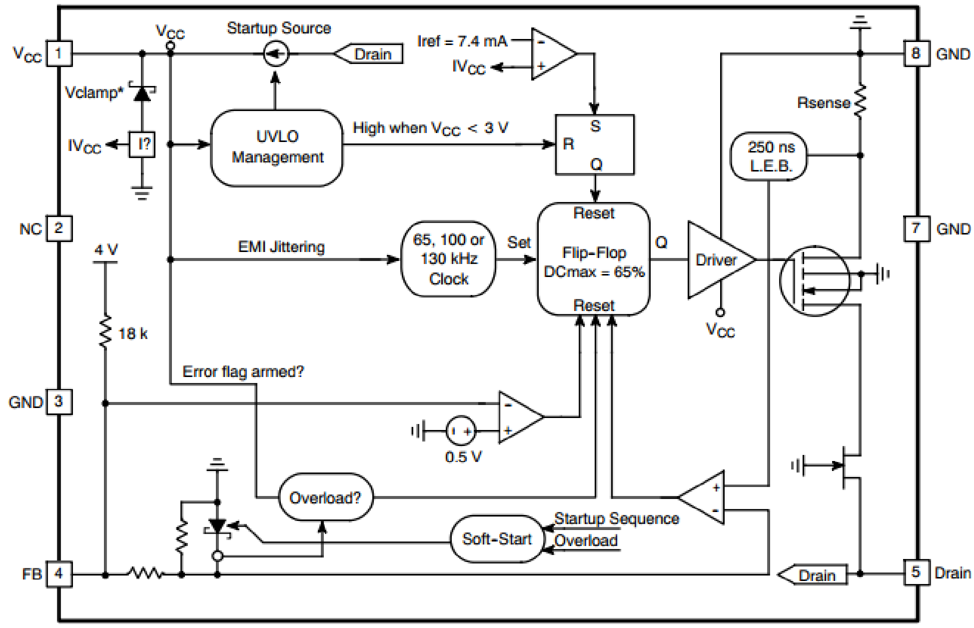
	Part Number	Fsw (KHz)	Standby Power (mW)	Built-in High Voltage MOSFET	Logic Protection	Design Support
ON Semiconductor:	NCP1014	65 - 100	100	Yes	Yes	Design Notes
	NCP1052	40 - 100 - 136	680	Yes	Yes	Minimum
Texas Instruments:	UCC28701	130	30	Yes	Yes	Moderate

Table 4.3.3.a-IC Selection

The NCP1014 offers a relatively low standby power consumption of 100mW. The low standby power rating will provide lower power dissipation when the battery charger is not operating but still powered on. An expanded list of the NCP1014 features has been provided below in Figure 4.3.3.a. The NCP1014 offers a built in high voltage MOSFET which will reduce component count and design size. Another nice feature with the NCP1014 is the ability to select the switching frequency. The ability to adjust the switching frequency will allow for an optimized design.

- Built-in 700V MOSFET with Typical R_{dson} of 11 Ω and 22 Ω
- Large Creepage Distance Between High-Voltage Pins
- Current-Mode Fixed Frequency Operation:
  65kHz – 100kHz – 130kHz
- Skip-Cycle Operation at Low Peak Currents Only: No Acoustic Noise!
- Dynamic Self-Supply, No Need for Auxiliary Winding
- Internal 1.0ms Soft-Start
- Latched Overvoltage Protection with Auxiliary Winding Operation
- Frequency jittering for Better EMI Signature
- Auto-Recovery Internal Output Short-Circuit Protection
- Below100mW Standby Power if Auxiliary Winding is Used
- Interal Temperature Shutdown
- Direct Optocoupler Connection
  [Permission Pending from ON Semiconductor (NCP1014 Data Sheet)]

Shown below in Figure 4.3.3.b is a simplified block diagram from ON Semiconductor's NCP1014 Data Sheet. It is important to understand the internal workings of the NCP1014 to design a fully functioning Flyback converter. It is clear that the High Voltage N-Channel MOSFET is internal to the NCP1014. This reduces the external component count and simplifies the design process of selecting the proper switching MOSFET. The complete NCP1014 internal circuit schematics are not available, but the block diagram offers useful insight to the parts functionality. There are a few logic protecting futures, such as Under Voltage Lockout (UVLO), Soft-Start, and Overload protection.



*Vclamp = VCC_{OFF} + 200 mV (8.7 V Typical)

Figure 4.3.3.b-Permission Pending from ON Semiconductor

The NCP1014 was selected for many different reasons. Some of the major reasons for selecting the NCP1014 were that it offers high efficiency, low component count, logic protection, and the deciding factor was the large amount of design and application notes offered to aid in the AC-DC battery charger design.

Switching power supply design can be a complex process. For this reason, ON Semiconductor has provided ample amounts of data sheets, design notes, and application notes to aid the designer through the process.

4.4 Compass Selection

The use of GPS in the “SenseWalk” requires the need for a compass to help in the navigation of the user. Without a compass, the orientation and direction the user is facing would be unknown to the “SenseWalk” and could potentially cause errors in real-time direction and decision making.

The Honeywell HMC5883L is a surface-mount, multi-chip module designed for low-field magnetic sensing with a digital interface for applications such as low-cost compassing and magnetometry. The HMC5883L includes the state-of-the-art, high-resolution HMC118X series magneto-resistive sensors plus an ASIC containing amplification, automatic degaussing strap drivers, offset cancellation, and a 12-bit ADC that enables 1° to 2° compass heading accuracy. The I2C serial bus allows for easy interface. The HMC5883L is a 3.0x3.0x0.9mm surface mount 16-pin leadless chip carrier (LCC).

Features and Benefits

- Small size for highly integrated products. Just add a microcontroller interface, plus two external SMT capacitors
- Enables 1° to 2° Degree Compass Heading Accuracy
- Low Voltage Operations (2.16 to 3.6V)and Low Power Consumption (100 μA)
- Compatible for Battery Powered Applications
- I2C Digital Interface
- Popular Two-Wire Serial Data Interface for Consumer Electronics
- Wide Magnetic Field Range (+/-8 Oe)
- Sensors Can Be Used in Strong Magnetic Field Environments with a
- 1° to 2° Degree Compass Heading Accuracy
- Fast 160 Hz Maximum Output Rate Enables Pedestrian Navigation and LBS Applications

[10]

The Honeywell HMC5883L is shown attached to an MSP430 in figure 4.4.b. The compass is inlayed upon the board and the board must be taken to a company for it to be imprinted. However, the group also has the option of laying out and soldering the board. The decision has not been made to which avenue will be taken between the two options. It is a relatively minor fee to get the board professionally laid out and often they will offer student discounts to those students that are working on design projects.

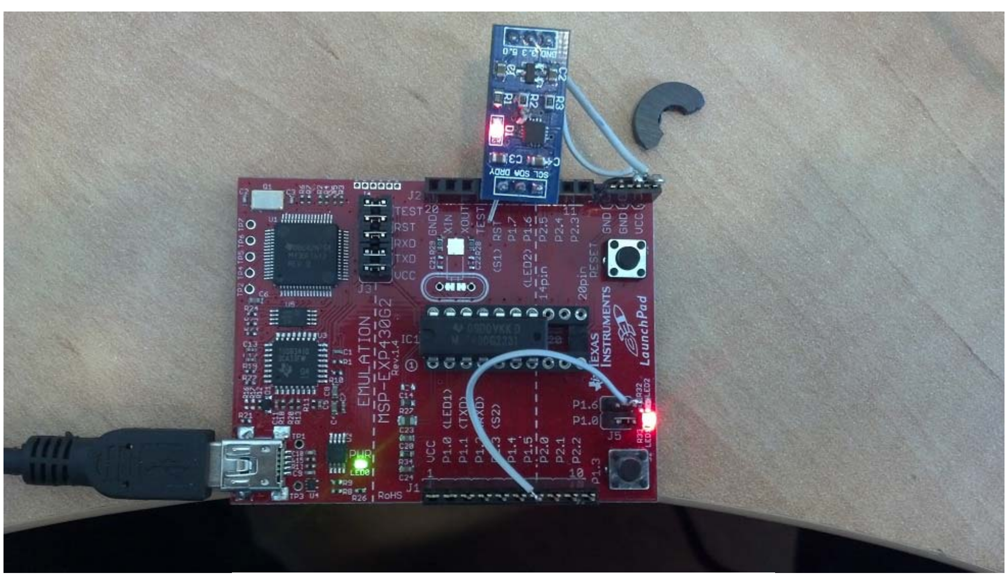


Figure 4.4.b: HMC5883L and MSP430

The compass selection came down to the fact that there is a lot of documentation about the integration of the Honeywell with the MSP430 over I2C. There is a strong user community that has combined an MSP430 and the Honeywell and it is good to know that the combination works together in many different applications. Many user made tutorials detail exactly how to code communication from the MSP430 to the HMC5883L. This allows for many avenues to resolve issues in case of trouble during the integration stage. Therefore, only one digital compass was researched and deemed adequate for the project at hand and no other compasses were researched.

4.5 Microcontroller System

After researching what will be required of the microcontroller during the research phase, various microcontrollers were found to hold most to all of the specifications that are needed for this application. Various design decisions were considered with the biggest question being how much computing power would each of the microcontrollers listed below deliver to making the “SenseWalk” cane come to fruition. Also, the microcontroller that was chosen must abide to the low battery-powered, lightweight design while still maintaining good processing power.

The parts that were most considered were the Texas Instruments (TI) line of microcontrollers alongside the Arduino line which mostly consists of Atmel microcontrollers. The Texas Instruments product line was selected for consideration due to its popularity and success in many past design projects for this class. However, TI has a notorious reputation for having a steep learning curve for first-time embedded developers, in which this case, all members of the group have little to no experience in implementing embedded systems for a given design. Arduino on the other hand was chosen due to its reputation as being very user friendly for beginners with a gradual learning curve, while offering microcontrollers of similar processing power. Both companies also offer development boards and software IDEs that are advantageous to embedded system developers.

4.5.1 MSP430

Texas Instruments’ MSP430 family of microcontrollers is used in a broad range of embedded systems applications. This 16-bit architecture would be sufficient for the design needs. The MSP430 has different lines of microcontrollers based on how much processing power and capability is needed depending on the application that you want to use it for. For this, the decision had to be made on which microcontroller out of the vast choices that the MSP430 family offers would be most optimal for the “SenseWalk” application. Because this project will require much processing power, there is no need to consider the lower-level MSP430s as those hold less memory, lower operating frequency and are not able to take in signals from a number of peripherals. Therefore, this decision was down to determining between two very similar high-level MSP430 models, the MSP430BT5190 which is based on the other model to be considered, the MSP430F5438A.

What is most beneficial for the MSP430BT5190 model is that it is designed to be used with the TI Bluetooth controller model CC2560, which is an ideal controller for audio needs (see 4.6 Bluetooth Selection for more information about this specific controller). This is advantageous to the design since Bluetooth technology will be implemented. The MSP430BT5190 offers the highest amount of flash memory that the MSP430 family offers at 256 KB, as detailed in table 4.5.1.a, which should be a sufficient size to hold the program that will be upload to the microcontroller. The MSP430BT5190 also comes with a licensed hardware Bluetooth stack provided by MindTree. This means that no Bluetooth stack programming will need to be done for the “SenseWalk” which will eliminate a task to focus on, leaving room for other tasks to pursue such as ensuring that the microcontroller and Bluetooth module are interfacing correctly.

However, the only drawback to using this MSP430 is that a full-licensed version of TI’s IAR Embedded Workbench IDE is needed in order to use the MindTree Bluetooth stack. The stack is completely restricted to IAR and will not work with TI’s other IDE, CCS. A full-license of IAR is very costly and typically costs about $500 for purchase, which can be a hindrance due to the group's limited budget as detailed in section 8.1. One way around this however, is to write a Bluetooth stack independent of the one provided through the other microcontroller, the MSP430F5438A, but that will still require a full-license version of either IAR or CCS because that will take up a significant chunk of the program code size. The free versions of both software programs have code size limits that they will only compile within. In order to circumvent this issue, CCS does not place code size limits on programs written in assembly, therefore, there is the option that the Bluetooth stack will need to be written in assembly. As a result, there would be no other need to just stick to using this specific microcontroller as the Bluetooth stack is its only defining feature that offers ease during developing the design.

	MSP430BT5190
Frequency (MHz)	25
Voltage Range	1.8 V to 3.6V
Flash (KB)	256
SRAM (B)	16384
Timers – 16-bit	3
GPIO	87
Watchdog	Yes
Real-Time Clock	Yes
Brown Out Reset	Yes
SVS	Yes
USCI_A (UART/LIN/IrDA/SPI)	4
USCI_B (I2C & SPI)	4
DMA	3
Multiplier	32x32
Temp Sensor	Yes
ADC	12-bit SAR
ADC Channels	16
Pin/Package	100LQFP, 113BGA MICROSTAR JUNIOR

Table 4.5.1.a-Design specs for the MSP430BT5190 **[13]**

Besides the Bluetooth stack, this microcontroller also supports UART which will allow serial communication with the peripheral devices such as the Bluetooth controller. Also, there are sufficient ADC channels with a good bit-size to offer a good resolution of incoming signals that the microcontroller will receive.

Next, the MSP430F5438A is taken into consideration. As show in table 4.5.1.b below, the design specifications for this given microcontroller are exactly the same specifications to that of the MSP430BT5190.

Frequency (MHz)	25
Voltage Range	1.8 V to 3.6 V
Flash (KB)	256
SRAM (B)	16384
Timers – 16-bit	3
GPIO	87
Watchdog	Yes
Real-Time Clock	Yes
Brown Out Reset	Yes
SVS	Yes
USCI_A (UART/LIN/IrDA/SPI)	4
USCI_B (I2C & SPI)	4
DMA	3
Multiplier	32x32
Temp Sensor	Yes
ADC	12-bit SAR
ADC Channels	16
Pin/Package	0DIESALE, 0WAFERSALE, 100LQFP, 113BGA MICROSTAR JUNIOR

Table 4.5.2.b-MSP430F5438A Design Specifications **[14]**

Because this MSP430 also resides in the 5 series family of microcontrollers such as the MSP430BT5190, the basic design specifications are the same with differences in available pin packaging. In fact, the MSP430BT5190 is essentially a MSP430F5438A with a hardware license for a Bluetooth stack. Besides that, the MSP430F5438A basically has the exact same processing power and capabilities as the MSP430BT5190. Referring back to the Bluetooth stack programming issue mentioned about the MSP430BT5190, a Bluetooth stack can be written for the MSP430F5438A model as well. The MSP430F5438 meets the criteria established for memory-size, low-power, and peripheral communication requirements.

In either case, each microcontroller choice is advantageous because the MSP430FA-line offers an experimental board that would be perfect for the “SenseWalk” design. The MSP-EXP430F5438 experimenter board can be used for either MSP430 models mentioned as they have the same pin layout. The board will allow for quick programming and debugging. Other features that the board offers that will prove beneficial for the “SenseWalk” is that the board offers an audio jack (for the situation in which the Bluetooth will not be developed and performing correctly on time), push buttons (which are part of the “SenseWalk” design) and an LCD screen that will also allow the user to directly interface with the GPS if time allots. This makes the MSP-EXP430F5438 a perfect choice for development to work with either one of the MSP430 microcontrollers mentioned.

4.5.2 Stellaris M3 8962

The biggest difference between the MSP430 family and the Stellaris family of microcontrollers is that the Stellaris line is a 32-bit ARM processor which is essentially in itself a RISC-type architecture. This is basically the most powerful line of microcontrollers that TI offers. What is appealing about the Stellaris microprocessor is that we can obtain the highest flash memory available through TI which is set at 512 KB, which should be more than sufficient to hold our program. Because of the large bit size and higher operating frequency, this makes the Stellaris a much faster microcontroller. The only tradeoff is it consumes much more power than the MSP430. Furthermore, since this is the best microcontroller that TI offers, the cost will be greater to purchase it in addition to purchasing whatever development tools are made for those microcontrollers. The higher end chips which are typically more expensive always have more expensive development tools than those associated with the MSP430 line.

CPU	ARM Cortex M3
Max Speed (MHz)	80
SRAM (kB)	96
GPIOs	65
Operating Temperature Range I	-40 to 85
SSI/SPI	2
I2C	2
UART	3
ADC Channels	16
ADC Resolution (Bits)	12
Watchdog Timers	2
EPI/EMIF	Yes
I2S	Yes
RTC (Real time clock)	Yes
ADC Units	2
Maximum 5-V Tolerant GPIOs	65
ROM Software Libraries	Yes
Battery-Backed Hibernation Module	No
UART Modem Signalling	1
Analog Comparators	3
Digital Comparators	16
Boot Loader in ROM	1
CAN MAC	2
16 MHz Precision Oscillators	Yes
Capture Pins	8
Timers	5
ADC Ext Reference	Yes
Interrupts (Count)	53
Pin/Package	100LQFP, 108NFBGA
Flash (KB)	512

Table 4.5.2.a-LM3S9D96 Design Specifications **[15]**

Judging by the long list of attributes that are shown in the design specification table, table 4.5.2.a above for the Stellaris, it would be more than sufficient to implement the “SenseWalk” project. In fact, the vast amount of capability that the Stellaris offers would be simply overkill, with many parts of the Stellaris being left underutilized. It is interesting to note that the Stellaris offers the same amount of ADC channels as the MSP430 with the same resolution of 12-bits but since the Stellaris operates at a higher frequency. It will perform processes with such conversions included at a much higher speed.

Though the Stellaris is the most powerful choice from TI, there is the drawback of its higher power consumption which would hinder the goal of achieving a low-power console for the “SenseWalk”. As a result, even though a microcontroller with a good amount of memory is needed, the learning curve for the Stellaris would be far too steep. This is due to the many features to it that must be learned. In addition, it consumes much more power than a lesser microcontroller that is just as capable for the application.

4.5.3 Arduino 2560 (Atmega2560)

The Arduino Mega 2560 microcontroller board holds an Atmel designed microcontroller, the Atmega2560. The Atmega2560 is an 8-bit RISC architecture that operates at a 16 MHz frequency. Based on the specifications shown in the table below, the Atmega2560 is closely similar to the MSP430 line despite it being an 8-bit architecture. It holds the same amount of flash memory as the MSP430 yet holds less SRAM. Compared to the MSP430, it operates slower due to its smaller architecture and slower clock speed, but that difference in speed should be negligible toward the application.

Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Max I/O Pins	86
Analog Input Pins	16
SPI	5
UART	4
ADC Channels	16
ADC Resolution	10 bits
Analog Comparators	1
Timers	6
Flash Memory	256 KB of which 8 KB used by boot loader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Table 4.5.3.a-Atmega 2560 Design Specifications **[16]**

The advantage to using this microcontroller paired with an Arduino microcontroller board is that the board can be easily connected to any external power supply or AC-to-DC adapter, making it beneficial to use for the

"SenseWalk". Having 4 UART channels is sufficient for communication with on-board peripherals.

For software development, Arduino has its own programming language that is modeled after the C programming language using the Arduino development environment. This environment is its own IDE with many libraries available for use. Many of the commands are simplified, thus making programming an easy task with not too steep a learning curve. The development board connects via USB to any PC allowing for rapid prototyping.

4.5.4 Final Microcontroller Selection

With the choices ranging between three types of microcontrollers that are suitable for implementing this design, pragmatism comes into mind when making the final selection. The Stellaris microcontroller is an amazingly powerful microcontroller that would be more than able to perform the tasks required of it for this project; however, this microcontroller would use more power than the other two available microcontrollers, requiring additional battery supply that will go against the objectives to the overall design of the "SenseWalk". Therefore, the choice of microcontroller is then narrowed downed to the choices of the remaining two.

Within the MSP430 line that was discussed, there are two microcontrollers to choose from. Both technically offer the same functionality and power but only one of them is advertised as having a licensed Bluetooth stack, which restricts it to only being used under TI's IAR IDE. Not having to worry about writing the Bluetooth stack on the microcontroller would greatly save development time and would make interfacing with the Bluetooth module to be much simpler. Thus, out of the MSP430 line, the MSP430BT5190 was chosen for its being designed to interface easily with a Bluetooth module and for easy development on the experimenter board designed for that microcontroller.

Lastly, the final decision is left between the MSP430BT5190 and the Arduino Mega 2560, which uses an Atmega2560 microcontroller. For the purposes of this design, it seems that an 8-bit architecture that the Atmega2560 offers would not be sufficient. Though it is enticing to use the Arduino Mega 2560 for its ease of interfacing with peripherals and straightforward programming, the microcontroller that it utilizes seems too underpowered for this application. Furthermore, the experimenter board associated with the MSP430 is a great attribute to use as it will allow for rapid prototyping of the design as it already includes a button, ports designed for TI modules, and audio capabilities. Therefore, the final selection of microcontroller has been determined to be the MSP430BT5190. The ease of integrating other TI products to this device, such as Bluetooth and GPS modules, is a benefit worth taking advantage of. The main processing and functioning of the "SenseWalk" now lies within the MSP430BT5190.

4.6 Bluetooth Selection

A Bluetooth module is needed in order to implement the transmission of Bluetooth audio to the user's headset. The module consists of the Bluetooth controller chip and a transceiver module that can incorporate transmitting, receiving signals and setting up a piconet network communication according to the protocols established in the Bluetooth stack found in the microcontroller.

Selection is based on various factors that would be deemed most beneficial to the "SenseWalk" design requirements that include interface integration and data rate speed which is the most essential factor to consider.

4.6.1 CC2560-PAN1315

One of the choices for a Bluetooth controller includes the CC2560 controller offered by TI. The main reason for this selection is that this controller is advertised as being able to handle wireless audio solutions by having the AD2P audio profile included. In addition to this, the CC2560 is designed to interact with both MSP430 and Stellaris microcontrollers with the proper stack integration provided. This controller is able to operate in dual mode, meaning that it is able to run in LE and EDR mode, thus achieving the low power design for the "SenseWalk" with a max data rate of 4000 kbps alone but the data rate as a transeiver module is set at 2.1 Mbps as shown in table 4.6.1.a below. It is designed to work with seven active devices which are more than enough for the design needs for connecting only to one headset. The controller will be part of a Bluetooth module that allows it to interface with the microcontroller. The module also acts as a transceiver, thus providing all the necessary hardware needed to establish a connection with outside devices, transmitting and receiving signals as needed. However for this case, the module will only be required to provide transmission.

Data Rate (Max)	2.1 Mbps
Dimension	6.5x 9x1.7 mm
Bluetooth Standard	V2.1+EDR
Frequency Range	2.4GHz
Receiving Sensitivity	-93 dBm
Transmit Power	10 dBm
Supply Voltage	3.3 V
Host Interface	I2C, SPI,UART
Pin/Package	76VQFN
Modulation Techniques	GFSK,EDR

Table 4.6.1.a-CC2560-PAN1315 Design Specifications **[17]**

An advantage to using the CC2560-PAN1315 module is that it is designed to interface with the MSP-EXP430F5438 experimenter board, allowing for rapid development. TI offers a Bluetooth evaluation kit called the PAN1323 evaluation module kit that uses the CC2560-PAN1315 that connects to the mentioned experimenter board. The PAN1323 is designed to interact with the MSP430BT5190 that uses the same stack as the module itself.

4.6.2 Rayson BTM 730

The second possible Bluetooth module to consider for the Bluetooth design is the Rayson BTM730 module. This module is also designed for wireless headset applications and contains the A2DP audio profile, allowing it to be a good choice to consider for this project's Bluetooth design. Table 4.6.2.a shows that the module is able to interface with the microcontroller through UART connection. This module also upholds the same Bluetooth standard as the CC2560-PAN1315, giving it the same enhanced data rate and the most up-to-date Bluetooth features currently available.

Dimension	16x15x2 mm
Bluetooth Standard	V2.1+EDR
RF Power	-6dBm to +4dBm
Receiving Sensitivity	-82dBm
Voltage Supply	1.8-3.6 V
Audio Interfaces	Analog, PCM, I2S and SPDIF
Host Interface	USB and UART

Table 4.6.2.a-Rayson BTM 730 Design Specifications **[18]**

The voltage supply range for this module is within the same range as the previous module, therefore there is no advantage to this one using up less power than the other. With regards to features such as receiving sensitivity, these specifications should not matter much with consideration to the implementation to this design. Overall, this module can be considered to be on the same level as the CC2560-PAN1315.

4.6.3 Final Bluetooth Module Selection

After inspecting both Bluetooth modules, it can be safe to say that they are about the same level in terms of functionality as they both offer A2DP profiles and can be used for wireless audio solutions. Both modules operate with the same voltage supply range, thus making both applicable to the low-power constraint of the design. However, what makes one stand out over the other is the ease of integration that the CC2560-PAN1315 offers. Because another TI product was chosen, the MSP430BT5190, this Bluetooth module was designed to easily integrate and communicate with this given microcontroller since it shares the same licensed Bluetooth stack with the module. Furthermore, the experimenter board that is used for this microcontroller was also designed to easily connect this module to the board. The ease of integrating and developing the Bluetooth communication is present with the design of these products. Therefore, the CC2560-PAN1315 was chosen for these reasons.

4.8 Button/Controller Selection

The “SenseWalk” is a device to help visually impaired people navigate between locations using sonar to avoid objects and GPS to navigate them in the right direction. The buttons on the “SenseWalk” will need to be easily identified and easy to use. The “SenseWalk” will have seven buttons: power, volume rocker, GPS select 1, GPS select 2, enter, home, sonar off/on, battery life.
The power switch turns on and off the device. A simple rocker switch with a raised dot on one side can be used so that the person operating the device can easily know if it is on or off. The next button is a volume rocker. This will allow the volume to the Bluetooth headset to go up and down. This volume rocker will be similar to the one found on cell phones. The next button is the GPS select 1 and 2. These buttons will allow the user to select between the different GPS routes programmed into the “SenseWalk”. The enter button allows for the selection of the route. The home button allows for the GPS to select a route back home.

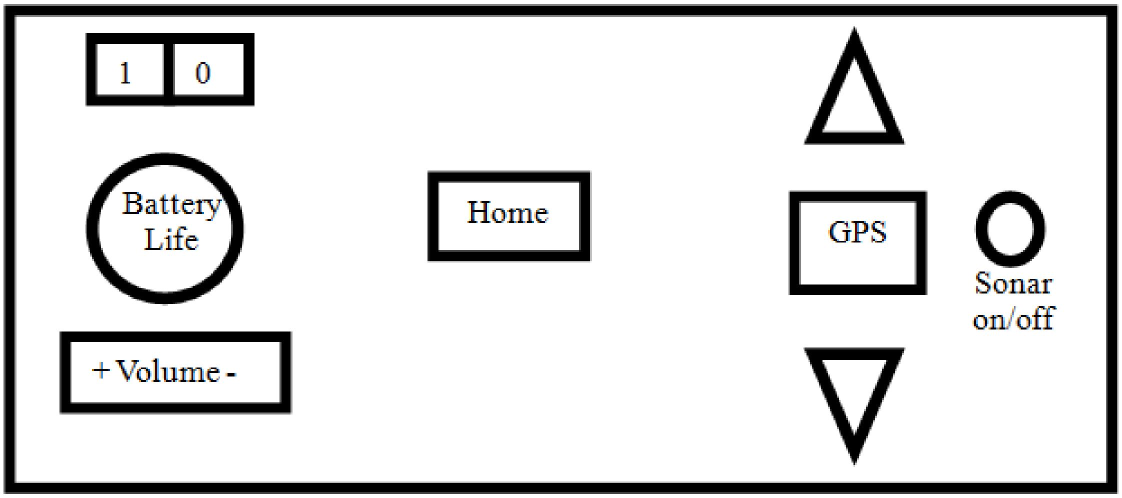


Figure 4.8.a-Design layout of button/controller selection

The button layout is in figure 4.8.a shown above. This picture shows where the different buttons will be located on the device. These buttons will be in variety of sizes and shapes. This way a visually impaired person can locate the different buttons on the device without being able to see them and just using touch. These buttons will need about a medium amount of pressure to press them similar to a TV remote control. This allows for easy access by not allowing it to be too sensitive so that they are accidently pressed.

4.9 External Memory Selection

This section details any external memory sources that will be connected to the MSP430. Many options are available in the forms of SD Cards, serial flash, micro SD, and USB thumb drives. For the “SenseWalk” only SD cards were taken into consideration. This is due to the overall cost and efficiency of using an SD card. The prices of SD cards have significantly dropped over the years and they have become a viable option for mass data storage on mobile devices.

4.9.1 SD Card Selection

An SD card will be used to deliver waypoint data and other information from the user’s home computer to the embedded microcontroller on the “SenseWalk” device. A physical interface for connecting the SD card to the MSP430 is standard on most of the MSP430 development boards the team is considering. The decision to use SanDisk manufactured SD cards come from the company’s reputation and widespread use of its products. SanDisk offers a wide variety of cards for every need.

Two sizes of SD cards are available today. There are micro SD cards and then there are standard SD cards. For the “SenseWalk” application we will stick with standard SD cards because of the availability of accessories to such as a USB adapter. The use of the larger SD card allows us to wire each individual pin to the MSP430 board much easier than dealing with a tiny card. Also, the micro SD cards are very brittle and seem to be easily misplaced.

Two cards are considered for use in the “SenseWalk”. Both have very similar feature sets and are directly comparable to each other. The major difference between the two is the speed at which the card reads and writes data. The standard card is class-4 while the ultra-card is class-6. Both cards are water-, temperature-, and shock-proof. The “SenseWalk” is a mobile device, so out in the urban environments, water or shock damage is a certainty and the ability to be resilient will be a strong factor of the “SenseWalk”.

4.9.1.1 SanDisk Standard 8GB Card

The 8 GB regular card is the standard run of the mill memory card that is widely available for use today. It is very popular for its high capacity and low price. It however does not provide read or write speeds that are fast enough for any high-end applications such as DSLR cameras or HD video. This memory is very low power and does not require much voltage or current to be provided from the MSP430 to run.

Features:
- 8GB* Memory Card. SanDisk® also offers 16 & 32GB Capacities--Not available in all stores
- Class-4 speed performance for recording up to 720p HD[1] video clips
- Easy labeling for multiple storage uses – photos, music and videos
- Solid-state memory with no moving parts for proven reliability
- Waterproof, temperature proof, shock proof, vibration proof, and x-ray proof[2]
- Built-in write-protect switch prevents accidental data loss
- Backed by a 5-year limited warranty*

[11]

4.9.1.2 SanDisk Ultra 8GB Card

This 8 GB card comes from the Ultra line from SanDisk. It comes with the basic features available on the standard card but improves on the read and write speeds. This makes it a great candidate for HD video or RAW images that are taken by expensive cameras. The only downside is the price is roughly double of the standard card. This memory is very low power and does not require much voltage or current to be provided from the MSP430 to run even though it is the Ultra version of the SD 8 GB card.

Features

- 8GB[3] Memory Card. SanDisk® also offers 16, 32, & 64GB Capacities--Not available in all stores
- Class-6 speed performance for recording up to 1080p HD[1] video clips
- Transfer photos and videos at read and write speeds of up to 20MB/sec*
- Solid-state memory with no moving parts for proven reliability
- Waterproof, temperature proof, shock proof, vibration proof, and x-ray proof**
- Backed by a Lifetime Limited warranty[2]

[11]

4.9.1.3 SD Card Selection

The selection between the two SanDisk cards comes down to price and speed. The ultra-card on average is almost double the price of the standard card. With enough shopping the user can get the difference in price between the two cards to be around 50%. The main advantage of the ultra-card is the transferring data in 1080p video format.

Since the “SenseWalk” does not necessitate the use of 1080p video nor is any video information being loaded onto the card, the standard SD card should be sufficient for moving CSV files between a computer and the “SenseWalk” application.

4.9.1.4 SD Card USB Adapter

TOPRAM products are used for high capacity high performance data storage and communication media. Many devices are compatible with this SD Card USB adapter including cell phones, PDAs, cameras, desktops, laptops, and more. Many laptops and desktops today do not have SD Card slots but USB slots are standard, which requires the use of an adapter. This adapter will be used as an easy interface to plug the SD Card into a laptop or desktop.

Features:

- Support USB Version 1.1 Interface.
- Support Secure Digital (SD) Spec., Multi-Media Card (MMC) Spec. & Memory Stick (MS) Spec.

- Plug & Play
- No external power required
- LED indication for Power On & Busy Operation.
- Support driverless solution for Windows 2000/ ME/XP, Mac OS 8.6 or later version and Linux 2.4
- Support driver for Windows 98
- Bundled with USB Cable

[12]

5. Design Summary

This section will consist of the design approach for the design used for the microcontroller. This includes everything from the GPS, to the software, hardware, and other minor details. After that the hardware design will be talked about. In the hardware the circuits for the receiver and the transmitter as well as the power supply and management will be talked about.

5.1 Software Architecture Overview

Software is a major component of functionality for the design. Software is needed to make sense of the four parts of the “SenseWalk” that need to be programmed in order to perform within the goals of the design. Due to the fact that no actual implementation of the hardware and software has occurred at this point, a basic overview detailing the plan of how the software should work according to its provided specifications is necessary for design.

There are two components of the “SenseWalk” that are very software dependent. This entails of software for the GPS module, in order to meet its software requirements specifications, and software for the microcontroller that also meets its specific design requirements. Sections 5.1.2 and 5.1.3 both examine the software overviews for the two components in detail with regards to the functions that they must perform.

5.1.2 Microcontroller Software Overview

Because the microcontroller is the central processing unit that works with its peripherals to obtain a necessary behavior, software programmed to meet this requirements are needed. This includes programming the microcontroller with relation to the Bluetooth and the GPS modules, and the sonar signals that are being sent to the microcontroller. The following figure shows a diagram depicting the basic overall processes that the microcontroller must perform by taking in certain inputs and providing the necessary outputs.

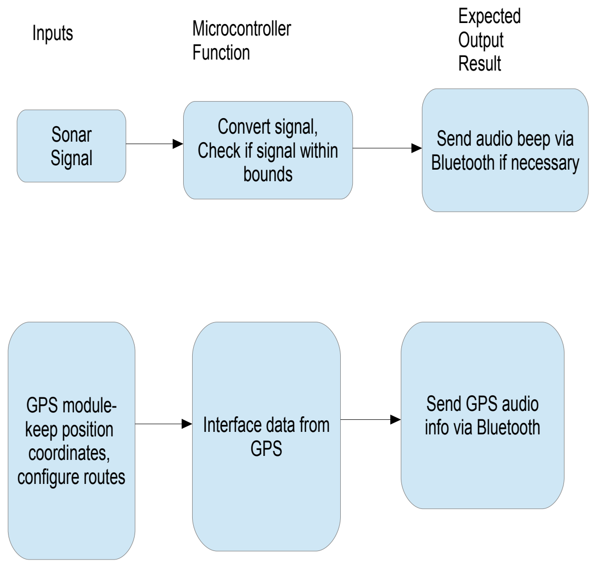


Figure 5.1.2.a-High-Level Software Requirements Overview

From the basic software requirements displayed in Figure 5.1.2.1, there are two main processes that the microcontroller functions to serve. First is making sense of the signals sent to the microcontroller from the sonar sub-system. The signal to be sent from the sonar sub-system will be of the analog type. The microcontroller program must first perform an ADC conversion that will find the signal's digital counterpart. If this digital signal is within a certain range of signals, this correlates to the fact that there is indeed something within the user's path. If it is within certain proximity of the user, then the microcontroller will emit an audible beep via the Bluetooth module to the headset. Otherwise, if the signal does not correspond to a signal denoting an obstacle, no audible beep should be sent to notify the user, meaning that the current state of their path is clear of obstructions.

The second process to perform within the microcontroller's program is to make sense of its interface with the GPS. The GPS module has its own software that it runs on which will be discussed in greater detail in section 5.1.3. From the microcontroller's software perspective, it does not need to interface with the GPS software that deals with maps and route configuration. Instead, the microcontroller just needs the output results that are gained from the GPS-related software. This information correlates to current coordinate position and route information. The program must be able to relay this information to a designated audio format that will inform the user of this data via the Bluetooth module. This translation of information will include providing audio instructions to the user along a given configured route and notifying the user of their current position at significant intervals as they traverse their path.

5.1.3 GPS Software Overview

The GPS software has two basic requirements; routing and position determination. The software has to be able to route the user along a predetermined path. This requires the “SenseWalk” to know the user’s location and direction at all times. Latitude and longitude will be provided by the use of a GPS module built into the embedded systems of the “SenseWalk”. The direction of the user will be determined by the use of a digital compass. Both the GPS module and digital compass will send the data using the appropriate transmission protocols to the MSP430 for analysis.

Using the GPS module and Digital Compass the MSP430 should use its onboard software algorithms to determine the proper actions to be taken at all times. Efficient and effective algorithms must be created to ensure that the user is always routed correctly and that the “SenseWalk” surpasses its requirements that are set forth in this document.

5.2 Hardware Architecture Overview

The “SenseWalk” is composed of both a substantial amount of software and hardware. This section will focus heavily on the system hardware design and functionality. Shown below in Figure 5.2.a is a complete system block diagram for the “SenseWalk”. It is important to understand the overall system level design. Once the system has been designed, the various sub-systems can be designed to meet the requirements.

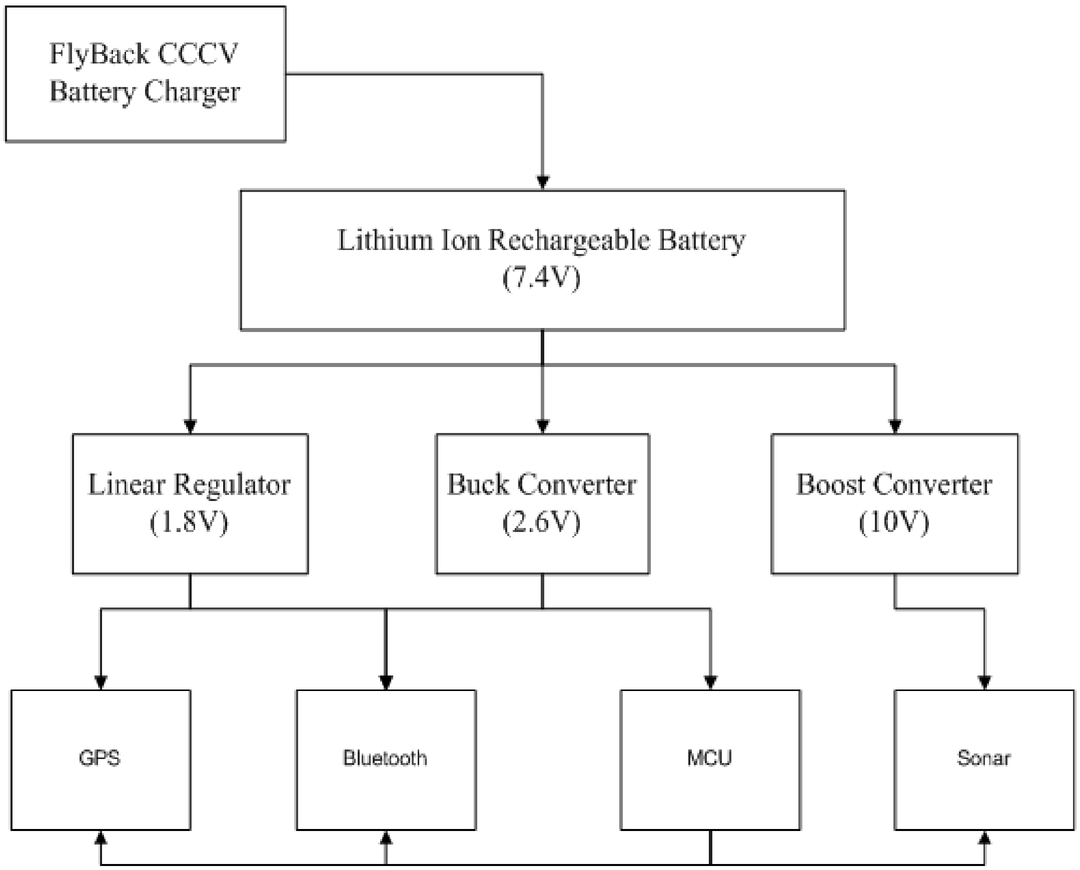


Figure 5.2.a-Hardware block diagram

As seen from Figure 5.2.a, the “SenseWalk” will be fully powered by a 7.2V rechargeable Lithium Ion Battery pack. The batter pack will allow for mobile functionality, which is a necessity. Because the Lithium Ion battery will require charging after the battery has been drained, there needs to be a battery charger. A CCCV battery charger will be designed which will serve to recharge the Lithium Ion battery pack after use.

The Lithium Ion battery pack will provide power to all of the “SenseWalk” sub-systems. There are four main sub-systems, the GPS unit, the Bluetooth unit, the Microcontroller unit, and the Sonar unit. Because each of these listed sub-units requires either a higher or lower supply voltage then the 7.8V produced by the Lithium Ion battery, DC-DC converters are required. There are three DC-DC converters that will be designed for the “SenseWalk”. The first is a linear regulator. The linear regulator will provide a constant 1.8V for both the GPS and Bluetooth units. The second is a switching Buck converter. The Buck converter will provide a constant 2.6V for both the Bluetooth and microcontroller units.

(Note: The Bluetooth unit requires two voltages, 1.8V and 2.6V). The third is a Boost Converter. The Boost converter will provide a constant 10V which is required for the Sonar unit.

The microcontroller will be required to communicate with the GPS, Bluetooth, and Sonar units. This interfacing is explained in more detail in the Software Architecture Overview, Section 5.1 above. Shown below in Figure 5.2.b is a block diagram illustrating from a hardware perspective, of how the four sub-systems will connect and the direction of communication from sub-system to sub-system. The Microcontroller will serve to control each sub-system. It will be responsible for turning on and off the Sonar and interpreting Sonar data. Also the Microcontroller will be responsible for processing GPS data and transmitting relevant information to the Bluetooth sub-system. The Bluetooth sub-system will provide the "SenseWalk" user with audible information.

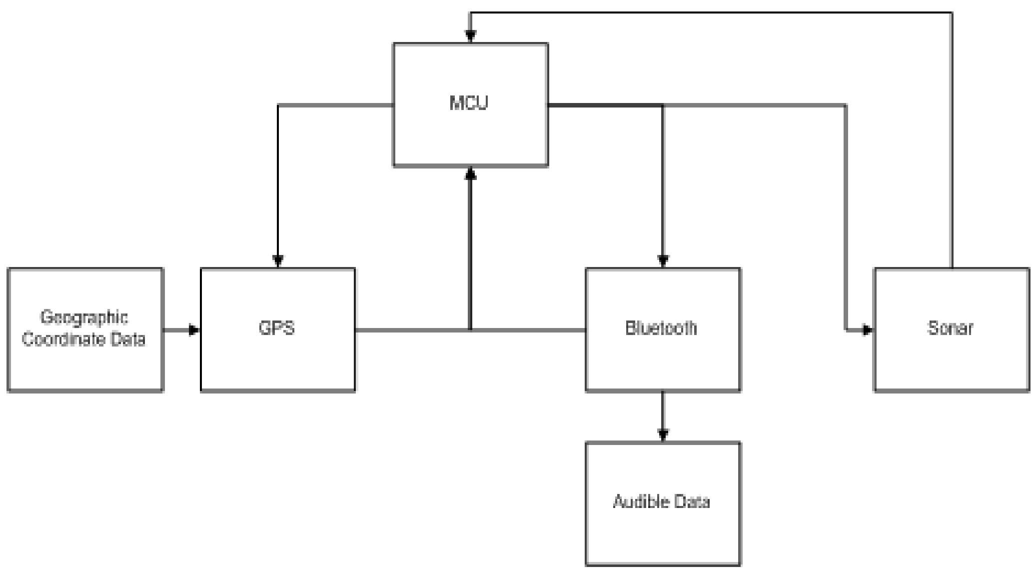


Figure 5.2.b-Block Diagram

6. Project Prototype Construction and Coding

Prototyping is a necessary step to the engineering design process and occurs once all hardware and software selection has been done. For the hardware end, prototyping involves the construction of the power supply circuitry, constructing the sonar system hardware, and interfacing both Bluetooth and GPS modules and microcontroller onto the development board. This entails implementing the design. In the end, the prototype must be able to successfully deliver power from the power supply system to all necessary sub-systems with all sub-systems providing their needed implementations. This prototype as a whole must be able to implement all requirements of the “SenseWalk” design. Most of the prototype will occur on a development board which will allow rapid prototyping and quick error handling.

Coding of the software needed for both the microcontroller and GPS will be done during this prototyping phase as well. The software code will guide the functioning of these components, allowing the microcontroller to make sense of its peripherals’ inputs and dictating the GPS module’s interfacing with route configurations and position on the map software.

Lastly, once all software and hardware has been fully integrated as a single working system, the system may be deemed as a working prototype that will need testing to ensure that all overall design requirements have been met.

6.1 Object Proximity Detection Circuit Design

After the sound wave is transmitted and bounces off an object, it then is received by another transducer. For this design, the signal will be received from the transmitter then put through a first stage op amp with a gain of R2/R1 +1. The value will be the minimum gain needed for the microcontroller to accept the value.

Once the signal is passed through the first stage amplifier it will then be sent to a comparator. This IC will compare the voltage to a reference voltage. If that voltage is higher than the reference voltage, then transistor A will be opened and the signal will be passed through a band pass filter and then to the microcontroller. If the signal is less than the reference voltage, then transistor B is opened and the signal is passed through the second stage amplifier. This signal is then placed into a feedback loop and placed back into the comparator. This process repeats until the signal is amplified so that it is larger than the reference voltage.

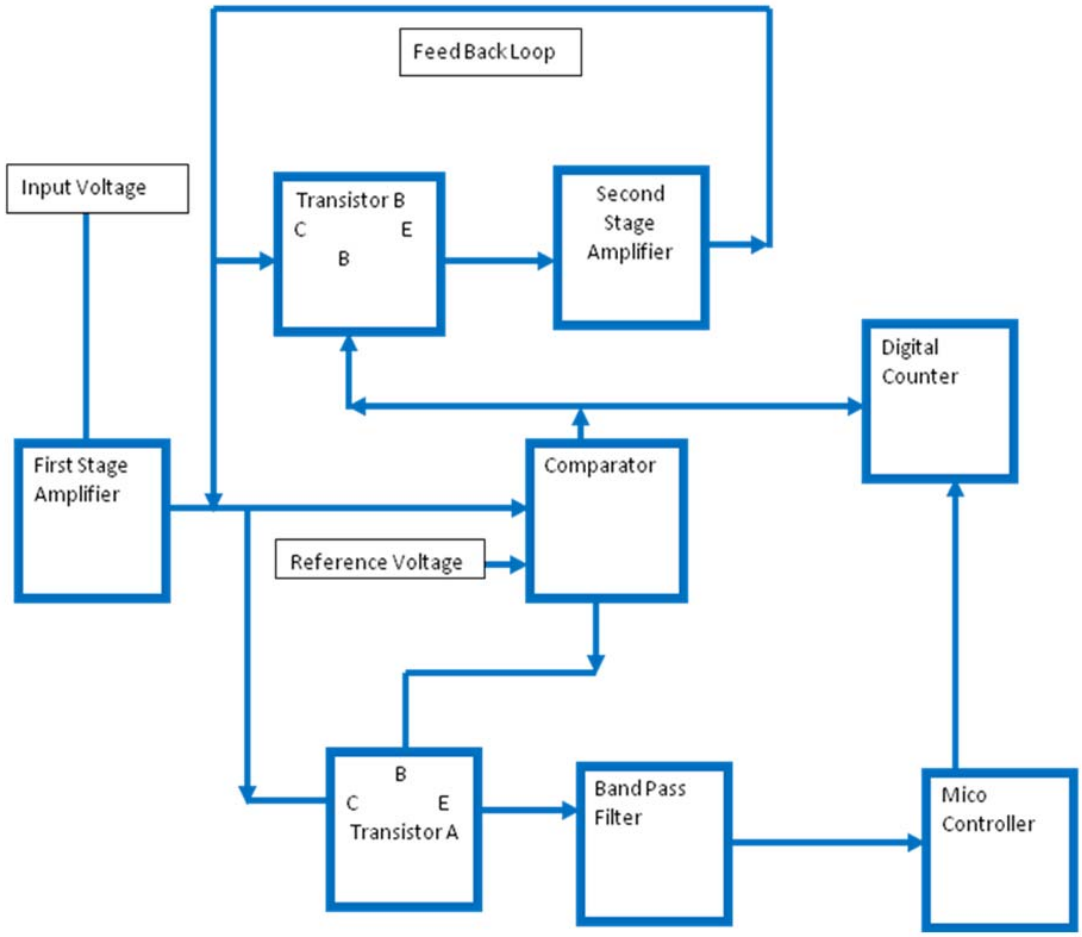


Figure 6.1.a – Block diagram of the sonar receiving circuit

A digital counter is added to count the number of times the signal is placed through the second stage amplifier. This serves two purposes; one is so that microcontroller can account for the time it takes to amplify the signal so it can properly account for the distance. The second reason is so that the signal will not wind up in an endless loop if there is no signal for it to amplify. A block diagram is shown above in figure 6.1.a.

The detailed schematic of the sonar receiving circuit is shown in figure 6.1.b. This circuit uses two amplifiers to boost the signal from the transducer. The comparator is used to see if the signal is large enough. This comparator has two outputs one is the inverse of the other. When the signal is large enough it is passed through a band pass filter. After the signal passes through the band pass filter it goes to the microcontroller to be processes.

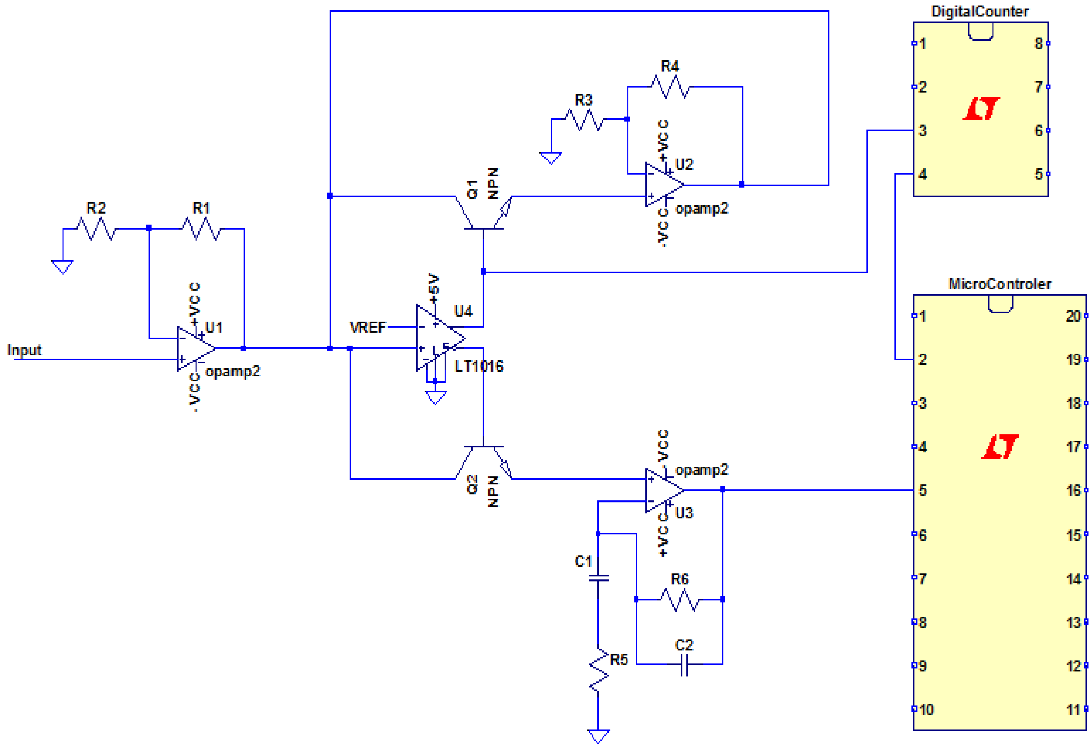


Figure 6.1.b- Schematic of sonar receiver

6.1.1 Object Proximity Detection Part Selection

For the proximity detection circuit, several different types of parts will be used. These include three operational amplifiers, a comparator and two NPN transistors. For the comparator, a couple of different devices were inspected: one from Linear Technology called LT1016 Ultra-Fast Precision 10ns Comparator and the other from Texas Instruments called the LM111 Voltage Comparator [28].

	Linear Technology LT1016	Texas Instruments LM111
Supply Voltage	5V	5V
Supply Current	25mA	6mA
Switching speed	10ns	200nS
Operational Temperature	-40C^o to 85 C^o	-55C^o to 125 C^o
Output high voltage	3.4V	50V max
Input Bias Current	5µA	60nA
Minimum voltage input	-3.75V	-15V
Maximum voltage output	3.5V	15V
Output max current	20mA	50mA

Figure 6.1.1.a- Comparison table of the two comparators

These parts are both supplied with a simple 5 volt digital logic. They will take in a voltage at the positive terminal and compare that with the reference at the negative terminal. We will be using a reference voltage of 3 volts for the comparator. If voltage is lower than the reference voltage of 3 volts, a low signal will be outputted and will turn on transistor A. If the positive terminal is higher than the reference, a high voltage will be outputted and transistor B will turn on. The basic function of these parts is the same.

The Texas Instrument LM111 can handle larger voltages and supply more current than the Linear Technology LT1016. The LT1016 has two outputs, one connected to Transistor A and the other to Transistor B. If the LM111 is used, then an inverter will be needed to drive one of the transistors while the other transistor can be connected directly to the output of the comparator. Since the design will be dealing with low voltages and there is only a need to drive a transistor, the Linear Technology LT1016 will be used. More capable, the LM111 will require an extra inverter and the voltage and current ranges it supplies are not necessary for the application. For the transistor, the group looked at the common 2N2222 by Multicomp and the On Semiconductor General Purpose Transistor MMBT2222LT1 [29].

	2N2222	MMBT2222LT1
Collector-Emitter Voltage Max	30V	30V
Collector-Base Voltage Max	60V	60V
Emitter-Base Voltage Max	5V	5V
Max collector current	800mA	600mA
Operation Temperature	-65 to 200	-55 to 150
Mounting type	Hole through	SMD
Package	TO-18 Metal Can	SOT-23 Case 318 Style 6
Delay Time	10ns	10ns
Rise Time	25ns	25ns
Storage Time	225ns	225ns
Fall time	60ns	60ns
Output capacitance	8pF	8pF
Input capacitance	30pF	30pF

Figure 6.1.1.b-Data comparison table for the two transistors

Both of these transistors are NPN and meet the voltage and the current requirements needed. Both have a max collector emitter voltage of 30 volts and the design plans on exceeding 5 volts for the application. Both parts have a very fast rise and fall time in the nanoseconds. The max current it can handle is more than enough for the application. The biggest difference is the package. The 2N2222 comes in a TO-18 Metal Can with a hole-trough mounting style. This is a very common transistor package. The MMBT2222LT1 comes in a SOT-23 case which is very small and a SMD mount. This mounting style is ideal because you can populate both sides of a board. For the “SenseWalk”, the decision has gone with using the MMBT2222LT1 for both Transistor A and Transistor B [30].

In the design for the proximity part selection, three operational amplifiers are need. For the design, the Texas Instruments TL084I and the ON Semiconductor SA55332 Operational Amplifiers. The TL084I is the same amplifier used in the Electronics 2 lab. The part comes in package of 4 op amps in one IC. The SA55332 is similar to the Tl084I. The IC contains 4 op amps in the same package.

	Tl084I	SA55332
Supply Voltage±	18V	22V
Operating Temperature	-40^{o}C to 85^{0}C	-40^{o}C to 85^{0}C
Slew Rate	13V/μs	9V/μs
CMRR	86dB	100dB
Internal Resistance	10^{12}Ω	300k Ω
DC Voltage Gain		50000
Input Noise Voltage	18nV/(Hz)$^{0.5}$	5nV/(Hz)$^{0.5}$

Table 6.1.1.e

In Table 6.1.1.e shows the difference between the two operational amplifiers. Both of these amplifiers have the proper temperature range and the Supply Voltage that is greater than 10V. Both of these op amps can be used for the first stage amplifier and the second stage amplifier, as well as the band pass filter [31]. Because of the familiarity with the TL084I in pervious labs we will be using this part in for the “SenseWalk”.

6.2 Power System Design

The “SenseWalk” will operate from a single Lithium Ion battery pack. The various sub-systems will each require specific supply voltages. For this reason, the sections below outline all of the power supply circuits. Also the “SenseWalk” will require an AC-DC battery charger to recharge the Lithium Ion battery.

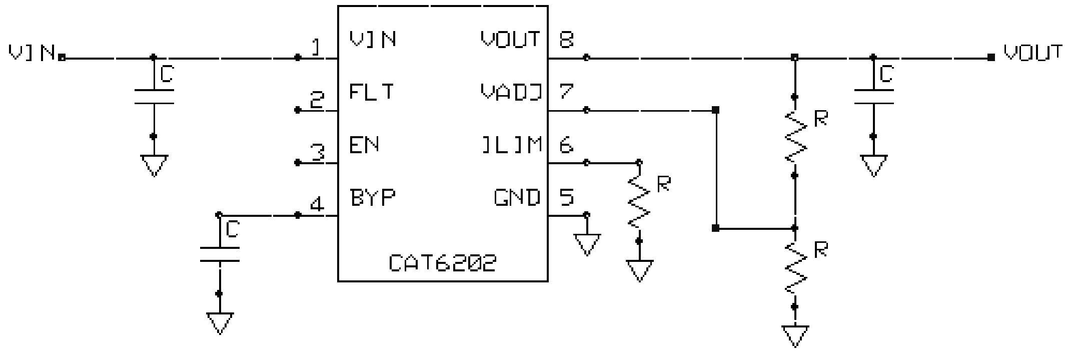
6.2.1 Linear Regulator Design

After considering many options, it has been decided to select ON Semiconductor’s Linear Regulator IC, CAT6202, to provide a regulated 1.8V supply for the Bluetooth and GPS ICs. A general application schematic is show below in Schematic 6.2.a; which was produced from ON Semiconductor’s CAT6202 datasheet.

A capacitor can be connected between Pin 4 (BYP) and ground. This capacitor allows for soft-start feature. When a regulator is first turning on, there can be large current spikes on the supply line. To reduce and prevent damage associated with turn-on current spikes, a soft-start technique is implemented. The value of the capacitor connected to Pin 4 will determine the speed at which the CAT6202 turns on.

A resistor can be connected between Pin 6 (ILIM) and ground. This resistor will set the over-current level. If allowable current is exceeded, the CAT6202 will enter a fault shutdown. Typically the over-current threshold should be set to 150% of the expected load current, this will prevent frequent and undesired fault shutdowns. The over-current protection circuit will protect both the CAT6202 and Load.

A resistor voltage divider network is used between Pin 8 (VOUT), Pin 7 (VADJ), and ground. This will allow for a selected output voltage of 1.8V. Pin 2 (FLT) can be used to detect fault conditions such as over-current, under-voltage, and over-temperature. This data could be feed to the microcontroller and processed. Pin 3 (EN) can be used to enable and disable the CAT6202. Pin 3 could be controlled by the microcontroller to save power when the CAT6202 is not needed.



Schematic 6.2.a-Linear Regulator

6.2.2 Buck Converter Design

After considering many options, it has been decided to select Texas Instrument's Buck Converter IC, TPS62050, to provide a regulated 2.6V supply for the Microcontroller and Bluetooth IC. A general application schematic is show below in Schematic 6.2.b; which was produced from Texas Instrument's TPS62050 datasheet.

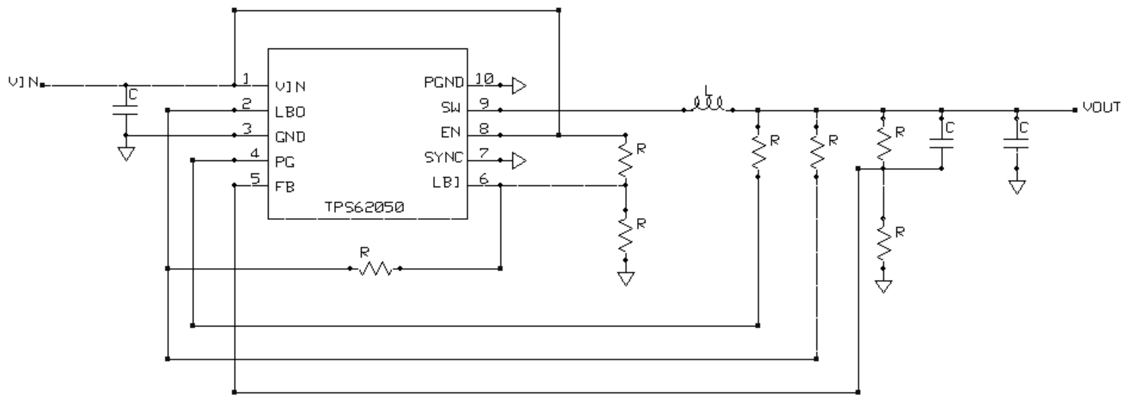
Both the input and output capacitors should be only MLCC, to reduce layout size. The value of the input and output capacitance will need to be tuned. The input capacitor will reduce input ripple voltage. The max input ripple should not exceed 100mV. The output capacitor will reduce output ripple voltage. The max output ripple should not exceed 30mV.

The inductor value will be calculated for the specific operating conditions. Once the inductor value has been selected, the value will need to be tuned to optimize efficiency and output ripple. Inductor selection is an important design step, an Inductor with a relatively low DCR value should be selected to optimize efficiency.

The inductor can be calculated from the equation V_L = L*di/dt. The equation should be solved for L. V_L is simply Vin-Vout, di can be found from the maximum allowable ripple current, and dt can be found from the switching frequency. The ripple current is typically set to 30% of the load current.

The compensation network will need to be tuned to provide an optimized transient response to dynamic load steps. As the microcontroller changes operating stages, the current can rapidly change. The compensation network will keep the TPS62050 output voltage stable. If the compensation network is not designed correctly, the TPS62050 output voltage can become unstable, or have a sluggish to transient response.

Pin 2 and 6 offer under-voltage fault protection, which is set by the use of a resistor voltage divider network.



Schematic 6.2.b-Buck Regulator

6.2.3 Boost Converter Design

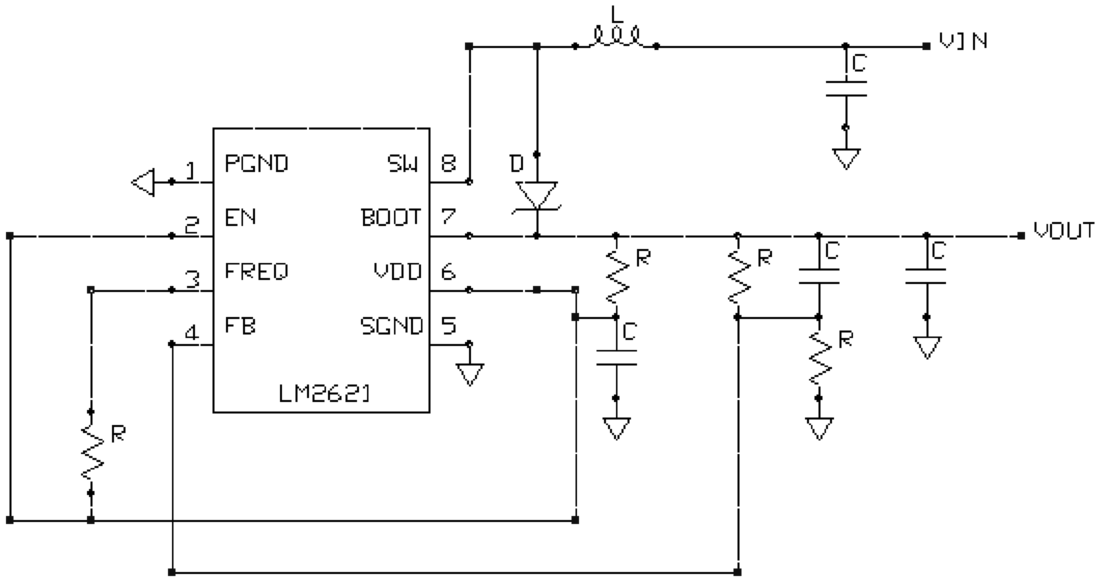
After considering many options, it has been decided to select Texas Instrument's Boost Converter IC, LM2621, to provide a regulated 10V supply for the Sonar sub-system. A general application schematic is show below in Schematic 6.2.c; which was produced from Texas Instrument's LM2621 datasheet.

The inductor value will be calculated for the specific operating conditions. Once the inductor value has been selected, the value will need to be tuned to optimize efficiency and output ripple. Inductor selection is an important design step, an Inductor with a relatively low DCR value should be selected to optimize efficiency.

A resistor can be connected between Pin 3 (FREQ) and Pin 6 (VDD) to set the switching frequency. A higher switching frequency will allow for a smaller Inductor. The switching frequency and Inductor values will be tuned for optimum efficiency and minimum layout space.

The LM2621 will also require a compensation network. The compensation network will need to be tuned to provide an optimized transient response to dynamic load steps. As the Sonar transducer changes operating stages, the current can rapidly change. The compensation network will keep the LM2621 output voltage stable. If the compensation network is not designed correctly, the output voltage can become unstable.

The output diode should be a Schottky diode because they offer faster switching speeds; this will improve the efficiency. The output capacitor will reduce ripple voltage caused by the switching states. The value of the output capacitor should be selected to achieve a maximum ripple voltage less than 60mV.



Schematic 6.2.c-Boost Regulator

6.2.4 Flyback Battery Charger Design

After considering many options, it has been decided to select ON Semiconductors Flyback Converter IC, NCP1014, to provide a constant current constant voltage (CCCV) to recharge the lithium ion battery pack. A general application schematic is show below in Schematic 6.2.d; which was produced from ON Semiconductor's NCP1014 datasheet and design note.

The design offers complete isolation, by utilizing the Flyback topology. An optocoupler is used to provide secondary side current and voltage regulation. The optocoupler is used because it still allows for primary and secondary side isolation. Constant Current Constant Voltage is provided by a combination of resistors, a diode, and a BJT. It is important to have CCCV because this Flyback converter will be used to charge a lithium ion battery.

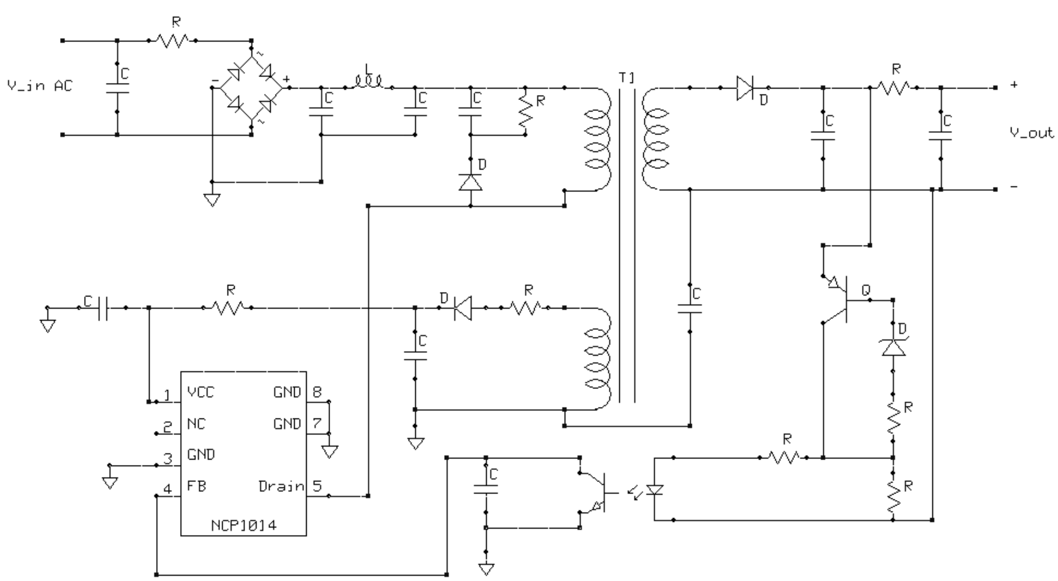
There is a full wave rectifier bridge on the input which will convert the AC voltage to a high voltage DC value. The bridge is followed by a high voltage DC capacitor and a LC network. The LC network is used to reduce EMI.

There is a secondary side rectification diode to convert the AC voltage produced by the transformer to the desired DC Voltage. The output capacitor will reduce any ripple voltage.

On the primary side of the transformer is a RCD Snubber network. This Snubber is used to reduce the overshoot and ringing of the high voltage switching MOSFET, which is internal to the NCP1014. The Snubber will decrease efficiency, but it is necessary to protect the MOSFET. Without a Snubber network, the switching MOSFET could see high voltage levels which could possibly damage the device. It is common to see a few hundred volts on the switching FET.

The most important section of the Flyback design is the transformer. The transformer allows for isolation and energy transfer between the primary and secondary side. A bad transformer design will result in either a nonfunctioning design or a poor efficiency. There are many factors that need to be considered and calculated such as the output voltage, core material, core gap, inductance, number of turns for the primary secondary and auxiliary windings. ON Semiconductor has provided a design note for the NCP1014 which will greatly simplify the transformer design process. Magnetic design for switching power supplies can be a very complicated process. This is one of the main reasons for using ON Semiconductors NCP1014; the large amount of resources and design notes provided online.

The transformer will require three windings, the primary, secondary, and auxiliary. The primary and secondary are used to transfer energy between switching states. The auxiliary winding is not required, but it serves to reduce the standby power draw. The auxiliary winding also serves to supply power to the NCP1014.



Schematic 6.2.d-CCCV Battery Charger

6.3 Software Detailed Design

There are currently 2 plans that have been thought out to handle the input of location data (.osm) and the routing of the individual from point A to point B. The first option uses readily available Open Source software to integrate with each other and to present an elegant solution with a multitude of features for the user to work with. Option B is a fallback option that is used in case the source software has problems interacting with each other and a solution is not readily available.

6.3.1 Plan A

The ideal solution involves all of the Open Source software that is currently maintained by the respective developer communities to work without issue. This involves using a high-spec MSP430 to be able to load TinyOs, TakaTuka, and GpsMid onto onboard memory and the different software layers harmonious interacting. Memory will be in short supply so microcontroller selection will be critical to enable the software to be used and implemented. This will be the first time that all of these programs will be loaded together and documented.

GpsMid
TakaTuka
TinyOs
MSP430

Figure 4.4.1.a-Independent software layers

6.3.2 Plan A Route Creation

The user must plan the route, load the route data, and then the walking stick must guide the user in real-time. In order for this to happen, software on the user’s desktop to create the route is needed. This will be accomplished by using Osm2GpsMid, a map creation software that is able create GPS ‘midlets’ that will be stored onboard the walking stick. It is noted that the user must have someone that has no visual disability to use the map creation software and upload the resulting midlet to the device.

In order to use the “SenseWalk”, routes must be premade and loaded onto an SD Card. The user will open up Osm2GpsMid to create route files. The result is an .osm file, an XML file that contains OpenStreetMap data, which will be loaded onto the SD card. Routes and other map data can be bundled into one file using Osm2GpsMid. If Osm2GpsMid is unavailable to the user or would prefer to create a bundle of .osm files, the user can use a converter tool and configuration file creator.

Once this data is loaded onto the SD card, the “SenseWalk” will be powered on and initial configuration will take place. The user will select the appropriate route via the button interface and routing will begin. This Plan uses GpsMid software as the routing algorithm.

6.3.3 Plan B

In the event that the software in Option A is unable to properly interface with each other, a new routing plan will be put to use. Dijkstra's algorithm or some other route creation software will be used to route the user along a loaded set of waypoints.

Using the Code Composer suite, algorithms will be used to route the user as they walk along their chosen path. In real-time, the software and microcontroller will take inputs from the GPS card and compare them to the generated waypoint. With this comparison made, the software will have to be resilient enough to recognize how close the user is to the current waypoint and send an appropriate response to the Bluetooth enabled headset. If route correction is necessary, the conditionals must point the user in the right direction and route accordingly. This plan relies more on the use of new code and will not use much of the software that is used in Plan A. Algorithms will be written for much of the direction and routing.

6.3.4 Plan B Route Creation

Plan B takes place incase Plan A becomes impractical. The user must plan the route, load the route data, and then the walking stick must guide the user in real-time. In order for this to happen, software on the user’s desktop to create the route is needed. This will be accomplished by using Osm2GpsMid, a map creation software that is able create GPS ‘midlets’ that will be stored onboard the walking stick. It is noted that the user must have someone that has no visual disability to use the map creation software and upload the resulting midlet to the device.

In order to use the “SenseWalk”, routes must be premade and loaded onto an SD Card. The user will open up Osm2GpsMid to create route files. The result is an .osm file, an XML file that contains OpenStreetMap data, which will be loaded onto the SD card. Routes and other map data can be bundled into one file using Osm2GpsMid. If Osm2GpsMid is unavailable to the user or would prefer to create a bundle of .osm files, the user can use a converter tool and configuration file creator.

Once the SD card is loaded into the “SenseWalk” the button interface will be used to select the route and begin routing. The user will know what they are doing because of audible messages via the Bluetooth headset. The overall outcome and message over Bluetooth are essentially the same as Plan A. The major difference comes from the inner workings and routing of the user which makes the plans different.

6.4 Embedded Software Detailed Design

The software for the embedded system or microcontroller will be done so through Texas Instrument's Code Composer and IAR Embedded Workbench IDEs. The software will be designed to meet the requirements expected of the microcontroller which will include utilizing the Bluetooth stack, interfacing with the appropriate peripherals, and outputting the necessary signals. More information is discussed about the embedded software design in the microcontroller software overview in section 5.1.2. The software will be implemented through the microcontroller's memory with the help of the experimenter board.

6.4.1 Digital Compass Interface

The Honeywell HMC5883Ldigital compass connects to the MSP430 family of microcontroller by used of the 16 pins in figure 6.4.1.a. The pins will be connected to their appropriate terminals. The ground and voltage will be supplied by the battery pack. The internal clock with be supplied by the microcontroller. The output pins will be directed back to the microcontroller. [10]

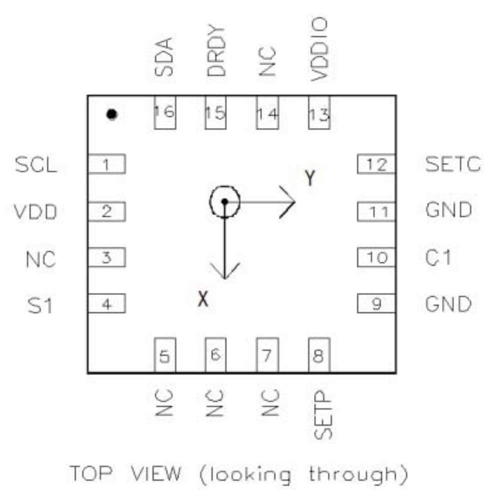


Figure 6.4.1.a-Honeywell HMC5883L Digital Compass Pin Diagram

6.4.2 Bluetooth Interface

The Bluetooth module's main source of interfacing will be between itself and the microcontroller. The CC2560-PAN1315 is designed to easily interface with the MSP430BT5190 through the setup of its pin configuration. This is especially done so with the MSP430EXP5438 experimenter board which has a port designed to easily connect the CC2560-PAN1315 in direct communication with the microcontroller. Since the MSP430BT5190 already has a Bluetooth-licensed stack programmed into its memory that is in accordance with the CC2560-PAN1315, programming the interface between these two sub-systems will require little effort on integration. Figure 6.4.2.a shows how the hardware is set up between the two components and how they interface with one another.

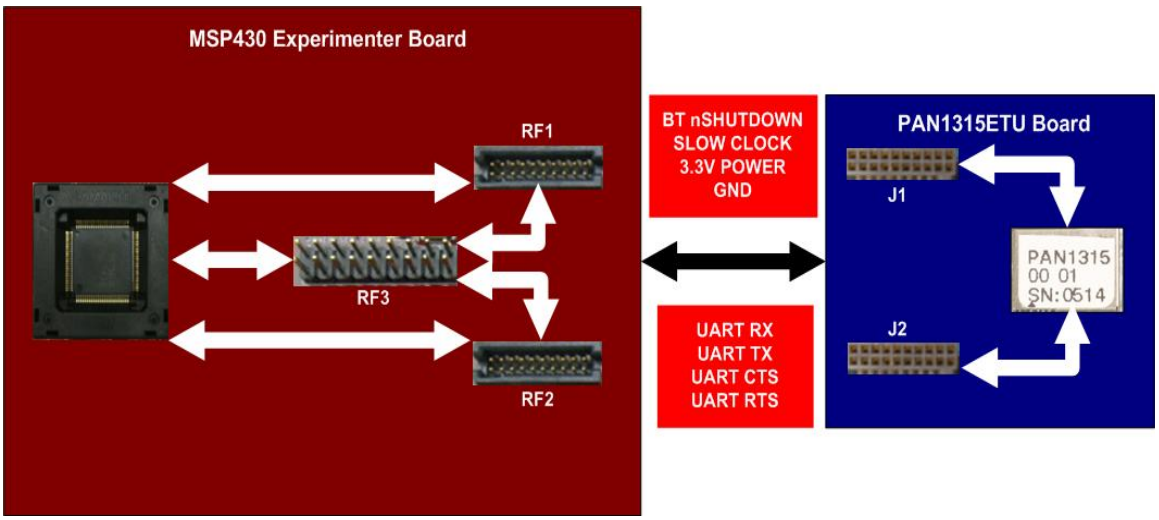
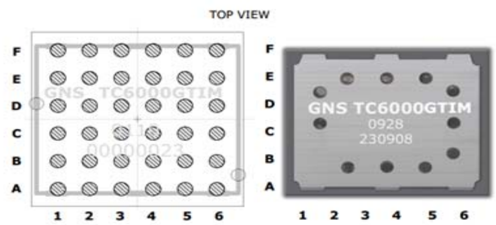


Figure 6.4.2.a-Hardware architecture between Bluetooth module and MCU
"Courtesy of Texas Instruments"

6.4.3 GPS Interface

The CC4000-TC6000 series of GPS Modules are able to connect to the MSP430 family of microcontrollers using the 36 pin interface shown in figure 6.4.3.a. There are many pins that are not used and must be left unused. Figure 6.4.3.b shows a typical application diagram for the CC4000-TC6000. The diagram shows the inputs and the outputs to the module. The inputs to the module are 1.8 V, the RTC clock, and the GPS antenna. The resulting GPS data is bidirectional and is exchanged between the microcontroller and the self-contained module.



F	VBAT	VDD_IO	NU7	NU8	NU18	RTC_CLK
E	TCXO_CLK	GND2	NU19	NU20	NU10	NU12
D	NU13	NU14	GND1	GPS_UART_TX	GPS_UART_RX	NU9
C	NU15	NU16	GND3	GPS_ENABLE	NU11	NU6
B	NU1	NU2	NU3	NU4	TIMESTAMP	GPS_PPS
A	NU12	GPS_GND1	GPS_RF	GPS_GND2	NU17	NU5
	1	2	3	4	5	6

Note: Do **NOT** connect **NU (not used)** pins to anywhere! These pins must be left open!

Figure 6.4.3.a-CC4000 interface
“Courtesy of Texas Instruments”

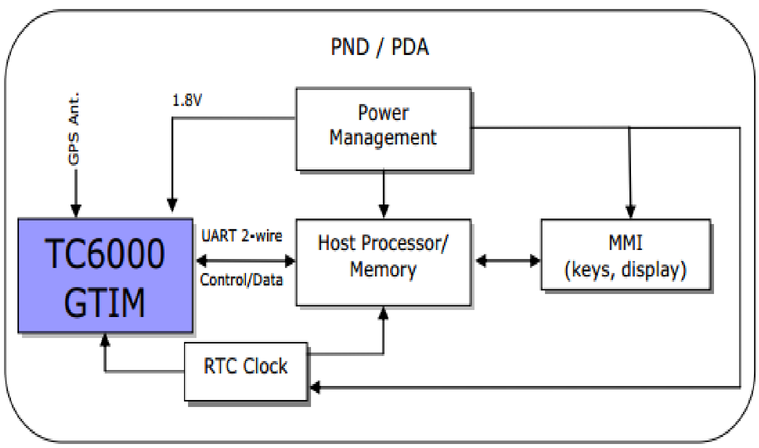


Figure 6.4.3.b CC4000 application diagram
“Courtesy of Texas Instruments”

6.4.4 External Memory Interface

The MSP430 is used to communicate with the MMC or SD card via the SPI interface. SPI is a fast and efficient protocol that allows for simultaneous bidirectional data transfer. Serial data is transmitted and received by the MSP430 using the USART module in SPI mode. Both of the SD cards above use the same pins for connection to the MSP430 over SPI. The wiring diagram in Figure 6.4.4.a shows how to wire the SD card to the MSP430. Figure 6.4.4.b shows the physical connections of a real MSP430 and SD card [11].

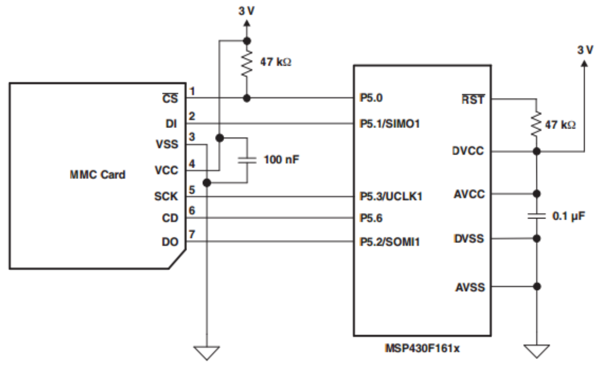


Figure 6.4.4.a-SD Card Wiring Diagram
"Reprinted with permission from SanDisk"

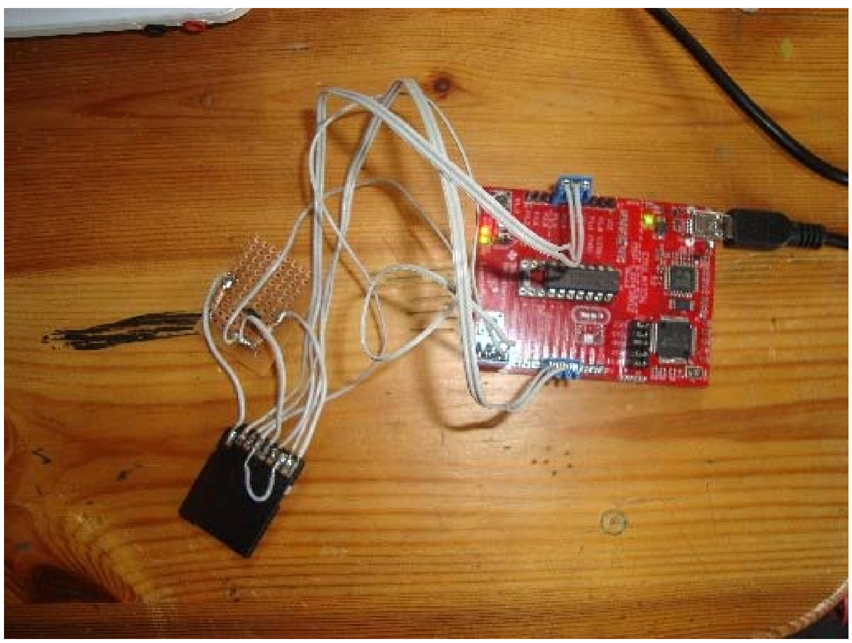


Figure 6.4.4.a-SD Card wired to MSP430

6.5 PCB Design and Construction

For the "SenseWalk" we will need to have a two PCB boards. The first PCB board will house the both the transmitting and receiving transducers. The board will be mounted vertically on the front of the Module. This is because of the way the Transducers need to be facing. The PCB will include the 555 timer to generate the square wave for the transmitter. This PCB also the have amplifying and filtering circuits will for the receiving transducer. This vertical PCB will be two layers a inch tall and six inches wide. The vertical PCB will be connected to a larger horizontal two layer board about six inches wide and eight inches long. These two PCB will be connected by a PCB flex. On the second PCB will include the microcontroller, GPS unite, digital compass, and the Boost and Buck power management circuits. In order to get these boards printed we will use the $33 special by 4PCB. The layout of the different IC and the connection between the nodes will need to be done on software before the board is printed. This layout will be on Eagle.

7. Project Prototyping and Testing

This section describes how the “SenseWalk” will be configured and checked for accuracy. The software, hardware, and overall functionality of the “SenseWalk” will be tested to ensure proper operation.

7.1 Hardware Test Environment

The “SenseWalk” will need to be tested properly in all the right environments. In order to do this it will need to be tested in all the conditions a visually impaired person might use the “SenseWalk”. The “SenseWalk” will have to be tested both inside, outside. Because the “SenseWalk” will be used outside it should be able to handle heat and cold. The temperature element will be difficult to test sense we will need large chamber for the sonar beam. For the temperature elements the group will have to make sure all the parts used are within the proper temperature range of 100 degrees F to 20 degrees F.

7.2 Hardware Testing

Hardware must be tested due to ensure the functionality meets or exceeds all of the design requirements set forth earlier in section 2.3. These testing procedures will ensure that our design will work when it is all finally put together. The different modules will first be tested as individual sections. This is to reduce variables and narrow down any problems. The different modules will then be combined and tested as a whole unit.

7.2.1 Hardware Test Overview

Before the circuits are made into PCB they will go through several steps of testing. First everything will be simulated on a Spice program like LTSpice or Multisim. The circuits will first be tested as individuals and then combined as a whole and tested. The simulation values will need to be the same as the values expected from the calculations. The next step will be to bread board the circuits.

Like in the Spice simulations each circuit will be isolated and tested by its self then the circuits will be combined and tested as a whole. The bread boarded circuits will need to match the results of the simulation with a small amount of experimental error before we will proceed in have the PCB printed and finalized.

7.2.2 Object Proximity Testing

Testing the Object Proximity circuit is one of the most important parts of the project. The first part will be hooking the transmitting transducer to the function generator and setting the function to a 10V square wave at 40kHz with a 10% duty cycle. The next part will be setting up the receiver transducer to the oscilloscope. We will then up different objects in front of the transducers and various distances. We will start with a large flat object that will reflect the sound wave well at one foot and increased the distances by one foot at a time until we reach ten feet. We will then move to smaller objects that will not reflect the sound wave very fell and start it off at 1 foot and make the way back up to 10 feet. After taken all these measurements we will then

7.2.3 Power System Prototyping

After completing all circuit simulations and design schematics for the various power supplies, prototyping needs to be completed. There are four power supply circuits that will need to be prototyped and tested; they are the linear regulator, Buck converter, Boost converter, and Flyback battery charger. All initial prototyping will be completed on individual breadboards and solder boards. This will allow for easy design and component modifications. Each of the four power supplies will be constructed on an individual bread board for initial testing. After all initial prototyping has been completed and each design is successful, then the designs will be transferred to a PCB. Finial testing and part modifications will be completed on the PCBs. The Linear, Buck, and Boost power supplies will all be located on the main PCB. The Flyback battery charger will be located on an external PCB.

7.2.3.1 Linear Regulator Testing

Once the Linear regulator circuit has been constructed, final specification testing is required. Shown below in Table 7.2.3.a is a listing of all specifications that the linear regulator circuit must be tested for and pass. Because the input voltage will vary, due to the discharge of the battery, the linear regulator must pass all specifications at two separate test conditions; the maximum and minimum battery charge voltage.

	Specification
Efficiency (Max)	80%
Load Regulation	2%
Load Current (Max)	100mA
Output Voltage	1.8V

Table 7.2.3.a-Linear Regulator Specifications

For testing conditions an electric power supply will be used to supply the input voltage, an electronic load will be used to provide the load current, and a multimeter will record all required measurements. To measure the load regulation, the output voltage will be measured as the load is increased in specific increments, up to 100mA. To measure the efficiency, the input and output power will be measured as the load is increased in specific increments, up to 100mA.

7.2.3.2 Buck Converter Testing

The Buck converter will require testing after the final design has been completed and constructed. Table 7.2.3.b below shows the required specifications that the Buck converter must pass. Because the input voltage will vary, due to the discharge of the battery, the Buck converter must pass all specifications at two separate test conditions; the maximum and minimum battery charge voltage.

	Specification
Efficiency (Max)	80%
Load Regulation	2%
Load Current (Max)	100mA
Output Voltage	2.6V
Output Ripple Voltage	2%
Input Ripple Voltage	8%
OCP Setpoint	150%

Table 7.2.3.2-Buck Regulator Specifications

For testing conditions an electric power supply will be used to supply the input voltage, an electronic load will be used to provide the load current, and a multimeter will record all required measurements. To measure the load regulation, the output voltage will be measured as the load is increased in specific increments, up to 100mA. To measure the efficiency, the input and output power will be measured as the load is increased in specific increments, up to 100mA. The input and output ripple voltage will be measured with the oscilloscope and must pass the required percentage of the input and output voltage. The OCP Setpoint will be measured with a precision current shunt and should be set to 150% of 100mA.

7.2.3.3 Boost Converter Testing

Once the Boost converter has been constructed, final specification testing will be required. Shown below in Table 7.2.3.c is a listing of all specifications that the Boost converter must be tested for. Because the input voltage will vary, due to the discharge of the battery, the linear regulator must pass all specifications at two separate test conditions; the maximum and minimum battery charge voltage.

	Specification
Efficiency (Max)	80%
Load Regulation	2%
Load Current (Max)	500mA
Output Voltage	10V
Output Ripple Voltage	2%
Input Ripple Voltage	8%
OCP Setpoint	150%

Table 7.2.3.c-Boost Regulator Specifications

The testing procedure for the Boost Converter will be the same procedure as the Buck Converter, which has been described above in Section 7.2.3.2.

7.2.3.4 Flyback Converter Testing

The Flyback battery charger will require testing after the final design has been completed and constructed. Table 7.2.3.d below shows the required specifications that the Flyback battery charger must pass. Because the input voltage could vary, due to universal use, the Flyback battery charger must pass all specifications at three separate test conditions; 80Vac 120Vac, and 280Vac.

	Specification
Efficiency (Max)	60%
Constant Current	2%
Constant Voltage	2%
Load Current (Max)	1.2A
Output Voltage	8.4V
Output Ripple Voltage	5%
Input Voltage (Min)	80Vac
Input Voltage (Max)	280Vac
OCP Setpoint	120%

Table 7.2.3.d-Flyback Converter Specifications

7.2.4 SD Card Integration Test

Purpose: The purpose of the SD card test is to verify that all the connections between the pins on the SD card and its dock are functioning and data on the SD card can be accessed by software on the “SenseWalk”.

Description: An SD card will be loaded with a fake waypoint with latitude and longitude. Next, it will be inserted into its appropriate slot on the MSP430 microcontroller. The MSP430 microcontroller will be turned on. Code Composer or Java test code for the SD card test case will parse the waypoint stored on the SD Card into local variables on the microcontroller. The microcontroller will then store these variables back onto the SD card in a file ‘output.txt’. The MSP430 will be powered off and the SD card inserted into a computer to validate that the waypoint was parsed correctly.

Expected Result: The SD test case is designed to verify that the SD card is able to communicate to the microcontroller without error. Once communication is established, uncorrupted data should be able to be accessed by the microcontroller and verified. The same waypoint on the ‘output.txt’ file should be the same as in the input file.

7.2.5 GPS Module Integration Test

Purpose: The point of the GPS Module test is to verify that connection has been established between the GPS Module and the MSP430, the GPS module is establishing connection with its network, and it transmits its resulting location to the MSP430 for software analysis.

Description of Test: The tester will open a mapping service such as Google maps or OpenStreetMap data and write down their current latitude and longitude. Once the current location is known, the MSP430 and GPS module will be powered on with a SD card connected. One minute will be allowed for the GPS module to synchronize with its network for a cold start. Once synchronization is achieved, the resulting NMEA string will be sent to the MSP430 for analysis. Using test code, this string will be output to a csv file on the SD Card. The SD card will then be loaded onto a computer for comparison with the location data found on the mapping service.

Expected Result: The expect result is to have the GPS module output the correct latitude and longitude of its current location verified by Google maps, OpenStreetMap, or any other mapping service.

7.3 Software Test

Once software has been written, testing needs to be applied to ensure that the software has met the software requirements and specifications. This process consists of outlining how a test should be set up for the particular software. The test will determine if the requirements have been met. Once the test has been implemented, the results of the test are to be examined to see if any debugging or any other changes to the program need to be done. There are four levels of testing the software that need to be done before testing the program in its entirety. They consist of unit testing, integration testing, and system and acceptance testing.

- Unit testing will test sections of programming code that is typically a function to see if that function has served its purpose
- Integration testing will test various software modules working together as a whole to determine if they are interfacing with one another correctly. For example, testing two functions that call and use the results from one another
- System testing tests how the entire program runs with all the code in its entirety making sure the overall requirements have been met.
- Acceptance testing in this case is testing the software as it works as a whole product meaning making sure the software will run properly once it is in the user's hands as a complete, package product.

Figure 7.3.a-Software Testing Lifecycle
Permission pending from “softwaretestingfundamentals.com”

The testing life cycle is cyclic and repetitive as the test plan may have to be reconfigured to start over again after any changes and improvements have been done to the software. Errors will appear in the debugging process such as compilation errors, runtime errors, and logic errors that need to be found during unit, integration, and system testing. Fixing an error will require that a new test must be run again after changes have been made to the code in order to that the problem has been solved in the code. The debugging process is shown here in Figure 7.3.2.

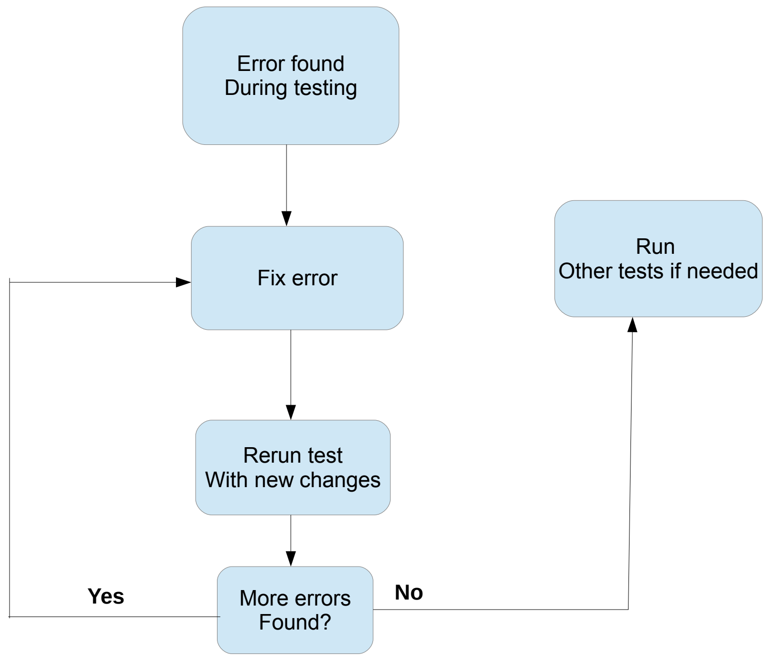


Figure 7.3.2 Debugging Process

Software testing must be done for all written code done by the group and to any other software that is being used for the project to ensure that all requirements are being properly met.

7.3.1 PC, Embedded Communication

The microcontroller will perform whatever functions are required of it from the program that is stored in the microcontroller's flash memory. This program must be tested to determine that the microcontroller is performing within its requirements. For the design, the microcontroller program must be able to perform the requirements that were detailed in section 5.1.2 regarding the microcontroller software overview. Therefore, unit testing will be done for functions serving to do the following:

- Interface and obtain analog signal from the sonar detection
- Perform analog to digital conversions for signals gained from the sonar detection
- Use converted digital signal to determine whether the signal correlates to

an obstruction found or whether the path is currently clear in order to send an audible beep to the Bluetooth
- Interface properly with the GPS module
- Obtain information from the GPS and transmit certain audio data that corresponds to that information
- Interface with the Bluetooth module

Integration testing will then be done for these modules as they are all combined together with other modules that rely on each other such as gaining information from the GPS and transmitting the necessary information into audio format to the user's headset via Bluetooth as one function relays information parameters to the other. Once all modules have been integrated and form the entire program for the microcontroller, system testing will be done for the entire program to determine if the software is performing up to its requirements expectations. System software testing will need to be done when all hardware has been successfully integrated, meaning that both the Bluetooth and GPS modules and sonar are interfaced with the microcontroller. The system testing will be done in the following manner:

- An analog signal indicating an obstruction in the path within a set distance has been found must be successfully sent to the microcontroller
- Program must be able to perform a successful analog to digital conversion in one of the microcontroller's channels
- Program must be able to recognize digitized signal as being within the range of signals that correspond to an upcoming obstruction in the user's path
- An analog signal indicating no obstruction in the path has been found must be successful sent to the microcontroller, digitized and recognized as a clear path by the microcontroller therefore not emitting any beep signal via Bluetooth to the headset
- Program must then emit an audio “beep signal” to the Bluetooth module to send to user's headset
- Program must be able to set up a piconet network between “SenseWalk” console's Bluetooth and the user's Bluetooth headset, thus establishing a successful protocol network
- Microcontroller does not use or recognize GPS if the user turns that feature off by pressing a button
- When GPS is selected, program must be able to obtain real-time information from the GPS module corresponding needed information such as current position, route configuration, next direction user must take
- Program must be able to relay mentioned GPS information relating to current position and/or next direction via Bluetooth in audio format to the user's headset

Any failures to meet any of these requirements in the system testing, will require debugging and examining units of the code to determine where the failure has occurred. The program will be written using either of TI's Code Composer Studio or IAR IDE, which will help keep track of compilation and runtime errors found in the code. However, logic errors will not be detected by the IDE. The program must be able to run and implement all of these requirements all the time without any fail for any situation that occurs during the user's use. Furthermore, the program must be successfully uploaded and stored into the microcontroller's flash memory.

7.3.2 GPS Route Creation Testing

The main focus of the software test cases is to check the maturity of the “SenseWalk” algorithms. In this section, the test cases are designed to expose any scenarios that could lead to an error or incorrect response from the “SenseWalk” on any software level. This could be from the OS up to the Java Byte code.

7.3.2.1 OSM2GpsMid to Embedded GpsMid Test

Purpose: The purpose of this test case is to check that a waypoint file generated by the OSM software is correctly parsed onboard the “SenseWalk” by the GpsMid embedded software.

Description: The tester must first load the osm data file onto the SD card. To do this, the user must open up Osm2GPSMid on the computer. Next, the user must select a route to export as a midlet to the SD card. Once the route is loaded on the SD card, the SD card will be loaded onto the “SenseWalk” and the “SenseWalk” will be powered on. The “SenseWalk” will then read the information from the SD card and will write back to the SD card in an “output.txt” file. The information in this output file will contain the original information that the SD card contained.

Expected Result: The expected result is to find that the GpsMid software onboard the “SenseWalk” was able to parse the data from the midlet and correct store that information.

7.3.2.2 GpsMid Single Waypoint Test

Purpose: A sample waypoint will be loaded onto the "SenseWalk" and the tester will attempt to use the "SenseWalk" to get to the test waypoint. No wandering should accompany this test as it should strictly follow the route selected.

Description: The tester must first load the osm data file onto the SD card. To do this the user must open up Osm2GPSMid on the computer. Next, the user must select a route to export as a midlet to the SD card. Once the route is loaded on the SD card, the SD card will be loaded onto the "SenseWalk" and the "SenseWalk" will be powered on. The "SenseWalk" will then read the information from the SD card and initialize its routing algorithms.
A second way to test this is to connect an LCD monitor to the "SenseWalk". With this connected, the user can load a route as above using the SD card and the route will be processed and displayed on the LCD for verification.

Expected Result: The expected result is to have the "SenseWalk" guide the user through each waypoint correctly. The tester should end up at the desired end point without any difficulty. Any wandering should be properly handled by the routing algorithms onboard the "SenseWalk".

7.3.2.3 GpsMid Single Waypoint Test (with wandering)

Purpose: A sample waypoint will be loaded onto the "SenseWalk" and the tester will attempt to use the "SenseWalk" to get to the test waypoint. However, the tester will purposely walk off course in attempt to have the "SenseWalk" reroute or notify the tester of the misdirection.

Description: The tester must first load the osm data file onto the SD card. To do this, the user must open up Osm2GPSMid on the computer. Next, the user must select a route to export as a midlet to the SD card. Once the route is loaded on the SD card, the SD card will be loaded onto the "SenseWalk" and the "SenseWalk" will be powered on. The "SenseWalk" will then read the information from the SD card and initialize its routing algorithms.

Expected Result: The expected result is to have the "SenseWalk" guide the user through each waypoint correctly. The tester should end up at the desired end point without any difficulty. Any wandering should be properly handled by the routing algorithms onboard the "SenseWalk".

7.3.2.4 GpsMid Route Test

Purpose: The tester will attempt to use the “SenseWalk” to navigate a route using multiple waypoints. No wandering should accompany this test as it should strictly follow the route selected.

Description: The tester must first load the osm data file onto the SD card. To do this, the user must open up Osm2GPSMid on the computer. Next, the user must select a route to export as a midlet to the SD card. Once the route is loaded on the SD card, the SD card will be loaded onto the “SenseWalk” and the “SenseWalk” will be powered on. The “SenseWalk” will then read the information from the SD card and initialize its routing algorithms.

Expected Result: The expected result is to have the “SenseWalk” guide the user through each waypoint correctly. The tester should end up at the desired end point without any difficulty. Any wandering should be properly handled by the routing algorithms onboard the walk sense.

7.3.2.5 GpsMid Route Test (with wandering)

Purpose: The tester will attempt to use the “SenseWalk” to navigate a route using multiple waypoints. However, the tester will purposely walk off course in attempt to have the “SenseWalk” reroute or notify the tester of the misdirection.

Description: The tester must first load the osm data file onto the SD card. To do this, the user must open up Osm2GPSMid on the computer. Next, the user must select a route to export as a midlet to the SD card. Once the route is loaded on the SD card, the SD card will be loaded onto the “SenseWalk” and the “SenseWalk” will be powered on. The “SenseWalk” will then read the information from the SD card and initialize its routing algorithms.

Expected Result: The expected result is to have the “SenseWalk” guide the user through each waypoint correctly. The tester should end up at the desired end point without any difficulty.

7.3.2.6 Alternate Testing

An alternate way of testing the waypoints is to connect an LCD monitor to the “SenseWalk”. With this connected the user can load a route as above using the SD card and the route will be processed and displayed on the LCD for verification. The tester can follow the onscreen route to make sure all of the other parts of the “SenseWalk” including the routing software, GPS module, and other pieces are working in tandem. This testing can be done for cases **4.5.2.2-4.5.2.7** to more easily identify issues or problems with the software.

8. Administrative Content

This section details the administrative content for the “SenseWalk” project. Organization is a necessary factor that is often times underutilized in many design projects. This often leads to a lack of progress and can be a huge hindrance toward making a project come into fruition. This organization consists of how to budget the project, meeting significant milestones, and outlining what tasks need to be completed within these milestones. Here the group introduces a budget, financing plan and the intensive scheduling for Senior Design 1 and Senior Design 2. Project milestones and timelines are proposed in order to keep a structured pace in development and design progress.

8.1 Project Financing and Budget

The funding for the “SenseWalk” project will be self-funded by the members of the group and will not seek any sponsored funding by any outside sources. This choice was established due to the desire of all group members to keep all intellectual property within the group. This choice also provides the advantage of giving the group the freedom to make any sudden changes to the design if needed without requesting permission from sponsors due to financial obligation. Due to this being self-funded, costs will be evenly distributed among group members to pay.

The elements in the table below are estimates of the cost associated with parts that need purchasing for the “SenseWalk”. As with any project design, there are always unforeseen costs that may occur due to broken parts or alternative parts purchased due to current ones not working up to the design as expected. At this point of development, any miscellaneous expenses have been estimated at about $100 currently. However, the total budget estimated for the total cost of the project is estimated to be at about $1000 if more miscellaneous expenditures should happen to accrue. The breakdown of our planned expenditures are shown in Table 8.1.a.

Items	Cost
PCB	$33.00
Lithium-ion battery	$40.00
White cane	$30.00
GPS module	$40.00
Microcontroller experimenter board	$150.00
Microcontroller debugging interface	$100.00
Bluetooth module	$99.00
SD card 8GB	$7.00
SD USB card adapter	$12.00
Digital compass	$5.00
Sonar hardware	$50.00
Power supply hardware	$50.00
Miscellaneous expenses	$100.00
Total estimated cost	**$716.00**

Table 8.1.a-Budget and financing table

*All costs were estimated and rounded up to the nearest dollar for current cost of products on the market

8.2 Project Scheduling / Milestones

This project is configured to take two semesters to complete. The first semester is designated for composing a group of team members, discussing various project ideas that conform to the scope of the engineering program topics learnt. Once a topic has been decided amongst the group and approved by the teacher's discretion, research is done for a given set of weeks to determine how to make the project come to fruition. Research is needed in order to determine what parts will be needed, which parts to actually select, how to design electrical systems and set specific software requirements for whatever programs are deemed necessary for the project. This research is needed and makes up the content for this design paper that is to be written by the end of the first semester.

The next semester consists of ordering the needed parts, implementing the design, and lastly testing the design to determine proper functionality. A more in-depth milestone chart is shown in the table below, with an estimated amount of weeks shown. The following sections also take a more detailed look into what occurs during each phase of the engineering design process for this project. The details of necessary tasks and estimated timeframe is shown in Table 8.2.a.

1st Semester	Tasks	Estimated timeframe
	Project proposal	3 weeks
	Research project	8 weeks
	Complete paper	4 weeks
2nd Semester	Design	5 weeks
	Implementation & integration	6 weeks
	Testing & debugging	3 weeks
	Final project presentation	1 week

Table 8.2.a-Project Milestone chart

8.2.1 Research

Research is the most vital step toward the completion of a design. For any project idea, once the initial purpose of the project has been established, the engineer(s) must figure out which method would be most efficient in implementing the design. This occurred throughout the beginning of the project for establishing what the proximity detection, GPS, Bluetooth, power supply, and microcontroller sub-systems must achieve. For this specific project, it was easy to divide sub-systems out of the main system which is represented as the whole “SenseWalk” console operating with all of these sub-systems integrated together.

There are many way to go about implementing the various sub-systems. Therefore, it is up to the discretion of the engineer to find the method that proves most efficient and lives up to whatever constraints the project may hold. For this case, low-power and low-weight were constraints that had to be considered for all sub-systems research. For example, the choice of microcontroller revolved around researching low-power microcontrollers that held the processing capabilities needed for the “SenseWalk” operations.

The choice of batteries was restricted to something that did not take up much weight and could be easily rechargeable with a long battery-life for the user. For the proximity detection system, there are various ways that detecting the surroundings of a point can be done. Therefore, research into sonar, infrared and laser range were done to determine which solution would offer the most benefits to the “SenseWalk” project. Research was also done into existing Bluetooth and GPS modules that are currently on the market. It was also necessary to research how both modules could properly interface with the microcontroller chosen and transmit/receive their respective data for use.

Lastly, which software would be needed was a critical component for research as this project employs both electrical and computer engineering foundations. Software is used for the Bluetooth, GPS, and microcontroller sub-systems. Determining which programs could be acquired and utilized for both Bluetooth and GPS had to be researched while understanding how to program the microcontroller to interface with its peripherals were objectives to be met.

Once research has been done for all sub-systems with an understanding of how to integrate all sub-systems into a final, working system, final decisions are made on parts to acquire and order for the next stage.

Note: The entire research phase was documented as it occurred with much further detail in section 3 of the paper.

8.2.2 Design

With proper research done, there is an exact understanding on what needs to be done in order to make the "SenseWalk" come into being. The design phase is the end result of research. Electrical sub-systems have been designed, which in this case, was the power supply system designed with the proper battery chosen that will be low-powered and will deliver power to all necessary sub-systems. The embedded system has been chosen alongside with the appropriate peripherals. A solid understanding from research has revealed how the embedded system should perform as it interfaces with its respective peripherals.

The correct microcontroller has been chosen that will be powerful enough to perform all of its design requirements. An understanding of what software to use to program the microcontroller is another aspect that has been determined in this design phase. The programming language to program the microcontroller under the given software has also been researched and understood at this point so that there is an understanding on how exactly to write the program for the microcontroller to process. Software has also been found for the GPS module to interface with that will allow it access to available maps for the user. Furthermore, software has been found that will also procure route configurations for a start and end point. The Bluetooth module should also be decided upon at this point in the process with an understanding of how Bluetooth stack protocols exchange information to other Bluetooth devices.

The design phase is basically the planning and selection phase which should be done at the end of the first semester. With all devices selected and electrical designs drawn, parts can now be ordered so that the next stage of the process can occur which is the integration and implementation phase.

8.2.3 Integration & Implementation

The integration phase occurs at the beginning of the second semester. Now that specific parts have been selected, purchasing of the hardware, software, and modules can be done. With the parts acquired, the design can finally be built. This means that the power supply will be laid out on a printed circuit board along with all other necessary electrical hardware. The microcontroller will be interfaced with the sonar, GPS and Bluetooth thus making the entire “SenseWalk” console which will then be attached to any standard white cane. During this time, all necessary software will be set up for their respective hardware components. Programming of the microcontroller and GPS will take place at this point as well.

As each sub-system reaches completion of its construction for both hardware and software modules, they may then be integrated. The end goal is to have a functional device that is ready for the next stage, testing the device to ensure that it has met all functional requirements of the design. This means that once the program has been written for the microcontroller, it will be uploaded to the microcontroller's flash memory for the microcontroller to access and implement. Because the microcontroller that has been selected already has its own Bluetooth stack, no programming of the Bluetooth stack will be needed for this component.

The GPS map software will also be interfaced with the GPS module, allowing the module to access the software and configure routes as well as keeping track of the user's current position. Because the Bluetooth module that has been selected is already configured to interface with the MSP430, less development time will be needed in that area to make the module interface with the microcontroller chosen. As each level of integration occurs, it is important to ensure that all sub-systems are compatible and interfacing correctly with their software and other peripherals as demonstrated in figure 8.3.

As these sub-systems are all developed, the final step is to integrate these sub-systems into the complete system which is the “SenseWalk” console. This approach is called a bottom-up approach in which small portions of the sub-system make it up. As a result, once they've been completed, another level is gone up until the entire system has been fully integrated and completed as shown in the chart in figure 8.3. As shown in the chart, the power supply basically powers every sub-system and the microcontroller serves as taking in inputs for the “SenseWalk” console.

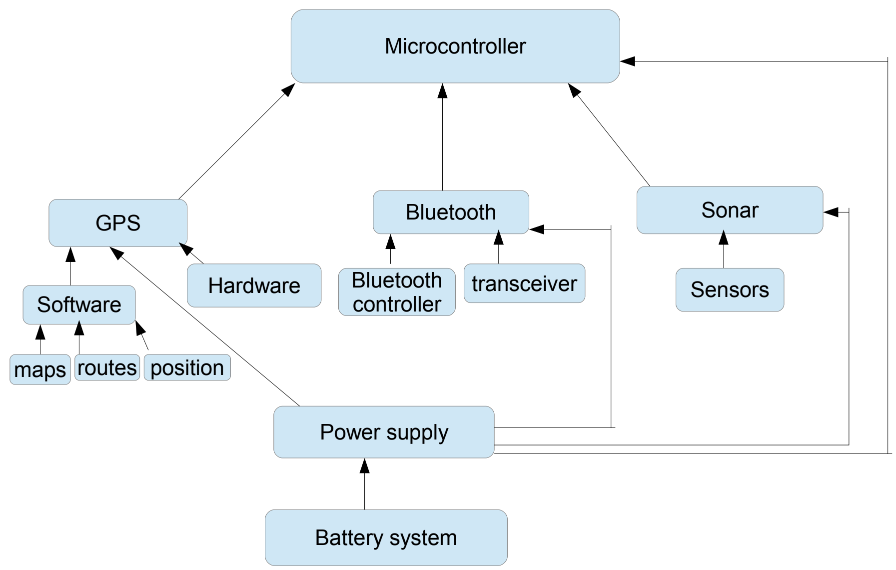


Figure 8.2.3.a-Integration chart starting from the bottom-up

Another step to undertake during the integration and implementation phase is for the group to select a panel of professors at the university that are willing to review the design. This panel will serve as advisers offering insight into the design, deeming it to be a good approach or not.

Now that integration of the entire system has occurred, the implementation of the "SenseWalk" console can be done to ensure that it has met all design requirements. This leads to the next phase of the process, which is testing to ensure functionality. This phase of development should occur during the first half of the second semester.

8.2.4 Testing

Testing must be done at every sub-system level in addition to testing the overall system as a whole once every sub-system has been integrated. A detailed explanation of testing of the sub-systems with regards to both software and hardware components is discussed in all of section 7 of this paper. Testing is scheduled to occur during the last quarter of the second semester.

Once testing of a sub-system has been deemed successful, it can be considered that that sub-system has met its functional requirements. Individual test cases unique to the component that is being tested are set up for the component to undergo evaluation. Any issues that arise that fail to meet proper functioning will require an inspection of the sub-system to address the error. Once the error has been found and fixed, the test must be run again.

After testing of every single component has been done, including the “SenseWalk” console system in its entirety, the entire design implementation may be deemed successful, with the discretion of the panel included. The system must be able to perform by having all sub-systems interface correctly with each other. This means that proper power was delivered correctly to all sub-systems that need power to run.

With a successful working system that has passed all testing, the project may now be prepared for demonstration during the project presentation.

9. Conclusion

In conclusion the “SenseWalk” is a simple and easy to use device to help the visually impaired people. This device will be a box strapped to a white cane. The “SenseWalk” will be able to operate for over an hour without having to be recharged. The “SenseWalk” will also need to locate object in front of the visually impaired person and alert the user.

The identifying of the object will be accomplished with the use of a sonar system. This system will consist of a transmitting and receiving transducer. For the transmitting transducer a square wave will be generated by a 555 timer. The receiving circuit will have two layers of amplification and a band pass filter. This is to amplify the signal because the single received will be several magnitudes smaller than the single sent out. The band pass filter will get rid of any noise that is generated by the outside world to prevent false readings being sent to the microcontroller. The difference in the time after the transmitting of the sonar wave to when the sonar wave will be received will be calculated using the microcontroller.

The microcontroller will be used to calculate the distance of the object. Once the distance is detected the user will then be alerted by a Bluetooth headset. In addition to alerting the user the Bluetooth head set will be used to have GPS directions to the visually impaired person. The GPS directions will determine instructions and be sent to the Bluetooth headset using the GPS CC4000 and CC2560-PAN1315.

These different modules will be powered by a 7.2V Lithium Ion battery. In order to generate the variety of voltages need for the several different types of power conversion modules will be used. In order to drop down the voltage to power the microcontroller, GPS unit and the Bluetooth a Buck Converter will be used. A Boost regulator will be used to boost the voltage to the 10V needed for the sonar transmitter. Since AC 110V outlets are common and easily accessible the battery pack will be charged using this supply. The Lithium Ion battery cannot be charged using 110VAC directly, so a Flyback circuit will be used. This circuit will charge the battery 8.4VDC at 1.2A.

The “SenseWalk” will give the millions of members of society who are visually impaired and a new method of navigation. Using modern technology the “SenseWalk” we be able to navigate the visually impaired person and well help them to avoid obstacles. This device will greatly help the visually impaired members have the freedom of movement that the rest of us take for granted.